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FIFTH GENERATION (5G) NETWORKS

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ALEXIS PRESS
JERSEY CITY, USA

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Published by: Alexis Press, LLC, Jersey City, USA
www.alexispress.us

First Published 2022

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication Data

Includes bibliographical references and index.

Fifth Generation (5G) Networks by *Bhavesh Neekhra, Neeraj Kaushik*

ISBN 978-1-64532-327-3

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CHAPTER 1

A STUDY ABOUT THE FIFTH GENERATION (5G) NETWORKS

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ABSTRACT:

The first generation of mobile networks, 5G, was created specifically to cater to the diverse demands of vertical businesses. In addition to providing huge connection for everything from human-held smart devices to sensors and machines, 5G delivers infinite mobile internet service. But perhaps most crucially, it has the capacity to enable vital machine communications with rapid response and very high dependability. The first 5G standards are already available, with the main goal being to meet the demands of mobile operators for very mobile internet services. A second edition with various features to help vertical in terms of Industrial IoT enablers will be shortly released by the end of 2019. To create a 5G system that satisfies the demanding criteria from the vertical industries, more improvements and optimizations are still required.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

The structure of the White Paper is as follows. In order to satisfy particular needs from vertical industries, the general design in Chapter 2 makes a number of improvements to the 3GPP Rel.15 system architecture. The RAN design is described in length in Chapter 3, along with the importance of the edge in enabling local processing and local paths to fulfil a range of needs for latency, throughput, and dependability. The preceding chapter's description of the CN architecture and the interconnectedness of the infrastructure made possible by the Transport Network architecture is supplemented. As described, the management and orchestration architecture is crucial in achieving the necessary flexibility. Offer examples of architectural deployments looked at and analysed in the 5GPPP projects to allow diverse verticals and a vast diversity of needs to be addressed. With a specific emphasis on 3GPP and ETSI, Chapter 7 concludes by summarising the standardisation effect that the work done has already accomplished in various standardisation organizations [1]–[3].

A highly mobile, fully connected society has certain needs, which 5G networks are designed to accommodate. Applications that are both centred on humans and machines will establish a wide range of functional and performance criteria that 5G networks will need to be able to serve. End-to-end network slicing (E2E), service-based architecture, software-defined networking (SDN), and network functions virtualization (NFV) are seen as the fundamental pillars within the 5G System (5GS) to support the heterogeneous key performance indicators (KPIs) of the new use cases in an effective manner. Mobile network operators now have a rare opportunity to meet the needs of consumers, businesses, vertical markets, and third-party tenants by introducing new services thanks to the 5GS. To this purpose, the primary components of the 5G architecture have been developed and defined by 5G Infrastructure Public Private Partnership (5G PPP) Phase I/II joint research initiatives and standardisation organisations.

By using virtualization, standardised interfaces and protocols, or open APIs, for example, the 5G ecosystem should make it possible for manufacturers, solution integrators, network and service providers, and Small and Medium-sized Enterprises (SMEs) to compete and collaborate effectively. SMEs will be able to provide technical solutions that are compatible with the total system, such as new infrastructure hardware or management and organizational software components. To boost innovation, manufacturers and solution integrators may provide quick deployment made possible by virtualization and standardised interfaces. In order to meet the needs of vertical businesses, mobile network operators (MNOs) and infrastructure suppliers will design customized slices with particular features and Over-The-Top apps and services.

Focus mostly on single-domain service delivery; do not go into detail about things like cross-operator situations. The 3GPP duties are also described from the perspective of an operator. As shown in Service Customer (SC): Uses Services Offered by a Service Provider (SP), 5G PPP Phase I/II joint research projects have expanded these roles to enable many conceivable customer-provider connections amongst verticals, operators, and other stakeholders. Vertical industries are seen as one of the key SCs in the context of 5G.Depending on the service offered to the SC, the Service Provider (SP) has three sub-roles: Network Slice as a Service (NSaaS) Provider, which offers a network slice along with any services that it may support and configure, Digital Service Provider, which offers digital services like enhanced mobile broadband and IoT to various vertical industries, and Communication Service Provider, which offers traditional telecom services. Utilising aggregated network services, SPs create, develop, and manage services.

Resource management is the responsibility of the network operator (NOP), who may coordinate resources from several virtualized infrastructure providers (VISP). Network services that are made available to SPs are designed, built, and run by the NOP using aggregated virtualized infrastructure services.

A virtualization infrastructure service provider (VISP) creates, constructs, and manages virtualization infrastructures, which are composed of computational and networking resources (such as those used in mobile transportation). Data Centre Service Provider (DCSP): Creates, constructs, and manages its data centres in addition to offering data centre services. By providing "raw" resources (host servers, for example) in relatively centralised locations and basic services for consumption of these raw resources, a DCSP differentiates from a VISP. Instead, a VISP makes a range of resources available via a single API by combining several technological domains.

5G Enhanced Overall System Architecture

The potential for network slicing, or running several logical mobile network instances on a single shared infrastructure, necessitates ongoing alignment between customer-focused service level agreements (SLAs) and network performance capabilities at the infrastructure level. By supplying "customer-facing" on-demand service need descriptions to Service Providers, service clients, such as those from the vertical sectors, request the production of telecommunication services. Operators used to manually implement this mapping on a select few service/slice types, namely mobile broadband, phone, and SMS. An E2E framework for Service Creations and Service Operations would consequently need to demonstrate a much greater degree of automation for the lifecycle management of network slice instances due to an increase in the frequency of these client requests.

Closed-loop Service Assurance, Service Fulfilment, and Service Orchestration functions must be used to cover all lifecycle phases on the service level, including the preparation phase, instantiation, configuration and activation phase, run-time phase, and decommissioning phase. Softwarization, such as the virtualization of network functions, as well as software-defined, programmable network services and infrastructure resources are two essential technology enablers. Functions for Management of Domain Resources and Functions interface with E2E Service Operations functions. Examples of domains include NFV, MEC, RAN, Core & Transport Network, and others. Building components within each management domain include orchestration in addition to closed-loop processes for resource fulfilment, resource assurance, and network intelligence. Domain-specific controllers, including SDN controllers, may be configured to effectively implement policies and rules on the Resources and Functional Level on a more fine-grained temporal and geographic level[4].

Finally, scalable data exposure governance and access control mechanisms are used to provide services for data acquisition, processing, abstraction, and distribution on a common platform where data can be accessed by system entities at all levels. This information contains information about subscribers, the network and its supporting resources, network slices and service instances, and, if the vertical client so desires, information about applications.

A recursive structure is realised using the suggested design. A design, rule, or process that may be used repeatedly is referred to as a recursive structure in the context of 5G. This recursive structure in a network service context relates to a particular area of a network service or the deployment platform. It is described as the capacity to create a service from of pre-existing services, such as another instance of the same service. A recursive structure in the 5G architecture may be repeatedly created and connected, much as a recursive service specification. As the same service category can be deployed multiple times, simultaneously, at various locations, it increases scalability. A logical technique to manage increasingly complicated and expansive workloads or service graphs is to delegate portions of the service to numerous instances of the same software block.

Such a recursive structure in the context of virtualized infrastructure enables a slice instance to run on top of the infrastructure resources supplied by another slice instance. For instance, every tenant is permitted to purchase and install a separate Management and Orchestration (MANO) system. The administration of each slice and the control of the underlying virtual resources must be done via a layer of abstraction that is transparent to the level of the hierarchy at which the tenant is operating in order to enable the recursion. Through these APIs, various tenants can request the provisioning of slices. Each tenant determines the desired amount of resilience, management, and control in addition to the slice characteristics (topology, QoS, etc.) via a template, blueprint, or service level agreement (SLA). Following the cloud software platform-infrastructure paradigm, many items in 5G will be made available as a service, such as platforms, software, and infrastructure. In all network segments, the idea of network slicing is anticipated to meet the demand for specialised, service-specific combinations of service components and network functions. Service Development Kits (SDKs) make service lifecycle management (LCM) technologies possible. Services may be updated or new versions of existing services can be developed using SDKs. Service development is the first step in the service lifecycle. It may be deployed to the production environment after the Quality of Service (QoS) requirements of the end users have been satisfied. The lifecycle's last step, operations, sees continued monitoring of the deployed services. Several H2020 projects, among them, propose a range of SDK approaches to optimise the service development with QoS expectations.

Network service descriptors may also be created and modified using descriptor creation tools. This makes it possible to define VSBs vertical service blueprints with detailed SLA specifications for the services. VSBs may include a variety of parameters, including extra VNF packages, IP addresses for external components, and numbers of supported users. A customised vertical service descriptor (VSD) may be made by an industry vertical (or by other clients) by providing real values for these characteristics. The choice of various NSDs, their deployment styles, and instantiation levels are made easier by SLA criteria like route latency, service availability, or the deployment of energy-efficient services [5].

Multi-Domain Management

A continual alignment between customer-focused service level agreements (SLAs) and network performance capabilities at the infrastructure level is required due to the possibility of network slicing, or operating many logical mobile network instances on a single shared infrastructure. Service customers, such as those from the vertical industries, request the creation of telecommunication services by providing "customer-facing" on-demand service requirement descriptions to Service Providers. On a small number of service/slice types, namely mobile broadband, phone, and SMS, operators used to manually implement this mapping. The lifecycle management of network slice instances would thus need an E2E framework for Service Creations and Service Operations to exhibit a significantly higher level of automation owing to an increase in the frequency of these client requests.

All lifecycle phases on the service level, including the setup phase, instantiation, configuration and activation phase, run-time phase, and decommissioning phase, must be covered by closed-loop service assurance, fulfilment, and orchestration functions. Two crucial technological enablers are software-defined, programmable network services and infrastructure resources as well as softwarization, such as the virtualization of network operations. Functions for Domain

Resource and Function Management communicate with E2E Service Operations functions. NFV, MEC, RAN, Core & Transport Network, and other domains are examples of subdomains. In addition to closed-loop procedures for resource assurance, resource fulfilment, and network intelligence, orchestration is a key building block inside each management domain. It is possible to set up domain-specific controllers, including SDN controllers, to efficiently apply policies and regulations on the Resources and Functional Level on a more granular temporal and geographic level.

On a common platform where data can be accessed by system entities at all levels, scalable data exposure governance and access control mechanisms are used to provide services for data acquisition, processing, abstraction, and distribution. This data includes details on the network and its supporting resources, network slices, service instances, and, if the vertical client so chooses, details about applications. It also includes information about subscribers.

The recommended architecture is used to realise a recursive structure. A recursive structure in the context of 5G is a design, rule, or procedure that may be applied again. This recursive structure pertains to a specific component of a network service or the deployment platform in the context of network services. The ability to generate a service from an already-existing service, such as another instance of the same service, is what it is referred to as. Similar to a recursive service definition, a recursive structure in the 5G architecture may be repeatedly generated and linked. Scalability is increased since the same service category may be delivered several times, concurrently, at different locations. Delegating parts of the service to several instances of the same software block is a natural method for managing workloads or service graphs that are becoming more complex and expansive.

In the context of virtualized infrastructure, such a recursive structure allows a slice instance to execute on top of the infrastructure resources provided by another slice instance. For example, each tenant is allowed to buy and set up a unique Management and Orchestration (MANO) system. To allow the recursion, the administration of each slice and the management of the underlying virtual resources must be carried out via a layer of abstraction that is transparent to the level of hierarchy at which the tenant is working. These APIs allow different tenants to request the supply of slices. A template, blueprint, or service level agreement (SLA) is used by each tenant to specify the degree of resilience, management, and control they want as well as the slice characteristics (topology, QoS, etc.).

Many 5G components, including platforms, software, and infrastructure, will be made available as a service in line with the cloud software platform-infrastructure paradigm. It is envisaged that network slicing will be used in all network segments to address the need for specialised, service-specific combinations of service components and network operations. Service lifecycle management (LCM) technologies are made feasible by Service Development Kits (SDKs). SDKs may be used to create new services or updated versions of existing services. The initial phase of the service lifecycle is service development. Once the Quality of Service (QoS) demands of the end users have been met, it may be deployed to the production environment. Operations, the last phase of the lifecycle, involves ongoing monitoring of the deployed services. A number of

H2020 projects among them suggest a variety of SDK strategies to optimise service development while meeting QoS standards [6].

Using descriptor creation tools, network service descriptors can also be created and modified. As a result, it is feasible to create VSBsvertical service blueprints that include comprehensive SLA standards for the services. Numerous parameters, such as additional VNF packages, IP addresses for external components, and the number of supported users, may be included in VSBs. An industry vertical (or other customers) may create a customised vertical service descriptor (VSD) by giving genuine values for these attributes. SLA requirements such as route latency, service availability, or the deployment of energy-efficient services facilitate the selection of different NSDs, their deployment methods, and instantiation levels.

Application-aware orchestration

In accordance with the various orchestration approaches provided by the 5G PPP projects and aiming at bridging an identified gap between the cloud computing orchestration solutions and the network services orchestration solutions, the multi-domain orchestration framework comes up with a novel and holistic approach for overall lifecycle of applications' design, development, Deployment, and orchestration in a 5G ecosystem. Novel concepts include the separation of concerns among the orchestration of the developed applications and the underlying network services that support them, as well as the specification and management of application-aware network slices. In this top-down approach, application design and development lead to the instantiation of application aware-network slices, over which vertical industry applications can be optimally served.

Applications' Orchestration Layer and the Programmable Infrastructure Slicing and Management Layer. The Applications Layer is oriented to software developers, the 5G-ready Application Orchestration Layer is oriented to SPs and the 5G Infrastructure Slicing and Management Layer is oriented to NOPs, VISPs, and DCSP, cf. The Applications Layer takes into account the design and development of 5G-ready applications per industry vertical, along with the specification of the associated networking requirements, which are tightly bound together with their respective applications' graph. The graph defines the business functions, as well as the service qualities of the individual application. The Applications' Orchestration Layer supports the dynamic deployment and service-aware adaptation of the applications, by using a set of optimization schemes and intelligent

Algorithms that select the needed infrastructure resources from different domains. The Programmable Infrastructure. Slicing and Management Layer is responsible for setting up and managing the application deployment and operation by means of an application-aware network slice. Network slice instantiation, activation, run-time management and orchestration, as well as monitoring are realized. According procedures can also be triggered by the Applications' Orchestration Layer via according APIs.

MANO systems enable an integrated and holistic approach towards NS and VNF management. While MANO processes can be standardized on a high level of abstraction, specifics of both the infrastructure and the service implementation need to be considered on the implementation level.

For example, although a generic placement algorithm is able to instantiate all VNFs of, e.g., a content delivery network service at some location, the result might not be optimal. A specialized placement algorithm can bring in additional knowledge about the service and its components and, for example, place caches close to users.

As service developers have the best understanding of the MANO requirements and other peculiarities of their services, they are in the best position to add such service-specific knowledge to their services. To that end, a plug-in approach for NFV MANO systems allows the integration of service and function-specific managers into specific MANO processes. Service and function-specific management components are shipped together with their associated services as part of the service package. The managers are then integrated into the NFV MANO system, cf. and called as part of the generic, standardized processes of the MANO system on both the NFVO level and VNFM level.

Programmable Networks

One of the fundamental principles in the development of 5G systems has been network programmability. Programmability assures that infrastructure, network operations, services, and applications may all be flexibley adapted. Examples for the programmability of data plane, transport networks, and RAN functions are provided in the corresponding sections that follow [7].

DISCUSSION

The data plane landscape is composed by a wide range of heterogeneous resources, geographically grouped in three main tiers: radio access, edge nodes, and central datacentres:

1. **Tier 1:** edge area where radio access nodes are deployed;
2. **Tier 2:** edge area with limited computing resources, corresponding to, e.g., street cabinets;
3. **Tier 3:** central area with massive computing resources, corresponding to a datacentre.

Through the creation of abstract views on the resources of the underlying infrastructure, all tiers offer features for programmability and flexible configuration. The approach involves using the SDN paradigm to implement data plane configuration in a manner that is completely integrated with management and orchestration plane and independent of the underlying hardware architecture. The functional component that initiates SDN control plane activities is WAN Resource Manager (SDN Application). It ensures that external connection information stored at orchestrator level is translated in a proper route between NFVI PoPs by translating the abstracted view at orchestrator level into a network domain-specific view. There are two different kinds of SDN Controllers, one for configuring the network domain and the other for configuring the RAN domain; each Controller is backed by appropriate SDN agents situated on the appropriate network components. Network components that make up the infrastructure layer include WLAN Access Points, LTE small cells, Core NFVI, backhaul network, edge NFVI, and front haul network [8].

CONCLUSION

Exemplifies how the suggested method for data plane programmability may be implemented in a Cloud Enabled Small Cell (CESC) context. The supply of SDN capabilities is made possible by a two-tier virtualized execution environment in the form of the Edge data center. By converting the abstracted view at the orchestrator level into views related to the network domain, the CESC Manager (CESCM) initiates SDN control plane actions. To make large-scale choices across a number of tiny cells, or so-called CESC clusters, the SDN strategy of separating control and data plane operations is appropriate. The NFV Infrastructure (NFVI), which consists of the compute, storage, and networking resources of the edge data centers, is controlled by the Virtualised Infrastructure Manager (VIM), which also builds and manages CESC clusters. Small cell use is divided into logically isolated slices and made available to various operators or tenants.

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CHAPTER 2

VERTICAL-SPECIFIC ARCHITECTURE EXTENSIONS

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ABSTRACT:

The little cell is active. Additionally, it oversees and coordinates the use of radio resources and service provision. It regulates the communications between network operators and the infrastructure level. CESCM includes telemetry and analytics features for controlling the total network in an effective and SLA-compliant way for service assurance and fulfilment. The VIM services for properly controlling, monitoring, and optimising the entire functioning of the NFVI resources at the edge ate centre will be the foundation upon which the CESCM functions will be developed. A set of APIs will eventually be used to provide the NFV resources, enabling the execution of network services across the dispersed CESCs.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

It has been suggested that data plane programmability is the ideal way to handle the heterogeneity of 5G networks and to enable quick and simple network function deployment. Solutions in the transport network domain must be flexible enough to meet future RANs' highly variable bandwidth needs while still being resource and energy efficient. A unique idea called "Disaggregated RAN" adopts the idea of "disaggregation" of HW and SW components across the wireless, optical, and compute/storage domains. Disaggregation provides improved scalability, upgradeability, and sustainability possibilities in addition to greater flexibility. These qualities are especially important when supporting a constantly expanding range of devices and services as well as cutting-edge features like the idea of flexible functional splits. By separating the hardware and software parts, "resource disaggregation" creates a shared "pool of resources" that may be separately chosen and assigned as needed.

The fundamental group of elements that may be separately integrated to create any infrastructure service is made up of these parts. Novel solutions are required to raise the density and power efficiency of the "pool of resources" and enable high bandwidth communication between them in RAN contexts in order to take use of the idea of disaggregation. Such solutions will depend on two key components: (i) hardware programmability, which enables resource sharing that is dynamic and on demand; and (ii) network software, which enables the transition from the conventional closed networking model, which focuses on network entities, to an open reference platform that instantiates a variety of network functions [1].According to the designs, SDN is used to take use of the high-performance switching hardware's supplied configurability, and NFV's complete programmability of network operations through software on commodity hardware platforms. To create a unified, programmable control and management framework that can be used to coordinate the underlying heterogeneous technology domains and support end-to-end service provisioning across various infrastructure domains, they adopt the concepts of transport network slicing and resource and service virtualization across technology domains.

Network function programmability in RAN

The RAN architecture adopts the baseline architecture, which includes the latest 3GPP Release specification on 5G RAN, addition of Service Data Adaptation Protocol (SDAP) layer, and F1 interface with CU-DU split. The baseline architecture also includes the 5GPPP Phase 1 consensus and the 3GPP status as of the publication time. Here, a RAN controller layer is imagined, which offers a way to implement RAN control functions in certain applications. It is important to note that the application functions (AFs) included in the service-based architecture (SBA) already provide the CN with this flexibility. The RAN architecture is shown in a high-level graphic. Cross-slice (XSC) and intra-slice (ISC) controllers are included in this layer, along with the related applications (APPs) that are operating on the northbound interface (NBI). The southbound interface (SoBI) is used for communication between the control instructions and the gNBs.

The RAN Controller Agent (RCA), which is introduced in the CU to connect dispersed and centralised NFs to the logically centralised controllers, is intended to serve as a communication channel between the Controller layer and the RAN NFs. The RCA often serves as a middleman between the controller and the NFs and has a local data storage that may house the most current monitoring data from the NFs. This makes RCA one of the common platform functions; see for further information. The RCA therefore controls the amount of data to be exposed to the Controller layer. For the purpose of monitoring and reconfiguring NFs, the SoBI serves as a uniform interface between RCA and the controllers. For the purpose of sharing control information with northbound applications installed on top of the controllers, each programmable NF in DU and CU allows contact with RCA [2].

The so-called RAN data analytics function (RAN-DAF), with which the RCA interfaces, is in charge of gathering monitoring data pertaining to both UEs and RAN, including Channel Quality Indicator (CQI), power level, path loss, radio link quality, radio resource usage, Modulation and Coding Scheme (MCS), Radio Link Control (RLC) buffer state information, etc. The controllers and subsequent northbound applications, such as slow inter-slice RRM, slice-aware RAT selection, elastic resource management, etc., may get the information acquired via RAN-DAF from the RCA. Additionally, RCA sends re-configuration data from the controller to the appropriate NFs in the CU and DU.

Vertical-specific architecture extensions

They show how the 5G system may be adaptably customised and expanded to meet the needs of vertical industries. The creation and distribution of media material, as well as energy utilities and vehicular communications, are used to exemplify this.

Extensions for Energy Utilities

The suggested changes to the overall architecture, are intended to speed up the digitization of energy utilities and help them make the transition to more decentralised systems that concentrate on renewable energy. Extensions that are pertinent include a number of VNFs that provide SaaS and IaaS, Self-X features, and smart energy (application) VNFs. Energy grid KPIs must be taken into account during self-optimization procedures since energy grids are an essential component of critical infrastructures.

The Radio Access Network, the Management of Domain Resources and Functions, and the Creation of E2E Services. New techniques for IoT device identification and the optimisation of data routing for tiny and very small devices are made possible by extensions in the Radio Access Network. This includes edge-deployed application-specific VNFs on the level of resources and functions. These VNFs emphasise

i) The digitization of the current energy grid control,
ii) The decoupling of the smart grid assets from the physical devices by using so-called digital twin technologies,
iii) The introduction of blockchain technologies towards the storage of critical data in an unambiguous, traceable manner,
iv) The extensive monitoring of the energy grid and networking infrastructure, and
v) The quickening of media focused on infrastructure maintenance and security, and
vi) The opening of high-accuracy mobility management services allowing for improved control of next-generation technologies like drone swarms for automated inspection.

The service-aware configuration and orchestration of particular resources and functions are made possible by extensions in the Management of Domain Resources and Functions. Such changes may be utilised at the network level to build isolated end-to-end network slices on the same infrastructure for usage by several heterogeneous services at once. The three 5G flavorseMBB (drones for remote infrastructure inspection), mMTC (connecting 5G-ready advanced smart metering infrastructure deployments), and URLLC (connecting scalable installations of phasor measurement units)are in fact used by the energy utility vertical depending on the operational environment. Additionally, analytics-based optimisation mechanisms, which are governed by a utility-based policy, govern the behaviour of network services and also take into account application-level metrics, such as KPIs related to the energy grid, in order to better coordinate various resource categories. In order to do this, two new interfaces are introduced: the Operations-Analytics (Os-An) and the Analytics-Management (An-Ma) interfaces connect the Analytics component with the Service Operations component and the Domain Management component, respectively.Finally, different multi-tenant applications and particular "Smart Energy as a Service" applications are launched in the E2E Service Creation. Indeed, "killer applications" like advanced metering infrastructure as a service, predictive maintenance as a service, as well as dispatchable demand response as a service would be made possible by 5G-enabled energy grids, which have the potential to completely transform the operational workflow of energy utilities.

Extensions for Vehicular Communications

Vehicular communications simultaneously involve multiple use cases, traffic types, and communication paths. In fact, in addition to transmissions routed through the core network towards remote servers, links between vehicular UEs in proximity may involve the PC5 link for direct Vehicle-to-Vehicle communications, whereas local breakout can be applied for network-assisted links routed through the edge network. In this latter case, the base station or road side unit can locally relay the messages to the UEs in proximity, and/or route them to UEs attached to neighbouring base stations via short routing paths passing through the edge data centre.

Automotive applications include a wide set of services, offered by different providers, each imposing a specific set of requirements. For this reason, vehicular communications rely on the network slicing feature, where the lifecycle management of each slice is tailored to support the related service, cf. This collection is composed by slices belonging to the standard types already defined by 3GPP, notably eMBB and URLLC, thus exploiting the flexibility provided by the standardised slice types.

For the automotive vertical, it is important that network functions can be deployed both in the edge and central cloud, according to the requirements they are designed to serve. The edge cloud hosts NFs which need to be allocated in proximity of the UEs, potentially including additional features such as Multi-access Edge Computing (MEC) and storage facilities. The central cloud, on the other hand, contains the slice-specific network functions for use cases requiring connectivity with a remote public network. The concept of multi-tenancy is leveraged in vehicular applications, wherein the tenant is the company, vertical, or service provider offering the services supported by one slice, or one set of slices. Examples of tenants for automotive applications are mobile network operators, road operators, and automakers.

Road authorities may provide Cooperative Intelligent Transportation System (C-ITS) services like hazard warning, in-vehicle signage, and in general cooperative perception and cooperative manoeuvre services. These services involve information that is both strictly time-sensitive and location-sensitive: messages are in fact transmitted and received by vehicles to spread and acquire safety-critical information about the instantaneous traffic conditions in their surroundings. These services hence require a low latency slice with high reliability, providing timely reception of these messages. For this reason, network resources are foreseen to be mostly allocated in the edge cloud, as close as possible to the road users. Alternatively, sufficient transport network resources towards the central cloud must be allocated for the slice.

Automakers may offer different classes of services to their clients, such as remote maintenance and tele-operated driving. Both require connectivity between the vehicle and the automaker's cloud, although each with completely different service level requirements. In the former case, the machine-type communications, which could be delivered via an eMBB slice, is used to retrieve data from the on-board sensor to plan ahead the maintenance of large vehicular fleets. In contrast, remote driving requires low latency, high data rate, and high reliability in the uplink to provide a real-time video flow and instantaneous sensor data to the remote driver. Similarly,

DISCUSSION

The driving instructions must be sent to the car through the downlink. Both services have varying levels of redundancy, despite the fact that they both primarily rely on network functions that are hosted in the operator's central cloud. The carmaker may also run Vehicle-to-Everything (V2X) application servers on their premises and provide additional authentication features beyond those provided by the network. In any event, network slices may make use of dedicated bearers to provide certain applications or flows inside the same slice of the network a customised QoS. Specific bearers (in the RAN) and flows (in the core network) are assigned to different applications, and they are each given a different level of priority [3].

Extensions for enhanced content delivery

There are use cases that call for content distribution to a group of end devices employing broadband connection through mobile and convergent networks among the wide range of services that 5G networks are intended to provide. Live video streaming, mission-critical communication, and information sharing in the IoT and V2X sectors are a few examples of such use cases. Since HTTP streaming became a feasible option for providing live media, live video streaming has been expanding for many years as a result of network performance advancements. However, live video streaming over unicast connections poses a number of problems. Particularly, significant, short-lived peaks in network throughput demand may occur, requiring network operators to overprovision their networks to handle such peak demands.

By using "Function X" on the multicast server end and "Function Y" on the multicast terminating end, a unique architecture enables the distribution of content via mixed network types, including fixed and mobile, as well as unicast, multicast, and broadcast connection types. The encapsulation of (unicast) data into multicast is handled by function X. The positioning of Function X is influenced by a variety of factors, such as cache placement schemes and the capabilities of the underlying network fabric. It is acknowledged that Function X may be situated either outside of converged network (Function X.1) or inside converged network (Function X.2) in this condensed portrayal of the framework. Function Y would typically be present in the Home Gateway or maybe partially in the UE, and it would take input from the upstream network in both unicast and multicast mode before presenting unicast to the clients downstream.

Extensions for media production and delivery

Cloud services should use Function-as-a-Service (FaaS) technologies (like Open Whisk) to better enable video creation and distribution over 5G networks. FaaS covers use cases where an elastic communication service must be immediately set up because they arise out of the blue. By adopting organised mobile content contribution, remote and smart media creation, and low-latency and high-bandwidth media distribution (for example, streaming) via 5G networks, such an approach seeks to overcome the current constraints placed on conventional broadcast productions. The VIM enhancements for FaaS support that are compatible with the ETSI MANO standard architecture are shown in Figure 2-12. On the northbound, the "FaaS-VIM" supports the typical Vnfm-Vi, Or-Vi, and Nf-Vi interfaces. The implementation of the FaaS framework is particular to the southbound interfaces of the FaaS-VIM. The FaaS framework may operate directly on bare metal computers or on any underlying PaaS that uses IaaS virtualization technologies. The architecture was designed to be compatible with the ETSI NFV standard without firmly attaching the FaaS paradigm to any particular deployment or implementation alternatives.

Here is an example of a typical workflow: A reporter covers a significant event and sends a live signal to the broadcaster's facilities using their smartphone. The faces visible in the video feed cause the Face Recognition Engine to be activated, instantly launching the FaaS capabilities. As soon as it is operational, the Face Recognition Engine begins labelling the individuals in the video frames and organising the data in the broadcaster's archive according to the appropriate tags. Another FaaS might alert an editor if the detected material in the frames is included in a current narrative [4].

The overall Radio Access Network (RAN) architecture shown in is based on a baseline architecture that includes the latest 3GPP Release specifications for NG-RAN and the 5GPPP Phase 1 consensus, which includes the addition of the Service Data Adaptation Protocol (SDAP) layer and the F1 interface with Centralised Unit - Distributed Unit (CU- DU) split. The cutting-edge architecture, enhanced with a two-tier architecture that includes a first distributed tier for providing low latency services and a second centralised tier for providing high processing power for compute-intensive network applications, is capable of providing Small Cell (SC) coverage to multiple operators "as-a-Service". High-performance virtualization approaches for data isolation, latency reduction, and resource efficiency, as well as coordinating lightweight virtual resources to enable effective placement and live migration of Virtualized Network Functions (VNFs), further increase the architecture's adaptability. The proposed method, in particular, attempts to divide and virtualize small cell capacity while simultaneously supporting improved edge cloud services by enhancing the network architecture with an edge cloud.

The CU may be further divided into two parts: the Control Plane (CP), also known as CU-C or CU-CP, and the User Plane (UP), also known as CU-U or CU-UP. This separation makes it possible to apply CU-C and CU-U in various places, as shown in Figure 3-1. The bottom layer split is an extra split option that may be used with a DU. It is important to remember that a DU may function as a tiny cell. By incorporating functional models resulting from 5GPPP advancements, as described in the following sections, the RAN design improves the baseline architecture. One such expansion is the controller layer, which allows for the RAN to be programmed in terms of RAN control functions as specialised application (APP) implementations. The North-Bound Interface (NBI) may be used by the APPs over the Cross-Slice Controller (XSC) and Intra-Slice Controller (ISC), and the South-Bound Interface (SoBI) can be used to maintain connection with the RAN. Such APPs might theoretically enable RAN control features like Radio Resource Management (RRM) and offer slow-scale control capability. Additionally, local end-to-end paths are introduced to reduce latency between vehicles and road users who are in close proximity in order to satisfy the most demanding use cases, such as safety-critical vehicular applications [5].

With no additional cost for signalling with the 5G Core, Network Function Virtualization (NFV) technology allows the deployment of many small cells, such as visible light communication gNBs in buildings. According to the illustration in, by installing a VNF in the cloud as a kind of Multi-access Edge Computing (MEC), numerous small cells may be perceived as one small cell. The alternative small cell deployment options include employing dual connection mode or having all small cells directly linked to the 5G Core through the NG interface, making them visible and manageable to the 5G Core. Separation of Control-User Plans and Centralized-Distributed-Radio Units The 3GPP's list of core technologies is used as the foundation for a number of 5G PPP Phase 2 and Phase 3 projects, which are then augmented with further tailored extensions to fit their unique needs. The majority of systems contain CU-DU split, and some go even farther to expose CPRI, dividing the radio equipment into Remote Units (RU), Distributed Units (DU), and Centralised Units (CU).

The identification of eight alternatives is the exposure of the CPRI interface, whereas Option 7 is known as enhanced CPRI (eCPRI). In, potential options for the breakdown of the RAN environment are investigated. Both ultimately result in the RU being cut off from the Base Band Unit (BBU). Only Option 2 has led to a substantial amount of additional effort among the other possibilities. In option 2, a distributed unit and a centralised unit are divided, and the F1 Reference point is established to link the CU and DU.

Additionally, work was done to divide the CU into its user plane and control plane components, as documented in and illustrated in, which emphasises the breakdown of the F1 interface into control and user plane components and the exposure of the E1 reference point between the CU's control plane and user plane functions.

1. Protocol Extensions for Vertical Support
2. RAN Part of Network Slicing
3. Fundamental Slicing Support in RAN

The 3GPP standards in the RAN include the following core functionality for network slicing: A so-called late drop of 3GPP Release 15, which includes more architectural choices, was originally scheduled to be frozen by the end of 2018, but was later extended to the end of March 2019. Release 15 for Next Generation-RAN (NG-RAN) was frozen in June 2018. This standard includes network slicing awareness in RAN through Network Slice Selection Assistance Information (NSSAI), including one or more Single NSSAIs (S-NSSAIs) that enable network slicing identification. Although Release 15 provides the basic slicing functionality, such as granularity of slice awareness and network slice selection, there are still a number of improvements and optimisations that can be taken into account for subsequent releases. These include, for example, specification-relevant signalling changes and implementation-dependent algorithms, such as those that deal with the management of shared resources between slices.

Network slicing provides previously unheard-of levels of flexibility because Network Functions (NFs) may be customised to meet the various Quality of Service (QoS) demands of various slice tenants. These might, for example, only differentiate performance in terms of latency and data rate, or they might also include additional Service Level Agreement (SLA) requirements, like the number of connections for a specific period of time and location. Therefore, various network slicing implementation variants can support slice tenant requirements.

Some of these variations allow network slices whose SLA differentiation can be carried out with QoS enforcement to share the entire RAN protocol stack. According to the most recent 5G Release 15 standards, and as shown in, the 5G Core (5GC) may create one or more Protocol Data Unit (PDU) sessions for a network slice instance; a PDU session is exclusive to one and only one particular network slice instance. The user planes of the enhanced Mobile Broadband (eMBB) and Low-Latency eMBB (LL-eMBB) network slice instances are depicted in Figure 3-4. These include the User Plane Functions (UPFs), the User Equipment (UE) connected via the Uu radio interface, the NG-U, or N3 interface, the UP processing in the RAN, and the interface between the UPF and the RAN. A PDU session may include one or more QoS flows, and the RAN maps packets from various PDU sessions to various Data Radio Bearers (DRBs) [3-1]. As a result, distinct network slices may be treated by the RAN using RRM schemes that are based on the QoS profiles of the QoS flows that have been mapped onto the relevant DRBs. Performance traits including the Packet Delay Budget (PDB), Packet Error Rate (PER), and Allocation and Retention Priority (ARP) are included in QoS profiles [6].

Since it provides a method for cross-slice optimisation, inter-slice (or multi-slice) Resource Management (RM) is crucial for enhancing system efficiency, particularly with regard to shared infrastructure resources. Thus, the inter-slice RM takes the slice SLAs into account, for example by changing the allocation of the instantaneous radio resources. Slice awareness may be extended to the so-called hard network resources, meaning the wireless access nodes, in addition to the slice-adaptive radio resource allocation, notably in self-backhauled dynamic small cells. This is known as the extended notion of a resource. In other words, the slice support may not only include the traditional radio resources, such as time and frequency resources, but it may also include the adaptation of the network topology, taking into account the dynamic small cells available in a particular region. As a result, the slice-adaptive resource management must take into account the evolving radio topology as well as various kinds of access nodes, including micro-cells, pico-cells, relays, and vehicular nomadic nodes (VNNs).

Wi-Fi virtualization and slicing

The growth of LTE, the 5G New Radio, and Wi-Fi-based technologies are only a few of the several radio technologies that 5G includes. One of the key components of 5G networks is network slicing, which calls for the creation of several virtual networks over a single, shared physical infrastructure. Network slicing in wireless network media requires virtualization, which may be accomplished in a variety of methods. Sharing a wireless interface across many tenants is an easy technique to virtualize wireless interfaces. To distinguish between the tenants on the same carrier, for instance, a Public Land Mobile Network (PLMN) ID may be created for each tenant in LTE.

The Linux operating system is used to design one potential implementation of Wi-Fi virtualization, which is accomplished by using the mac80211 module to instantiate virtual wireless interfaces that operate in "user space" and utilise the "kernel space"-running mac80211 module. As shown in Figure 3-5, the hardware drivers connect the actual Wi-Fi Network Interface Card (NIC) with the mac80211 kernel module. Virtual access points and virtual mesh interfaces are only a few of the several virtual interfaces (vifs) that Wi-Fi offers. As with a physical access point, each virtual access point in use has a unique Service Set Identifier (SSID) that is broadcast using specific beacons. For instance, this form of virtualization enables the instantiation of specialised settings for crucial concepts like security (WPE/WPA/WPA2, etc.), as well as dedicated SSIDs for individual tenants or services [7].The virtual interface (vif) scheduler and the netopeer agent are two additional software modules used in this implementation sample to achieve RAN slicing. While the netopeer agent hosts a NETCONF server that is used to set up and configure the virtual interfaces on top of the physical interfaces, the vif scheduler is in charge of applying isolation in the form of airtime slicing to the available radio resources.

Although the hardware specification can provide some upper data rate limits for wireless communications, the actual available data rate of a wireless link can vary greatly. Due to the position of the equipment, obstructions, or even mobility, each User Equipment (UE) connected to a Wi-Fi access point may have a different nominal data rate than other users attached at the same time. In addition, different User Equipment may not support all data rates provided by an access point. Another factor affecting the accessibility of wireless resources is the fact that Wi-Fi's Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) access protocol causes the real data rate to drop when more users connect to an access point. Therefore, it is not possible to promise a tenant a certain data rate as part of their network slice. A Wi-Fi RAN slice in this context is consequently described as the allocation of a proportion of the real radio resources, expressed in terms of airtime. The true time that a packet transmission takes up on the radio medium is known as "airtime." The vif scheduler, which is divided into two halves, is in charge of managing this kind of slicing.

The wireless nodes' local scheduler, an agent piece of software. This programme is built as a kernel module that can be dynamically loaded and is added on top of the mac80211 module. Any underlying virtual access points in the downstream traffic may have precise airtime ratios applied by the scheduler. The SDN controller has a software module called the global scheduler. The global scheduler is in charge of setting up the local schedulers' airtime ratios and keeping track of them to see whether they are being used appropriately.

Network slices may be created using SDN software components after a physical interface has been virtualized and one or more virtual interfaces are operating on top of it. The fundamental process is adding virtual interfaces to software switches that are virtualized, such as Open Virtual Switch (OvS), thereby bringing them to the data plane of the SDN-based solution. The NETCONF module uses the NETCONF protocol to manage the RAN elements, whereas the SDN controller manages the Wi-Fi nodes using OpenFlow and Open vSwitch Database

(OvSDB). The RAN controller provides Representational State Transfer (REST) APIs to the NETCONF module and the OpenDaylight (ODL) SDN controller.

RAN Analytics

Real-time analytics are needed for RAN NFs like radio resource management, which is why the RAN Data Analytics Function (RAN-DAF) is being suggested. Since the RAN must make quick decisions, analytics based on the analysis of real-time measurements must remain local in order to dynamically optimise performance. Additionally, from a business perspective, RAN, Core Network (CN), and Management may all have different stakeholders involved. Therefore, it may be necessary to restrict the storage and analysis of radio-related measurements to CN or Operations Administration and Maintenance (OAM). A more complicated RAN deployment with CU-DU splits as an example might better justify the need of such features. It is possible to investigate several RAN analytics options, including: RAN-DAF might be a management or Self-Organizing Network (SON) feature, or it could be a control functionality in the RAN. Both RAN-DAF implementations will rely on the inter-domain message bus interface because the proposed Service-Based Architecture (SBA), which is intended for both control and management functionalities, is dependent on it. Provides some example features that may be developed and set in accordance with various slice needs and network circumstances given the kinds of analytics and the suggested architectural upgrades that are further discussed.

Virtualized Small Cell (Cloud-enabled small cell) at the Light Data Centre

By deploying mobile core operations near to the mobile edge using current virtualization technologies, the proposed architecture enables more efficient service delivery close to end users. In order to provide MEC capabilities to the mobile operators, improving the user experience and the agility of service delivery, a two-tier virtualized execution environment is envisioned. This environment is materialized in the form of the edge data centre [8].

The Light data centre, which is the first tier, is housed in Cloud Enabled Small Cells (CESCs) and facilitates the operation of the VNFs that make up Small Cell access. Network services enabling traffic interception, GPRS Tunneling Protocol (GTP) encapsulation/DE capsulation, and certain distributed RRM and SON are expected to be hosted by the Light data centre. It might also host VNFs with modest processing requirements like Machine-to-Machine (M2M) Gateway and Deep Packet Inspection (DPI). The network Functional Application Platform Interface (nFAPI) enables the connection between the small cell Physical Network Functions (PNFs) and the small cell Virtual Network Functions (VNFs). The CESC will also provide backhaul and fronthaul transmission resources, enabling the necessary connection.

The Main data centre, which is the second cloud layer, is designed to house more computationally demanding jobs and operations that must be centralised to have a worldwide understanding of the underlying architecture. This includes the centralised Radio Resource Management (cRRM) over the entire CESC cluster as well as the centralised Software-Defined Radio Access Network (cSD-RAN) controller, which is implemented as a VNF running in the Main data centre and controls all radio elements in the geographical area of the CESC cluster. Security applications, traffic engineering, mobility management, and generally any other network End-to-End (E2E) service that can be built and managed on the virtual networks, efficiently and on demand, are additional possible VNFs that might be hosted by the Main data centre.

The Small Cell Enabled by the Cloud. In our context, a CESC consists of a multi-Radio Access Technology (RAT) 5G small cell, together with its standard backhaul interface, standard management connection, and appropriate data model changes [3-19] to enable sharing of radio resources among several operators in the core network (MOCN). A physical small cell unit connected to an execution platform built on a certain microprocessor architecture, such as x86, ARMv8, or MIPS64, makes up the CESC. The implementation of various Small Cell features and capabilities uses the shared compute, storage, and networking resources of the micro servers found in each CESC to provide edge cloud computing and networking. In order to exchange network and IT resources at the mobile network's edge, network operators and virtual network operators may use the CESCs as a neutral host.

By design, the CESC is intended to support many operators (tenants), providing Platform as a Service that may provide the actual physical infrastructure used by several network operators. The CESC environment may host several VNFs for various tenants. Additionally, this offers support for mobile edge computing applications that are installed for each tenant and which, by operating very close to the end users, can considerably speed up service delivery and automatically deliver composite services. The GTP-User Plane (GTP-U) tunnelling protocol also terminates at the CESC, encapsulating user IP packets from the core network entities, such as the Evolved Packet Core (EPC) Serving Gateway (SGW) in LTE, that are headed to the UE and vice versa.

The CESC provides many views of the network resources, divorcing the platform's administration from that of the virtual small cells. These views include the per-tenant small cell view and the physical small cell substrate, which is maintained by the network operator. Instead of providing various S1 (or Iu-h interface) connections from the physical small cell to different operators' EPC network parts like Mobility Management Entity (MME) and SGW, the CESC does such fan-out at the Light data centre. Additionally, as in S1-Flex, the CESC is the termination of numerous S1 interfaces linking it to numerous MME/SGW entities. The connection of several CESCs creates a "cluster" that allows one or more operators (even virtual ones) to reach a larger geographic region while yet preserving the necessary agility to be able to supply these expansions on demand.

The Main data centre and Light D data centre are included in the Edge data centre. In 5G networks, the Edge data centre plans to enhance the MEC and NFV concepts with Small Cell virtualization to support multi-tenancy. Its objectives are to provide cloud services inside the network architecture and to ease the exploitation of network resource data by supporting and aiding in that process. To do this, virtualization methods will be used to offer all the typically hardware components of the Light data centre and the Main data centre as resources. Open frameworks like the Open Platform for NFV (OPNFV) will be used to build extensions for both networking and computation virtualization. Higher levels of flexibility and scalability can be attained by combining the proposed Edge data centre architecture with the ideas of NFV and

SDN. The Main data centre will be able to run various small cells and serve VNFs under the supervision of the Cloud-Enabled Small Cells Manager (CESCM), as shown in the comprehensive architecture. The cSD-RAN controller, which executes cRRM decisions for managing effectively the heterogeneous access network environment made up of various access technologies including 5G RAN, LTE, and Wi-Fi, is specifically hosted by the Main data centre. These radio access networks are controlled by the centralised controller and are customizable. The global network state is updated and maintained by the cSD-RAN controller.

CONCLUSION

a database titled "RAN Information" that contains, among other things, an abstraction of the CESC cluster's radio resource availability. This concept represents the resources in the time, space, and frequency domains as a 3D Resource Grid. The cRRM will make resource allocation choices (like scheduling) using the RAN Information.

The Inter-Cell Interference Coordination (ICIC) services, for example, are centralised SON (cSON) features that may be hosted by the cSD-RAN controller but are not suitable for execution at the Light data centre. The Light data centre will host additional distributed operations such as low complexity distributed RRM (dRRM) and/or distributed Self Organising Network (dSON) operations that do not need the coordination of several tiny cells. An admittance control function, for instance, may do this by basing all of its choices only on the volume of patients already occupying a particular cell.

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CHAPTER 3

A STUDY ON MULTICARRIER MODULATION

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ABSTRACT:

Edge computing with many access points and energy-efficient radio access networks. One of the main responsibilities of the cSD-RAN controller is radio resource management control, which is carried out by a group of RRM algorithms. These algorithms generally include a scheduler, admission/congestion control, and other processes related to the Medium Access Control (MAC) layer. The scheduler assigns physical resource blocks in LTE-like systems depending on the traffic type (or QoS criteria) and the underlying channel quality. There are several special design challenges that must be overcome in order to effectively manage radio resources for the virtualized RANs (also known as the edge cloud), which have the ability to virtualize different parts of the usual wireless stack.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

Assuring the target 5G Key Performance Indicators (KPI), taking into account the Mobile Network Operator's (MNO) need to cut costs (Operational Expenditure OPEX, and Capital Expenditure CAPEX), and attending to the needs of energy optimization are the main objectives of such centralised resource control. Baseband processing for the wireless stack may be virtualized entirely or in part, allowing for resource sharing and right-sizing to reduce over-provisioning. The various solutions employ SDN technology (two tier virtualization) to overcome geographical restrictions and technological gaps in both vertically tier-based and horizontally celled heterogeneous networks in order to provide ubiquitous and universal network services in a variety of use-cases. Additional (deeper) requirements for the design of a centralised scheduler are presented in this section, primarily based on. The support of virtualization via the usage of general-purpose platforms with real-time upgrades [1].

1. Cloud RAN virtualization and resource pooling;
2. Identification of effective function split between network functions (virtual or physical) at the level of 3GPP radio stack;

3. Effective interference mitigation techniques are necessary (especially as a way towards “cell less” architecture);
4. To cope with demands of 5G networks it is needed to consider the need to mitigate issues related with: network convergence, load balancing in cell networks and handover.
5. The above design challenges for the centralized scheduler are discussed in the following paragraphs, one by one.

Application of virtualization using General Purpose Platforms (GPP): When GPP are used for RAN functions, it is difficult to guarantee real-time operation so that millisecond requirements for the Layer-1 function split can be met. However, within extremely constrained time bounds (lower than 100 us), GPP can be used for other compute-intensive baseband components, such as the MAC scheduler. Scheduler and MAC must carry out a certain set of operations during each Transmission Time Interval (TTI), however specialised patches, such as "run to completion," which eliminates the erratic nature of kernel interrupts to wake up jobs during each TTI, may be required. Additionally, the DPDK environment can be used to use and accelerate the Open Event Machine on Intel x86 processors an open source framework for a user-space run-to-completion model. A virtual machine (VM)'s virtual CPUs may be tied to real CPUs. Such modifications have the effect of establishing an essentially exclusive environment for RAN operations.

The mapping between virtualized entities (VM, containers), cells, and Central Processing Unit (CPU) cores must be established since cloud-RAN allows dynamic right-sizing of the processing resources depending on workload. The possibility of dividing RAN modules into "per-user" and "per-cell" activities is particularly important to take into account. Since the scheduler for a cell must take into account the channel state, scheduling metrics, and available resources in order to make the best resource allocations, scheduling is considered to be a "per-cell" operation. The trade-off between virtualization advantage and implementation complexity should be considered, for instance, when deciding whether to distribute resources on a per-user or per-cell basis.Cloud/centralized-RAN's virtual passive optical network (VPON) may be reconfigured to accommodate changes in traffic volume. Resource sharing and Base Station (BS) cooperation are both made possible by VPON creation. By forming VPONs, the whole radio access region may be divided into several service zones. Resource sharing and BS coordination are both made possible by VPON creation. A VPON may be formed of nearby RUs and managed by a single DU.

Identification of an effective split at the level of the 3GPP radio stack: The fronthaul link's latency and bandwidth requirements are largely determined by the functional splits of the radio stack, which have been studied by NGMN [3–24] and included in the 5G New Radio (NR) specification. For example, a delay of 0.5 ms on the fronthaul link roundtrip time is necessary to guarantee peak throughput and maximise the impact of centralization, the split low at the Physical layer (PHY), breaking the Hybrid Automatic Repeat request HARQ loop. As baseband processing (PHY) must be installed close to the Remote Radio Head (RRH), splitting at the non-real-time Layer 2/3 (such as MAC-MAC) offers larger scale centralization and lower latency/bandwidth requirements on fronthaul, while pooling gains are lowered. According to the ETSI Management and Orchestration (MANO) framework, the VNF Manager or Orchestrator should collaboratively optimise the placement of certain PHY, MAC functions. Currently, agreement has not been reached on how network resources will be virtualized from a radio network segment to the centralised baseband processing units and how fronthaul traffic will be transported between RUs and DUs.

Techniques for mitigating interference: With more cell sites, there is a greater likelihood of interference as a result of poor design (more sites need more work to optimise site parameters). The enhanced ICIC (e ICIC), Coordinated Scheduling and Dynamic Point Selection (CSDPS) for downlink, Joint Reception (JR) for uplink, operating at low time-scale, and Coordinated Multi-Point (CoMP), operating at fast time-scale, are a few techniques that need to be taken into consideration in order to combat interference. The performance of multi-cell coordination is significantly influenced by the latency of information flow between cells and the bandwidth available for coordination. Given that distributed BSs in RAN (DRAN) lack the processing power necessary for CoMP, signalling experiences lengthy delays (4–15 ms) over

BSs are connected to the main network through backhaul lines. Therefore, with their virtualization mechanism in place, centralised RAN (CRAN) solutions are required. CoMP offers fluid communication while a user is moving about by reorganising dynamic clusters of RUs that may collectively communicate signal to the user. Edge cell design principles need a cross-layer optimisation framework for resource allocation in SD-RAN. This framework allocates resources end-to-end, that is, by assigning (baseband unit) processing resources, fronthaul transmission resources, and radio resources for each user.

Mitigate concerns with 5G traffic needs and mobility: In contrast to macro cells that can smooth the random fluctuation in the space domain, when cells grow smaller in 5G networks, the issue of traffic load balancing arises. Rapidly moving terminals cause frequent handovers and more delay is unavoidably introduced since 5G cellular networks have cell sizes down to tens of metres. The high overhead will reduce the effectiveness of data exchange when handovers take place across various kinds of heterogeneous wireless networks. Enabling "zero" interference is the ultimate objective of constructing an efficient scheduler. The term "cell-less architectures" is used in literature to describe this development. According to the needs of the mobile terminal and the wireless channel state in various circumstances, the proposed method permits adaptively adjusting the number of Baseline Schedulers for Access Points (BSs/APs).

DISCUSSION

Simple round robin (made for benchmarking) and sophisticated channel-aware proprietary scheduling are the two adjustable scheduling algorithms that will be utilised in the baseline LTE eNB scheduler. It is advised to communicate with the LTE eNB protocol stack using the Functional Application Platform Interface (FAPI), which has been modified to accommodate carrier aggregation and is compatible with the Small Cell Forum. Standardised FAPI interface use makes it possible to collaborate with well-liked open-source protocol stacks (like Open Air Interface) right out of the box. The criteria taken into account by LTE eNB Scheduler while generating scheduling decisions will serve as a strong foundation for creating a centralised scheduler that takes into account the needs and capabilities mentioned above. LTE PHY Lab's functions expand the 3GPP standard by include prospective 5G technologies like the Universal Filtered Multicarrier Modulation (UFMC) modulator and demodulator since it is focused on 5G experiments. Due to its modular software design, LTE PHY Lab may be utilised as a foundation for extensive 5G exploration in our 5G projects, allowing for the validation and verification of any novel waveforms or algorithms that could be included in next 3GPP releases. Many projects and experiments successfully used LTE PHY Lab after successfully verifying it. In showcase 3 of the eWINE project, where the mutual effect of Generalised Frequency Division Multiplexing (GFDM) and Orthogonal Frequency division Multiplexing (OFDM) is explored, LTE PHY Lab is one of the major components [2].

Multi-link Cooperation

As shown in Figure 3-7 for Vehicle-to-Everything (V2X) communications, 5G networks are being developed to enable a wide variety of connection patterns and communication pathways. Infrastructure-based linkages through the Uu interface, which provide Vehicle-to-Network (V2N) communications, as well as direct links via the PC5 interface (also known as "Sidelink"), which facilitate Vehicle-to-Vehicle (V2V) and Vehicle-to-Pedestrian (V2P) message exchanges, are actually envisioned in V2X. For example, the sidelink is anticipated to offer better resource efficiency, latency reduction, and out-of-coverage support, whereas Uu is anticipated to offer higher reliability and higher data rates. These two links have different characteristics, and as a result, are associated with different features. Additionally, Uu supports connectivity to both local and remote functions and servers through the use of local breakout, a concept that avoids having to cross the entire core network by routing the data plane locally through the edge cloud.The use of many communication channels may be advantageous for the complicated V2X environment. As each RAT offers a different level of performance in terms of, for example, reliability, capacity, and latency, there are additional challenges that can be introduced when using multiple Radio Access Technologies (RATs) in certain environments.

It is also important to note that choosing the best communication technology should not only be based on the QoS requirements of the relevant traffic; rather, the specific use case being served at the time should be carefully considered, along with other details like the use case's relevant geographic areas and expected vehicle trajectories. Such information is important because some V2X use cases need solid support to be completed after they have begun. This is the case, for example, with the lane merge service, which controls the speed and trajectories of both cars arriving and already travelling on an interstate in order to ensure seamless insertions. In this situation, the network and application's interaction should be improved to support information exchange, allowing the network to decide which link and radio access technology configuration should be focused on assisting with the completion of the action and taking into account information on the vehicle's trajectory for network tasks (scheduling, etc.) [3].

The answer found to deal with the aforementioned problems is to use multi-connectivity cooperation techniques, where Uu and sidelink communication modes are simultaneously employed for different functions. Particularly, various configurations that might improve reliability or data rate have been taken into consideration. Establishing a supplementary Uu connection for redundancy in case of sidelink failure is one potential approach to increase dependability while utilising sidelink as a main link. Alternately, using both links at once would add redundancy at the expense of high resource usage. Another example involves the Base Station's (BS) dynamic selection of the Uu or SL mode while taking into account the V2X service's QoS needs and mapping the service to the mode (or modes) that are more suitable. On the other hand, dividing the traffic between the Uu and sidelink may increase data rate while also expanding a UE's access to channel resources.

The aforementioned examples can be expanded to include multi-RAT scenarios, taking into account the availability of various communication technologies. Rather than maximising performance on a single traffic type, or per-packet basis, multi-link/RAT selection can be designed to allow the completion of a certain action or man oeuvre associated with the use case. The advantages of techniques for multi-connectivity cooperation include better performance in terms of dependability and data rate, as well as stronger resistance to link failure. By combining different communication technologies or modes, rather than depending just on one mode or technology, which may not be able to handle all use cases on its own, benefits may also include increased service availability [4].

The notion of an RSU-enabled smart zone is developed, offering smart local radio access coverage particular to individual roads under the coordination and control of a macro radio access coverage. Road Side Units (RSUs) may also be used to facilitate multi-connectivity cooperation. The effective exploitation of Uu and SL multi-connectivity, including both RSUs placed along highways and gNBs of macro coverage layer, is made possible by the smart zone, which constitutes an intermediary layer abstracting mobility and channel resource management.

Local end-to-end Path

The data traffic that is transferred between vehicles (V2V) has localised relevance in many V2X use cases (for example, cooperative movements and sensor information sharing). This indicates that different transmission modes (unicast, broadcast, and multicast) may be necessary, but that communicative vehicles involved in the same use case are situated in the same area and do not need connection to a distant server. Depending on the radio settings and the surroundings where the V2V use case occurs, either the cellular (Uu) interface or the sidelink (PC5) interface might be utilised for localised V2X communications. Particularly in situations where there is no line-of-sight between communication vehicles, poor PC5 radio circumstances, or significant PC5 interference, the NR-Uu interface might provide QoS (i.e., high dependability, low latency). However, existing cellular solutions built on the Uu interface might require some updates to support the demanding performance requirements that localised V2X services have, such as the need for quick and secure localised data transmission [5].

To allow the quick and reliable transmission of localised data traffic among the involved devices while supporting their QoS requirements and the characteristics of the V2X services, the establishment of local end-to-end (E2E) radio data routes over the Uu interface is suggested. In contrast to the "local" term, which indicates that the paths are established through the BSs, the "end-to-end" term indicates that the (user plane) radio data paths are established among the involved communicating end devices (i.e., vehicles). Since the data traffic is localised and handled directly among participating BSs, the focus of local E2E paths is on preventing the nodes of the core network from taking part in user plane transmissions. Without having to interface with external entities like the Multimedia Broadcast Multicast Service (MBMS), local E2E pathways through the BS may support several communication modes (unicast, multicast, and broadcast) [6].

A data routing/forward function that sends data packets among cars quickly and reliably must be added to the BS (gNB) in order to provide localised communication over the Uu interface. This routing table in the BS links and maps the uplink (UL) and downlink (DL) radio bearers of various UEs in order to establish local radio pathways, which in turn enables the forwarding of localised V2X traffic to occur more quickly. The routing table at the BS takes on the responsibility of forwarding the data packet to one or more UEs in the same or neighboring cells depending on the kind of traffic [7], [8].

CONCLUSION

For localised V2X traffic and to send and receive data packets through a local E2E link, a UE requests the formation (or update) of the local cellular V2V pathways utilising Radio Resource Control (RRC), Non-Access Stratum (NAS) protocols. The starting UE should give information that is needed for the setting of the routing tables as well as for the construction of the pathways, such as the kind of service and the identities of other involved UEs in the related V2V service. In order to create, update, and release local cellular V2V pathways between UEs via gNB(s), as well as to update and configure the routing table required for the forwarding of localised data traffic, RRC and NAS protocols must be extended. The establishment, modification, and release of this new kind of link (local cellular V2V paths), as well as the updating and configuring of the routing tables that are introduced at the BSs in order to form V2V paths for localised V2X traffic over the Uu interface, can all be controlled by the core access and mobility management function (AMF) and session management function based on these RRC or NAS messages.

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CHAPTER 4

A BRIEF DISCUSSION ON FORWARD ERROR CORRECTION

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ABSTRACT:

Broadcasting and multicasting in RAN. Both the launch of an NR mixed mode with multicast capabilities and its expansion to a terrestrial broadcast mode with characteristics comparable to the LTE en TV MBMS but based on the new 5G-NR air interface have been taken into consideration while designing the introduction of multicast and broadcast capabilities. The NR mixed mode, which is intended for use in a variety of sectors including media and entertainment, automotive, the internet of things (IoT), and public warning, provides dynamic and smooth switching between Point-to-Point (PTP) and Point-to-Multipoint (PTM) transmissions. The NR mixed mode air interface's design principles include forcing the same cell scrambling sequence on nearby cells to enable multiple cell coordination, maximum compatibility with the NR air interface for PTP, inclusion of crucial PTM features like scheduling and channel acquisition for large user groups using a common Group Radio Network Temporal Identifier (G-RNTI), and new DCI format. To enable single-frequency network (SFN) regions and wider deployments, negative numerologies and the idea of mini-slots are added.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

Users on mobile and/or stand-alone broadcast networks without uplink capability may receive TV and radio services using the terrestrial broadcast mode. Transmission across broad coverage areas in High-Power High-Tower (HPHT) networks with single-cell, multi-frequency network (MFN), and SFN topologies is one of its architectural tenets. The allocation and delivery parameters of terrestrial broadcast services delivered in an NR frame have been added to the NR mixed mode to enable this. The current NR mixed mode architecture is not much impacted by the single-cell or MFN techniques. It is necessary to define a new physical channel as well as new cyclic-prefix values and reference signals with very small carrier spacings (even smaller than those offered in the NR mixed mode) in order to accommodate the big area SFN with extremely wide inter-site distances [1].

The 5G multicast services need to be accessible in dynamic regions where the multicast area's user distribution is likely to fluctuate over time and where the number of users during popular events may be considerable. The RAN is aware of the UE's desire to accept data from an IP multicast group in the context of multicast and the NR mixed mode. The NG-RAN's Dynamic RAN Multicast Areas (RMA) with synchronization point may handle a wide range of deployments, from one cell under one DU to several cells under various DUs, all under the direction of the same CU.

The setup of multi-cell transmission would be handled by a separate network entity, which is not included in the proposed RAN design. The method instead makes advantage of run-time transmission parameter setting. To guarantee that the same material is sent by gNB-DUs at the same time and frequency across different cells, there must be a point of coordination and synchronisation. In the RAN design, the coordination point is positioned hierarchically above the gNB-DUs, for example in the gNB-CU. The user plane activities to transmit the multicast data to one or more DUs joining the multicast transmission inside the RMA are covered by the multicast capability within gNB-CU, which may be referred to as gNB-CU-MC.The protocols and RRM features are made to enable the new radio's flexibility and efficiency, which are needed for current and upcoming services like media, group communications, and V2X communications. Multiplexing of unicast, multicast, and broadcast is anticipated to be the key strategy in attaining the required efficiency in this regard[2], [3].

According to user distribution or service needs, the RAT is anticipated to provide dynamic adjustment of broadcast and multicast regions as well as dynamic selection of unicast (PTP), multicast, and broadcast (PTM) broadcasts. These functions are intended to be enabled by the proposed Xcast L2 protocol architecture, which includes a switching function between the Radio Link Control (RLC) and Packet-Data Convergence protocol (PDCP) layers. The switching capability is provided in gNB-DU for cloud-based deployment. RRM features that are very adaptable, effective, and dependable.

Support for smooth switching between PTP and PTM transmission modes at the radio access level for flexible delivery of multicast or broadcast data. If a small number of UEs are using a service in broadcast or multicast mode in a particular region, mapping PTM radio bearers to PTP radio bearers may improve spectral efficiency. Additionally, switching from PTM transmission to PTP transmission by mapping PTM radio bearers to PTP radio bearers may increase spectral efficiency by taking advantage of PTP advantages like link adaptation and HARQ (taking the latency constraint of the service into account) if a UE using PTM transmission is experiencing poor radio channel conditions[4], [5]. Whenever switching from PTM to PTP transmission modes, support for selective Forward Error Correction (FEC) is provided. To enable the radio access network to intelligently choose just source packets for the PTP radio bearer and both source and repair packets for the PTM radio bearer, the Application Layer FEC (AL-FEC) selective FEC technique is utilised.

Support for PTM gearbox modes' feedbacks. The possibility of feedback and error correction systems has been looked at to help with the large packet losses that threaten the technical requirements under subpar channel conditions of PTM transmission. In order to achieve this, a Layer 2 Error Correction (EC) and link adaption for PTM in the radio access network are suggested. Support for HARQ feedback optimisation in PTM bearers using QoS-aware feedback. When there are a large number of UEs, ACK/NACK feedbacks may cause a significant increase in signalling overhead, which significantly reduces overall network efficiency. The HARQ feedbacks are optimised depending on the service's QoS requirements in order to reduce the signalling overhead to some degree [6].

Support for effective broadcast and multicasting over at least the time and frequency domains. Support for link adaptation mechanisms in coordination with higher layer error correction schemes, such as layer 2 EC, is necessary to achieve an effective and dependable broadcast / multicast wireless link that satisfies the minimum expected Quality of Experience (QoE) requirements of a service at the lowest possible cost without sacrificing the network's spectral efficiency.

X-cast tunnel

RAN Deployment Options

1. To ensure integration with existing legacy 4G systems, and to allow independent deployments of 5G RAN and 5G Core, 3GPP has specified a set of architecture options. The numbering of options by 3GPP is not incremental in terms of the likely chronological order that deployments may occur – it is easier to consider the first likely implementation to be one of the “Non- Stand Alone” (NSA) options which will then be followed by one of the “Stand Alone” (SA) options.
2. Whilst 3GPP has defined a number of options, most implementations base their NSA deployment on Option 3/3a/3x. Options 3, 3a and 3x (Non-Standalone) allow NR deployments reusing EPC with the support of LTE eNB. With these options, the LTE eNB is connected to the EPC with Non-standalone NR. The NR user plane connection to the EPC goes via the LTE eNB
3. (Option 3) or directly (Option 3A). In Option 3x, the solid line shown between LTE-eNB and gNB is used for user plane data transmission terminated at the gNB, i.e., S1-U data from EPC is split at the gNB.

This often leads to Option 2 Standalone deployment. A complete 5G system, comprising a 5G Core and GNB, is defined under Option 2 (Standalone). Future analysis may cast doubt on the usefulness of this evolutionary step.

LTE eNodeB and EPC are clearly necessary for Option 3, and they will remain operational long after Option 2's 5G-NR SA deployment is complete. Indeed, interfaces between 5G and 4G systems will be required to enable handover and fallback from 5G to 4G unless Option 2 5G-NR has coverage that matches or exceeds LTE in a network. Because of this, even if Option 2 may be the most pure form of 5G-NR deployment, Option 3's legacy will persist practically, despite a reduced need on an LTE Anchor attachment [7].

The implementation of new 5G radio capacity will be dependent on a variety of practical considerations that will address the top priorities, including the following: Previous 4G radio infrastructure: The NSA alternatives may be simpler to implement if the radio operator already has some 4G deployed radio. The placement of the new locations for installing the new 5G radio antennae will also depend heavily on the presence of old radio infrastructure.

Covered area of the deployment: we can classify the deployment in the following types:

1. **Far Edge:** Provides the smallest latency, but requires deploying the MEC services in many locations. Ideal for localized deployments like factories;
2. **Aggregated Edge:** Providing low latency, covering several radio nodes, ideal for city size deployments;
3. **Regional:** This deployment is ideal for services that must be provided at region level, the solution is optimal for the deployment of capacity in a regional area, covered with a few MEC servers;
4. **Central:** Massive deployment, the new applications will be available in the whole network just by deploying a few MEC servers.

The many frequency ranges and their accessibility to operators at the national level or in the various covered regions are referred to as carrier aggregation and frequency availability, respectively. In certain deployment scenarios, the baseband bandwidth capacity for the various new 5G radio frequencies and combinations with carrier aggregation of the various 5G frequencies or 5G/4G frequencies will result in highly resilient deployments with very high user bandwidths.

Using the "Capabilities exposure" functions, MEC's new applications will support the creation of new KPIs and monitoring support. The Network Exposure Function (NEF) in the ETSI MEC is a particular function for exposing the capabilities and services of the 5G CN Network Functions to outside parties. Some services and capabilities may be exposed via NEF, such as the following [8]:

1. **Monitoring:** Allows an external entity to request or subscribe to UE related events of interest. The monitored events include a UE’s roaming status, UE loss of connectivity, UE reachability and location related events.
2. **Provisioning:** Allows an external entity to provision expected UE behavior to the 5G system, for instance predicted UE movement, or communication characteristics.
3. **Policy and Charging:** Handles QoS and charging policy for UE based requests made by an external party, which also facilitates sponsored data services.

Visible Light Communication-based GNB

As stated in, Visible Light Communication-based gNB (VLC-gNB) is a 5G small cell solution for indoor settings made up of two interconnected major subsystems: the networking and services subsystem and the radio access network subsystem. The visible light communication and mmWave modules used in the radio access network subsystem release radio resources for interior situations at 60 GHz unlicensed or 40 GHz licensed bands. The VLC-gNB can provide Gbps data throughput and sub-meter location precision inside thanks to these technologies.

The Intelligent Home IP Gateway (IHIPGW) is a component of the networking and services subsystem. For the VLC-gNB, it provides intelligent management, adaptable deployment, and add-on services. Utilising SDN and VNF technologies provides the intelligence and flexibility needed to deploy UE's location server with sub-meter accuracy, which in turn supports the deployment of ancillary services like smart TV services and location-based data access services [9]. A smart solution is offered by the VLC-gNB for a variety of interior settings, including tube stations, homes, museums, and shopping centres. To enhance user experience and to lower backhaul traffic and latency, it delivers local internet breakout and higher QoS for UEs. The deployment of the VLC-gNB as a component of MNO RAN is the next step; however, the integration of the VLC-gNB with RAN has to be carefully thought out in order to offer a solution that does not degrade the advantages obtained during operation in the standalone contexts. The VLC-gNB indoor small cells may be installed in a variety of ways, as seen below.

Standard topology Deploying All-Connected (AC): Every VLC-gNB small cell is present and linked to the main network. UE traffic is traversed back to the core without the assistance of the outside gNB. The VLC-gNB small cells connect to the 5G core using the NG interface (N2/N3) while connecting to all other VLC-gNBs and gNBs via the Xn interface. In comparison to other possible deployments, adopting AC-VLC-gNB deployment results in higher flexibility and lower latency at the expense of relatively higher cost and handover signaling.

1. **Dual Connectivity (DC) deployment:** DC supports Stand Alone (SA) and Non-Stand Alone (NSA) deployments, the latter is considered to enable gradual transition to 5G network by enabling indoor gNB small cell to work with LTE outdoor eNB.
2. **gNB and VLC-gNB DC:** UE is connected to outdoor gNB acting as a Master Node (MN) and one VLC-gNB small cell acting as a Secondary Node (SN), as shown in Figure 3-17. The MN is connected to the 5G core via NG interface and to the SNs via Xn interface.
3. **eNB and VLC-gNB DC:** UE is connected to outdoor eNB acting as a Master Node (MN) and one VLC-gNB small cell acting as a Secondary Node (SN). The MN is connected to the Evolved Packet Core (EPC) via S1 interface and to the SN gNB via the X2 interface. The SN gNB might also be connected to the EPC via the S1-U interface and other SN gNBs via the X2-U interface.

Adopting DC deployment makes the cost relatively high, while enabling more flexibility, lower latency and handover signalling compared to other deployments.

VLC-gNB as Distributed Unit (DU) deployment: In DU-VLC-gNB deployment, each VLC-gNB only includes the RLC layer, MAC layer, and physical layer, while the Centralised Unit (CU) for a collection of the VLC-gNB DUs is retained as a VNF at the gNB and is known as the Virtual Gateway (V-GW). The F1 interface is used by V-GW to connect to VLC-gNB DUs, as illustrated in. The gNB connects to the 5GC using the NG interface and the other gNBs via the Xn interface. By giving all linked VLC-gNB DUs a single point of contact with gNB, V-GW is built as a VNF that resides inside gNB to optimise signalling and operation of the VLC-gNB DUs. Additionally, because it makes use of NFV technology to offer virtualised network entities like V-proxy/cache servers, it allows the VLC-gNBs to offer intelligent services. Adopting DU-VLC-gNB deployment results in relatively low costs, flexibility, and handover signalling, but relatively higher latency.

Due to the extraordinarily high data speeds needed on the CPRI Fronthaul (FH), the introduction of huge Multiple-Input Multiple-Output (MIMO) with many dozens or even hundreds of antenna components makes present CPRI-based C-RAN systems unfeasible. Parts of the baseband's Digital Signal Processing (DSP) must be included into the remotely deployed radio modules in order to prevent this. With full analogue and Radio Frequency (RF) processing, as well as some baseband capability, the RRH and distributed unit merge.

DISCUSSION

Several Radio Sub-Units (RS-Us) and an Interface Sub-Unit (ISU) can be distinguished from one another. The RS-We is in charge of each antenna's processing, including calibration, analogue and RF processing (filtering, amplifiers, and data converters), local power distribution, and an interface with the ISU. The ISU manages and controls all joint processing, including partial baseband processing, and interfaces with the CU. The AADU employs a modular strategy, assembling the antenna array from many identical RS-Us. This provides the following benefits: Analogue components are located close to antenna elements, avoiding long RF routing distances; per-antenna processing can be performed on distributed hardware, reducing processing requirement per RS-U; and finally, the data rate between the RS-U and ISU can be reduced, as each link only transports data of a subset of the antennas. The functional split that is selected has a significant influence on how an AADU is designed since it affects both the processing power and the interface specifications. The proposed AADU design includes an extra, inter-CU functional divide between ISU and RS-U in addition to the standard functional break between CU and DU. Three distinct functional split possibilities that are being thought about for the AADU. The associated qualities are mentioned below.

Option 1:

1. Time-Division (TD) beamforming in RS-U, ISU serves only as interconnect, remaining PHY processing on CU.
2. High FH and ISU/RUS data rate, but reduced compared to per-antenna transport.
3. Limited processing capabilities in AADU (TD beamforming only).

Option 2:

1. TD beamforming in RS-U, partial PHY processing on ISU, remaining PHY processing on CU.
2. Higher computational requirements for ISU due to Fourier Transforms.
3. Beamforming weights and pilots need to be transferred between CU/DU.
4. Further reduced FH data rate.

Option 3:

1. Partial PHY processing in RS-U, remaining PHY processing on ISU.
2. Higher computational requirements for RS-U due to FFT/IFFT.
3. Possibility to perform FD beamforming.
4. Higher computational requirements for ISU (full PHY processing).
5. GPP+FPGA required in ISU.

Low FH data rate.

The interconnect design of the AADU, which is connected to the functional divide, also affects the interconnect data rates. Daisy chain, star, or column-wise interconnect are the three possibilities that may be taken into consideration. Data is transmitted from one RS-U to the next in the daisy chain design, and only one RS-U is directly linked to the ISU. In this situation, the data stream from all RS-We must be carried through the final RS-U/ISU interface. For split options 1 and 2, where the beamforming is done at the RS-U, this has no effect, but for option, it could effectively quadruple the interface data rate. In contrast, each RS-U in the star design is directly coupled with the ISU. The data rate on each particular interface is therefore constrained. Longer route distances are a drawback, because the ISU must still send and receive data at the full pace. Last but not least, the column design combines daisy chaining across various rows of RS-We while employing a star architecture for various columns.

Optical Beam forming

The Optical Beam Forming Network (OBFN) is a photonic-based device that uses a single arrayed antenna to generate several reconfigurable RF beams for wireless access. With regard to the radiating pattern form and the beam's directivity, reconfiguration is accomplished individually for each produced beam. The number of output beams produced is equal to the number of feeding (input) data streams, and the arrayed antenna's number, type, and arrangement of antenna components define the form of the output beams. Since the signals are fed in parallel to the antenna elements (by the photonic OBFN chip), the overall complexity, power consumption, and footprint are significantly reduced when compared to the single beam forming (electronic) solutions. The number of arrayed antennas and driving circuits needed for an equivalent single beam solution would be the same as the number of created beams.

A Blass matrix and genuine time delay circuits are implemented on an integrated optical chip (such the SiN TRIPLEX® integration platform) to create the foundation of the OBFN solution. The optical data signal is accepted at each of the OBFN's inputs so that it may be broadcast across a specific beam by the antenna array linked to the output of the OBFN. The antenna components of the array that is connected match the OBFN's output ports. Consequently, a MxN OBFN can theoretically produce up to M distinct beams from a set of N antenna elements. When multiple copies of a signal with different phases are transmitted from a set of equally spaced antenna elements, the signal copies constructively interfere at a specific angle from the antenna array. This is how the system works: each of the input optical signals is broadcast to all (or designated) outputs of the matrix, providing certain phase differences. The phases of the OBFN matrix components may be adjusted to steer the produced beams.

A coherent and an incoherent OBFN have both been offered for examination in Incoherent processing denotes the employment of a number of wavelengths (i.e., lasers) that are mixed in the OBFN and processed incoherently in the detector. The greater optical power at the photodiode and thus improved RF connection performance is one benefit of using multiple lasers. The main implementation flaw is the need for a close proximity between the OBFN module and the antennas in order to prevent fiber dispersion from affecting phase discrepancies.

Since each input data stream comes from the same optical source during coherent processing, dispersion is not a problem. To ensure that the various copies appear synchronized at the antenna elements in the latter scenario, all parallel output routes to the antenna elements must precisely preserve the same length.

The incomprehensible version may be used right near the cell site and installed beside the antenna in both the uplink and downlink directions. The use of Multi-Core Fiber (MCF) connections in the optical fronthaul distribution network is a promising approach for the coherent version. In this scenario, the OBFN chip may be situated in the network's Central Office (CO), which would allow it to remotely feed the OBFN antenna array at the cell site. This is because MCFs may maintain (in theory) the rigorous phase difference criteria since there are almost no length variances between their cores. However, in practice, slight temperature differences may result in subtle variations that affect overall performance, necessitating additional research.

The preliminary general designs for the incoherent OBFN uplink and downlink pathways are shown here. This article adopts the Analogue Radio over Fiber (ARoF) scheme as a more adaptable method of RF spectrum allocation. The downlink's resource requirements are reduced in the ARoF instance because the beam contents may share the same optical carrier while being divided at the RF spectrum domain. The received signals are pushed via the OBFN in the uplink direction by all of the antenna components carrying the supported beams' spectrum mixing. The data streams for each beam are split up into various optical carriers at the OBFN output, where they may either be multiplexed and transmitted back to the CO or delivered in parallel on MCF lines. It should be noted that Digital Radio over Fiber (DRoF) transmissions may also be used to construct the OBFN-based multi-beam generation system, with each signal occupying a different wavelength channel in the optical backhaul distribution in this scenario.

CONCLUSION

In addition to the RF spectrum allocation, optical beamforming theoretically adds a spatial resource allocation component to radio access. As long as the users are separated by distance, this enables the allocation of a certain RF band to many wireless users using various beams from the same arrayed antenna. Furthermore, as long as the spatially overlapping beams carry different RF bands, two or more users located in the same direction from the antenna can still receive/transmit at the maximum rate of the defined standard. The combined spatial and spectral dimensions from a single multi-beam RRH enable the provision of a greater number of connections at high data rates while optimizing the distribution of the shared resources. The optical fronthaul domain uses the same mixed spatial-spectral allocation method, which is repeated with the inclusion of MCF linkages or, more realistically, with the consideration of fiber bundles linking various RRHs at cell locations. In an architecture that depends on the simultaneous (spatial) transmission of signals from the CO to the antenna elements, both options may be used, depending on the location of the beamforming integrated chip.

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CHAPTER 5

A COMPERHESIVE STUDY ON GENERAL CORE VNFS

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ABSTRACT:

The virtualized MEC computer, networking, and storage resources make up the xMEC hosting infrastructure. On top of that is the MEC NFVI. The VNFs created and used to allow the smart energy services are also provided by the xMEC. General VNFs, General Application VNFs, and Utility Specific VNFs are the three categories into which they are separated. In order to allow smart energy services, the edge computing platform makes communication, processing, and storage resources accessible for (designed) service functionalities of many domains in an integrated manner. Independent of the kind of VNF, the flavour (i.e., the quantity of dedicated resources and scaling behavior), location, and policy are all maintained in the same manner.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

The xMEC will host all complex time critical functions, as it will be in close physical proximity with the specific network element. The xMEC also provides the VNFs developed to enable the smart energy services. These VNFs can be classified in the following groups [1]:

General Core VNFs:

1. **vTSD (virtual Terminals Self-Discovery):**This VNF, offers device and services discovery services at a local area level (depending on the area covered by the base station hosting the xMEC stack);
2. **vSON (virtual Self-Organizing Networks):**Offers device topology determination as well as optimized routing services to groups of devices that have limited network connectivity capabilities;
3. **vMCM (virtual Machine-Cloud-Machine):**Allows utility resources to be stored in the cloud and accessed by multiple users overcoming any scalability issues;
4. **vMME (virtual Mobility Management Entity):**An extension to the standard LTE MME, which provides for idle mobile devices paging and tagging including GPS location (like when safeguarding the location of EVs, mobile terminals or drones);
5. **vBCP (virtual Block chain Processing):**Offers an easy-to-use and universal API gateway allowing multiple applications to benefit from the security, immutability and transparency properties of the block chain technology;

6. **vAAA (virtual Authentication, Authorization, Accounting):**A VNF similar to the AMF, which provides services related to the administration of the field devices at the level of AAA.

General Application VNFs

1. **vMPA (virtual Media Processing & Analysis):** performs near-real-time video stream processing and analysis so that results of the drone-transmitted video data are managed in real time, for instance);
2. vDFC (virtual Drone Flight Control) performs real time autonomous remote control of drones.

Smart Energy Specific VNFs

1. **vPMU (virtual Phasor Measurement Unit):**Monitors the state of the grid by measuring voltage levels and frequency values of selected grid locations;
2. **vESR (virtual Electricity Substation & Rerouting):**Enables control of the local substation and electricity rerouting activities;
3. **vRES (virtual Renewable Energy Sources):**Provides low-latency flexibility services to the grid operator that can be used in demand response (DR) campaigning to keep the grid balanced;
4. **vDES (virtual Distributed Energy Storage):**Provides energy flexibility in a certain time interval; the function deals with flexibility provisioning services to the grid operator that can use it to issue demand DR campaigning.

According to 3GPP specifications, the 5G System (5GS) architecture consists of a core network (CN) and one or more access networks, including a radio access network (RAN). The CN can support both mobile and converged networks, and it is made up of network functions (NFs), NF services, and the interaction between NFs to support data connectivity and other services. Deployments using methods like network function virtualization (NFV) and software defined networking (SDN) are made possible by the CN. A logical explanation of the design is provided by the 5GS architecture.

The provision of infrastructure connection, also known as transport network connectivity, from the Access Points (APs) to the CN is clearly necessary in this situation. The network fabric linking NFs, CN, and RAN, as well as the RAN units, is provided by transport networks, which serve as the 5GS basis. The 5GS is intended to support newly developed services. This has significant implications for transport networks, which must adapt to meet the demands presented by these services. The RAN designs covered in-depth in the prior chapter are capable of implementing the Cloud-RAN (C-RAN) concept, which calls for infrastructure connection inside the RAN, for instance between centralised units (CUs) and distributed units (DUs), also known as fronthaul (FH).

In order to address the issues provided by growing services, the C-RAN concept presents the requirement to enable new operational network services across the transport network. It is also possible to leverage the transport connection to provide various RAN split options, which enable the breakdown of the conventionally monolithic RAN processing services stack into a number of distinct units. The number of units is determined by the RAN functions' functional split option. The functional split, or the distribution of duties among the RU, DU, and CU, has a significant effect on the transportation network and has the ability to loosen the relevant constraints for overall capacity, delay, and synchronisation. The best split choice for the C-RAN relies on a number of factors, including supported services, service needs, FH and BH technology and protocol, among others. It is suggested that BH and FH be supported concurrently in a shared infrastructure to maximize coordination and resource sharing advantages. This will enable management simplicity and efficiency improvement, which will have real advantages for cost, scalability, and sustainability [2].

Core Network Architecture

With reference to the 3GPP system architecture outlined in Release-15, the support for multicast, broadcast, and integrated data analytics framework in the 5GS is examined. To understand the demands on the transport network in terms of the employed transport protocols on these interfaces, we first provide an overview of the interfaces in the 5G CN, including the interface between the CN and RAN. User and control plane separations are one of the core ideas behind the design of the 5GS. Through an HTTP-based service-based interface (SBI), control NFs provide their services to other control NFs. The N4 reference point serves as the conduit for communication between the control plane and the user plane of the CN, or between the session management function (SMF) and user plane function (UPF), respectively. PFCP and GTP-U are used for the control plane and user plane portions of this interface, respectively. GTP-U and PFCP are both delivered through IP/UDP. Additionally, GTP-U is used between UPFs and between an access network and a UPF. NG Application Protocol serves as the control protocol between CN and the access network at reference point N2.

Multicast and Broadcast

The multicast and broadcast design philosophies of the CN are compatible with those of the 5GS. Even though the architecture is discussed with a mobile CN in mind, a converged network can also use this network design. From the standpoint of the CN architecture, additional multicast and broadcast capability concepts include the following: On top of the current unicast architecture, enabling multicast and broadcast capabilities should only need a tiny footprint [3]. Treat multicast and broadcast as internal optimisation tools within the network operator's domain whenever possible. Consider terrestrial broadcast as a service that may be provided as a self-contained service by a subset of multicast and broadcast architecture that is available to UEs with and without uplink capabilities. To keep the system cost minimal, streamline the setup process. The design tries to create a system that uses resources efficiently and has a straightforward architecture and protocol. However, the architecture should also allow for flexible session management. Pay attention to the protocols that enable effective IP multicast. Enable the network's caching capability.

It is believed that the system's multicast and broadcast capabilities are available as a service or as a component of transportation, which has a direct bearing on the envisioned NR mixed mode and

NR terrestrial broadcast mode. The interchange of multicast and unicast PDUs between a data network and a user equipment (UE) is provided by a connection service that includes multicast and unicast as components. The N6 interface itself and the UPF terminating it are both multicast enabled in this arrangement. Existing NFs, such SMF and RAN, are improved to allow for the resource-efficient delivery of multicast PDUs. Similar to unicast, content providers may control how multicast PDUs are transmitted across the system by supplying QoS requirements using the services provided by Policy Control Function (PCF). Transparent multicast transport is the term used to describe this operation since the system does not provide any additional services like dependable multicast delivery.

The system provides a number of multicast and broadcast services, also known as point-to-multipoint services, which may be accessed using an interface with well-defined APIs, such the xMB interface. For instance, xMB provides sessions in the streaming, file, application, and transport modes.

A content provider may have control over the usage of related services, including metrics reporting, audience size measurement, and dependable delivery via application layer forward error correction and retransmissions. The xMB interface may be used to implement a geographical broadcast, such as file delivery, streaming, or terrestrial broadcast for the dissemination of TV and radio services geographically. Because UEs are not required to be connected and registered to the network, the terrestrial broadcast only needs a portion of the core and access networks' functionalities.

XCF, SMF, UPF, NRF, and NEF are the main network operations involved in providing terrestrial broadcast services. The upgraded network architecture for multicast and broadcast is shown in. Both new NFs and new features are added to the current NFs by the architecture. It should be mentioned that a different option was looked at.

A 5G 3GPP modem, a converged middleware, a non-3GPP modem, and an application make up the deconstructed UE. Multicast PDUs are passed from modems to a network interface provided by an operating system in the case of transparent multicast transport, from which point they can be used either directly by the application or by converged middleware, such as an HTTP client library that implements HTTP over multicast QUIC. Converged middleware is a peer entity to Xcast Control Function (XCF) and Xcast User Plane Function (XUF) in the case of point-to-multipoint services.

1. The XCF functionalities related to the control plane of xMB interface include authentication and authorization of XCF for a content provider and vice versa, creation, modification and termination of services and sessions. The XCF interacts with other NF over service-based interface and over an Nx reference point with XUF.
2. The XUF is an ingress point for content from a content provider. The use plane of the xMB interface offers both pull and push options for content ingestion. The XUF functionalities include, for example, reliable data delivery over unidirectional transport and application-layer forward error correction (AL-FEC). The XUF sends multicast IP packets via an N3 tunnel to UPF.

3. The UPF is enhanced to support multicast group membership discovery, e.g. Internet Group Management Protocol (IGMPv4) or Multicast Listener Discovery (MLD), and multicast routing (e.g. Protocol-Independent Multicast) in addition to the functionalities already specified [4].

A system's configuration for multicast or broadcast is done using the session management features of SMF. Either a request from UE, a request from XCF, or a notice from UPF will start the session management operations. To allow multicast or broadcast, NFs and other architectural components must fulfil a number of processes. Here, we provide a brief explanation of the PDU session modification process that produces system configuration and transparent multicast transport.

This process is covered in full in along with others. The UE broadcasts a message (such as IGMPv4) in the first stage to join a multicast group. The SMF is informed of a user plane event at the UPF that results from the receipt of this message. If the event is triggered for the first UE joining the group, the SMF looks for an existing multicast context for this group or creates a new multicast context. The RAN then learns about the multicast group and the UE joining it through the PDU session update operation that the SMF then starts. Each UE that joins the multicast group has its information stored in the RAN. The data is used by the RAN to configure the UEs' RAN. A set of unicast, single-cell point-to-multipoint (SC-PTM), and multi-cell point-to-multipoint (MC-PTM) transmissions are determined to be the most efficient transmission by the RAN based on this data; see section.

Analytics Framework

The integrated data analytics framework takes into account data analytics capability at various layers and introduces data analytics functions (DAFs) into the application function level (AF-DAF), Big Data and Management & Orchestration (Big data/MDAF), UE/RAN-DAF, and data network (DN-DAF). For various use cases and objectives, numerous instances of each logical data analysis module are built. For instance, the Management & Orchestration layer's Big Data Module might be implemented in several ways at various levels (e.g., cross- and intra-domain) for various domains (e.g., RAN data analytics, VNF data analytics, etc.). Such a framework enables cross-layer optimisation and the building of specialised data analytic modules at various levels. SBIs and a variety of data analytics modules can link.

1. **Interface 1:** NWDAF interacts with AF (via NEF) using NW layer SBI.
2. **Interface 2:** N1/N2 interface.
3. **Interface 3:** O&M layer configures the NF profile in the NRF, and NWDAF collect the NF capacity information from the NRF.
4. **Interface 4:** MDAF interacts with application/tenant using northbound interfaces (NBI).
5. **Interface 5:** MDAF interacts with RAN DAF using O&M layer SBI.
6. **Interface 6:** NWDAF consumes the services provided by MDAF using cross layer SBI.
7. **Interface 7:** MDAF consumes the services provided by MWDAF using cross layer SBI.
8. **Interface 8:** MDAF collects data from NW layer via trace file/monitoring services.

DISCUSSION

Data Analytics Characterization

First, depending on the predicted or expected parameter, we divide the prediction/analytics functionalities into various levels. This may relate to a UE session, the use of resources in a certain domain, the functioning of an application or service, or any combination of these. Parameters connected to the UE/Session: These characteristics could contain UE context/behavior predictions to help the network better allocate resources. One example is the user's or group's mobility, which may be utilised for handover management, or the forecast of the interference the UE will experience at a certain location. Prediction of QoS for one or more UEs in a certain region is another example.

Parameters relating to the network these criteria may be categorised in this area according to the domains they pertain to. In RAN, parameters may relate to traffic (such as user density) as well as radio resource availability and conditions (such as average channel quality, load, and interference), as well as other real-time or non-real-time aspects. The factors that may be estimated in transport and backhaul relate to the availability, dynamicity, topology, resource circumstances, and backhaul/fronthaul (BH/FH) type. The processing load and availability of CN functionalities are the last two characteristics for the CN that may be monitored [5].

Parameters relating to services: This category contains analytics that may be carried out inside the context of an application (for example, at the terminal or at the application function), and which the 5G network may employ to enhance the functioning of a service. The prediction of UE trajectory/route, traffic conditions, or anticipated Level of Automation (LoA) for a certain location are a few examples that are peculiar to the V2X slicing application. Parameters for management: According to 3GPP SA5, this category comprises analytics for Performance Management (PM) and Fault Management (FM). The MDAF will get analytics from this set of parameters, which may also take into consideration the slice/subnet's current performance and information on things like radio failures.

Cloud-Related Metrics

This contains the cloud processing characteristics, such as load and resource availability, which may influence the choice to virtualize NFs on cloud platforms. The aforementioned types of parameters may be delivered on demand in edge or core cloud platforms in a distributed cloud-based architecture. For activities like shifting the processing load to other cloud processing units, analytics on the expected computational resource load/conditions are crucial because to the stringent latency and reliability requirements of various virtualized NFs (e.g., in the RAN domain) [6].

Granularity of analytics

Real-time: The analytics can be performed in real-time operations (e.g., channel prediction in ms time scale). However, this is a more challenging task due to the fact that additional processing might be required and the overhead may affect the performance. Near-real time / Non-Real time: In this case the analytics is performed in sec/min/hour time scale and may apply to certain types of prediction (e.g., load distribution in a geographical area). In Open-RAN (O-RAN), near-real time operations have been defined to capture operations like QoS management, traffic steering, mobility management, which may be semi-dynamic (e.g., 100 s of ms timescale).

On demand: This can apply to both real-time and non-real time analytics, and is the case when the vertical or the operator requires enabling this feature as a service, for a given area or time window in order to meet the requirements of a network slice.

Type of analytics

1. There are different types of analytics that can be useful for the network according to the Gartner's Graph on stages of data analysis:
2. **Descriptive Analytics:** Explaining what is happening now based on incoming data.
3. **Diagnostic Analytics:** Examining past performance to determine what happened and why.
4. **Predictive Analytics:** An analysis of likely scenarios of what might happen.
5. **Prescriptive Analytics:** This type of analysis reveals what actions should be taken.

Integrated Analytics Architecture

This section covers functional design considerations and architectural improvements. Because of this, the front-end is specifically mentioned as a placeholder for using analytics. Since this is an implementation-specific aspect, the actual processing and data mining (e.g., what kind of predictors or algorithms are used on top of these functionalities) and whether this involves multiple iterations and interaction between different entities are not shown. Our goal is to set the stage in the 5G architecture for enabling analytics on several levels with various goals, while allowing any authorised functionality to consume them in a slice-tailored way. Since both network operators and verticals can easily implement analytics on demand, the need for new analytics functionality in the 5GS may become a reality, preferably using a service-based architecture. Analytics functions, for instance, might be implemented as (part of) a new AF that interacts closely with, say, CN functions via SBI or as CN/RAN functions that communicate with MDAF utilising control-to-management interfaces.

The features offered by RAN-DF, NWDAF, MDAF, AF-DAF, and DN-DAF may be regarded as essential components of the E2E analytics design framework. They may be deployed in two important domains beyond the 3GPP 5GS, namely the AF domain and the DN domain. Functions that transmit information on the performance or service of non-3GPP networks (such as metropolitan wide area networks and wide area networks) to other DAFs inside the 5GS or an Operations, administration, and management (OAM) domain may be included in the DN by the network operator or the vertical. AF- DAFs may communicate with the CN-domain NWDAF using either the 3GPP Network Exposure Function (NEF) or an inter-domain message bus. Using AF-DAFs, the operator can quickly roll out new functionality that is tailored to the needs of the AF domain, or the vertical can run analytics to support the operation of the E2E service. For vertical sectors like IoT and V2X, where the vertical demands exposure of chosen data from 3GPP network operation, a greater degree of control of the network, as well as flexibility of deployment, this might prove to be quite advantageous [7].

For RAN NFs like radio resource management to improve, real-time analytics are needed. As a result, real-time analytics are gathered from real-time measurements and utilised locally to dynamically improve performance. Additionally, RAN, CN, and Management may not be the only stakeholders involved in the business aspects. It is possible to abstract RAN analytics to CN or OAM. More complicated RAN installations with CU-DU splits, which better justify for such capability, are shown by an example deployment of this feature in. RAN-DAF might be shown in the system design as a management or SON feature, or as a control function in RAN. Through the inter-domain message bus interface, RAN-DAF connects to other network functions.

The capability for registration, discovery, and consumption of services inside or across domains is provided via intra- and inter-domain message buses. A service catalogue function may keep an up-to-date list of services that are accessible for consumption thanks to service registration and deregistration. The ability to find available services, direct customers who are looking for them to them, and give access to them are all made possible by service discovery capability. The ability to consume services enables customers to use them, for instance by automatically routing requests and answers between service consumers and providers. This could include platformlike features like load balancing, failover, security, message delivery rules, or protocol conversion / adaptation, as well as the exposure of services to the its service catalogue and inter-domain message bus [8].

Connecting DUs and CUs using widely used digitized forms is one of the major issues the transport network has to deal with. These are already standardized or are in the process of being standardised, such as the Common Public Radio Interface (CPRI) and the enhanced CPRI (eCPRI), which adopt more flexible interface options in the RAN and enable the adaptation of functional splits between CUs and DUs to use case requirements as well as transport network capabilities. In addition to the digitised FH solution, analogue FH solutions that attempt to benefit from Radio over Fibre (RoF) solutions' lower complexity are also receiving a lot of attention. However, these solutions provide less flexibility in terms of architecture and connection. The development of innovative solutions at the transport network for the interfacing of the RUs with dispersed (MEC-type) or centralised compute resources (Data Centres) for the processing of the BB functions is necessitated by the changing service needs of 5G RANs. High degrees of flexibility, resource efficiency, and energy efficiency must all be offered by these solutions at the same time. A future-proof solution to the problems caused by existing and upcoming RANs is the deployment of high capacity and flexible transport networks that depend on scalable and energy as well as cost-efficient programmable technology.

When network soft warization and sophisticated hardware (HW) solutions are taken into account together in this context, a range of activities may be dynamically dispersed between centralised and distributed parts. This will make it possible to properly mix and deploy physical and virtual network services on top of any programmable computing and/or network device. For instance, programmable NFs may be installed either remotely no stringent latency limitations or locally at the network nodes ideal for low-latency applications. The most cutting-edge transport technologies being investigated in several European 5G testbeds are highlighted in the sections that follow. Advanced optical network solutions are adopting very flexible and dynamically changing network architectures and technologies that directly address the nature and characteristics of services in terms of data types, traffic flows generation, and end-to-end connectivity requirements to address the frequently required network reconfigurations. To meet the very varied and quickly shifting high bandwidth connectivity needs of the 5G network, optical networks must have programmability characteristics in addition to flexible designs and dynamically adopting technologies. Utilising active and elastic optical technologies that can be programmed and controlled in accordance with service level requirements, this programmability. Although commercially available solutions support wavelength switching granularity and perform optical switching, the extremely varied needs of operational and end-user services necessitate new strategies. These methods would use more dynamic and adaptable solutions to provide finer sub-wavelength granularity together with more optical spectrum flexibility. The Time-Shared Optical Network (TSON) is one such instance of an active optical transport. Sub-wavelength switching granularity is provided by this frame-based optical network system.

The idea of virtual BBUs (vBBUs) may be enabled through TSON, which also enables communication between RUs, DUs, and CUs. This allows for the efficient sharing of computational resources. At the time frame level, TSON provides elastic bandwidth allocation. TSON can manage Ethernet frames natively, but it may also be configured to handle a wide variety of framing structures and communication protocols, including as CPRI, eCPRI, and Open Base Station Architecture Initiative (OBSAI), either directly or through their packetized variants. TSON depends on a general and adaptable resource allocation architecture to do this, adopting a hierarchy of three levels of resource granularity: connections, frames, and time-slices. Connection is the development of a sub-wavelength light channel between any two TSON domain end points. The smallest units of network resource, or the real sub-lambda resources, are separated into time-slices for each frame. The least granularity that the TSON network is capable of achieving depends on the frame length and the amount of time-slices within a frame. With frame durations ranging from 64 nanoseconds to 25.6 seconds and variable bit rates ranging from 30 Mb/s to multiple Gb/s, with a 30 Mb/s step, the TSON architecture provides a very adaptable optical platform.

The TSON system consists of two distinct node types, the edge and the core nodes, which each have a unique degree of complexity and capability. The interconnections with different technological domains, such as RAN, Passive Optical Networks, MEC, or data centre domains housing compute/storage resources, are provided via TSON edge nodes. Here is a typical illustration of how passive wavelength division multiplexing (WDM) can be used to create flexible FH connections between RUs at the antenna side and BBUs at the central office (CO). The edge nodes are a hybrid subsystem that can manage Ethernet traffic as well as continuous (I/Q streams). Since it can be elastically defined based on each service's needs, the optical bandwidth allotted to the various services is not fixed. The TSON core nodes only switch the traffic optically without doing any data processing. As a result, the fast-optical switches are controlled by the FPGA-based TSON core node to set the way up in accordance with the service demands.

By properly allocating the right resources (wavelengths, timeslots), and establishing various priorities for different traffic flows according to the required QoS, TSON also offers the ability to multiplex eCPRI and CPRI traffic. Two Ethernet-based eCPRI flows are combined into a single flow by TSON Edge 1, which is then multiplexed with the CPRI flow and gives each of them a separate wavelength as an illustration of this procedure. The Wavelength Selective Switch 1 (WSS 1) is then provided with these two wavelengths. Then, WSS 1 sends eCPRI and CPRI packets to WSS 2 by multiplexing them over a single fiber. The upstream flows are received by the WSS 2 and are de multiplexed depending on their wavelength into eCPRI and CPRI packet flows. The Ethernet and CPRI ports send packets to the TSON Edge 2 node, which then sends each packet on to its clients separately.

CONCLUSION

Two of the main goals for carrier Ethernet and SDN are the reduction of overall expenses and the enhancement of operational efficiency. The "all IP, the all Ethernet" technology on the transport network aims to offer the foundation on top of which the MNOs will construct their future slice-ready, programmable networks based on SDN. Additionally, Ethernet bridges were initially created for best-effort traffic with no requirements for the fastest possible network speed. There has been a push in IEEE 802.1 Ethernet standardisation for methods assuring zero congestion packet loss, as well as control on delay and Packet Delay Variation (PDV), due to the requirement to use Ethernet for audio and video transmission in professional studios. Industrial control and automotive applications have recently been the key forces for further standardisation evolution, with mobile FH being the most recent.

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CHAPTER 6

A BREIF DISCUSSION ON PHY LAYER

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ABSTRACT:

Ethernet over Multi-Protocol Label Switching (EoMPLS), Ethernet over SONET/SDH, Ethernet over DWDM, and Ethernet over Optical Transport Network (OTN) are the key operations for the transport network. Recently, strategies have included Flex-E and X-Ethernet technologies in order to achieve larger capacities, manage load elasticity, and ensure performance. As shown in Figure 4-8, Flex-E technology is presented as a thin layer called Flex-E Shim that sits between Ethernet MAC and Physical Coding Sublayer (PCS). The Flex-E Shim layer is in charge of driving the asynchronous Ethernet flows over a synchronous schedule through various PHY layers, time multiplexing between client groups, and mapping Flex-E clients (i.e., Ethernet flows) to groups of PHYs. The MAC layer speed of a client may be separated from the PHY layer speed using Flex-E, and numerous MAC clients can be handled across multiple PHY layers even at data speeds beyond the typical range provided by existing Ethernet standards. On top of an OTN-WDM-based PHY, Flex-E can operate.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

In particular, each aforementioned layer supports: Data Link Layer: Logical Link Control (LLC) for multiplexing network protocols over the same MAC, Media Access Control Sublayer (MAC) for addressing and channel access control mechanisms, and Reconciliation Sublayer (RS) that processes PHY local/remote fault messages.

PHY Layer:

a. PCS performs auto-negotiation and coding,
b. PMA sublayer performs PMA framing, octet synchronisation/detection, and scrambling/ descrambling, and
c. Physical Medium Dependent Sublayer (PMD) is the transceiver that is physical medium dependent.

Each Flex-E client has a unique MAC and RS that operate at the Flex-E client rate. As required for Ethernet, the layers below the PCS are utilised in their entirety. Every Flex-E client flow begins with a 64b/66b encoding operation to speed up synchronisation processes, enable clock recovery, and enable alignment of the data stream at the receiver. Then an idle insert/delete procedure is carried out. All Flex-E clients must complete this stage in order to be rate-adapted and synced with the Flex-E group's clock [1].

According to IEEE 802.3, the rate adaption is carried out via an idle insertion/delete procedure. To enable alignment markers on the PHYs of the Flex-E group and the insertion of the Flex-E overhead in the steam, this rate is a little bit lower than the rate of the Flex-E client. Following that, each Flex-E client's 66b blocks are sequentially distributed into the Flex-E group calendar, where multiplexing is carried out. Google provides an overview of Flex-E and potential use cases for it in the authors' presentation of an integration strategy for the control and administration of Flex Ethernet via OTN.Statistical multiplexing in conjunction with reduced latency in Ethernet has recently been made possible by Time Sensitive Networking (TSN) Ethernet techniques. The IEEE TSN task group has established the TSN set of IEEE 802 Ethernet sub-standards. Multiple mechanisms for enhancing or even guaranteeing real-time delivery of Ethernet traffic are described in the new standards.

There are also private solutions available to provide a low-latency transport FUSION technology, including a Guaranteed Service Transport (GST) class with ultra-low PDV, in addition to the relevant IEEE initiatives and the IETF activity in the Detnet WG. An Ethernet FUSION TSN network for aggregation, transport, and de-aggregation in FH is illustrated, and Figure 4-10 shows how the Ethernet FUSION-TSN may be further combined with WDM aggregation to enable a scalable FH transport. This enables high accuracy synchronisation by timing transparent transport of IEEE 1588 - Precision Time Protocol (PTP) - packets. A comprehensive programmable data plane architecture that includes SDN and programmable Ethernet transport networks is now under investigation. The required control systems are controlled by a built-in 5G orchestration and management solution [2].

Additionally, a programmable Ethernet solution can be used to modify the necessary functionality to meet the needs of the different functional split options. Different requirements for latency, bitrate, and traffic pattern are defined by the various FH functional split types. For instance, a CPRI over Ethernet mapping will result in a Constant bitrate (CBR) stream of data that has a higher bitrate than the user data rate that is being given. The eCPRI splits, in contrast, provide statistical multiplexing and lower bitrates for the same given user data-rate while maintaining the same stringent latency constraints as the CPRI divides. For higher level splits, the latter are even more relaxed. As a result, a programmable Ethernet transport may be able to adjust functionality to satisfy the various needs from the various functional divides.

Programmable Metro Network - Disaggregated Edge Node

Today, there is a need for cost-effective, energy-efficient, agile, and programmable metro network design. When designing such a network, scalability must be taken into consideration as well. Some characteristics of such a network are anticipated to be:

Design of multi-Tbit/s elastic CNs and all-optical metro nodes with complete computing and storage capabilities that work well together. New, spectrally effective, and adaptive optical transmission networks for interconnection. The disaggregated central office architecture is shown by the implementation of cutting-edge principles, such as hardware disaggregation and virtualization of the different aspects of transmission, switching, networking, computation, and storage, and orchestrating dynamic solutions for several 5G applications. This design uses NFV and SDN technologies, assigns computing and storage resources closer to clients, and offers dynamic, on-demand, and cost-effective services for 5G use cases. This compares to the old central office [3].

The disaggregated edge node may be configured to handle various FH/BH protocols as needed. They can aggregate and disaggregate any access traffic combination (such as Ethernet, WI-Fi, Life, eCPRI, etc.) to and from either TSON (metro) or coherent (core) optical networks on demand since they are SDN capable. The Disaggregated Edge Node architecture, which consists of the TSON technology, Voyager, and WSS.

The first multi-protocol programmable interface that satisfies 5G Key Performance Indicators (KPIs) is TSON, as mentioned above. The Voyager is a switch built on the Broadcom Tomahawk platform that has additional DWDM ports and functions as a disaggregated optical transponder. It supports the modulation formats of PM-QPSK, 8-QAM, and 16-QAM. The optical signal is switched and filtered by the WSS. The control plane is made up of an SDN controller and device agents that enable dynamic configuration and programming of the various elements of the disaggregated edge node.

Space Division Multiplexing

Advanced transport topologies and architecture models are needed in light of the support of densely placed 5G small cells for applications in crowded areas, smart offices, and industrial network environments, in which a large number of closely located users or devices seek high bandwidth access and support for advanced services. The amount of aggregated capacity that can be transported from the associated RUs and processed at a large central pool of base-band units (BBUs) may be greatly increased with the aid of space division multiplexing (SDM) [4].

The overall idea relies on the use of an optical FH Infrastructure architecture that takes into account: a) Multiple single mode fiber (M-SMF) links, which currently make up the majority of the fiber infrastructure investments made by all major operators; or b) Multi-core fiber (MCF) links, which are the compact high capacity alternative for future capacity expansions in optical. Each of the aforementioned factors affects the network architecture in a different way by influencing the technological solution that can be used and how easily and inexpensively it can be expanded in the future.

Small cells that are separated either in the spectral or spatial dimension are taken into account by the general design principle. The Optical Distribution Network (ODN) may feature dynamic wavelength or spatial add/drop nodes for a portion of the supplied CS or may have fixed pathways to the different CS. The two dimensions create a spectrum and space-based allocation method that may even be handled independently by several CSs. The maintenance of the BBU (for pure ARoF) or DU (for DRoF) pool of components, as well as the link to the ODN outputs, are where the complexity is transferred, however.

Technology Considerations

Increased capacity (or equivalently higher cell densification) can be obtained when using the SDM FH with legacy DRoF connectivity. There is also the possibility of using the space dimension for dynamic resource optimisation in response to user demands. By combining sophisticated optical beam forming (OBF) processing with ARoF transmission in the mm Wave range, more advantages may be reaped. By using parallel fiber communications across the SDM-fiber connections, several antenna elements per RRH may be addressed. Additionally, by using the optical beam forming network (OBFN) element, multiple data streams can be transmitted simultaneously by the same antenna arrays. Some important enabling solutions have been developed and are described below in order to manage the distribution of spatial and spectral resources over the transport infrastructure (data plane) [5].

A hierarchical Transport SDN control solution with modular capabilities is used to supply and manage spatial/spectral resource discovery and network topology information. For the FH, BH, and NGFI segments, three child SDN controllers are introduced, with one parent SDN controller serving as the FH/BH transport network controller on top. SDN node agents are installed at the cell sites (CS) and the central office (CO) (aggregate node or edge) that work with the child SDN controller using the NETCONF protocol to manage the data plane resources on the FH segment. As of right now, NFV network services for mobile communications are supplied with management of the physical network functions (PNFs). To communicate with certain PNFs, namely physical RRUs and BBUs, the SDM design now includes a new component called PNF Agent. The orchestrator must also communicate with a PNF manager. In addition, multi-tenancy and network slicing are used to offer high levels of flexibility in the supply of dedicated services with tailored QoS while optimizing the use of the physical infrastructure via virtualization and resource sharing approaches [6].

The RF spectrum-related resources in the access portion and the spatial-spectral optical resources in the FH are divided for the purposes of physical network resource planning. With the capabilities of the used SDM-assisted ARoF technologies, the NR15 parameters are implemented and can be expanded. The ideal distribution may take into account a variety of optimisation factors, such as minimizing total consumption (by lowering the number of active performance of end users, or nodes). Initial planning (offline allocation) is crucial for determining the right number of resources to meet anticipated demands, particularly in regards to the quantity of necessary BBUs and transceiver modules combined with the total number of RRH at the cell sites and the connections served. For the dynamic reallocation of resources among the wireless access sites as the needs change, an online planning option is also taken into account. PNF agents are used to construct and operate programmable FPGA-based BBUs, optical transceiver integrated chips, and dynamically adjustable beam steering options at the OBFN chips.

Wireless

In order to connect a wide range of end devices, network heterogeneity in 5G requires the integration of cutting-edge wireless technology. In order to increase data speeds, reliability, and energy efficiency, the wireless transport and access network will be built using Sub-6 technologies, mm Wave technologies, and massive MIMO methods employing considerably more antennas at the gNBs. To provide greater coverage and availability, better network densities, and improved mobility, they will coexist alongside traditional (2-3G), Long Term Evolution LTE (4G), and Wi-Fi technologies [7].The transport network is presently taking a close look at a thick layer of tiny cells operating in the 100 MHz to 100 GHz frequency band. Operators implementing wireless BH, especially in complicated urban installations, often realise that seamless integration of mm Wave BH technology with Sub-6 Non-Line-of-Sight (NLoS) technology is the technology delivering the optimal mix of capacity and coverage.Furthermore, we see the use of satellite communications as a transport network for the 5G network, enabling connectivity between regions.

Millimeter wave (mm Wave)

The higher data speeds needed to serve congested metropolitan areas make millimeter wave technology an important solution. In addition, one of the important aspects that this technology may soon enable is the union of high data rate and high-resolution range. This capability may be helpful for emerging services like augmented reality, assisted living, and safety-critical applications.

Currently, multi-gigabit meshed BH technologies based on WiGig (IEEE 802.11ad) operating in the V-band at 60 GHz are used to establish Mm Wave wireless BH links. These approaches employ electrical beam-steering to create various topological combinations. These nodes are improved with programmable network processors to make it possible for network operations to be quickly setup, updated, or controlled by an SDN controller. They are intended to enable beam-tracking and Multiple-Input Multiple-Output (MIMO) methods.

As Sub-6 solutions enable NLoS operation and can supplement mm Wave nodes in circumstances where mm Wave nodes encounter NLoS conditions, these technologies are currently coexisting with Sub-6 GHz technologies in order to benefit from their co-location. Self-backhauling capabilities will be made available for Sub-6 technologies. The localization of additional stations may also be aided by the co-location of various technologies. For instance, mm Wave beam pointing mechanisms employing greater beam widths may be supported by Sub-6-GHz angle measurements to the point where the latter can provide accurate localization of stationary and mobile nodes [8].The integration of configurable parallel processing and optimised hardware accelerators is a crucial component of mmWave technologies. Specifically, by having a software-defined MAC and PHY, enabling the exploration and ongoing customization of the performance of unique mmWave wireless algorithms in the context of cutting-edge research platforms.

The integration of multi-antenna (MIMO) systems at these frequencies is yet another specialised effort in mmWaves. Particularly relevant for wireless BH applications, where extremely high data rates must be maintained, is the mmWave Line-of-Sight (LoS) MIMO design. The antenna array configuration and the wavelength-transmission range product are two variables that affect how many concurrent data streams these systems can accommodate. This implies that the attainable connection range (i.e., the distance between transmitter and receiver) and the spacing between antenna parts are connected. In other words, either the array size has to be expanded or the wavelength or range needs to be reduced when more streams are required.

Figure 4-15 displays the maximum rates that may be achieved for various antenna designs. These findings serve as a theoretical upper bound on the pace that can be achieved. This rate is lower and constrained in practical systems by RF deficiencies. For instance, the data rate of 4.62 Gb/s might be provided by the IEEE 802.11ad standard, which has an estimated SNR of 25.95 dB and the highest modulation and coding method (MCS12). So, for a system represented by indices 1, 2, 3, 4, 5, and 6, the corresponding aggregated data rates would be 18.48, 27.72, 36.96, 41.58, 46.20, and 73.92 Gb/s.

Multi-tenant small cells with IAB

To satisfy the capacity promises of 5G, fresh technologies must be developed to facilitate the widespread deployment of outdoor small cells. The idea of multitenant small cells with Integrated Access and Backhaul (IAB) capability is a crucial technological enabler. This section demonstrates how this idea is put into practice [9].

The proposed solution enables an infrastructure operator to dynamically create connectivity services, or virtual networks, on behalf of its tenants (i.e., MNOs), while managing a small cell deployment. A deployment scenario where two MNOs offer connectivity services over a shared small cell infrastructure is shown. The provisioned virtual networks enable the MNO's customers to connect to the small cells in a transparent manner and carry the customer's traffic to each MNO's core network.

DISCUSSION

Here, we discuss an implementation specifically suited to IEEE 802.11 technologies, which we refer to as SWAM, despite the fact that the suggested IAB architecture is independent of the Radio Access Technology (RAT): The phrase "SDN-based Wi-Fi Small Cells with Joint Access-Backhaul and Multi-Tenant capabilities "The SWAM's services may be broken down into two categories: (i) Instantiate an access connectivity service made up of virtual APs across a group of physical APs, and (ii) Allocate a connection via the wireless backhaul, which carries traffic from such an access service till a fiber attachment point.

Technically speaking, SWAM is made up of the following parts: The physical radio nodes have multiple interfaces for access and backhaul (wireless Network Interface Cards, or NICs); each physical radio node has a software-based data path; and the SWAM controller has a provisioning module for managing the lifecycle of virtual Access Points (vaps), a backhaul module for creating paths over the wireless BH, and an access bridge module for connecting the vaps to the connections in the wireless bac The SWAM data path’s objective is to handle packets originating from tenants' customers (vap interfaces) and transport them to the proper SWAM gateways through wireless backhaul (mesh interfaces). For this, software switches with a three-level hierarchy are used: per-tenant access bridges, integration bridges (br_int), and backhaul bridges (br_bh). A logical division between the access and the backhaul (BH) is the fundamental concept underpinning the SWAM data path. The access side's responsibility is to match traffic arriving from the tenants' vaps to the relevant BH tunnels, while the wireless BH's responsibility is to transfer packets along a system of end-to-end tunnels. A BH tunnel in SWAM defines a unidirectional link between two interfaces of a per-tenant access bridge using a VLAN tag. The right portion of has a thorough depiction of the SWAM data path, and the interested reader is directed there for a more in-depth exposition.

The right portion the CDFs of the total handover and BH tunnel reallocation time recorded for two distinct devices in an indoor testbed, which on average is about 30ms, to assess the performance of SWAM. Figure 4-18's left side shows an unbroken TCP connection after the controller reallocates a SWAM gateway for load balancing.

Satellite Backhaul

The 5G network may employ a satellite system as a transport network to offer connection between locations. Therefore, the BH between the AN and the CN may rely on such a system. In many situations, satellite systems are still the sole or most practical option for connection. There are four key use cases for satellite and terrestrial integration in 5G that may be researched:

1. **Use Case 1:** “Edge delivery & offload for multimedia content and MEC VNF software”: Providing efficient multicast/broadcast delivery to network edges for content such as live broadcasts, group communications, Multi Access Computing, VNF update distribution
2. **Use Case 2:** “5G fixed backhaul”: Broadband connectivity where it is difficult or not (yet) possible to deploy terrestrial connections to towers (remote/isolated areas);
3. **Use Case 3:** “5G to premises”: Connectivity complementing terrestrial networks, such as broadband connectivity to home/office small cell in underserved areas in combination with terrestrial wireless or wireline;
4. **Use Case 4:** “5G moving platform backhaul”: Broadband connectivity to platforms on the move, such as airplanes, trains, or vessels.
5. The identified indirect access implementation options can be classified in two main categories, as proposed in.

Between the 5G core and the RAN, the satellite network provides the 5G network with transport characteristics through the transport network (TN). The TN interfaces provide improved administration and sophisticated functions for satellite networks (such as 5G QoS adaptation to satellite class of service, dynamic satellite resource management, etc.). Two methods for backhaul deployment using TN exist, and they are primarily distinguished by the functionality offered by satellite networks at their interfaces with terrestrial networks. These interfaces may either be developed using an adaption layer (TN not based on 3GPP system specifications) or they can be natively 5G ready (TN based on 3GPP system specifications).

CONCLUSION

Relay Node based implementation choices (RN) depict a satellite-capable user equipment (UE) adopting a relay feature (i.e., multiplexer node role) that may service other UEs and being back haulled to the "donor RAN" and 5G CN over a satellite connection. According to the kind of access between the RN and the 5G CN, this solution offers three implementation options: 3GPP access, trusted non-3GPP access, and untrusted non-3GPP access. As a crucial 5G feature, Multi-access Edge Computing (MEC) must be supported by all backhaul implementation alternatives. This covers edge delivery and delocalization support for network functions (NF). Hybrid Multiplay Functions are anticipated in the event of multilink support (satellite and non-satellite connections) in order to enhance service Quality of Experience (QoE). Therefore, traffic steering, switching, and splitting would be carried out at the (R) A level over the various backhaul links that are currently available. The support of network slicing by all domains is a crucial prerequisite for effective 5G satellite and terrestrial integration. The application of SDN/NFV paradigms to satellite communications has been recognised as one of the important assets for providing the right tools and interfaces to provide effective support of end-to-end network slicing.

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CHAPTER 7

ROLE OF THE POINT TO MULTIPOINT IN NETWORKS

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ABSTRACT:

Management approaches of the future integrated satellite-terrestrial 5G network have been analysed and the two main approaches regarding the Network Management System (NMS) are: Separated NMSs with coordination between the 3GPP NMS and the satellite NMS: in this case, the 3GPP NMS only manages the terrestrial 3GPP components, while the satellite components are entirely managed by a separate management system (satellite NMS). Coordination between the two NMSs is therefore foreseen for an efficient resource usage and to ensure appropriate responses to the requests (e.g. service, monitoring, etc.) from one domain to another. This approach is typically applicable to backhaul implementation option based on satellite transport network Single integrated network management: in this case, the 3GPP NMS ensures the management of the whole satellite-terrestrial network, including the satellite terminal. This approach is typically foreseen for relay node implementation cases in which the satellite terminal acting as a relay node would be managed by the same entity managing the terrestrial network i.e. the 3GPP NMS.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

The idea in proposes a point-to-multipoint (PtMP) network that links eCPRI-capable hardware. This approach takes use of analogue RoF transmission's great spectral efficiency, the V-band's wide spectrum, the chutzpah of OBFNs, and enormous MIMO antennas. By enabling flexible wireless last-mile installation of the Remote Radio Heads (RRHs) throughout the service area while keeping compatibility with standardised eCPRI equipment, it is able to address the issue of cell densification. Depending on where the technology is placed in the 3GPP Centralised Unit (CU)/Distributed Unit (DU)/Remote Unit (RU) stack, the architecture may operate as BH, MH, or FH. Depending on whether the network is utilised for BH, MH, or FH, the solution represents a Fiber-Wireless (FiWi) PtMP bridge between the CU and the RU(s), connecting the many Service Access Points (either gNB, DUs, or RUs) [1].

In order to steer the gearbox using an OBFN to various lamp posts at mmWave frequencies (V-Band), using multiple sub-bands and pencil beams, several units that leverage ARoF gearbox to a Rooftop RRH are used as an example of the solution in FH operation. The Control Plane (CP) is comprised of the C&M and Synch traffic, whereas the eCPRI traffic constitutes the Data Plane (DP). Three major types make up the eCPRI traffic:

eCPRI traffic: The actual eCPRI traffic, which includes all of the other packets necessary for the services as well as the user data, real-time control, and rest. UDP and IP levels are used to transmit eCPRI communication to the Ethernet MAC layer.

Control and management data (C&M): The control and management traffic that is sent to the distant unit is carried by this data. This data is sent through the UDP/TCP and IP layers using management protocols like SNMP. Data for synchronisation (Synch): Information used to synchronise the clocks of the centralised and remote devices. The PTP protocol, which runs on top of the UDP and IP layers, is what it usually employs, although it may also be used with synchronous Ethernet to get the maximum level of precision. The C&M and sync messages are sent and received by the lamppost RRHs through out-of-band channels, which are distinct from the DP frequencies. The Control Plane Lamppost channels (CP-LP) are what these channels are known as. For control of the Rooftop antenna in the downlink direction, there is additionally one additional channel (the CP-RT). A broad beam that encompasses all of the served lamppost antennas is used to transmit the CP-LP to the lampposts. Since only the rooftop transmits in the DL direction, there is no difficulty. But we have to deal with the multiple access issue in the UL direction. Depending on the choices made by the owner of the infrastructure, there are two possible solutions to this issue.

The Frequency Division solution (FDD): In this method, we give each lamppost a single UL CP-LP band. The CP-LP has extremely little traffic, hence these bands only require a tiny amount of bandwidth. Using an Orthogonal Frequency Division Multiplexing (OFDM) strategy might be a variation. Multiple access is made possible in OFDM by allocating different users different subsets of subcarriers. This enables several users to transmit low-data rates simultaneously.

The Code Division Multiple Access solution: This method uses spread spectrum technology and a unique coding system where each emitter is given a code to deliver data concurrently over a single communication channel. There are two ways in which this design allows for resource allocation flexibility: When using a single wavelength, the resource allocation method can give the lampposts access to different DP sub-bands based on how much traffic they will be carrying. One lamppost may get several sub-bands for connecting with the Rooftop antenna, whilst others may just receive one or have their DP totally switched off if there aren't enough users, according to a high layer split example where the traffic in the FH varies according to the actual user traffic.

Turning on or off different Rooftop antennas allows us to disperse the traffic coming from the lampposts to other roofs, and ultimately to other wavelengths, in the case where we use WDM and hence many wavelengths in the optical domain. This adaptable approach enables RRH/Small

Cell densification without requiring the installation of new fibre to all lampposts. In order to offer coverage in a particular location, an infrastructure owner might use this option to allow operators to mount their RRHs/Small Cells to the lamppost antennae. The same lamppost antenna may be used by two or more RRHs or Small Cells, which allows them to share the same sub-bands. Installation of several functional-split RRHs is another method of multi-tenancy, allowing each operator to choose the functional splits they like [2].

In the framework of 5G PPP, a programmable Data Plane that can be deployed as the data channel in non-RAN segments like the Edge Network, the Transport Network, and the CN has been planned and prototyped. The goal is to provide data plane-based network slicing that is QoS-aware by enabling network traffic/slice Quality of Service (QoS) management. Demonstrates the architecture of the configurable data plane. Two host computers are shown as an example depiction of the Edge Network (MEC) and the Core Network (CN), respectively, in this condensed overview diagram. Through the Transport Network, the Edge and Core Networks are linked. A physical switch connects the DU and the antenna to the MEC computing. Possible programmable places in the data route for traffic management, etc. are shown by the solid red circles.

This architecture provides data plane programmability that is either hybrid, software-based, or hardware-based. The diagram illustrates a hybrid strategy that combines software- and hardware-based strategies. The software-based method investigates software data pathways such as Open Switch (OVS), Data Plane Development Kit (DPDK), as well as virtual NICs, while the HW-based plan makes use of the programmability at the HW, particularly the network interface cards (NICs). The hardware-based method is advised for performance, while the software-based or hybrid approach would provide a more economical and adaptable solution. Consequently, the selection of a particular approach depends on particular use cases.

The hardware-based technique has been used for prototyping in order to improve data plane performance. The goal is to provide traffic management, offer QoS-aware network slicing at the data plane, and minimise overhead, particularly the added latency. The workflow is similar to the Simple Sume Switch in that traffic flows pass through the Parser, Match/Action, and Deparser pipelines before being categorised and handled appropriately depending on the specifications of the various network slices in the data plane. A flow or flows associated with a network slice may be subject to specific traffic management procedures such as dynamic prioritisation, dropping, mirroring to another interface, being processed further by the CPU, etc.

Stateful Packet Processing in Hardware

The existing programmable data planes nowadays cannot act directly for stateful functions due to various recent inadequacies in the solutions for data plane programmability. The lack of a distinct per-flow stateful model for storing directly in the data plane the data obtained on the various flows under investigation is one of the most significant shortcomings in the present programmable data planes. It was not yet possible to achieve the objective of running stateful network functions (NFs) to improve the programmability of transport solutions. The programmable data plane design is severely constrained by the HW limits on the amount of memory and the number of operations that can be performed for each packet that has to be processed by the network. These restrictions stand in stark contrast to the NFs' need for freedom. Fortunately, recent research has demonstrated that the key hardware components making up the data plane could offer sufficient adaptability and programmability to implement a number of network functionalities directly in the data plane.

Examples of programmable data planes have recently come to light as the perfect target devices for implementing these intricate NFs without the help of the control plane. These programmable data planes will be able to manage programmable parsing of the protocol stack for general field extraction and packet encapsulation/decapsulation and give protocol independence. They may be set using particular programming languages (such as P4 or POF). Using programmable pipelines of match/action stages, these systems are being expanded both in terms of switch matching capabilities and in terms of actions to apply to the processed packets. This architecture, called Flow Blaze, is designed to overcome the aforementioned restrictions of the programmable data plane while maintaining wire-speed packet processing. Flow Blaze is made up of a pipeline of elements, where each element can either be a stateless element (such as an Open Flow/P4 match-action table) or a stateful element, capable of executing per-flow extended finite state machines (XFSM), which provides stateful functionalities. Tables and counters/registers are the two categories of stateful components found in programmable data planes.

Tables can currently only be controlled from the control plane (insertion, update, and deletion operations can only be carried out via appropriate control-plane instructions). Arrays of registers and counters can be directly updated in the data plane, but it might be challenging to map a row of the array to a particular flow. A matching table may also be used to realise the mapping between the flow and the array items, but doing so prohibits the data plane from updating the table when new flows or their expiry call for the participation of the control plane. These problems are resolved by Flow Blaze by offering a particular kind of table that can be updated directly in the data plane. As described in the deliverable, designing an effective data plane updatable table while maintaining wire speed is a difficult technical effort. This allows for the in-data plane administration of a number of per-flow network activities, ranging from programmable Network Address Translation (NAT) services to flow monitoring, from QoS regulations up to the implementation of data-driven routing and forwarding techniques[3].

Flexible functional splits are enabled by the Flow Blaze technology. Stateful per-flow functionalities at the data plane level enable avoiding the throughput bottleneck and latency overhead for the network function primitives needed to deliver the functional split. The creation of a routing algorithm for DCs that can dynamically evaluate the optimum route in terms of latency/throughput is an example of network features on top of Flow Blaze. This will enable routing choices based on the flow needs, allowing for the forwarding of latency-critical flows through low latency channels, for example.

Finally, it is true that the concept of resource disaggregation enables effective provisioning of the network's available HW and SW resources. However, the actual use of these resources must include some functionalities that must be independently deployed and carried out in various heterogeneous computing resources. These functionalities must be at least loosely categorised as network functions. The same function might theoretically be implemented in an FPGA, a GPU, an off-the-shelf x86 host, a fixed functionality ASIC chip, a highly specialised processor (DSP for signal processing or in a network processor for packet level operations). All of these resources have various interfaces with the outside world and different programming languages. Scalability cannot be achieved by creating identical functions across all potential platforms on which the function may be performed. This is because there are so many various platforms and programming paradigms that need to be used. In order to address this problem, a Flow Blaze engine's per-flow network operations may be described using an ad-hoc high level programming language dubbed XL, the XFSM Language, independent of the hardware implementation (ASIC, FPGA, or SW) the engine uses[4].

DISCUSSION

To date, MPLS label tagging and VPN tunneling, in which each flow was identified with a specific label and/or transferred within a specific VPN tunnel, respectively, were the methods used to slice the transport network in the MAC and IP layers. SW ensured bandwidth for each slice/flow using packet categorization and hop-by-hop traffic rate limitations. Based on the network infrastructure's capacity to slice (e.g., nodes, connections) and integration between overlay and underlay networks, VPN innovations have recently emerged in order to offer dedicated network resources for each network slice. Guaranteed performance, isolation between separate network slices, and sharing where practical for services within the same slice are essential criteria. However, the aforementioned approaches fall short of other goals, such as fast convergence times for routing protocols or delay guarantees. Segment Routing (SR) is seen as an exploitable technology that may offer enhanced functions for the virtualized network in Layer 3 and assure service levels.

A novel protocol called SR uses the source-based routing paradigm to route data packets across a network. It is anticipated to play a significant role in deterministic networks and networks where "plain" VPN solutions are insufficient since, apart from encryption, current VPN solutions are best efforts and cannot ensure service to the virtual "sliced" network. The behaviour of the routing protocol and the applied policy still have an impact on the end-to-end network performance even when MPLS-TE solutions are installed [5].

An illustration of a source routing-based architecture looks for the ideal ratio between distributed intelligence and centralised programmability. In order to accomplish routing, SR breaks a network route into many segments as opposed to executing routing on a node-to-node basis. Each forwarding route is built using a segment list that has been organised sequentially. A segment could be connected to a route, a node, a link, or a service instruction. By directing packets via a set of segments (SIDs), which are used to express topological, service, or other instructions, SR uses the source routing paradigm to perform source routing. A packet is guided by an entrance node via a segmented, ordered sequence of instructions. Each of these commands denotes a function that will be called at a certain place in the network. A function may be as simple as moving ahead in the segment list or as sophisticated as any user-specified action, and it is locally defined on the node where it is run. In order to accomplish a networking goal that goes beyond basic packet routing, network programming combines simple and advanced segment routing methods.SR has a number of advantages, including the ability to simplify the control plane of MPLS-type networks, provide effective topology independent-loop-free alternate fast re-routing protection, increase network capacity expansion capabilities, and enable the smooth integration of SDN technology.

The topic of controlling and orchestrating services in 5G networks is covered in this chapter. This relates to high-level architectural considerations concerning how to organise this challenge, including how to characterise functions (physical or virtualized), link them to services, and where and how to deploy them. The high-level architecture for this has mostly been established at this point, but a deeper look shows that many design options are still available within the limitations of such an established meta-architecture. These decisions are explained and contrasted with conventional responsibilities. The influence of DevOps is then examined. Beginning with: High-level MANO architectures currently in use. How to organise the administration and operation of a 5G system has recently drawn a lot of attention. This issue arose as a result of the push to soft warize networking infrastructure in the hopes of reducing costs, increasing flexibility and versatility, and enabling telecom operators to use their infrastructure to support new business models, giving them a competitive edge over simple over-the-top players.

The old cliché "the network is the computer" is becoming true since all of these objectives need a greater capacity to control the lifetime of various software components operating within a network. As part of the Management and Operations challenge, which has already produced a reference design, this lifecycle management problem has been addressed. This architecture was developed as a result of work done in the framework of an ETSI working group, and it has since undergone further fine-tuning from both an ETSI context and from several 5G PPP initiatives. This section provides an overview of ETSI and 3GPP advancements, resulting in a consensual "meta architecture [6], [7]."

CONCLUSION

In conclusion, Point to Multipoint (P2MP) is a network communication topology that enables a single node to communicate with multiple nodes. P2MP networks are commonly used in applications such as broadcasting, video conferencing, and content distribution. They are highly efficient and scalable, as they eliminate the need for multiple point-to-point connections.P2MP networks can be implemented using various technologies, including broadcast, multicast, and anycast. Each technology has its advantages and limitations, depending on the specific requirements of the network.Overall, P2MP networks provide a cost-effective and reliable means of communication for organizations and individuals. They allow for efficient distribution of information and resources, making them an essential component of modern network infrastructure.

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CHAPTER 8

A STUDY ON MULTI-ACCESS EDGE COMPUTING - STANDARDS

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ABSTRACT:

The ETSI Industry Specification Group (ISG) on Network Functions Virtualization is perhaps the most influential of ETSI's recent efforts; it helped to kick off the network functions virtualization field on a large scale. ETSI defined basic notions (NFV, VNF, NFVI, architecture, key interfaces, etc.) that still are shaping the field to a large degree. Much of the remainder of this document is based on this early initiative. The Zero touch network and Service Management Industry Specification Group (ZSM ISG) in ETSI focuses on service automation and management that leverages the principles of NFV and SDN. The goal of ZSM is to define a new, future-proof, E2E operable framework enabling agile, efficient and qualitative management and automation of emerging and future networks and services. In a nutshell, the aim of ZSM is to have all operational tasks, including delivery, deployment, configuration, assurance, and optimization, executed automatically.

KEYWORDS:

Communication, Fifth Generation (5g), Mobile, Networks, Technology.

INTRODUCTION

ETSI ZSM intends to make it easier for relevant standardisation organization's and open source initiatives to coordinate and work together. In order to accomplish automated end-to-end network and service management solutions and architecture, it coordinates and gives instructions for the deployment of management interfaces. The required management architecture and interfaces to provide end-to-end zero touch network and service management in multi-vendor environments are being identified as part of the end-to-end solution[1].

ETSI ENI

The "observe-orient-decide-act" control model, which is a variation of the well-known MAPE-K idea, is the foundation of the Cognitive Network Management architecture being defined by the Experiential Networked Intelligence Industry Specification Group (ENI ISG) of ETSI. It adapts the services it offers depending on changes in user demands, environmental circumstances, and organisational objectives by using AI (Artificial Intelligence) tools and context-aware rules. The system is experiential in that it gains information about how to respond in the future by operating and by the choices that operators give it. For the purpose of enabling the use of AI in network management and operation, ETSI ENI creates reference architecture. The ENI engine connects to the current network to improve the network's AI capabilities. ENI has so far created use cases, specifications, a rough architecture, and interfaces[2]. ENI's work is scheduled to be completed in 2021.

ETSI MEC

One of the fundamental ideas for meeting some of the demands of vertical services is multi-access edge computing (MEC), which may be seen as a more specialised version of the MANO/NFV concept. The ETSI MEC017 paper examined MEC and its integration in an NFV setting and gave a reference architecture with the following important findings: The ETSI NFV procedures for these techniques are employed since the mobile edge platform is deployed as a VNF; Mobile edge apps are seen by ETSI NFV MANO as ordinary VNFs that enable the reuse of ETSI MANO functionality (perhaps with certain enhancements); The virtualization infrastructure is set up as an NFVI, and the VIM is in charge of managing its virtualized resources.

3GPP

Mostly SA2 (architecture) and SA5 (telecom management) are 3GPP-related activities that are pertinent here. "Network slicing" is a crucial idea in the basic design of SA2, which underlines it significantly. A slice is seen as a logical network that user equipment (UEs) may access and that spans the access & core for both the user plane and the data plane. A slice instance is thought of as a collection of network functions (ETSI and 3GPP terms) with necessary resources; issues like the identification of slices under dynamic function changes are still up for debate. The managerial viewpoint of SA5 is more pertinent to orchestration as explained below. TR 28.801 in particular covers the link between services and slices and how to manage them in further detail. But since slicing is not the main topic of this chapter, we won't address it here. Putting the ETSI and 3GPP viewpoints in context required a lot of work and continues to need more[3], [4].

Status and Consensus Architecture

Based on these advancements, a consensus architecture (or possibly a consensus meta architecture, since it is not always accurate enough to be directly implementable) with a common structure is forming. It entails managing state between instances of a function, bringing up or down instances, and choosing where to execute how many instances of a function; controlling individual network functions (including the distribution of their software artefacts, deployment on an execution environment, and state management between instances);the organisation of discrete tasks into services (i.e., chains or broad graphs), made possible by a variety of networking techniques, including but not limited to software-defined networking;

The capacity to use various underlying execution environments, from various virtualization strategies (like virtual machines, containers, or even just plain processes) in clusters of wildly disparate sizes (from a straightforward additional CPU board in a base station to an entire large-scale data centre), over various, specialised, accelerated hardware (like FPGAs), to various networking environments (wireless, optics, cable) - This is frequently referred to as "technological domains." The capacity to collaborate with or across various administrative domains, including various network operators to provide a service at vast geographic scales across numerous operators), or businesses with various business models (for example, network operators and independent cloud infrastructure operators); this is referred to as "organisational domains" at times. In this context, it is important to stress that the debate is about business roles rather not necessarily firm organisation; the same company may take on several responsibilities, and in certain cases, a single duty can even be shared among many businesses (for example, via subcontracting); support for a wide variety of applications with varying resource, deployment, and orchestration requirements as well as optimisation objectives (for example, cost vs latency). Although this term has more connotations and is less well-established than the others, it is sometimes used to refer to "application domains";

The concept of "slicing," which involves dividing the infrastructure required to run a service into separate logical infrastructures with dedicated resources (or at least, guaranteed service performance), can also be seen as a component of a management and orchestration system. However, in this area, the consensus is less established than in the other areas[5]. A slicing system might be positioned inside of a MANO system as well as below or above it as an integrated component. These six structural factors have led to the emergence of many key functions. These are further explained in the glossary, but generally speaking, we distinguish between:

End user,

1. Function developer,
2. Application developer,
3. Validation and verification entity,
4. Tenant (owner of applications),
5. Operator; typically, but not necessarily encompassing slicing operator; could also be separate
6. Infrastructure provider; often divided further into network infrastructure provider, cloud infrastructure provider, etc.

There are common overlaps between function and application developer, validation entity and tenant, or application developer, validation, and tenant, from the standpoint of an application. An operator and an infrastructure supplier would be considered typical conjoint roles from the standpoint of infrastructure. Uncommon but yet possible, an operator operating as a tenant and managing its own applications.

It is important to note that these responsibilities are relevant at various stages of a service's lifetime. They cover everything from the creation of particular features or entire services to their validation by potential outside, unbiased parties, as well as their actual deployment and operation. The combination of these factors, known as "DevOps" in the software industry, is currently being researched by numerous initiatives and has not yet reached complete agreement.

The fact that various processes occur at extremely different time scales is the last point to make. This results in a distinction between "control" actions (on short time scales, relatively light-weight operations, such as the routing of a specific flow to a specific service instance) and "orchestration" actions (on long time scales, relatively heavy-weight operations, such as optimising overall structure of a service or a group of services, possibly also of slices). This results in a separation of orchestration and control in certain systems (considered as improvements of the meta architecture described above); however, this is not always the case and is not present in all analysed architectures.

In the end, the ETSI NFV components are still the conventional ones at a high level: An NFV orchestrator (NFVO), a specific virtual network function manager (VNFM), and perhaps physical network function managers (PNFMs) make up an NFV service platform. A virtualized infrastructure manager (VIM) hides the specifics of managing deployment units (such as virtual machines vs containers); VIMs may be found anywhere and are often referred to as edge computing or mobile edge computing (with minimal effect on the architecture as a whole). Providing specialised layer 2 connectivity is one example of a concrete network configuration duty that is often delegated to a different SDN controller operating on behalf of the NFVO. As previously mentioned, the NFVO may sometimes be divided into an orchestrator and a controller (similar to, but not the same as, an SDN controller). Different architectures strongly differ in terms of whether slices are supported and in what flavours; occasionally, slice management is integrated directly into the NFVO (with the justification that a network slice instance is nothing more than a network service operating on guaranteed resources); other times, a separate slice manager is anticipated (with both NFVO triggering the slice manager and the other way around being options under consideration).

Sometimes resource management is seen as a separate activity from service management, and vice versa. NFVOs can federate with peer NFVOs in almost every situation, whether they are part of a single organisation or several. In some cases, there is also a hierarchy of service management instances (starting with a more abstract multi-domain to specific single-domain MANOs in addition to - usually intra-domain - peered MANOs). OnAP and other open source MANO platforms are often employed at the lower tiers. These options are summed up by adaptors, which enable the mapping from abstracted activities towards more precise underlying implementation technologies. It should be emphasised once more that not all concrete realisations of this meta architecture include all components or interfaces. The single-domain instance on the left side highlights the link between SDN and MANO controllers and the real resources, which may have been abstracted away by a VIM. In order to emphasise potential connections between multi-domain and single-domain service administration (hierarchy vs. federation), the right side displays a multi-domain scenario (simplifying resource issues). In a further variation, in addition to the single-domain service management features, orchestration capabilities could also be included.

Let's use heterogeneity as an example to show the adaptability of this meta design. This occurs in a variety of settings. First, the MANO framework as a whole needs to handle extremely diverse services with wildly divergent requirements, such as latency. In order to maintain low latency, a suitable MANO framework must be able to process such formalised requirements and deploy service functions close to the edge. In the part that follows, we use two example services a push-to-talk service and a vital chat/content delivery service to demonstrate our point. Second, heterogeneity also applies to the platform's foundation, including its hardware and software infrastructure. The subsections that follow provide examples of these features.

Heterogeneous Service Deployment

Push-to-talk services or content delivery services for mission-critical public-safety applications are two examples of services that must be provided while coexisting with regular services that have far lower service needs. Decisions on orchestration must be carefully considered unless one believes in slicing with complete control over all resources.

The majority of traffic in these apps remains local and inside the mobile edge, which is a key observation. Data transfer and function execution do not need the usage of the core network; in fact, keeping traffic and function execution local increases roundtrip times and user pleasure. As a result, an orchestrator must be aware of these local traffic characteristics, have access to resources in the mobile edge, and then deploy the necessary network functions there and route traffic appropriately (this is obviously unrelated to any slicing-related issues, but slices must provide an orchestrator with adequate topology information and exist at the necessary locations).

Options for distributing workloads across the edge and core networks are available in detail. One option is to keep certain administrative tasks central (such as call handling) and merely send media-related tasks to the periphery. Or, all pertinent VNFs and services are pushed to the edge. Operational complexity, the need to operate several instances of the same services, a decrease in tunnelling overhead, and other factors are trade-offs. In such mission-critical contexts, there are choices for chat and content delivery services. Low latency is the main goal here once again.

DISCUSSION

An infrastructure supports a MANO system. In order to execute functions and transmit data between these functions, the infrastructure's role is to offer real resources (potentially after performing many mappings from virtual to virtual infrastructures before arriving at the actual, physical resources). Additionally, the infrastructure offers an interface through which such function executions can be started, stopped, paused, or moved to another location. The interface also offers ways to affect the transport of data (where the abstraction level of the first part of the infrastructure control interface is still up for debate) [6].

The kind of running resources, however, need not be specified using this control interface. Whether a certain function is run as a process, a container, a unikernel, a virtual machine, or in a hardware accelerator like an FPGA is irrelevant at some abstraction level. It is important that it is functioning and that data can be moved into and out of it.

There are several conceivable divisions of issues with various trade-offs. The following prominent alternatives are currently being discussed: Infrastructure conceals its potential: Infrastructure and MANO framework are not communicating about the kinds of execution components that are accessible. A VNF that only exists as a virtual machine image cannot be performed on a Container-only infrastructure, hence it is the role of the infrastructure management to choose the correct realisation of a function, where "right" also means "functionally possible" and "performance-optimal".

From the standpoint of the MANO system, this is a useful notion, but its realisation does not seem to be possible. It presumes the existence of (almost) every function in every conceivable execution form and the infrastructure manager's capacity to determine what is "performance-optimal"; these assumptions don't seem plausible in the absence of knowledge regarding the performance requirements of an entire service, as well as the connections to other services.

As an alternative, an infrastructure gives details on the kinds of execution resources that are accessible, together with their quantities and locations. In order to choose the ideal mixture of function executables and locations, the MANO framework may utilise this information as input to an associated optimisation problem [7].

There is a common control or "plumbing" difficulty in addition to this decision/orchestration issue. Although it is not simple to ensure that data of a service chain flows correctly between functions located inside various virtualization systems (for example, a Kubernetes cluster hosting some functions in containers and an OpenStack cluster hosting other functions inside virtual machines), progress has been made to guarantee that such heterogeneous service chains do in fact function correctly.

The use of such heterogeneity support makes new strategies conceivable. For instance, when employing FaaS settings, a service chain's ability to adjust to demand may be greatly enhanced since in such an environment, spinning up additional instances occurs much quicker. This is also a nice illustration of how to comprehend the service/function semantics required inside the MANO architecture.

A potential method for many 5G networking operations, such as signal processing in mobile base stations, is to include hardware accelerators. There are some obvious difficulties in accomplishing that, such as the requirement that a network function be made available in a variety of formats beyond the virtual machine and container discussions of the previous example; for instance, it should be available in both an FPGA implementation and a GPU implementation. Although this does present some difficulties for the binary formats and the description formats for functions and services, they are manageable.

The fact that there are so many variations of a particular function must be staged in various ways is less straightforward to manage. The fact that hardware accelerators, unlike CPUs, can essentially only be multiplexed if such multiplexing is able to state-share across various functions that are prepared correctly presents a unique problem. Additionally, the deployment times on an FPGA can differ significantly from those for starting a container on a CPU (depending on the previous state, whether the entire FPGA needs to be reprogrammed or just certain portions).

They are thus entirely focused on that one task. When deciding which function to execute on such accelerators, this results in various algorithmic trade-offs [8].

Heterogeneous services

Business model concerns seem to be the main driving force behind the idea of classifying services into "network services" (such as forwarding and load balancing) and "application-level services" (such as caching, video transcoding, and web servers). However, it influences a lot of architectural choices that aren't always governed by technical considerations. In the end, there isn't much technical reason for this divergence. Services are made up of computational artefacts (containers, virtual machines, and processes) and the hardware needed to operate those (CPUs, GPUs). Whether the calculation consults a forwarding table or transcodes a video file has minimal bearing. Similar to this, all services need communication, whether it is for routing table updates or real data exchange.

It seems that if operators adopted the idea that both types of services could be coordinated in the same way (and maybe even with the same orchestration infrastructure), significant additional value might be realised. As technology advances, it seems that the reasons in support of (a) separating these kinds of services and (b) separating the orchestration infrastructure (one orchestrator vs. separate network/service orchestrators) will need to be continually examined. Buildings should be constructed in a way that acknowledges this reality and supports this strategy.

This chapter's earlier parts have presented what might be considered as the general agreement about the structure of a MANO system. It paves the way for (now ongoing) standardisation operations by laying the basis for the critical interfaces and interactions of such a MANO system with its surroundings. However, there is still room for interpretation and distinction between various realisations of such a system within this consensus. In addition to providing reasonable variants for interpretation, this section describes some of the most notable of these open areas.

There is sometimes a distinction made for services between "application-facing services" (services that comprehend the semantics of the packets, such as an add-insertion service or even just a webserver) and "network-facing services" (services concerned with transporting packets in the broadest sense of the word, such as packet forwarding, filtering, etc.). Even if this distinction is debatable, it poses a concern for the once we accept that it makes sense and that these services can be consistently recognised (or are expressly labelled) as such.

The advantages and disadvantages of each strategy are evident. Separated orchestrators unquestionably complicate the architecture, necessitate assigning areas of responsibility from a resource perspective (which orchestrator has control over which resources), resolving the issue of which orchestrator is responsible for which services, possibly dividing a heterogeneous service description into its "network" and "application-facing" components, and coordinating control decisions made by these two orchestrators. All these issues vanish when using an integrated orchestration strategy.

The clear division of areas of responsibility over resources might actually be seen as an advantage for operational stability (e.g., a segregated RAN orchestrator could still maintain basic RAN services like phone calls even if an application-specific RAN orchestrator failed). On the other hand, an integrated orchestrator might prove to be very complex if there is indeed a need to treat such different services substantially differently (a one-size-fits-all orchestration approach is indeed unlikely). There is a strong case to be made that although an integrated orchestrator would provide an overall simpler design, it would be harder to develop from a reliability and performance standpoint. Numerous projects have sought examples for both strategies. However, a sound comparison and a final judgement are still pending. Actually, standardising this option is unnecessary in the context of the Meta architecture because both could be implemented there.

Flat vs. hierarchical orchestration

With regard to resource and service kinds, the prior debate over integrated vs. segregated orchestration considered whether there should be one, two, or even more different types of orchestrators. The question of whether there is only one instance of a specific orchestrator type in charge of all delegated resources (a "flat" orchestrator) or whether there are multiple orchestrators (a "hierarchical" model, when orchestrators are aware of each other's communication channels) is orthogonal to that one. This is mostly a problem with performance and scalability, with some reliability issues. Since all hierarchy members would deal with the same kind of services, a hierarchical orchestrator is not necessarily a segregated orchestrator.

A hierarchical approach seems to be quite common in talks right now. There are a few unanswered questions in this situation: Is the number of hierarchy levels and each hierarchy member's area of responsibility predetermined (by, example, a setup operation for a certain infrastructure)? If the load changes, responsibility areas can be split or combined, new hierarchy levels can be added or removed, and new orchestrator instances can be started or stopped. Alternatively, the hierarchy could be auto-adaptive.

In a flat model, the NBI of an orchestrator takes service requests and communicates with the NBI of an infrastructure abstraction (usually a VIM) at its southern limit. These two NBIs are quite different structurally. There are thus two choices: Teach an orchestrator to communicate with several NBIs, including the NBI of a VIM and the NBI of a lower-level orchestrator, which requires the division of services into sub-services. As an alternative, an orchestrator might expose two separate NBIs, one of which would be an infrastructure-focused NBI and the other would be a standard "service-style" interface. The benefit of this would be that it constantly speaks to a VIM-style interface from the viewpoint of a higher-level orchestrator, which makes the concept of recursive orchestration simpler and more beautiful. An orchestrator really doesn't need to be aware of whether it is speaking to a genuine VIM or to another orchestrator posing as a VIM. To the best of our knowledge, a complete investigation of this design decision has not yet been conducted.

In such a hierarchy, how are siblings related to one another? Do they have the right to engage in direct negotiations (for example, to "borrow" resources)? If so, then an east-west interface must be defined so that orchestrators at the same level may communicate with one another without being in a controller-controlee relationship.

However, in a cross-organizational setting (also known as a "federation"), this could be the ideal model to pursue rather than relying on a controlling, higher-level orchestrator in charge of numerous organisations (who would run that multi-domain orchestrator, why would that be an entity trusted to be impartial, what about competition among such multidomain.

Despite this appeal, most of the time, in addition to such peering links between orchestrators on the same level, it is assumed that there are one or more such multi-domain orchestrators. While the east-west interfaces in this case are still up for debate, the north-south interfaces are unchanged from the previous case.

Are particular domains in the broadest sense associated with certain hierarchical levels or areas of responsibility? Is there a specific orchestrator or controller for an optical networking infrastructure, one for computational resources, and one for a wireless edge, for instance? Hierarchies along a technical area may be involved. Organisational and corporate borders, in the traditional meaning of the word, are another example of a domain. Last but not least, a "domain" might refer to the partition of a bigger infrastructure into many sub-domains such as an edge domain, a core domain, etc. each one spanning numerous technologies and dealing with various services, therefore not a segregated orchestrator in the sense of the preceding section.

The employment of two orchestrators (an NFV orchestrator and a MEC orchestrator) as shown in is an example of such domain-specific isolation. All requests are received, checked for suitability by a special "dispatching layer" that sits on top of the two orchestrators by looking at the descriptors and specifics of the target slices, and then sent to the proper orchestrator if a service deployment is feasible. This feature is offered by the "Multi-Tier Orchestrator" (MTO) component. This provides a straightforward interface for receiving "generic" service requests, which is an abstraction or straightforward "forwarding" of the underlying orchestrators' NBIs (Northbound Interfaces). Once again, there are clear trade-offs here, but they have not been fully investigated, nor have all the required interfaces been found.

CONCLUSION

Multi-access Edge Computing (MEC) is a promising technology that brings computation and storage capabilities closer to the end-users. It enables efficient and low-latency processing of data and applications, thereby enhancing the user experience and enabling new use cases. Standardization plays a crucial role in the development and deployment of MEC solutions.There are several standardization bodies and organizations that are actively involved in developing MEC standards. These include the European Telecommunications Standards Institute (ETSI), the Third Generation Partnership Project (3GPP), the Open Networking Foundation (ONF), the Institute of Electrical and Electronics Engineers (IEEE), and the Internet Engineering Task Force (IETF).ETSI has developed the MEC standardization framework, which includes various specifications and guidelines for MEC architecture, interfaces, APIs, and security. 3GPP has defined MEC as a key feature of 5G networks and has developed standards for MEC deployment in cellular networks. ONF has developed the Open Mobile Edge Cloud (OMEC) specification for MEC deployments in cloud environments.IEEE has developed the P1930.1 standard for MEC resource management, while IETF has developed several standards related to MEC, including the Network Service Mesh (NSM) and Interface to Network Security Functions (I2NSF) standards.In conclusion, standardization is critical for the successful deployment and interoperability of MEC solutions. The active involvement of various standardization bodies and organizations in developing MEC standards will pave the way for the widespread adoption of MEC technology and enable the realization of its full potential.

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CHAPTER 9

ABSTRACTIONS AND THEIR VIOLATIONS IN NETWORKS

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ABSTRACT:

The relationship of an orchestration system and a slicing system is still not settled. This is not surprising as there is still, despite several years of frantic work, no commonly agreed upon definition of what a slice actually is; many definitions compete and they entail very different relationships to an orchestration system. In a very straightforward view of slicing, a slice is simply a service with resource guarantees or guaranteed service level. This view fulfils most practical requirements towards a "slice". In this view, the slicing system and the orchestration system are, of course, identical. In a view that is more or less on the other end of the spectrum of opinions about slicing, a slice is a collection of resources computing, networking, storage that constitute a virtual network.

KEYWORDS:

Communication, Fifth Generation (5g), Mobile, Networks, Technology.

INTRODUCTION

The owner of such a piece is virtually unrestricted in what they may do inside it. For instance, it could be a good idea to orchestrate the services that are already there in such a slice, and an orchestrator might be put there to help. It makes reasonable to build yet another orchestrator outside of all slices to help with basic, essential services (such basic packet forwarding in the underlay) that are required outside of any slice. With N slices in this perspective, N+1 orchestrators may be active.The creation of a new slice is triggered anytime a new service requires one (many services may share a slice), and yet another view essentially integrates slicing functionality into the orchestrator (logically, implementation-wise it could be easily done as a separate subsystem). The only task of the slicing system is to distribute resources that are guaranteed. In this case, a single orchestrator would be in charge of a single slicing system [1].

There are supporters of each of these strategies as well as several additional combinations, but a consensus is still elusive. It is also doubtful that such a consensus will develop until the definition of "slicing" is established. Additionally, a lot of the viable options (such as a recursive approach where slices can be sliced multiple times, each time with their own orchestrator) frequently draw criticism and unfavorable responses that are ultimately based on a mistrust of a slicing approach to firmly guarantee resource isolation and the unavoidable fear that resource consumption does spill over between slices. On the level of orchestration, however, this is difficult to get around since either the slicing technique is trusted, in which case resources may be freely provided to a tenant to use anyway they see fit, or it is not trusted, in which case the whole strategy seems unnecessary and risky. Despite orchestration, the dread still exists.

Abstractions and their violations

It makes a lot of sense to abstract and simplify the real resources that are accessible on a lower tier when providing capabilities to a higher layer, regardless of how the hierarchical levels of orchestrators are organised. In addition to working in a federated context where the peer orchestrator is not fully trusted and is not expected to know the internal details of a domain but should instead obtain a condensed view only, this will be necessary to obtain any scalability and performance benefits from hierarchies.It's typical to have such an abstracted perspective. For instance, the concept of a "big switch" abstraction is often employed in data centres, where the whole internal network topology is disregarded in favour of the straightforward notion that all nodes are directly linked to a single, (very) huge switch. This may be a reasonable simplification for a data centre with enough bandwidth and little latency variations across channels. However, using such an overly abstracted representation of a network seems counterproductive when attempting to use an infrastructure to roll out NFV services for a widely dispersed customer base.

However, it is also unclear exactly how to create a streamlined view of a network. Let's have a look at a very basic illustration of a real infrastructure that has four nodes linked as indicated in the picture at the bottom, with a data rate of two units on each connection. We wish to show another orchestrator a condensed version of this configuration that just includes nodes A and D and a single connection connecting them. Should we pretend that this virtual link can support a certain data rate? The first option middle of the picture, left side may include claiming a data rate of 4 by adding together all the data rates in the infrastructure network more accurately, the maximum flow from A to D. The second option may be to simply assert the lowest data rate that can be sustained over a single route which is really not easy to determine in the general situation [2].

Let's say we now wish to deploy a service made up of the following three functions into this network, with X being at A and Z being at D. The service needs a data rate of three units from X to Y and Y to Z, therefore let's assume that there are no resources left at A or D to operate Y as well. It seems that the first version may transfer this to the abstracted network; but, if the service's network traffic is not split table, or, more precisely, if function Y cannot be executed in more than one instance owing to state fulness, this would be in violation of the criteria.

However, if the service is split table or if function Y can be executed in multiple instances due to its statelessness, the second abstraction would reject the service request, which is incorrect. Therefore, depending on the characteristics of the required service in this case, split table vs. non-split table flows, either of these straightforward methods for abstracting network details may be incorrect.

Even more advanced methods fall short. It is tempting, for instance, to show a multi-graph with several edges connecting the nodes as the abstracted model. In other words, there are three ways to go from point A to point D, but they can all be taken. Therefore, there isn't a clear-cut solution. In reality, it seems that not enough attention has been given to this issue, which calls for further study. It will become more difficult, if not impossible, to prevent conflicts between participating organisations as a 5G system becomes more complicated. Conflicts come in a variety of forms, for instance.

Resource clashes: Although many services have been accepted, they all require the same resources to live up to their quality promises. Inappropriate admission controls or too assertive oversubscription may be to blame for these problems. Even though such a dispute usually ends in fines being paid, it still needs to be settled in a workable system. When building a service comprised of functions that provide mutually incompatible packet forwarding behaviours, for instance, rules may clash with one another. Both an NFV context and an SDN context are possible for this to occur in (consider two distinct SDN applications operating at an SDN controller's NBI that both respond to the same PACKET_IN message with mutually incompatible options, such as "forward" and "drop"). Potentially, a MANO system is able to identify these conflicts.

There may be conflicts with feature interactions more broadly. The preceding rule conflicts serve as a basic, packet-level illustration. Such a service conflict may, at the level of the service, be as straightforward as the age-old "Call waiting" & "Call forwarding" feature interaction issue. It is more difficult since this is related to application semantics (which, in an NFV setting, are probably chosen by some VNF).In each of these scenarios, the disputes must either be avoided, which is famously difficult, or found and settled. Pre-fixed policies, either defined by the platform in general or by a service in particular, might be helpful in specific situations. However, prior experience has demonstrated that this strategy has its limitations. There are currently no known definitive study findings, however ongoing research efforts hint towards learning such conflict resolution actions from inside an operational network [3].Separating short-term activities with extremely quick necessary response times, such as flow-level actions, from long-term planning actions, such as choosing where to execute which functions or how to expand a service, might make sense. This might enhance performance and operational stability. A MANO system's design may also reflect this division by breaking it up into many subsystems, each of which is in charge of carrying out a particular set of tasks.

Such a division is sometimes referred to as being between "controls" for short-term operations and "orchestration" for longer-term activities. This division may, but need not, be translated to the division between a service- or function-level orchestrator and a flow-level control entity (such as an SDN controller). The orchestrator is therefore limited to dealing with long-term trends, such as altering the daily variation in the number of function occurrences. An SDN controller is a difficult enough piece of software, so this separation may be tempting from the standpoint of software development and maintenance, but it does add yet another interface and operational dependence to an already complex architectural model. Determining where to divide general functioning and which activities are short-term and long-term are also necessary.

Dealing with Load Spikes

Even with the separation of short- and long-term operations in place, traffic spikes may still exist that cannot be easily handled by activities under the control of the short-term system i.e., if there aren't enough active function instances, no amount of SDN rerouting will help. As a result, even the long-term orchestrator must be prepared to handle sudden changes which really puts into question the separation of control and orchestration.

Regardless of the design of the MANO system, the ability to swiftly call up more instances is a key advantage in coping with surges. Faas, which enables doing precisely that with little overhead: bringing up services on an as-needed, load-adaptive basis, is the cloud computing solution to this issue. There is no state preserved within a function, and it is not feasible to transport state across function instances, hence this necessitates that the realised code be in fact stateless and a function. FaaS is a potential choice as long as this criterion is satisfied, although it appears doubtful that all of its services will be stateless. In order to use FaaS, the MANO system must comprehend the semantics of the functions that make up a specific service and the many sorts of lifecycle management activities that are possible.

Technologies

The fundamental assumption of a layered architecture is that orchestration should be protected from the quirks of underlying communication technology. Crossing layer borders, nevertheless, could be advantageous in more depth. Here, we'll look at one instance of orchestration taking place inside a WDM/optical network.An NFV service platform for the management of network services and network slices for verticals, a transport SDN controller running the optical fronthaul network, and an edge computing controller allocating computing and storage resources in the central office (CO) are all integrated into the NFV MANO architecture used for the advanced SDM/WDM fronthaul network. This design employs common responsibilities and separation of concerns (NFVO, VNFM, PNFs, VIMs; the NFVO is also in charge of slices) at a high degree of abstraction. Through the VNFM and PNFM, the NFVO coordinates the configuration of both PNFs and VNFs. The transport SDN controller is given command of the optical fronthaul network, while the NFVO is still in charge of overall coordination.

The transport API (TAPI) standard provides the foundation for the communication between the NFVO and the transport SDN controller, with enhancements to address the unique optical technologies used in the fronthaul network. The optical beam-forming network (OBFN) system (both at the CO and the radio unit (RU)) and analogue radio over fibre (ARoF) transceivers are interacted with by the transport SDN controller using specific agents utilising a REST API. A network slice manager is added to the NFV service platform to enable multi-tenant virtual environments. The NFVO client is deployed, and it controls the lifecycle of network slice instances. The vertical requirements are converted into an appropriate NFV network service with the necessary QoS, which is created and terminated at the NFVO. The NSM's clients include the mobility and power management. It implements user mobility logic, such as decisions about activating and deactivating femtocells based on the users' location, and coordinates this with the vertical service instantiation procedures. On the one hand, it is in charge of life cycle management of the optical power channels between the CO and the RU [4].

Implementation patterns for MANO frameworks

For MANO systems, a number of widespread implementation patterns have surfaced. The monolithic orchestrator is one example. An orchestrator in the reference architecture is responsible for several different tasks. It may be possible to implement all of them in a single, monolithic piece of software, but doing so puts performance, reliability, and maintainability in grave danger. More appropriate implementation patterns are thus required.

A potential initial step is to divide an orchestrator into a controller for short-term activities and an orchestrator proper for longer-term actions, as was addressed in from a time-scale viewpoint. Numerous projects that do not specifically focus on orchestrator implementation patterns pursue this coarse-grained functional split. The software engineering community has devised a number of strategies to increase flexibility and make the development of such a complicated piece of software easier. One of these methods uses the idea of micro services and connects them using a software bus that implements a publish/subscribe paradigm between its parts. When this idea is applied to an orchestrator, the functional split becomes much more fine-grained, allowing multiple functional boxes to handle different facets of a request for a function or service (such as to switch off a service, for example). This method's extensibility, for instance, made it simple to include a data analysis framework into the orchestrator. Additionally, it did well to accommodate the addition of slicing support or support for numerous networking technologies.

A micro service-based orchestrator of this kind is not bound to a specific computer. It is simple to distribute the orchestrator's components over numerous computers for enhanced reliability and performance, provided an appropriate, high-performing pub/sub system was selected. Most pub/sub or software buses are built on top of open-source software that already exists. It is feasible to go one step further with this service-based platform's flexibility and straightforward extension. As management of VNFs and network services is highly specialised, for example for configuration and scaling actions, which are highly dependent on the specific functions and the environment they are running in, this feature has proven particularly advantageous in the VNF and service management domain. With the help of Service-Specific Managers (SSM) and Function-Specific Managers (FSM), the service developer may send the service package and service- or function-specific lifecycle management preferences to the service platform [5].The Service and VNF lifecycle management processes may be influenced by SSMs and FSMs, for example, by defining desired placement or scaling behaviour. The Management and Orchestration Framework of the service platform has a modular architecture that allows the service platform operator to alter it, for as by changing the dispute resolution or information management modules.

It seems to be the preferred option at the moment given the prevalence of such message-bus-based orchestrator architectures in several projects. However, before choosing that strategy, there are a few potential drawbacks that should be taken into account. While systems like Kafka or Rabbit MQ are known to easily scale to millions of events per minute, which should be enough for service lifecycle management actions even in a large-scale orchestrated network, the first is the challenge of providing real-time operation (message buses are, by definition, decoupled in time). The second are scalability concerns. The difficulty of debugging is another possible drawback. The dispersion of components and the attendant work of obtaining information from a possibly large number of components at various places is one cause for this. The fact that interactions between components are not immediately apparent is more significant. Additional tools that track, correlate, and visualise communication between components via message buses and, possibly, other technologies, such as REST-based interactions, are needed to examine these interactions [6].

DISCUSSION

Every orchestrator/MANO system must make a variety of algorithmic choices. The structure and duties of the orchestrator dictate which algorithmic issues must be handled; however, how those problems are implemented might vary greatly and provide a chance for vendor difference. Typical algorithmic problems that need to be solved include, but are not limited to: Placement refers to the decision of which instance of a service's functionalities should execute on which resource, backed by how many resources (like CPU clock). It should be noted that resources in this situation might be both real and virtual; when using virtual resources, the issue becomes recursive. Placement and the NP-hard facility location issue are closely connected.

Routing between chain-related functions Routes must be identified between function instances after they have been placed in order to link them in the proper sequence. This is an NP-hard multi-commodity flow issue from an algorithmic perspective. This is sometimes referred to as the virtual network embedding issue together with placement, with the service's application graph serving as the virtual network.

Scaling: When services can adjust to changes in demand by launching additional function instances, they become attractive. To guarantee that the appropriate number of instances is available to meet a particular demand, we must dynamically scale these graphs before embedding them. Otherwise, we cannot simply embed a fixed virtual network or fixed service graph. This is also NP-hard, of course.

1. **Load/traffic prediction:** How to predict traffic and load changes, to give an orchestrator sufficient time to react.
2. **State management between VNFs:** Assuming that VNFs are stateful and they should be scaled up or down, what is the best combination of state management actions to lead to the smallest overhead.
3. **Monitoring:** Which data should be monitored, where and how often to obtain the best possible approximation of ground truth at the smallest possible overhead.

Many of these building pieces constitute some kind of well-hidden optimisation difficulty. For certain of them, it is often viable and practical to directly use a solution (from basic open-source solvers like GLPK to more complex commercial solvers) in a deployment environment. Ideally, an approximation approach might be developed (typically with orders of magnitude faster runtimes but still with guaranteed performance ratios) since solving durations are often too lengthy. In the absence of such approximation algorithms, one is generally forced to resort to simple heuristics, which are again significantly quicker than optimizers but lack the performance guarantees of approximation algorithms. Heuristics have the benefit that they may often be created when previous efforts fail, and they frequently have both centralised and distributed versions [7].

Adapting the concept from autonomic computing is one current (again) popular method of structuring such heuristics. The idea behind this was to divide problems like these into several phases, including Monitoring (observing the system's actual state to a degree that is both feasible and desired), Analysis (deriving more compact representations of that state, the merits of which can be debated), Planning (deriving desirable state changes and deciding which actions can push the current system state towards such a desirable state), and Execution of such planned actions in the actual system. The MAPE loop gets its name from the fact that these four steps are often carried out continuously. MAPE-K is created by including an extra knowledge base where information such as earlier state observations, taken actions, and consequent state changes are kept. In order to enhance judgements, knowledge bases are often updated while operations are in progress.

This MAPE or MAPE-K loop is in fact contained within a single algorithmic black box in the most basic scenario. MAPE may transcend beyond boxes and become a fundamental design choice of an orchestration framework if activities to be conducted have an influence on the state of other boxes or execution has to be better coordinated. Depending on the orchestrator's specific implementation structure, incorporating a MAPE-K method may be simple. In particular, the above-described micro service/bus-based techniques are well suited for such an expansion, where MAPE-K algorithmic boxes may be quickly included. An entire MAPE-K loop can be contained in a single box connected to a message bus, depending on the scope of the individual decisions and the scope of the knowledge. It is also easily conceivable to factor out, for example, the knowledge component, connect this separately to the message bus, and use this to interact with multiple MAPE boxes [8].

Due to the fact that the knowledge component may produce events for the other, subscribing components, the event-driven nature of message buses makes them well suited to that strategy. Following that, execution components can either use the message bus once more to communicate commands to real low-level interfaces or act independently. Real-time operation is difficult, if not impossible, to guarantee using this technique which is largely derived from the message bus concept. To guarantee that all parts of a MAPE-K method really carry out all of their operations in finite time, regardless of load levels, highly careful design is required. However, "real time" is often an overly ambitious requirement or goal and "near real time," "soft real time," or "rather fast" are sufficient alternatives in the strict sense of "absolute guarantee of all execution times, even in the presence of failures".

The possibility of hierarchically structuring such MAPE-K systems is an intriguing one. As long as the hierarchy of MAPE-Ks is contained inside a single, message-bus based orchestrator, all messages may simply flow between them in the normal manner, making this mostly an algorithmic design problem. If MAPE-K boxes are dispersed between orchestrators that are also hierarchically organised, things become more interesting. Then, even if technically possible, it is probably not a good idea to distribute the message bus across multiple orchestration instances. It is anticipated that a different protocol between these MAPE-K instances will need to be built; this is not yet clearly specified and would probably benefit from further standardisation work.

There are descriptions for many different kinds of artefacts in a MANO framework, including infrastructure, functions, services, slices, policies, SLAs, tests, and perhaps business goals. It is sometimes necessary to map between several descriptions formats, both vertically, that is, from abstract to concrete, and horizontally, that is, between multiple descriptions formats for the same objects. Because different description formats are required by underlying systems (like a VIM), the descriptions in a MANO framework can be quite diverse. Support for several forms of these descriptions becomes desirable. Instead of developing the n+1st "standard" description formalism, it is a valid strategy to convert descriptions from one format to another [9].

A unified VNF package format is currently being defined and specified by ETSI based on the TOSCA CSAR standard. Although this package format is a good place to start, the specification still lacks some key features, such as support for full network services inside a package. Ideally, a generic package format appears that enables packaging VNFs and services for various target platforms to minimise as much as possible the on-boarding processes on various infrastructures.

Some extensions to descriptors which are currently being explored include:

Recursive NSDs that permit the definition of recursive network services, i.e., including both VNFs and other network services. By just reusing and referring the associated NSDs, allowing such recursive references makes it possible to reuse and extend existing network services more quickly and easily. By doing this, the process of developing new NSDs also becomes less prone to mistake.

Layered descriptors, such as SONATA and OSM descriptors describing the same VNF or network service, enable the packaging of several descriptor formats for the same VNF or network service within a single package. A developer may offer a service that is compatible with several platforms as part of a single package thanks to this idea. It is possible to design tool support that automatically generates many formats from a shared code or descriptor base.

Packets of test results that have been made and signed by a source of validation and verification. These packages provide information on the precise service or VNF for which the tests were run in addition to the test results themselves. Specified service attributes, such as specification compliance or QoS levels, are attested by the signed test result packages. The package's integrity and the attestations it contains may be checked using the signature.

Vertical mapping

Vertical service blueprints and vertical service descriptors (VSD) can be used to describe vertical services including their SLA requirements. The SLA requirements can be of different kinds, for example:

1. End-to-end latency and bandwidth requirements, necessary for the service to function correctly,
2. Number of supported users, coverage area, etc., related to the dimensioning of the service,
3. Availability and reliability,
4. Deployment time, energy efficiency, i.e., optimization targets for the deployment of the service.

With the proper choice of deployment flavour and instantiation level, the vertical service description, which includes such SLA criteria, may be converted to an NSD. In order to do so, the VSD is used to determine the NSD. Specific values of the SLA requirements are then translated into the choice of deployment flavour and instantiation level using a rule-based approach. The NSD itself can encode some of the SLA criteria. Continuing the prior illustration:

1. Bandwidth requirements can be expressed in the NSD as bandwidth requirements on virtual links,
2. The number of supported users can be mapped to a corresponding instantiation level with sufficient VNF instances handling the expected number of users,
3. Reliability can be mapped to a deployment flavour with or without redundant components,
4. Energy efficiency can be mapped to an orchestration policy for the NFVO to place VNFs in the most energy efficient way, trigger activation of corresponding features, even if these imply license fees.

Additionally, a vertical or other customer may need to instantiate a number of services, and they may have worked with the provider to establish a general resource budget for compute, storage, transport, and radio capacity. There must be an arbitration between the services if the resource budget is inadequate in every situation. The service priority should be taken into consideration during this arbitration, which may result in a change to the deployment flavour and/or instantiation level of the services. The NSDs may be instantiated when these actions have been taken on them [10].

Monitoring aspects in Orchestration

Every virtualized resource in a MANO framework, as well as the applications and services operating on the infrastructure, must be monitored by the monitoring system. The monitoring system generally contains three distinct resource domains with regard to the infrastructure, including:

1) NFVI resources;
2) SDN-enabled elements;
3) Physical devices that do not belong to the first two categories. With regard to the applications.

The monitoring system for services contains VNFs as well as service monitoring metrics and parameters, which are helpful for ensuring SLA compliance. The monitoring system is connected with the various orchestration layer components to help manage networks and systems and to provide dashboards and analytical tools access to a consistent and straightforward picture of the platform. It gathers all the data required to make a "monitoring as a service" paradigm possible. In addition to VNF-specific metrics like calls per second, subscriber count, rule count, flows per second, VNF downtime, video streaming start success ratio, video streaming start delay, video streaming stall frequency, video streaming download throughput, etc., the set of monitored parameters may also include VM-related data, such as CPU utilisation and bandwidth consumption. Depending on the logic used, one or more of these factors can potentially cause the QoS loop to respond. Monitoring parameters are metrics that are monitored at the service level to assess the degree of compliance with the current SLAs.

CONCLUSION

Abstractions can also be violated by attackers who exploit vulnerabilities in the network to bypass security controls and gain unauthorized access. For example, an attacker might exploit a vulnerability in the abstraction layer to gain access to sensitive data or perform unauthorized actions.To prevent violations of abstractions in networks, it is important to use best practices in network design, configuration, and management.

This includes implementing security controls, monitoring the network for anomalies, and regularly auditing the network for compliance with the abstract model.In conclusion, abstractions are a powerful tool in network design, but they can be violated by misconfigurations and security vulnerabilities. Network engineers and administrators must be aware of these risks and take steps to mitigate them through best practices in network management and security. By doing so, they can ensure that the network continues to operate effectively and securely, even as it becomes more complex.

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CHAPTER 10

DEVELOPMENT TIME WITH SOFTWARE DEVELOPMENT KITS

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ABSTRACT:

In many projects, Prometheus has been selected as open source package to fulfil the monitoring system requirements, along with Grafana for data analytics and visualization. As not everything can be instrumented directly, applications that do not support Prometheus metrics natively can be instrumented by using exporters. The use of exporters allows collecting statistics and metrics converting them to Prometheus metrics. NFV as such can already be seen as an embodiment of the micro services approach. With the discussion above, not only the services themselves, but also the orchestration components can be considered as micro services. This approach brings big advantages, including flexibility, continuous delivery (CD) and integration, reduced time-to-market (TTM) and time to deployment, faster resolution of problems, more stable operating environments, improved communication and collaboration, reduced costs and higher dependability, etc., but requires a new approach to development and operation.

KEYWORDS:

Communication, Fifth Generation (5g), Mobile, Networks, Technology.

INTRODUCTION

DevOps, or the integration of creation and operation of sophisticated software systems, is a recurring issue in the cloud and software sectors. This is undoubtedly a good candidate for NFV and orchestration as well, and it being explored from several angles. It is well understood that the right support tools are essential to a successful DevOps strategy. In particular, development time, pre-deployment time, deployment time, and runtime are all times for both services and orchestration software when tool assistance is required. This chapter has mostly concentrated on runtime support tools and functions so far. The stages before runtime are the main topic of this section. Depending on the specific orchestration strategy, the DevOps method also modifies an orchestrator's internal structure. In, a model design that takes these requirements into account differs between three possible frameworks: Monitoring and management are often known as CBTR coding-building-testing-releasing [1].

Development time: SDKs

Software development kits (SDKs) are required throughout the development phase. By providing NFV-specific requirements, they should supplement general-purpose SDKs for activities requiring generic programming. Support for service needs, service design, and particular implementation activities should all be included. These SDKs are often offered as standalone tools (rather than being incorporated into, say, Eclipse, which would lessen their practical appeal) and are accessible as a group of universally usable command-line tools, sometimes with a GUI. In certain instances, independent editors or extensions to editors (by providing specifications for a template as a domain-specific language) are also made accessible. For instance, both functions and services include support for template development. Different semantics are supported, ranging from straightforward ETSI semantics to those that are more expressive (allowing, for example, the specification of traffic-dependent resource consumptions or monitoring points).

There have been some initiatives to accommodate non-networking developers (such as tenants of a "vertical" tenant) with streamlined descriptions and models, and maybe even through specialised tools like a service composer (which generates comparable output to that of an editor but in a more user-friendly environment). This is a double-edged sword, however, since it by definition restricts universality and necessitates amortising expenses for such instruments across a considerably smaller number of scenarios[2].

Need for validation tools

The many descriptions of functions, services, infrastructure, SLAs, etc. that are included in an orchestrator are considered artefacts. If all of these artefacts were created manually, it is impossible that they would be error-free. Therefore, even at a basic syntactic level, specialised validation tools are required. These programmes examine things like the integrity of XML files, the accuracy of the descriptions, etc. They can determine if all necessary artefacts, such as function implementations, are accessible on a semantic level. They may also determine whether all necessary connections between functions are really declared or whether some function's gate has been left disconnected.These tools are often used in several tasks. Additionally, there is a class of tools that, within reasonable bounds, can verify the accuracy of claims made about a function or a service that are both functional and non-functional in its full generality, this would require resolving the incomputable halting problem[3].

These validation techniques may all be applied at various times. When a service is being on boarded, they are helpful during the evaluation and deployment phases. Additionally, they are helpful during the pre-deployment stage, when a tenant plans to deploy a service on a (virtual or actual) infrastructure and the infrastructure provider needs to verify claims about the resources needed to achieve the desired service quality level at a specific traffic level. A supplier of infrastructure must have these capabilities in order to guarantee service quality and be able to sign contracts based on such guarantees[4], [5].

It's critical to understand that, in contrast to a purely cloud context, the demand for such tools is increased in a 5G scenario. This is partly because of the intricate link between a network operator and potentially several software manufacturers, which introduces a lot of variety into a system where stability is crucial. Practically, a validation tool examines just syntactic and semantic features on its own. It might be challenging to verify quantitative and performance claims in general. It seems reasonable to delegate this to a different family of tools, in this case, referred to as assessment tools [6].

These tools are responsible for determining or verifying performance claims. In general, this is not an easy process; performance prediction of arbitrary code is a challenging challenge in software engineering. Using technologies that create the ideal environment and subjecting the service/function of interest to various loads, such as varying traffic volumes, is a viable strategy in this situation. Such a setting may be real very expensive and maintenance-intensive, but relatively precise and useful as a staging environment for actual operation or virtual, utilising emulation methods with sufficient accuracy at significantly lower resource demands.

It should be noted that these assessment methods may be utilised with various focuses and probably by players in various positions throughout development, pre-deployment, and deployment times. A neutral "Validator" role, for instance, might check a service package's performance claim made by its vendor before deployment using its own assessment techniques, providing an authorised witness to the claim or a counterexample disputing the claim.It should be noted that this method, along with other degrees of staging zones, is extremely widespread in the cloud computing world and is beginning to get acceptance as good and useful by the networking community. There have been many suggested concrete procedures for integrating such tools, but they are not currently in agreement.

Such evaluation methods may be used to fuel a knowledge pool in a MAPE-K setting with observations about the behaviour of a function or a service as a practical use case beyond validation. This may make it easier to start a MAPE cycle without having to depend on a knowledge base that is empty, while also providing a natural setting for upgrading such information with real-world observations made throughout a service's deployment. In the context of the vertical use cases that each project covers, this section analyses how the projects in the 5G PPP phase II implemented the overall architecture. It aims to assess how the projects used key 5G PPP system principles, such as virtualization, functional split at the Radio Access segment, or multi-access edge computing capabilities. Understanding the evaluation's consideration and measurement of the Key Performance Indicators (KPIs) for performance [7].

Performance KPIs

1. The technical Annex to the 5G PPP contractual arrangement defines the following KPIs:
2. Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
3. Saving up to 90% of energy per service provided.
4. Reducing the average service creation time cycle from 90 hours to 90 minutes.
5. Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision.
6. Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.

These KPIs have been improved during the 5G PPP program's implementation, as shown in a number of white papers, including "5G empowering vertical industries." Standards organisations like ITU-T and 3GPP have developed a more thorough and partially formal description of the KPIs that are important for the functioning of the 5G system. The radio interface-specific KPIs are defined in the report. These include the maximum data rate, the user experience data rate, mobility, latency for the user plane and the control plane separately, connection density, reliability, area traffic capacity, peak spectral efficiency, 5th percentile user spectral efficiency, average spectral efficiency, energy efficiency, mobility interruption time, and bandwidth.

End-to-end Key Performance Indicators (KPIs) for the 5G network and network slicing are defined by 3GPP in TS 28.554. Accessibility, Integrity, Utilisation, Retainability, and for next upgrades, Availability and Mobility are the new KPI categories introduced by 3GPP. ITU-T Rec.E.800 is used to determine the categories.

Accessibility includes Data Radio Bearer (DRB) Accessibility for UE services, Registration Success Rate of One Network Slice Instance, and Registered Subscribers of Network and Network Slice Instance via AMF and UDM. End-to-end latency of the 5G network, upstream/downstream throughput for the whole network and each network slice, upstream/downstream throughput at the N3 Interface (between RAN and UPF), and throughput between RAN and UE are all examples of integrity. Utilisation includes the Mean number of PDU sessions for the network and network slice instances as well as the Network Slice Instance's Virtualised Resource Utilisation. Finally, QoS flow sustainability is referred to as sustainability.

A Testing Framework for the NGMN 5G pre-commercial network experiments was also provided by NGMN. This paper details general testing requirements, deployment scenarios, trial setup requirements, trial test requirements, and service- or technology-specific requirements for a number of identified KPIs, including Latency, User throughput, Cell Capacity, Spectral Efficiency, Coverage, Mobility, Reliability and Retainability, User Experience, Energy Efficiency, Inter-RAT procedures, RAN architecture split, as well as Location/Positioning service and Fixed Wirel requirements.

DISCUSSION

As may be seen from the primary sources mentioned above, there are many KPIs with rather divergent definitions, while the standards organisations and the industry are working to consolidate these definitions. The 5G PPP's ad hoc work group has made an effort to provide a comprehensive picture of the KPIs being addressed by the different initiatives under the programme.

Types of evaluation and usability of KPIs

Performance indicators are created to track the effectiveness of services, apps, or networks that provide services to users, whose efficacy we must ensure in order for them to provide or deploy their services. Nevertheless, depending on the deployment state, it is necessary to categorise the deployment type for which we wish to produce these indicators. In three levels, we can create a first high level classification:

1. **Phase 1:** Interoperability of elements and adaptation to standards. In this phase, the main objective is to verify that the different devices interact in the expected way and conform

to established standards. Normally in this phase the UEs are validated and the elements are configured to eliminate any interoperability problems. In this phase, the use of instrumental equipment is usually required to perform low-level interoperability reports and exhaustive compatibility validations of different measures.

2. **Phase 2:** Before an actual implementation, proof of concept and scalability are required. The major goal of this phase, which comes before networks and services are deployed, is to demonstrate that the service and its intended applications can be offered effectively. Additionally, we want to determine the system's scalability and ability to support load tests. The tools used at this stage most often have load simulators or automatic tools for doing functional tests.
3. **Phase 3:** monitoring once installed in service. Once the services have been implemented in the actual network, this phase enables the monitoring of their quality, and they necessitate regular reports that permit the implementation of preventative measures and the regulation of the quality that is actually being provided to the end users. During this phase, a lot of data are combined in the most effective way possible, which typically necessitates the deployment of components in the applications that produce some of the data needed to track user satisfaction with the quality of the service. Due to the volume of data generated during this period, effective data aggregation procedures are essential.

When we talk about KPIs it is good to have as reference what is the objective in which we are considering their generation, since that allows us to use in the most efficient way instrumental equipment, load simulation equipment or possible applications development.

1. In Phase 1, interoperability tests of the UEs with the networks will be carried out, depending on the features and frequencies of the network that are being deployed, it is necessary to repeat these tests to ensure that we are within the parameters and configured expected and defined in the standards
2. In Phase 2, load and simulation tests will be performed in laboratory environments that will allow us, before making a real and massive deployment of the service for vertical companies, to optimize the resources used efficiently. In this phase we will verify that we can reach our goal of coverage and concurrency that have been established.
3. Phase 3 is the most critical and complicated, since having well controlled during the operation of the quality of service provided to users will allow us to anticipate any problem and in this way we can guarantee a better quality of service.
4. Any Vertical Industry will have to go through these three phases, and therefore the KPIs that will be implemented, tested and measured, should be applied in the most efficient way to each of these three phases.

Approach/options to generation of KPIs

An abstract 5G system partitioning has been employed in the context of KPI validation by the 5G PPP project, as shown in the picture below. The functional divide at the radio section, for example, is one of many architectural features that have been purposefully simplified in the picture.

1. For the analysis of the deployment options chosen for the architecture validation the following parameters have been considered:
2. This parameter considers the architectural option to use computing capacity near the application for meeting performance requirements such as latency
3. Functional split. This parameter considers the architectural option to implement functional split at the RAN for optimising performance parameters such as throughput and latency.
4. Cloud RAN. This parameter considers the architectural option to implement different Cloud RAN options for optimising performance parameters such as throughput and latency, as well as cost, complexity, and energy consumption
5. Transport technology. This parameter is used to assess the impact of the used transport technology mainly at the wide area network segment
6. Spectrum used. This parameter is used to assess the impact of the use of different 5G spectrum option when available
7. Implementation of SA/NSA. This parameter is used to assess the readiness of the technology to implement a full 5G system.
8. EPC/5G core. This parameter is used to assess the readiness of the technology to implement a full 5G system and the impact of using 4G components.
9. Some of the results below are based on pre-standards prototype implementations of the different components that comprise a 5G system according to 3GPP.
10. Architecture instantiations
11. The analysis of the instantiations of the architecture has been performed based on the following questions that were answered by all projects.
12. Do you use a MEC deployment? Can you make a statement about its location?
13. This question interrogates whether the concept of multi-access edge computing has been deployed and used and potentially at which location. A significant number of projects have used MEC [8]

It is noteworthy that the MEC capabilities of the 5G architecture were not deployed or used in use cases relating to media, such as immersive media, media distribution, or high resolution media. MEC capabilities have been implemented at the edge for pushing, pre-fetching, and caching material in the context of 5G/satellite integration. This result is consistent with the common presumption that the eMBB service class won't often employ MEC since it isn't latency-sensitive. Smart city use cases, however, have combined the two approaches. This fact suggests that the term "smart city" encompasses a diverse range of applications that may or may not need the deployment of MEC. Only a few projects have used and implemented the functional split concept at the radio segment. According to the 3GPP functional split choices suggestion as given in section 3.1.1, option 2 is the functional split that is most often employed. Option 4 RLC-MAC split, option 7 intra-PHY split, option 7 intra-PHY split with analogue radio via fibre, and option 8 PHY-RF split are other possibilities that have been deployed and researched. At least two projects have put numerous adjustable CU- DU split possibilities into practise and experimented with them. The functional split choices that have been implemented have not clearly been mapped to use cases or 5G service classes [9], [10].

CONCLUSION

Software Development Kits (SDKs) are a valuable tool that can help developers accelerate the development process by providing pre-built code libraries, tools, and APIs. By leveraging SDKs, developers can reduce the time required to develop and deploy applications, thereby improving time-to-market and increasing competitiveness.SDKs offer several benefits, including reducing development time, improving code quality, and enabling faster integration with other systems. They also provide developers with access to a wide range of tools and resources, including code samples, documentation, and support forums.

However, there are also some challenges associated with using SDKs. Developers must carefully evaluate the SDK's capabilities and limitations, as well as its compatibility with other systems and platforms. They must also ensure that the SDK meets their specific requirements and that it is reliable and secure.To effectively leverage SDKs, developers must strike a balance between using pre-built code and writing custom code. They must also stay up-to-date with the latest developments in SDK technology and regularly evaluate new SDKs to determine if they can help improve development processes. In conclusion, Software Development Kits (SDKs) can significantly reduce the time required to develop and deploy applications, thereby improving time-to-market and increasing competitiveness. However, developers must carefully evaluate the capabilities and limitations of SDKs to ensure they meet their specific requirements, and they must stay up-to-date with the latest SDK technology to maximize the benefits of using these tools.

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CHAPTER 11

A STUDY ON EMULATION FRAMEWORK

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ABSTRACT:

This question interrogates the use of different network transport technologies. The main network segment for transport is positioned between RAN/Edge and Core segments; however fronthaul, backhaul and other intermediate network transport technologies are included in the analysis. A number of projects rely on plain IP type transport such as UDP, TCP, and MQTT over TCP, MPLS or various types of VPNs to interconnect testbeds and their components. Various SDN technologies are not explicitly listed, because these can be considered common. In certain cases specific technology options have been chosen for the implementation of the transport network segment as listed below: It should be noted that due to the evolving standard for 5G core no complete Stand-Alone (SA) deployment was reported. In some cases this is planned in the last phase of certain projects. In many cases the deployments do not adhere to the NSA/SA deployment options.

KEYWORDS:

Communication, Fifth Generation (5g), Mobile, Networks, Technology.

INTRODUCTION

It should be highlighted that the deployed components should primarily be categorised as prototypes and do completely support 5G Core standards owing to the emerging standard for 5G Core. Architecture WP V3 Deployment and Analysis. The extensive soft warization of the 5G system necessitates enhanced automation of the management and orchestration tasks that control how the various functional parts of the system interact with one another. Emerges as one of the standards with linked technologies that implement this automation layer, as stated in section. This subsection examines how much advanced management and orchestration technology was used by the 5G PPP phase II projects in relation to their use cases. The study of the replies reveals that most deployed use cases leverage slicing and orchestration to accomplish some degree of automation at the resource and service levels (see next question). The usage of slicing and orchestration at either the service level or the resource level solely is indicated by a decreased number of projects[1].

Two areas for improvement may be found in the implementation of the slicing idea alone: the slicing concept is not yet sufficiently defined or standardised, and the RAN section has been excluded from slicing in at least two instances. Additionally, the transport network segment is the primary focus of the plans to continue implementing slicing in the deployed use cases, which may suggest that this segment receives priority in the application of the concepts. One project shows that the ideas of slicing and orchestration are not used.

At the level at which they are enabled, around half of the deployed use cases are capable of end-to-end orchestration. One-fourth of the use cases make modest use of orchestration.What claims can you make about the degree of automation you attained in relation to Scalability, Dynamism, and Number of occurrences. In terms of the attributes Scalability, Dynamicity, percentage of instances, etc., a startlingly large percentage of use case deployments reached automated levels. "Service composition" and "Service federation" are further features of automation that were also mentioned.

It should be noted that certain deployments of use cases have been approved as ETSI ENI PoCs (Proof of Concept), and for some of those deployments, the automation characteristics satisfy the prerequisites for pre-commercial deployment. This inquiry probes the implementation of autonomous features in the use cases. The application of cognitive algorithms or current autonomic computing ideas like MAPE (Monitor-Analyze-Plan-Execute) help to make sense of autonomous features. Autonomic qualities in contracts (see previous question) often relate to the use of policy-based management task execution to enforce service level agreement bounds. The remedies that have been proposed include [2]:

1. MAPE loop focused on optimization of media services
2. Autonomous wavelength control in passive WDM, with zero touch provisioning support
3. Semi-autonomous traffic type detection and prioritization
4. Early failure detection using monitoring, data analytics and autonomic closed loop management and control at network subsystem level
5. Autonomous SLA management based on configuration, monitoring and reaction to alerts
6. Resource assignment utilizing traffic prediction models.
7. Cognitive network management, enabling machine-learning-empowered autonomous control loops for slice FCAPS management and slicing control for pro-active failure detection and handover prediction.

An integrated Development and Operations (DevOps) approach is essential in 5G to shorten the time to market for networked services and to decrease the entry barrier for outside developers of Virtual Network Functions (VNFs) and Network Services (NSs). The Validation and Verification (V&V) of individual VNFs and NSs so that suppliers of these services may be confident in their conduct is one of the main problems in DevOps. Such a V&V process includes both functional and non-functional testing of VNFs and NSs, such as performance measurements for learning about the resources needed to meet SLAs and provide the anticipated Quality of Experience (QoE). All of these V&V processes must be completely automated and capable of qualifying any VNF or NS without additional human input in order to integrate smoothly into the expected DevOps workflow [3].

Different stakeholders are anticipated to play different roles in validating and verifying network services in the ecosystem of network services of the future. The network service provider will want to evaluate and verify all code before deploying it on their network, and the developer will want to assure the quality of their own code before release. The cost of verification and validation for independent network service providers and VNF developers who hope to supply many network service providers will be amortised, it is anticipated that a variety of third-party verification and validation organisations will exist. This internal architecture of a V&V platform and its surrounding building blocks is shown. It has a high degree of modularization and comprises primarily of the following elements to allow a fully automated V&V workflow: (i) The V&V API, which enables users of the V&V platform to submit packages for verification and validation; (ii) The Test Invoker, who is in charge of configuring, scheduling, and maintaining the test state; (iii) The V&V Catalogues, which hold the artefacts to be tested, such as VNFs and network services; and (iv) Several repositories, such as the Test Repository and the Test Result Repository, In order to abstract and standardise the interface towards the test execution platforms, where the VNFs or services under test (SUT) are installed and the tests are actually carried out, the V&V platform leverages the idea of plug-able Test Execution Platform Drivers. The instruments for test analysis are the last ones. The MANO system, which affects the performance of VNFs and NSs, particularly in regard to scalability and fail-over, is a key component of the system being tested.

It is possible to discriminate between functional, performance, syntactic, API, and security testing. The purpose of categorising the tests is to make it easier for the creator of the test suite or the V&V provider to quickly search for and locate the tests they need to thoroughly test a system, as well as to make it easier to determine the priority of tests in the event that testing resources are limited. To make it easier to utilise and analyse the data, test results from the V&V testing platform need to be controlled. Test data requirements also call for details on the test strategy, test profile, and test environment setup in addition to actual measurements. Test results are managed by other modules and end users (such as developers) thanks to the storage of the test results in a dedicated repository.

Emulation Framework

For local quick prototyping and lightweight local debugging of services and components, the emulator component is available. It was developed to aid in the local prototyping and testing of network service developers' network services in actual end-to-end multi-PoP situations. It enables the execution of actual network operations in simulated network topologies operating locally on the developer's computer and packaged as Docker containers. For each emulated PoP, the emulation platform also provides OpenStack-like APIs so that it may be integrated with MANO solutions, such as OSM demonstrates the emulator's capabilities and how they translate to a condensed version of the ETSI NFV reference architecture, in which it takes the role of both the virtualized infrastructure manager (VIM) and the network function virtualization infrastructure (NFVI). Standard Docker containers may be used as VNFs in the simulated network thanks to the emulator. For each of the simulated PoPs, it automatically launches control interfaces that resemble OpenStack, enabling MANO systems to start, stop, and manage VNFs. The emulator specifically offers OpenStack's Nova, Heat, Keystone, Glance, and Neutron APIs' fundamental features. Even though not all of these APIs are specifically needed to manage

VNFs, they are all required so that the MANO system can connect to the OpenStack-like VIM interfaces of each emulated PoP and pretend to be managing a real-world multi-VIM deployment.

The emulation platform may be installed locally on a developer's laptop and can serve as a local test execution platform. Fast turnaround times for the developer trying to address faults within a network service are an advantage of such a local platform. The accessibility of a test environment is advantageous to test developers at the same time. Although it primarily focuses on functional tests rather than performance tests because of the nature of such an emulation environment. The platform's ability to simulate VIM interfaces may be utilised to evaluate various MANO and service platform solutions in addition to acting as a testing environment for VNFs and NSs.

DISCUSSION

One of the high impact results anticipated from 5G PPP initiatives is contributions to standards that influence the development of 5G. In areas related to the development of 5G architectural ideas as previously described in this study, the contributions to standards made by various 5G PPP Phase 2 projects are surveyed in this chapter.This paragraph provides a short overview of the standards development organisations (SDOs) that have been the focus of the 5G PPP Phase 2 initiatives covered by this study. The big SDOs are given considerable attention, but other smaller ones and specialist industry alliances with interests in technical requirements that also have an effect on the development of 5G architecture are also highlighted [4].

3GPP

For the most part, the Third-Generation Partnership Project (3GPP) has been in charge of defining and upholding the standards for both the most recent and earlier generations of mobile communications technology. The Technical Specification Groups (TSGs) for Radio Access Networks (RAN), Service & Systems Aspects (SA), and Core Network & Terminals (CT) make up the 3GPP organisation for standards development. Additionally, each of these TSGs consists of a number of Working Groups (WGs). In addition, 3GPP uses a three-stage phased method to developing standards, with Stages 1, 2, and 3 focused on, respectively, service requirements, architecture, and detailed interface specifications.

The 3GPP SA WG2

Architecture makes decisions about how new functions will interact with existing network components from a system-wide perspective. Its primary duty is to create Stage 2 of the 3GPP network. It builds on the work done by SA WG1 Service Requirements, which identified the network's primary tasks and entities, as well as the connections between them and the information they communicate. The groups in charge of specifying the exact format of communications in Stage 3 utilise the SA WG2 outputs as inputs. SA WG4 (Codec), in addition to SA WG2, also contributes to the overall design. From a Codec viewpoint, its mission includes quality assessment, end-to-end performance, and compatibility issues with current mobile and fixed networks.

The Radio Access Network's Stage 2 standard is the responsibility of TSG RAN. Three RAN WGs include radio and edge architecture: Radio Layer 1 (RAN WG1), Radio Layer 2 (RAN WG2), and Radio Layer 3 RR (RAN WG3) are in charge of defining the overall UTRAN/E-UTRAN architecture and protocol. While RAN WG2 is in charge of the Radio Interface architecture and protocols, RAN WG1 concentrates on the radio interface's physical layer. The previously mentioned SA WG2 and CT WG1 are in charge of formulating specifications for the User Equipment (UE) - core network Layer 3 radio protocols and the core network side of the lu reference point, respectively. CT WG4 is in charge of the Bearer Independent Architecture, among other things [1].

SA WG5 - Network Management, which outlines the specifications, architecture, and solutions for providing and managing the network (RAN, CN, and IMS) and its services, is responsible for the MANO elements.

ETSI

The European Telecommunications Standards Institute (ETSI) has standardization activities that specify requirements and potential enablers or building blocks for an overall 5G system. This includes key aspects, such as, NFV, MEC and MANO, which have a significant impact on the 5G architectural developments. A number of ETSI Industry Specification Groups (ISGs), Technical Committees (TCs) and projects have active collaboration with 3GPP and, in some cases, provide direct input to 3GPP [7-1]. Some of these ETSI entities that are relevant in the scope of this report are briefly reviewed below.

ETSI Zero Touch network and Service Management (ZSM) is an ETSI ISG that specifies horizontal (i.e., cross-domains, cross-technology) and vertical (i.e., cross layers) end-to-end network and service management reference architecture to enable agile, efficient and qualitative management and full automation of emerging and future networks and services. Full automation in this context includes automation of delivery, deployment, configuration, assurance and optimization of networks and services.

1. ETSI NFV ISG defines requirements and architecture for the virtualization of network functions, as well as, addressing technical challenges of network virtualization. The outputs of this ISG group includes pre-standardization studies, detailed specifications, and Proof of Concepts.
2. ETSI Open Source MANO (OSM) is an ETSI-hosted project that focuses on providing an open source NFV Management and Orchestration (MANO) software stack aligned with ETSI NFV Information Models.
3. ETSI TC on Satellite Earth Stations and Systems (SES) focuses on all aspects related to satellite earth stations and systems. This includes satellite communication systems, services and applications; as well as, satellite navigation systems and services; all types of earth stations and earth station equipment.
4. ETSI MEC ISG aims for a standardized, open environment that will enable the efficient and seamless integration of applications from vendors, service providers, and third-parties across multi-vendor MEC platforms.

5. ETSI Experiential Networked Intelligence (ENI) ISG is currently defining a Cognitive Network Management architecture using closed-loop AI mechanisms that leverage context-aware and metadata-driven policies to improve the operator experience.

To further assure product and service interoperability and to offer input to various standardisation bodies (both within and outside of ETSI), ETSI also organises Plug tests. For instance, using several scenarios and test cases based on 3GPP Mission Critical Services, the ETSI Mission Critical Push to Talk (MCPTT) Plug tests events2 have offered a platform to show the compatibility of a broad variety of implementations [5].

ITU

The International Telecommunication Union (ITU) coordinates the development of global telecommunications standards in addition to fostering the growth and sustained development of the sector and ensuring universal access. The activities of ITU activities are focused on three core sectors, namely: Standardization (ITU-T) which standardizes global telecommunications;

The Plug test event name was changed from MCPTT to MCX (Mission Critical Services) in order to increase the event scope as vendors are moving beyond voice satellite orbit resources, and Development (ITU-D) that supports the ITU mission to ensure equitable, sustainable and affordable access to ICT. The ITU sectors include Study Groups (SGs), which assemble global experts for the development of international standards commonly referred to as ITU-x Recommendations where x stands for T, D or R depending on the ITU sector concerned. In terms of the scope of this report, SGs of interest include:

1. **ITU-T SG13:** Future networks, which focuses on IMT-2020 (that defined the requirements for 5G networks and services), cloud computing and trusted network infrastructure.
2. **ITU-T SG15:** Networks, Technologies and Infrastructures for Transport, Access and Home. This SG gives special consideration to the changing telecommunication environment towards future networks, including networks that are supporting the evolving needs of mobile communications (IMT-2020).

IETF

An open SDO for internet-related technologies is the Internet Engineering Task Force (IETF). Network slicing, MEC, machine learning at the network level, and Low Power IoT Networking (LPWA) are the primary aspects of 5G that the IETF is concentrating on. Working Groups (WGs), which are divided into several technical areas depending on subject, carry out the technical work in the IETF. After being created by the IETF, the standards are subsequently published as Internet Draughts, with the potential to become approved Request for Comment (RFC) papers [6].

The Common Control and Measurement Plane (CCAMP) Working Group is in charge of standardising a common control plane and a separate common measurement plane for non-packet technologies found on the Internet and in the networks of telecom service providers (such as optical cross-connects, microwave links, TDM switches, etc.).Additionally, within the IETF framework, pre-WG technical discussions can be organised as Birds of a Feather (BoF) sessions at IETF meetings[7]. Some of the BoFs could someday develop into full-fledged WGs, whereas others only serve as a discussion platform for subjects that might be of interest to the IETF community. Among the standards contributions of this report's subsequent BoFs are examples like Common Operations and Management on network Slices (coms).

Along with the significant SDOs previously mentioned, the 5G PPP Phase 2 projects also have targeted SDOs or technical specification groups based in industry alliances (representing interests of specific industry groups) and open source projects that use open source principles to produce standards or other open specifications.

The following groups are represented in the reported contributions in this report: Leading digital TV and technology businesses from across the globe form the DVB (Digital Video Broadcasting) consortium, which creates open technical standards for the delivery of digital TV and other broadcast services. Major SDOs like ETSI finally transform these DVB requirements into global standards. In DVG WGs, such as the DVB TM-IPI, which is in charge of creating technical specifications for the delivery and discovery of DVB services over IP networks, the specification work is done. The Open Networking Foundation (ONF) is a user-driven nonprofit with the goal of advancing SDN adoption via the creation of open standards. The LTE-based technology for use in unlicensed and shared spectrum is specified by the MulteFire Alliance. An industry organisation called MEF (previously the Metro Ethernet Forum) defines flexible, assured, and managed communications services over a worldwide ecosystem of automated networks [8].

CONCLUSION

Emulation frameworks offer several benefits, including the ability to test network configurations and services without impacting production environments. They also enable developers to test applications in a controlled environment, allowing for quick and efficient debugging and troubleshooting. However, emulation frameworks also have some limitations. They require significant resources and expertise to set up and maintain, and they may not be able to accurately replicate all aspects of a real network environment.To effectively use emulation frameworks, network engineers and administrators must carefully evaluate their specific requirements and choose the appropriate emulation framework that meets their needs. They must also ensure that the emulation framework accurately models the network environment and that the results obtained from testing are reliable and relevant. In conclusion, emulation frameworks are a powerful tool for testing and optimizing network configurations and services. While they have some limitations, careful evaluation and selection of the appropriate emulation framework can help network engineers and administrators to minimize downtime, improve network performance, and prevent data loss.

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CHAPTER 12

CONTRIBUTIONS RELATED TO RADIO AND EDGE ARCHITECTURES

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ABSTRACT:

The Open ROADM Multi-Source Agreement (MSA) defines interoperability specifications for Reconfigurable Optical Add/Drop Multiplexers (ROADM). The specifications consist of both Optical interoperability as well as YANG data models. The NGMN Alliance in an industry alliance that complements and supports SDOs (e.g. 3GPP) by providing a coherent view of requirements of mobile operators for next generation networks with a particular focus on 5G. The specification work in initiated through a number of projects. For instance, the NGMN Network Management and Orchestration (NWMO) project has been specifying the requirements for 5G Network and Service Management including Orchestration.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

This section provides an overview of more than 200 standards contributions from 5G PPP Phase 2 projects that have a direct or indirect impact on the evolution of 5G architecture. The reported standards contributions come in a variety of media, such as technical or specification documents, presentations, white papers, proof of concept tests, interoperability evaluations, source code, and more. Details on the contributing project, SDO targeted, title or brief summary, and current status of the contribution are supplied for each contribution. Additionally, each subsection that corresponds to one of the architectural topics covered in this report is represented in the listing of the contributions. The Annexe of Chapter 0 has a comprehensive list of these contributions, which is briefly examined below. Statistics on the maximum concentration to the target SDO are given in each instance. The 5G PPP Phase 2 projects' contributions to the 5G general architectures have mostly focused on the 3GPP TSG SA. These contributions cover a wide range of topics, but a significant portion relates to the rollout of 5G V2X systems and multimedia broadcasting or streaming services. The breakdown for 3GPP SA is shown in the bullet points below. Working groups that place a lot of emphasis on SA2 and SA4.

1. 3GPP SA2 – Architecture: 40 contributions.
2. 3GPP SA4 – Codec: 25 contributions.

3. 3GPP SA6 – Mission-critical applications: 3 contributions
4. 3GPP SA1 – Services: 1 contribution
5. 3GPP SA5 – Telecom Management: 1 contribution.

Contributions Related to Radio and Edge Architectures

The 3GPP TSG RAN WGs received the majority of the 5G PPP Phase 2 project contributions pertaining to RAN designs. These contributions concentrated on 5G NR improvements for V2X and multimedia broadcast in order to achieve this. Additional standards contributions are also aimed at the DVB industry alliance for the multimedia broadcast. The major forums for MEC-related contributions in the context of edge architectures have been ETSI (MEC and NFV ISGs), with a focus on 5G architectural enablers for MEC applications.

The bullet points below show the breakdown for 3GPP RAN:

1. 3GPP RAN1– Radio layer 1: 10 contributions.
2. 3GPP RAN2– Radio layers 2 and 3: 7 contributions.
3. 3GPP RAN3– UTRAN/E-UTRAN architecture: 4 contributions.

Contributions Related to Core and Transport Architectures

The contributions for 5G core network architectures have mostly been targeted towards WGs of 3GPP TSGs SA and CT. As for contributions related to transport architectures, those for microwave/millimeter wave transport have been towards IETF, whereas, those contributions for optical-based transport have targeted mostly ITU-T and IETF.

Sdos Targeted for Contributions Related to Core and Transport Architectures

1. The bullet points below show the breakdown for 3GPP SA and CT.
2. 3GPP CT1– Architecture: 8 contributions.
3. 3GPP CT4– Architecture: 11 contributions.
4. 3GPP SA2– Architecture: 21 contributions.

Frameworks for management and orchestration contributions. The majority of the 5G PPP Phase 2 projects connected to MANO have contributed to ETSI through the ZSM ISG, although there have also been contributions to the NFV ISG and OSM project. Contributions outside of ETSI have been focused on the SA WG5 (Telecom Management) of the 3GPP, which defines the architecture and methods for provisioning, billing, and managing mobile networks (including RAN and core) and associated services.

In addition to the 5G PPP Architecture WG, the 5G Infrastructure Association (5G-IA) Pre-Standardization WG is still keeping track of open source projects' contributions to 5G standardisation. It also keeps track of research and job tasks across pertinent SDOs. Its main area of interest is 3GPP. For instance, delivering updates on EU priorities, monitoring the progress of research and work items for Release 17 (March 2020), and developing a gap analysis for Release 18 and beyond. The WG has already on boarded professionals from Phase 3 projects in addition to the Phase 2 projects (first, projects from ICT-17 calls, followed by projects ICT-18, ICT-19, and 18); from June 2019, the WG will assist the smooth participation of ICT-19.

In addition, a separate Task Force on 5G Standardisation and Vertical Industries has been established. Important participants in the 5G-IA's Working Groups and the Task Force include: Chairman of the 5G-IA, head of the Verticals Task Force, head of the Trials Working Group, and head of the Pre-Standardization Working Group's Activity. It also includes prominent ETSI representatives as well as members of the 3GPP and its market representation partners, such as the 5G-IA, 5G Automotive Association, Public Safety Communications Europe, and 5G Alliance for Connected Industries and Automation (5G-ACIA). Through a series of workshops and helpful manuals, this Task Force seeks to support and encourage vertical industries to contribute to the 5G standardisation process. The results of this investigation will be incorporated into strategies for inputs and support of complementary needs and shared requirements. They will also aid in defining the future participation of other pertinent SDOs so that standardisation efforts are complementary and coordinated internationally [1], [2].

DISCUSSION

The first generation of mobile networks, 5G, was created specifically to cater to the diverse demands of vertical businesses. In addition to providing huge connection for everything from human-held smart devices to sensors and machines, 5G delivers infinite mobile internet service. But perhaps most crucially, it has the capacity to enable vital machine communications with rapid response and very high dependability. With 3GPP Rel. 15, the first 5G standards are already available; nevertheless, further improvements and optimizations' are required to create a 5G system that complies with the demands of the vertical industries.Accordingly, the 5G architecture creates new business opportunities and makes 5G future-proof by (i) enabling E2E network slicing, (ii) addressing both end user and operational services, (iii) supporting native soft variation and programmability, and (v) incorporating novel NR technologies (including fixed and wireless technologies).This white paper has emphasised the combined result from 5G PPP Phase 2 and Phase 3 projects, capitalising on the vision and needs stated in the earlier two editions of the white paper. The following summarises the key conclusions of this white paper.

In order to satisfy particular needs from vertical industries, the general design in Chapter 2 makes a number of improvements to the 3GPP Rel.15 system architecture. The establishment of management domains separates resources or functions based on technical or administrative standards and offers the interfaces to easily create and manage e2e communication services that are constructed from resources of one or more domains. Additionally, network programmability, like data plane programmability, makes it possible to customise NFs and underlying resources in a way that is both more dynamic and flexible. Additionally, the 5G PPP stakeholder model is supported by the structure of the overall architecture [3].

With an emphasis on the protocol modifications created to accommodate the vast range of needs brought by verticals, Chapter 3 describes the RAN and edge architecture. This diversity prevents a single solution from being able to support them all, which is reflected in the solution offered, which includes network slicing for supporting QoS differentiation as well as solutions like virtual small cells, MEC enhancements, and local end-to-end paths, each of which was created to satisfy a specific typology of requirements. Additionally, various access technologies are taken into account, such as Wi-Fi, 3GPPs, and visible light communication. The chapter gives a general overview of the radio and edge technologies that will be on the market to meet the unique requirements of the innovative applications that are anticipated to emerge in the next ten years.

In order for the expansion of 5G networks to properly fulfil the expectations from vertical industries, Chapter 4 highlighted improvements to the core network architecture and innovative transport technologies. Multicast and broadcast capabilities are not included in the first 5G standards. By improving the functionality of current NFs and interfaces, on the one hand, and building on the design concepts of 5G, multicast may be implemented as a component of connection services. On the other hand, additional NFs may be added to the fundamental network architecture in order to provide multicast and broadcast as a service through a clear API that supports terrestrial broadcast and a variety of other vertical use cases. For Rel. 17, the SA2 working group of the 3GPP SA approved a study item on architectural improvements for 5G multicast-broadcast services. Rel.17 of the 5G standard is anticipated to be the first to provide at least partial multicast and broadcast features.

Because of the varied needs that the 5G network is intended to address, operating 5G networks with several slice instances will become very challenging. The system must have a data analytics framework in place to function properly. The provided analytics framework adds data analytics capabilities that provide data collecting and data analytics features to the mobile system architecture (core network, RAN, data network, application function level, etc.). For network monitoring, analysis, optimisation, evaluation, and assurance, the analytics framework is a crucial enabler. Although network data analytics are a part of the 3GPP system architecture in Rel.15, their capabilities are restricted to providing load level data for each network slice instance. Activities including QoS management, traffic steering, mobility management, etc. have been characterised as near-real time activities in O-RAN. The requirement for greater standardisation of data analytics functions and interfaces in the system as stated in the analytics framework may arise as a result of an increase in the need for performance data and analytics when more commercial 5G network installations occur [4], [5].

On the other side, the transport network that links the NFs, CN, and RAN provides the infrastructural connection needed to connect the APs to the CN. Infrastructure connection inside the RAN known as FH is required for transport solutions employing the C-RAN architecture. Despite overcoming the limitations of conventional RANs, C-RAN needs the support of new operational network services over the transport network to handle the demands of emerging services. This problem may be solved by breaking down the conventionally monolithic RAN processing functions stack into a number of distinct units known as RAN split options, which may relax the related transport network constraints with respect to overall capacity, latency, and synchronisation. The best split choice is determined by factors like supported services, service needs, FH and BH technologies and protocols, among others. It is suggested that BH and FH be supported concurrently in a shared infrastructure to maximise coordination and resource sharing advantages. Several solutions, including both wired and wireless ones, have been put forth in light of this.

Numerous technical solutions for wired transport networks have been put forth, including Programmable Elastic Frame-based optical networks, Programmable Metro Networks that take advantage of disaggregated Edge Nodes, Space Division Multiplexing, and Ethernet transport. In addition, several wireless transport options are also put forward, such as mmWave strategies that take use of the idea of multi-tenant small cells with integrated access and BH, satellite BH, and fibre wireless point-to-multipoint solutions. The presentation of concrete instances of data plane programmability in non-RAN portions such the Edge Network, Transport Network, and CN follows. In order to provide network traffic/slice Quality of Service (QoS) management in the data plane and subsequently enable QoS-aware network slicing, this is necessary. These include segment routing and stateful packet processing in hardware.

There is significant agreement on how to organise such systems at a high level of abstraction, according to the examination of the architecture of different management and orchestration systems in Chapter 5 of the book. The ETSI NFV architecture is widely used and gives MANO systems a robust foundation. However, there is a lot of flexibility in how to implement such a management and orchestration system. This freedom is partly motivated by opportunity (evolving standards, but also technological opportunities like the growing importance of accelerator platforms and containers), and partly by a continuous debate for the best possible solution (for example, the choices of flat, hierarchical, or recursive orchestration, or the approach towards DevOps processes). A community-wide consensus on the usual workload assumptions a MANO system would need to handle (such as how many services will need to be instantiated in a typical operator network per second, per minute, or per day) will be helpful for the evaluation of various MANO implementations, which is now underway. Therefore, there is still room for more work in the MANO area, both from an architectural standpoint and from the standpoint of having to base the work on real-world, measurable scenarios and measurements. Provides the methodology for assessing the deployment of the architecture discussed in this paper in the context of the various use cases in the projects. To do this, the team has provided answers to many inquiries on the key characteristics of a 5G network [6].

In general, automated or autonomic techniques are used for the management and orchestration of the deployed network and services. Examples of such systems include the use of 5G new radio, the frequencies utilised, the deployment of a MEC, the kind of transport network technology used, the usage of 5G core. It also gives a brief overview of how the programme performance KPIs are evaluated. It proposes a method for measuring performance KPIs at the boundaries of the major network architecture segments in the context of KPI validation. Quantifying the performance of the systems requires more investigation, which is mostly being done as part of continuing work in the Test, Measurement and KPI Validation work group. Additionally, additional assessment by vertical actors is required to determine whether the deployed systems have actually complied with their requirements [7], [8].

CONCLUSION

Radio and Edge architectures have become increasingly important in modern networks, as more devices and applications require low-latency, high-bandwidth connectivity. Many researchers and industry professionals have made significant contributions to the development and advancement of radio and edge architectures, enabling new use cases and improving network performance.One significant contribution is the development of radio access technologies, such as 5G, that provide higher bandwidth and lower latency than previous generations. These technologies enable new applications and services, such as augmented and virtual reality, autonomous vehicles, and smart cities.Another significant contribution is the development of edge computing architectures, which bring computation and storage capabilities closer to the end-users. Edge architectures enable efficient and low-latency processing of data and applications, enhancing the user experience and enabling new use cases.Other contributions include advancements in network slicing, which enable the creation of virtual networks for different applications and services, and improvements in security and privacy to protect user data and prevent cyber-attacks.Overall, the contributions related to radio and edge architectures have been instrumental in advancing network capabilities and enabling new use cases. As networks continue to evolve, it will be essential to build on these contributions to ensure that networks remain reliable, secure, and efficient.

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CHAPTER 13

A BRIEF DISCUSSION ON INFORMATION MODEL

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ABSTRACT:

An information model is a conceptual representation of data that describes the relationships between different data elements and how they are organized. Information models provide a high-level view of the data within a system, allowing stakeholders to understand the structure of the data and its relationship to the business processes it supports.Information models are used in a wide range of applications, including database design, software development, and data analysis. They enable stakeholders to visualize data in a structured way, making it easier to identify patterns, relationships, and trends. Information models provide a structured and organized view of data within a system, enabling stakeholders to understand its relationships and the business processes it supports. Effective information modeling requires a collaborative effort and a deep understanding of the system being modeled.

KEYWORDS:

Communication, Fifth Generation (5g), Mobile, Networks, Technology.

INTRODUCTION

The standards contributions from Phase 2 5G PPP projects were then examined. The contributions were equally divided throughout the four major architectural areas taken into account in this report's Chapters 2 to 5, with 3GPP and ETSI serving as the projects' primary SDO targets. The promotion of the role of vertical industries in further strengthening the standards implications for 5G PPP Phase 3 projects was also mentioned. The essential terms used in this White Paper are defined in this section. The meanings of words are organised according to their domain, such as business or virtualization-related. The words that are explained here are the most relevant ones, particularly those that have varied meanings according to various organisations that are working to produce standards[1], [2].

Information model (IM): An abstraction and representation of the entities in a controlled environment, as well as their characteristics, functions, and interactions. It is not dependant on any particular platform, programme, protocol, or repository.

Data model: a transformation of an information model's contents into a format unique to a certain kind of data storage or repository. A "data model" is essentially an information model that has been rendered using a particular set of tools for describing, organising, storing, and managing data. There are three sections to it:

1. A collection of data structures such as lists, tables, relations, etc.
2. A collection of operations that can be applied to the structures such as retrieval, update, summation, etc.
3. A collection of integrity rules that define the legal states (set of values) or changes of state (operations on values).
4. Policy: Policy can be defined from two perspectives:
5. A definite goal, course or method of action to guide and determine present and future decisions. "Policies" are implemented or executed within a particular context (such as policies defined within a business unit).

Policies serve as a collection of guidelines for administering, managing, and controlling the system's hardware, software, and resource (networking, computational, and storage) lifecycles. Since specific rules can be defined to support organisational objectives, these two viewpoints are not mutually exclusive. a host, network element, or network's behaviour or operation. The "functions to be performed, the information required to perform these functions, and the information made available by the element to other elements of the system" must all be specified in order for a "service" to be fully specified. A "service" may be configured in a network or on a network element or host, its functionality can be called upon, and/or services can be coordinated in an inter-domain or end-to-end environment using policy [1].

Network function virtualization related:

The central concepts around network function virtualization and network services are based on the definitions of ETSI NFV.

Network Function (NF): functional block within a network infrastructure that has well-defined external interfaces and well-defined functional behaviour.

Network Service (NFV-NS): composition of Network Functions and defined by its functional and behavioural specification. “The Network Service contributes to the behaviour of the higher layer service, which is characterized by at least performance, dependability, and security specifications. The end-to-end network service behaviour is the result of the combination of the individual network function behaviours as well as the behaviours of the network infrastructure composition mechanism.” A network service can be seen as a set of VNFs or PNFs, connected by VLs as defined in a VNFFG [2].

Network Service Descriptor (NSD): template that describes the deployment of a Network Service including service topology (constituent VNFs and the relationships between them, Virtual Links, VNF Forwarding Graphs) as well as Network Service characteristics such as SLAs and any other artefacts necessary for the Network Service on-boarding and lifecycle management of its instances.

The NSD includes a number of deployment flavors, each referencing deployment flavors of all or a subset of the NFV-NS’s constituent VNFs and Virtual Links. The NSD also provides a list of pointers to the descriptors of its constituent VNFs (i.e. VNFDs) and additional information on the connectivity between them together with the traffic forwarding rules.

Network Service Instance (NFV-NSI): Refers to an instance of a network service (NFV-NS).

NFVI as a Service (NFVIaaS): The tenant is offered a virtual infrastructure including associated resources (networking/computing/storage) under its full control in which it can deploy and manage its own NFV network services on top of it. It is assumed that the tenant will deploy its own MANO stack. This is probably the most usual service consumed by M (V) NOs, given that they have the knowledge and need to customize their communication service offering to their own customers. Resources could be virtual cores, storage, virtual nodes and links, etc.

1. The tenant can deploy and connect VMs on these resources under its own control.
2. NFVIaaS includes the provision of network slices or network slice subnets as a service.

Network Service as a Service (NSaaS): Provide to a tenant the possibility to define and instantiate a network service.

1. **NF forwarding graph (NF FG):** graph of logical links connecting NF nodes for the purpose of describing traffic flow between these network functions.
2. **Physical Application (PA):** implementation of a VA via a tightly coupled software and hardware system.
3. **Physical Network Function (PNF):** implementation of a NF via a tightly coupled software and hardware system.
4. **VA Forwarding Graph (VA FG):** Forwarding graph among VA, VNF, PA, PNF nodes.

Virtual Application (VA): More general term for a piece of software which can be loaded into a Virtual Machine.

Virtual link (VL): Set of connection points along with the connectivity relationship between them and any associated target performance metrics (e.g. bandwidth, latency, QoS).

1. **Virtualised Network Function (VNF):** implementation of an NF that can be deployed on a Network Function Virtualisation Infrastructure.
2. **Virtualised Network Function Component (VNFC):** internal component of a VNF providing a defined sub-set of that VNF's functionality, with the main characteristic that a single instance of this component maps against a single Virtualisation Container.
3. **Virtualised Network Function Descriptor (VNFD):** configuration template that describes a VNF in terms of its deployment and operational behaviour, and is used in the process of VNF on-boarding and managing the lifecycle of a VNF instance.
4. **VNF Forwarding Graph (VNF FG):** NF forwarding graph where at least one node is a VNF.

Network slice (NS): A network slice is a complete logical network over a shared compute, storage and network infrastructure. E.g. a network operator can build a network slice including an Access Network (AN) and a Core Network (CN) to enable communication services. Network slice instance (NSI): a set of network functions and the resources for these network functions which are arranged and configured, forming a complete logical network to meet certain network characteristics. Network slices may be deployed in a variety of ways. A network slice instance might be installed as an NFV Network Service instance (NFV-NSI) in the framework of ETSI NFV. Different slices may be deployed in this scenario as instances of the same type of NFV-NS with various deployment flavours or as instances of various NFV-NS types.

Filling up an NSD and asking the NFV Orchestrator to instantiate an NFV-NS in accordance with the contents of the NSD and the chosen deployment flavour are typical steps in an NFV framework for establishing a network slice.

Network slice subnet instance (NSSI): an arrangement of network resources and a set of network operations that together make up a logical network (sub-network). One or more NSSIs, each of which may include one or more VNFs or PNFs, may be included in an NSI. Multiple NSIs may share a single NSSI. In this situation, it is necessary to setup the shared NSSIs properly to provide the necessary isolation and separation.

Vertical service related

1. **Vertical:** the stakeholder belonging to an industrial sector and consuming services. MVNOs are considered a special type of vertical.
2. The existence of network slices is transparent to the vertical and it is fully under the control of the Service Provider how to handle them, including, for instance, mapping services into network slices.
3. **Vertical Service (VS):** From a business perspective, it is a service focused on a specific industry or group of customers with specialized needs.
4. From a technical point of view, it is a composition of general functions as well as network functions

Vertical Service Blueprint (VSB): A parameterized version of a Vertical Service Descriptor, where parameters have to be provided to provide a complete VSD, which is ready to be instantiated.There are a variety of possible parameters. The parameters may be used to define both vertical service needs and management-related factors, such as virtual machine image file locations or service priority.

To convey needs, a collection of parameters includes: Bitrate of VAs and connecting connections, round-trip duration between two VAs, and the geographic region that the vertical service will cover[3].

Vertical Service Descriptor (VSD): A description of the deployment of a vertical service that includes the service topology (constituent VAs and their connections, Virtual Links, and VNF Forwarding Graphs), vertical service characteristics like SLAs, and any other artefacts required for the on-boarding of the vertical service and managing its instances throughout their lifecycle. A VSD may still include parameters that are instance-specific and must be supplied at instantiation time. This is comparable to the parameters supplied when VNFs are first instantiated [4].

Multi-access edge computing related

The central concepts around multi-access edge computing are based on the definitions of ETSI MEC and recent draft integrating NFV and M. Following the renaming of mobile edge computing to multi-access edge computing, the definitions from have been changed accordingly.

Multi-access edge application (MEA): application that can be instantiated on a multi-access edge host within the multi-access edge system and can potentially provide or consume multi-access edge services.

Multiple-access Edge Application Orchestrator (MEAO): It has the same functions as MEO, excepting that it should use the NFVO to instantiate the virtual resources for the MEA as well as for the MEP.

Multiple-access Edge Host (MEC Host): It provides the virtualization environment to run MEC applications, while it interacts with the mobile network entities, via the MEP platform, to provide MES and offload data to MEA.

Multiple-access Edge Orchestrator (MEO): The MEO is in charge of the orchestration and the instantiation of MEA.

Multiple-access Edge Platform Manager (MEPM): It is in charge of the life-cycle management of the deployed MEA. The MEPM is in charge of the MEP configuration, such as the MEC application authorization, the traffic type need to be offloaded to the MEC application, DNS redirection, etc.

Multiple-access Edge Platform Manager – NFV (MEPM-V): The virtualized MEPM maintains the MEP configuration while delegating the LCM of the MEA to one or more VNFMs. Multi-access edge platform (MEP): group of features needed to run multi-access edge applications on a particular multi-access edge host virtualization infrastructure, allowing them to provide and consume multi-access edge services, as well as the ability to provide multiple multi-access edge services on its own [5].

DISCUSSION

Multi-access edge service (MES): Service delivered over a multi-access edge platform, either by the platform itself or by a multi-access edge application. The location service and radio network information service are two examples of MES offered by the MEP. Some of the MEC concepts related to orchestration have NFV analogues, such as the MEAO and MEO playing a similar role to the NFVO in orchestrating virtual functions. These functionalities are known as MEAs in MEC while VNFs in NFV. Along with these related ideas, MEC offers predefined services for applications involving mobile devices.

Services: Different types of service providers may offer their services, such as communication service providers that offer traditional telecom services, digital service providers that offer digital services to different vertical industries, such as enhanced mobile broadband and the Internet of Things, or network slice as a service (NSaaS) providers that provide a network slice as a service to their clients. Additionally, the services provided to verticals may vary in their ability to be managed by the vertical itself.

Managed Vertical Service (MVS): vertical services that the vertical consumes as such and that the SP completely deploys and manages. Unmanaged Vertical Service (UVS): A vertical service that is deployed by the SP (i.e., when VNFs are instantiated and their connection is established), meaning that the SP manages the service's entire lifespan. However, the service logic is not entirely or even partially managed by the SP; rather, the vertical is in charge of it. This involves setting up the internals of the VNF to manage the vertical services' logic at the service level. The service adheres to the previously described NFVI aaS architecture if the vertical is also responsible for managing the lifetime [6].

Service Customer (SC): utilises services that a service provider (SP) provides. Vertical industries are seen as one of the key SCs in the context of 5G.Depending on the kind of service supplied to the SC, the Service Provider (SP) may take on one of three sub-roles: conventional communication service provider, digital service provider, or network slice as a service (NSaaS) provider. Utilising aggregated network services, SPs create, develop, and run services.

Network Operator (NOP): responsible for coordinating resources, maybe coming from a number of virtualized infrastructure providers (VISP). Network services that are made available to SPs are designed, built, and run by the NOP using aggregated virtualized infrastructure services. An organisation that plans, develops, and manages virtualization infrastructure is known as a virtualization infrastructure service provider (VISP). The infrastructure consists of networking (for mobile transportation, for example) and computational resources (from platforms, for example).

Data Centre Service Provider (DCSP): offers data centre services, as well as designing, constructing, and running its own data centres. By providing "raw" resources (host servers, for example) in relatively centralised locations and basic services for consumption of these raw resources, a DCSP differentiates from a VISP. Instead, a VISP makes a range of resources available via a single API by combining several technological domains.

DevOps-related terms and roles

Some of the high-level terms used in development-related contexts will be explained in more detail in this section. The terminology used here promote a more nuanced understanding of the contexts and functions in which software artefacts (of any kind, including but not limited to applications, general functions, or services like network functions, or network services) are created and used. The idea of a role naturally implies that these roles can be variously mapped to commercial entities; the same company can and frequently does assume multiple roles (for instance, frequently function, service, and infrastructure developer will overlap), sometimes even different subsets of roles in different business relationships. However, there isn't much of a requirement that some of these roles coexist within the same organisation (historical evidence or conventional business model setups aside); rather, there is some justification for requiring that some roles be kept apart and possibly realised by a neutral, dependable third party (e.g., validation entities). However, it should be noted that these are merely suggestions; any concrete changes should be left to market developments rather than being imposed by a technical document [3]. Note that the distinction between software and infrastructure becomes less and less meaningful with cloud computing-based technologies like Infrastructure-as-Code. a service's or an application's real user and intended audience. It might be a private individual or a technological tool acting on behalf of but apart from a real person. A person who creates functions is a function developer. In this context, a function is an executable entity in the atomic meaning of a MEC, an NFV VNF, or even an application-oriented micro service. There is no requirement stated here; the executable form may be given in a variety of forms, including source code, a virtual machine image, a container description, an executable process, a JAR file, etc. Usually, a function developer will assert certain functional statements about such a function. Service developer: A service developer creates the description of new services by using current functions and services. These descriptions are provided in one or more forms as network service descriptors (NSDs). A service description may include certain functional assertions, much like a function. The line between a function developer from a service developer is blurry sometimes [7].

Information models play a critical role in modern data-driven applications. They provide a high-level conceptual representation of data and its relationships, enabling stakeholders to understand and communicate about data structures and how they relate to the business processes they support. Effective information modeling requires a deep understanding of the system being modeled, as well as a collaborative effort from stakeholders to identify the key data elements and relationships. Standardized notations, such as entity-relationship diagrams and UML, enable stakeholders to communicate effectively and collaborate on data-related tasks[8].

CONCLUSION

Information models are used in a wide range of applications, including database design, software development, and data analysis. They are essential for ensuring that data is organized and structured in a meaningful way, making it easier to analyze, manipulate, and use for decision-making. As data continues to grow in importance, information modeling will become even more critical. Organizations must invest in developing and maintaining effective information models to ensure that they can effectively manage their data and derive insights that drive business value. In conclusion, information models are an essential tool for modern data-driven applications. They enable stakeholders to understand data structures and their relationships, facilitating collaboration and effective communication. Effective information modeling requires a deep understanding of the system being modeled and a collaborative effort, and it is critical for organizations to invest in this area to ensure they can effectively manage and analyze their data.

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CHAPTER 14

A STUDY ON PHYSICAL INFRASTRUCTURE

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ABSTRACT:

Physical infrastructure refers to the foundational elements of a system or network, such as buildings, power systems, communication lines, and hardware components. It provides the physical framework for technology systems to operate effectively, and is essential for supporting the delivery of data, goods, and services.Physical infrastructure is also becoming increasingly important in the digital economy, where data centers and other technology facilities require significant physical resources to operate effectively. The growth of cloud computing and other digital technologies has led to an increased demand for physical infrastructure, as more and more data and processing power is required to support these systems.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

Service developers and application developers may be thought of as doing the same position as the distinction between "services" and "application" is essentially dissolving. Developer of infrastructure the physical infrastructure developer and the virtual infrastructure developer are the two varieties of this position. The development of hardware IT infrastructure, such as data centres, is the focus of the physical infrastructure developer. The virtual infrastructure that an application or service is supposed to run on is becoming into a textual artefact thanks to the move towards infrastructure-as-code. The intended network architecture (for example, the configuration of Layer 2 networks), necessary resources like storage, necessary virtualizers, etc., may all be described using this artefact. The jobs of a service developer and an infrastructure developer sometimes overlap since a service's (virtual) infrastructure and the service itself are closely intertwined, but they are still distinct professions and aspects. It is also important to note that although though these infrastructure descriptions are architecturally different artefacts, they are often grouped with the function or service descriptions in today's description formats [1].

Assertions regarding the proper execution of a function or service, as well as statements about its intended role. These assertions are functional in the sense that they don't make any claims about how well they perform; rather, they are limited to what functions and services are carried out.

Non-operational assertions: Non-functional claims describe how well a function or service performs, usually in terms of some quantitative metric (achieved throughput, delay, error rates, availability, reliability) or in terms of some non-functional but non-quantitative properties like security ability to withstand attacks) or maintainability (ability to be upgraded, possibly while in operation. All of these measures may be thought of as rough realisations of LaPrie's idea of reliability.When seen in conjunction with a specific infrastructure on top of which a function or service is believed to be implemented, some of these assertions, particularly the quantitative performance claims, become understandable. Therefore, such a non-functional claim always refers to the tuple of (function/service description; infrastructure description), which is a key justification for the significance of the idea of an infrastructure description.

Non-functional claims developer: Unlike non-functional claims, which are more complicated and can only be generated in conjunction with an assumption about the utilised infrastructure, functional claims should be assumed to be made directly by the function/service developer. Therefore, it makes sense to classify the development of non-functional claims as a separate role. Of course, in reality, this function will inevitably overlap with other development responsibilities.

Validation and verification entity: An operator might, in theory, determine how many resources are required for a service to reach whatever service level with assertions about the functional and non-functional aspects of a function/service in place, often also assuming something about the load, number of users, etc. Even if the operator themselves built the function software and the claims, it is unclear if these assertions are reliable (they often are not). Therefore, a second role is required to support and confirm such claims. The approaches for doing so are many and beyond the purview of a whitepaper (e.g., simulation, experimentation with testing infrastructure, even formal proofs, etc.). In actuality, more specific artefacts are required (for instance, a description of the kinds of validation infrastructure that are accessible in this position). Additionally, this role is a typical illustration of one that would be carried out by an impartial third party acting on behalf of both developers and operators and supplying "validated claims".

Tenant: A renter often both owns and orders a product or service. There is no expectation that a tenant will belong to a specific industry (vertical or otherwise), be a business (although a private person may nonetheless act in the capacity of a tenant), or use the service or application for its own internal or private purposes [2].

Physical infrastructure provider: A supplier of infrastructure manages real, physical infrastructure. It builds a virtual infrastructure on top of which functions, services, and applications may be employed using descriptions of the infrastructure. Infrastructure may include any subset of the following: networking, computing, and storage infrastructure. To guarantee that the intended virtual infrastructure has the appropriate qualities, an infrastructure provider may use any technologies. For instance, it may employ SDN methods to provide a preferred architecture of servers and access points, giving its clients access to a virtual network.

Infrastructure provider: allows the physical infrastructure provider to provide both actual resources and virtual infrastructure, transform the former into the latter, and then sell the latter. by allowing for resale, effectively turns the idea of an infrastructure provider into a circle.

Market: A framework where numerous contracts may be used to exchange functions, service descriptions, active services, infrastructure descriptions, real or virtual infrastructures, and other artefacts. Markets may be quite complicated (including search tools, building desired services out of components, etc.) or very simple (simply listings of things with contact points).

Market provider: An entity realizing a market

Operator: Instead of being a position, an operator is a business model. However, it is distinguished by common role combinations, particularly one that combines an infrastructure provider and service provider with a customer relationship manager and a billing agency. The expansion of 5G networks may also allow for the emergence of other job combinations [3].

Specific terms Limited description of a resource with the purpose of hiding specific attributes (such as amount, vendors, location of the resource, etc.) and safe enough to be shared with other administrative domains is known as an abstracted resource or resource abstraction. Limited description of a service with the purpose of hiding specific characteristics (such as utilised resources, virtual linkages, interconnections, etc.) and safe enough to be shared with other administrative domains is known as an abstracted service or service abstraction. An administrative domain is a group of assets and/or services that are controlled by a single administrative body.

Resources Federation: A set of resources may be made accessible by a provider domain on the basis of pre-established terms and conditions; these resources may also be made available for usage by a consumer service provider domain under specific pre-established terms and conditions. Similar to the NFVI as a Service scenario in the framework of ETSI NFV, the resources in this instance are owned by the provider domain but are managed by the consumer Service Provider.

Services Federation: A provider domain may make a set of services accessible to potential consumer domains on previously agreed-upon terms and conditions. In contrast to the resource federation case, the provider domain fully manages the services along with their life cycle management and the resources needed for deploying them within the provider domain and providing them to the consumer domains. This is similar to the Network Service as a Service case in the context of ETSI NFV [4].

Consumer domain: Domain of administration that requests resources or services from other domains of administration. Note that a consumer domain may operate once again as a provider domain by using the resources or services it has already used. Federated Materials: Although owned by a provider domain (operator or infrastructure provider), resources are fully controlled and managed by a consumer domain (i.e., instantiation, reservation, allocation, scaling up/down, and release). According to pre-established terms and conditions (SLAs), the consumer domain is permitted (by the provider domain) to manage and use the resources. In this instance, the NFV (abstracted) virtual resources made available by the peer SP are used by the consumer SP. When an end-to-end NFVIaaS service is created by merging virtual resources from several SP administrative domains, this may be the case.

Federated Services: Services that are owned by a provider domain but are operated by a consumer domain. According to pre-established terms and conditions (SLAs), the consumer domain is permitted (by the supplier domain) to control and use the services. In this instance, the peer SP's NFV network services are used by the consumer SP. When an end-to-end service is broken up into component services that are implemented across many SP administrative domains, this could be the situation. According to their pre-agreed administrative relations and signed contract agreement of exchanging pertinent information between them, federation is a system for integrating resources and services from several administrative domains at various granularities. Local Repository: A database (in an administrative domain) that contains data on the resources that are available for federation, a list of services and services that have been abstracted from other provider domains. Administrative domain that provides resources or services to other administrative domains is known as a provider domain. Keep in mind that the resources or services offered may be based on resources or services used in another domain [5].

Service catalogue: Set of services or service abstractions that are composed using mutual taxonomies and agreed-upon use terms (SLAs) that are provided by a provider domain to possible consumers from other provider domains. The created service catalogue is shared and regularly updated amongst the federated administrative domains in the event of federation. A technological domain is a group of assets that are all related to the same technology (system) and fall under the same administrative domain. The internal structure is established and managed in line with technological specifications and guidelines. An administrative domain may include one or more technical domains.

DISCUSSION

5G is a new paradigm

Delivering Enhanced Mobile Broadband (eMBB), Ultra-Reliable and Low-Latency Communication (URLLC) and Massive Machine-Type Communication (mMTC), 5G applications represent tremendous opportunities for consumers, homes, businesses and communities.

a. 5G is expected to generate USD 12 trillion in revenues in 2035.
b. 80% of telecom revenues (broadband, hardware, and services) will be linked to 5G in 2035.

Additionally, 5G will contribute to the reduction of inequality by improving access to and lowering the cost of basic services like healthcare and education. 5G will aid in lowering our carbon footprint and preserving natural resources by extending the capabilities of wireless technology and enhancing the autonomy of gadgets. Finally, increased economic growth will increase both direct and indirect employment across all economies. Using 5G applications and supported by national strategies, telecom operators, equipment suppliers, and industry stakeholders are transforming their respective industries [6].

1. New 5G applications are emerging, supported by national strategies:
2. Telecom 5G for home (e.g. Fixed Wireless Access) and mobile
3. Media AR/VR gaming, and advertising, multi- broadcasting
4. Manufacturing Smart factories & connectivity over the full product lifecycle
5. Transportation autonomous driving, in-car infotainment
6. Public services healthcare (e.g. telemedicine), education
7. International standards drive cost efficiencies and speed 5G adoption

The first standards have been made available, enabling the rollout of both standalone and non-standalone 5G networks as well as the initial applications. The 5G ecosystem will need to be improved in the future years in order to extend the possibilities for applications, especially with Release. The 3GPP is in charge of 5G standardisation. Broad-based collaboration is required to reach agreement since 5G encompasses operators, equipment suppliers, and industry stakeholders. Spectrum management is a significant legal and technological challenge. To accommodate a variety of use cases, 5G needs numerous layers of spectrum.

1. A global harmonization of frequency bands would reduce complexity and costs for vendors, operators, their industry partners, and end-users.
2. National licenses should remain the main and preferred authorization model.
3. Network synchronization should be considered to mitigate harmful interference.

To function, 5G needs a secure and open environment. A favourable business climate will be just as important to 5G's long-term success as the technology's quality and cost-effectiveness. Long-term infrastructure investment should be backed by accurate national roadmaps that can be relied on and provide enough openness for all parties. Industry groups like 5GAA, 5G-ACIA, and 5G AIA should take the lead in fostering cooperation amongst stakeholders with shared interests. Government attempts to encourage new business should be combined with a regulatory framework that is friendly to the telecommunications sector and other businesses [7].The adoption of 5G will rely on operators, suppliers, and industry players' involvement and investment.

Operators are anticipated to be the obvious 5G investors. The whole 5G ecosystem will benefit from strong collaboration from equipment vendors and industry players in driving economies of scale. Progressive adoption of 5G will occur when performance and scale-related cost savings become a reality. As necessary, new businesses will profit from prior investments. The first national licenses have been given to MNOs, who will use network slicing technology to provide network access and solutions to vertical industries. As performance rises and economies of scale continue to develop, 5G adoption will be gradual. The pursuit of considerable economies of scale is a common objective shared by equipment suppliers, operators, and other industry participants. By constructing nationwide 5G networks, operators will make a significant contribution to economies of scale. The whole ecosystem will simultaneously invest in 5G applications for diverse economic sectors, using operators' networks as necessary [8], [9].

Physical infrastructure is a fundamental component of modern systems and networks, providing the physical framework for technology systems to operate effectively. It is essential for supporting the delivery of goods, services, and data around the world, and is a critical component of national infrastructure.Effective physical infrastructure requires careful planning, design, and management to ensure that it is resilient to unexpected disruptions and can support the needs of modern technology systems. This includes designing and constructing buildings, power systems, communication lines, and hardware components that can withstand environmental hazards and cyber attacks.

Physical infrastructure is becoming increasingly important in the digital economy, where data centers and other technology facilities require significant physical resources to operate effectively.

As more and more data and processing power is required to support modern systems and networks, effective physical infrastructure will become even more critical.Investing in physical infrastructure can bring significant benefits to organizations and society as a whole. It can lead to increased efficiency, improved safety and security, and better delivery of services. It is also a critical component of economic growth, enabling the development of new industries and supporting the expansion of existing ones.

CONCLUSION

In conclusion, physical infrastructure is a critical component of modern systems and networks, providing the physical framework for technology systems to operate effectively. Effective physical infrastructure requires careful planning, design, and management, and is becoming increasingly important in the digital economy. Investing in physical infrastructure can bring significant benefits to organizations and society as a whole, making it a critical area for investment and development.

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CHAPTER 15

A BRIEF DISCUSSION ON NETWORK OPERATORS

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ABSTRACT:

Enhanced Mobile Broadband (eMBB) will provide mobile network customers and industrial users with enhanced capacities, benefiting B2C, entertainment and media, and other service sectors. Ultra-reliable and Low-latency Communication (URLLC) will support new use cases in mission critical applications (e.g. autonomous driving, remote surgical operation, industry automation. Massive Machine-type Communications (mMTC) will enable industry players to connect massive numbers of devices with specific connectivity requirements, in sectors such as manufacturing, utilities, and logistics. Much more than any previous generation of technology, the 5G paradigm brings together mobile network operators, equipment vendors, and other industry stakeholders, due to the broad range of technical and business opportunities opened up by 5G.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

Since they will operate the 5G networks, network operators are crucial to the deployment of 5G technology. The majority of the required CAPEX and OPEX will be committed by them. Vendors of equipment create 5G technologies, specify 5G goods (RAN, core network, services, phones), and launch them. The new prospects with 5G are bringing industry players into the paradigm. Since 5G will enable significant innovation in both the product (connected vehicles, for example) and productivity (industrial IoT), many industries are involved [1].

1. Mobile network operators are the natural investors in 5G. Projected investments will reach USD 1 trillion between 2018 and 20251:
2. From an internal development standpoint, operator business models will be stressed by the exponential growth in demand for data, which will increase the costs of network management and the level of risk.
3. Operators also have external incentives, such as users demand for better services and new applications, changes in the global competitive landscape, and their home nation's infrastructure needs.

4. Growing demand for 5G will trigger investment from other industry stakeholders as well.
5. These massive investments will result in important scale effects. The cost of production and maintenance for 5G networks will fall, and the value of the networks will increase in the eyes of network users. These outcomes are supported by theories of network externalities (e.g. Katz and Shapiro3) or Metcalfe's law:
6. When more 5G products comply with the same technical standards, customers will benefit more from affordable devices and high-quality services.
7. As more vertical industries adopt 5G technologies, end users will receive more value from these industries, as broad adoption of technologies increases the potential for interoperability and cooperation and drives the creation of new services.
8. Investment and engagement by all stakeholders will lower the costs of 5G deployment and help to fulfill the potential of this new technology. The result will be better economies of scale and enhanced value creation throughout the whole 5G value chain, both of which will be key levers for 5G adoption and deployment costs, facilitate connectivity and foster interoperability
9. 5G standards will ultimately be required for microprocessors, devices, and device modules, as well as the 3 main layers of network infrastructure:
10. Core network, the backbone of network exchanges, gathering and dispatching data packages
11. Radio Access Network, made up of equipment that links the core network to user devices
12. Services and systems, overall architecture and service capabilities

The synchronisation of several hardware and software components created by various independent technology providers is necessary for each of these tiers. To maintain high network performance and manufacturing economic efficiency, they must cooperate. The goal of technical standards is to guarantee interoperability. The standardisation process for 5G is more extensive than for 4G since it contains standards for particular application interfaces and involves stakeholders from other sectors. Producing hardware with a broad design based on accepted standards and flexible network capabilities is essential for a successful, all-encompassing 5G. The industry would gain from improved scale effects and quicker adoption of 5G if modules and user devices have standardised interfaces and standards. 5G opens up new use cases and opportunities, which means the standardisation process must start again from scratch. For 5G, there has been increased collaboration between standards organisations and all stakeholders. Regional standards bodies established the 3GPP in 1998, which creates the Technical Reports and Technical [2].

Specifications that define 3GPP technologies:

Nature of the organization: Standard Development Organisations (SDOs) play a "nonpolitical" role in decision-making; consensus-based decision-making is prioritised, and the decision-making process is "a partnership" amongst SDOs. Procedures and structure: Technical specification groups (TSG) with agendas, due dates, and guidelines that are specified for the Radio Access Network, Services & Systems, and Core Networks & Terminals

The 3GPP develops 5G standards over the course of many releases. 2017 saw the commencement of Release 15. 2020 is when Release 16 is expected to be finished. Release 17, which is scheduled for 2021, will include new technology for commercial use. Release 15 is the first set of 5G specifications, and it includes standalone 5G (5G RAN and the 5G new Core Network) as well as non-standalone 5G (a migration architecture allowing MNOs transition from an LTE-based system to a 5G-based system). Both standalone 5G and non-standalone 5G were frozen in June 2018 and December 2017, respectively [3].

DISCUSSION

The 3GPP wants 5G NR to complement conventional Ethernet connectivity in industrial settings. The main improvements in Release concern URLLC. Release will also support additional vertical industries, including Media (5G Mobile Broadband Media Distribution), Transportation (e.g. Future Mobile Communication System for Railways), and Media. Additionally, improvements in positioning, MIMO, and power consumption that are generic and will benefit many industries are to be delivered.

Release 16 will further define the 5G Systems, including Wireless Wireline Convergence, Network Automation, Traffic Steering/Switching/Splitting, Improvements to Service Based Architecture, etc., in terms of overall 5G improvement. Later, Release will add new features to improve the technical features mentioned in releases 15 and 16, supporting more services and verticals. By the end of 2019, a comprehensive scope of work will be established. It might contain: Because harmonisation enables economies of scale, makes cross-border coordination and roaming for end users easier, it would support the development of 5G networks and the spread of 5G applications.

Automotive: For use cases like platooning, Release 16 will contain sophisticated V2X capabilities that are largely predicated on low latency.

Industrial automation: Release 16's definition of time-sensitive networking and high dependability will help industrial automation.

A multi-layer spectrum approach is required to address the wide range of 5G use cases:

1. The "Coverage Layer" exploits spectrum below 2 GHz (e.g. 700 MHz) providing wide-area and deep indoor coverage. When used in combination with bands in the 3,300-3,800 MHz range, the pairing allows operators to benefit from their features, thus delivering enhanced capacity and coverage.
2. The "Coverage and Capacity Layer" is spectrum in the 2 to 6 GHz range (e.g. C-band) that delivers the best compromise between capacity and coverage.
3. The "Super Data Layer" is spectrum above 6 GHz (e.g. 24.25–29.5 and 37–43.5 GHz), used to address specific use cases requiring extremely high data rates (e.g. FWA and hotspot).

Because fragmentation can affect spectrum efficiency and can increase costs, national governments and regulators should concentrate on making large blocks of contiguous spectrum available in these ranges (80 to 100 MHz per network in the Coverage and Capacity Layer, 800

MHz in the Super Data Layer).In order to offer improved 5G coverage and capacity, more medium-frequency bands will be needed during the next phase of 5G development (i.e., in 5–10 years). The medium-frequency spectrum between 5925-7125 MHz is a viable contender since it strikes a fair mix between coverage and capacity[4]. As incumbent services are already using this band in some nations, Huawei suggests adding a new WRC-23 Agenda Item to examine how IMT and incumbent services can coexist while also taking IMT identification based on ITU-R studies into consideration.For the seamless integration of the newest technologies and services in both current and new bands, regulatory frameworks should reflect the notion of technology and service neutrality. They ought to let LTE and NR to share uplink spectrum [5].

The primary and preferred authorization type for access to 5G spectrum should continue to be national licences since they allow operators the assurance to invest and maintain dependable network performance and service quality. To reduce detrimental interference, network synchronisation should be taken into consideration.

Between 2019 and 2035, traditional telecom operator revenue from hardware, services, and broadband is anticipated to increase by 1% annually. By 2035, 5G will provide mobile carriers new business prospects of USD 600 billion, and it will also propel the telecoms sector's expected 3% annual growth between 2019 and 2035. Due to new commercial prospects, industrial applications, and the replacement of present 2G, 3G, and 4G mobile broadband revenues, 5G will account for almost 80% of service provider revenues.

The bulk of their earnings between 2030 and 2035 will come from 5G chances, making telecom stakeholders the front-runners in this race. Some of the issues the telecommunications sector is currently facing, such as the rise in data consumption, may be resolved by 5G. By expanding capacity, mobile carriers want to increase the overall effectiveness of data delivery to consumers with 5G [6].

Main 5G Opportunities

Currently, 5G coverage creation and expansion at the national level, beginning with local pilots, is the focus of telecoms stakeholders. In low density regions in particular, superfast Fixed Wireless connection (FWA) presents a chance to assist governments in fulfilling the promise of high-quality, universal broadband connection to families. As a development of cloud computing, edge computing moves processing and data storage closer to the point of use. Wireless carriers have a significant advantage in the edge-computing competition because they control access to 5G high-speed telecommunication networks, which will be crucial in the transformation of the telecoms industry.

5G Network Requirements

While 4G can only support speeds of up to 100 Mbps, 5G is anticipated to support speeds of up to 1 Gbps, which will change the scale at which telecommunications is currently conducted. 5G may pave the door for easier global connectivity because to its increased power and efficiency.

Broadly adopted LTE-Advanced networks for fixed wireless broadband are demonstrating their ability to provide quick, high-quality access. Fixed wireless will advance with 5G FWA, with rates approaching 1 Gbps6.

Future deployments of Multi-access Edge Computing (MEC) will take place in 5G networks. To increase efficiency and the end user experience, MEC apps communicate with the 5G system to direct traffic for edge applications and to receive notifications of pertinent events, such as mobility events. One of the first industries where 5G will be extensively employed is the media and entertainment industry. Use cases will be implemented right away. High-quality audiovisual services and the capacity to post live films on social media are also possible with 5G.

Main 5G opportunities

Annual mobile media sales will quadruple to USD 420 billion in 2028 as a result of the additional network capabilities introduced by 5G during the next ten years. HD mobile video and multicasting will be made possible by 5G: With safe, quick connections that combine several picture sources, image processing functions may be situated in the cloud.

Between 2021 and 2028, augmented reality and virtual reality apps powered by 5G will bring in more than USD 140 billion in revenue.8 The commercial potential of volumetric 3D content and its ecosystem will likewise be unlocked by 5G. Using AR technology, gaming will be at the forefront of 5G-led innovation. Real-time streaming, high quality, and quick responses will also aid in enabling mobile cloud gaming. By 2028, 5G mobile game sales will reach $100 billion USD annually.

Long-term tactile feedback will be possible with 5G owing to extremely responsive haptic suits and cutting-edge VR capabilities. By 2025, this new VR experience will take off, and by 2028, it will be worth over $5 billion yearly. Due to the rise in data usage, 5G must support enhanced mobile broadband and a high device density. The seamless fusion of several network technologies would promote mobility and uninterrupted service consumption [7].

For the economy and all societal segments consumers, residences, enterprises, and communities 5G offers enormous prospects. The democratization of many services will be sparked by the potential cost savings and increased efficiency of new technology. All populations will benefit from increased knowledge and education thanks to connectivity. New commercial prospects in a wide range of sectors will increase investment and employment.

The long-term goal of lowering carbon emissions and preserving natural resources will be assisted by 5G by broadening the use of wireless technology and enhancing the autonomy of gadgets. More inclusive, forward-thinking, tested, and powerful than any earlier generation of communications technology, 5G will be. The sectors that will use 5G to update their business strategies and provide value. Telecommunications, media and entertainment, manufacturing, transportation, and public services are among the sectors with especially strong dynamics and commercial potential related to 5G. Each of these industries has unique commercial concerns related to 5G and its conceivable applications, some of which are currently being investigated in trial programmes. FWA may soon rank among the most important 5G applications. The market for 5G Fixed Wireless Access is anticipated to increase from less than $1 billion in 2019 to about $50 billion by 2026 (an annual growth rate of 97%)[8].

CONCLUSION

In addition to their technical responsibilities, network operators also have a critical role to play in promoting the development of digital infrastructure and ensuring that it is accessible to all. This includes working with governments and other stakeholders to address issues of connectivity and digital divide, and supporting the development of policies and regulations that enable the growth of the digital economy.

In conclusion, network operators are a critical component of the modern digital economy, enabling the delivery of goods, services, and data around the world. Effective network operation requires a range of skills and expertise, and must be able to adapt to changing technology trends and customer needs. Network operators also have a critical role to play in promoting the development of digital infrastructure and ensuring that it is accessible to all, making it a critical area for investment and development.

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CHAPTER 16

AN OVERVIEW ON 5G NETWORK REQUIREMENTS

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ABSTRACT:

According to market development insights, the deployment of AR and VR will let 5G reach its full transformative potential starting. Applications for immersive and innovative media will scale up later in the next ten years. Cyber physical systems and the Internet of Things, which will need the backing of 5G networks, are anticipated to be the driving forces behind Industry 4.0. Future factories will be able to be flexible, networked, and efficient thanks to this. AGVs in factories, such as autonomous transportation and machine control, with latency of less than 5 ms utilising URLLC, and more efficient production lines, such as with machine vision and high definition video for controlling operations, will all be made possible by 5G within factories. By allowing predictive maintenance and introducing responsive design to goods, for example, 5G might assist the manufacturing industry in improving product lifecycle management outside of factories. 5G may also improve business-to-business communication, allowing more efficient end-to-end monitoring of items or data transfers for simulations or collaborative design.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

Indoor mission-critical processes must adhere to strict specifications. More improvements to 4G and 5G technologies will be required to deliver ultra-low latency and ultra-high reliability in a heterogeneous environment. Utilising connected goods' product lifecycle data will also require new technologies with extremely high autonomy, low energy consumption, and low subscription costs. Germany is the leader, having introduced the 15-year "Industry 4.0" strategy in 2011. The development of cross-industry networks, standardisation, and research are all supported by the government. A national strategy to foster "American leadership in advanced manufacturing" was issued by the United States in 2018, which accounts for 17% of global manufacturing output. The development of new manufacturing technologies and their use will be key to achieving this leadership [1]. Different connectivity technologies were quickly adopted by the automotive sector. The development of connection-ready vehicles has received significant encouragement from automakers, who are making baby steps towards their long-term goal of controlling autonomous vehicles via eMBB and URLLC. On the road to autonomous driving, 5G will boost services in the automotive sector via vehicle-to-everything (V2X) connections as well as through better in-car "infotainment." Opportunities for remote diagnostics, pay-as-you-drive insurance models, and driver assistance utilising 5G technology also become available as automobiles become more connected and gather more data (location, use, performance, telematics).

Later on, same use cases might be applied to other modes of transportation including train, aviation, ports, and so forth. For use cases including autonomous driving, V2V connectivity, and certain in-car entertainment applications, 5G may be beneficial. In a mobile environment, 5G can provide real-time, low latency data interchange. The idea of a linked automobile goes beyond V2V communication. Additionally, it necessitates communication with pedestrians and the infrastructure (V2I and V2P). These are referred to as V2X communication when combined. Cellular-Vehicle-to-Everything (C-V2X), where C stands for 4G or 5G, is a growingly common method of V2X communication [2].

5G-V2X will provide enhanced functionality for autonomous driving starting with Release 16. Specifically, 5G capabilities (lower latencies and increased bandwidth) will be used for short-range direct communications. The specification process for 3GPP Release 16, which adds new functionality to 5G-V2X, is currently ongoing. At the earliest, 2021, may be the year when R16 sees its first deployments. Commercial concerns will also influence the market's maturation since cost reductions in the linked vehicle scenario are quite real. For instance, platooning trucks reduces fuel use by 10%. The expense of providing improved healthcare is increasing along with the demand for it, from 8.5% of global GDP in 2000 to over 10% in 201611. In addition to its favourable economic effects, 5G may enhance quality of life and provide long-term health advantages. Massive IoT and improved internet are required for 5G potential in healthcare in order to enable telemedicine. Dialysis at home for patients or remote control of medical equipment are two examples of conditions that would benefit from 5G. 5G will enable telemedicine and linked medical devices inside hospitals.

5G Network Requirements

To operate efficiently, wearable gadgets, distant sensor networks, and smart emergency vehicles all need quick data transfer and minimal latency. In 7 to 10 years, according to anticipated timeframes, 5G prospects in public services are anticipated to grow. The majority of current pilots are upgrades to telemedicine programmes or existing linked technologies that are readily expandable (like video). In pilot programmes, new business models are developing that bring together various stakeholders to provide innovative services. The emergence of 5G may cause changes in the connectivity sector and modernise the telecom operators' established business structures. To create new value models, operators and industry stakeholders will work together.

Operators and other industry participants now have new business models to choose from thanks to the variety of services and end users that 5G technology has to offer. Today's operators must meet a wider variety of requirements, including the need for more localised and dense coverage in critical locations, as well as greater security and isolation (for example, data privacy in factories). Operators and their partners will engage more closely with industry stakeholders to create networks that are tailored to their requirements. A public network-based approach could be effective. The network may be held by operators or by new companies working with the infrastructure owner to provide network slicing and/or APN services. Through slicing technologies, the industry's stakeholders can typically use the public network without having to pay for a privately owned network. The networks of the operators would be so strong that they could handle the specialised demands of the end users in terms of data isolation and management. Beyond cutting-edge technologies and sound business models, 5G applications will need to be widely adopted in order to be developed sustainably. Additionally, 5G requires a favourable external environment. Plans and activities for 5G are determined by governments and regulators, and regulatory regulations are more transparent. The majority of governments have spent time and resources developing a favourable regulatory environment, via:

a. Engaging with the international standardization process
b. Streamlining procedures to allow timely infrastructure deployments and spectrum availability
c. Adapting telecommunications and sectoral regulations to 5G needs
d. Anticipating public infrastructure sharing
e. Stimulating experimentations (e.g. economic incentives, bringing together stakeholders).

DISCUSSION

As infrastructure underpins the development for all stakeholders, regulatory efforts should focus on creating an adequate framework for 5G infrastructure. Regulation of other industries must evolve, which will require cooperation between institutions. With 5G involving many stakeholders in new use cases, industry regulation will need to be updated. Telecommunication regulators and the regulators of other verticals will need to collaborate closely to develop supportive regulations, and nurture business opportunities while ensuring safety at all levels. For example, the use cases in transportation (e.g. autonomous driving) and healthcare (e.g. remote surgery) will need specific regulations on liability law. A collaborative approach involving multiple government agencies will be necessary. Stakeholders should coordinate to build the capabilities required for potential applications, target business models, and the 5G ecosystem. Industry associations should work together with research institutes, operators, equipment vendors, and other industry players to achieve common objectives [3]:

a. Understanding and aligning on the needs of specific verticals.
b. Meeting the needs of verticals in standards.
c. Exploring commercial use cases and business models across verticals and fostering advanced research Some sectors are leading the way in terms of collaborating and coordinating on 5G developments.
d. 5GAA (5G Automotive Association) coordinates with the European regulator to promote C-V2X as a technology option. Industry stakeholders collaborated on the white papers concerning scenarios, roadmap, and key technical requirements.
e. 5G-ACIA (5G Alliance for Connected Industry & Automation), was founded in 2018 with the goal of applying industrial 5G in the best possible way.

f. 5G AIA, dedicated to the commercial development of industry use cases, encompasses 5 working groups from different verticals, which work to build coordinated value chains for their respective industries. There is also an Investment & Financing Group which is responsible for incubation funds to develop 5G industry pilot projects.

Since the introduction of the first mobile phones in the 1980s, telecommunications companies have been putting money into mobile networks to increase coverage, enhance services, and draw in new customers. Mobile voice conversations were supported by first-generation networks, but their capacity and coverage were limited. Second-generation (2G), third-generation (3G), and fourth-generation (4G) mobile networks were created and implemented by carriers to overcome these restrictions. Each iteration brought with it more features and services, increased capacity, and faster speeds [4].

The rollout of fifth-generation (5G) networks by telecom companies started in 2018 in response to the rising data needs of consumers and business customers. By supporting more connected devices such as medical devices, smart homes, and Internet of Things, supporting new industrial uses such as industrial sensors, industrial monitoring systems, performing advanced data analytics, and enabling the use of advanced technologies such as smart city applications, autonomous vehicles, 5G networks are expected to enable providers to expand consumer services such as video streaming, virtual reality applications.

It's anticipated that 5G would have a big impact on the economy. According to market experts, 5G may boost the GDP of the United States by $500 billion and result in up to 3 million new employment. By 2035, researchers predict that 5G technology will support 22 million employment globally and create $12.3 trillion in sales activity across various sectors. Experience has shown that businesses that launch new goods early may win the majority of sales, resulting in long-term profits for those businesses as well as large economic gains for the nations in which those businesses are based. As a result, technological firms all over the globe are vying to create 5G products, and certain nations (namely, central governments) are taking steps to promote the implementation of 5G. The "race to 5G" refers to the rivalry to create 5G goods and seize the worldwide 5G market [5].

Although each nation has adopted a unique strategy to corner the 5G market, certain factors, such as international decisions on standards and spectrum, are what determine when all deployments will take place. The protracted spectrum allocation process, opposition from local governments to federal small cell siting regulations, and trade restrictions that may influence equipment supply might all have an impact on the rollout of 5G in the United States. The 116th Congress may keep tabs on the development of 5G deployment in the US and the country's standing in the race to 5G. Congress may take into account regulations relating to trade prohibitions, spectrum allotment, and local issues with 5G implementation, among other regulations. Policies that encourage the deployment of 5G while safeguarding regional and local interests might benefit consumers significantly, modernise sectors, offer American businesses a competitive edge abroad, and result in long-term economic rewards for the country. Members may take into account other interests, such as the need to protect intellectual property and national security when trading, the privacy and security of 5G devices and systems, and the respect of local authorities and concerns during 5G deployment, in addition to the economic and consumer benefits of 5G technologies when developing policies.

Telecommunications providers continuously invest in their networks to provide quicker, more dependable service, increase network capacity to handle rising data needs, and enable new technological applications. A new technological solution that delivers significantly enhanced speeds, enables new features and functions, and generates new markets and new money for providers appears around every ten years as a result of industry studies and research. These technologies constitute the next generation of mobile technology because they significantly enhance networks and devices and alter how people utilise mobile communications [6].

There have been five generations of technology in mobile communications. An overview of the technologies. The first mobile phone was introduced to customers with first-generation (1G) technology. The phone and the service were pricey, and the basic analogue networks only provided voice services with a little amount of capacity and coverage.Using digital networks, second-generation (2G) technology allowed for voice and text communication. Adoption increased as networks were improved and phones became more affordable. Third-generation (3G) technology allowed for mobile internet access (including email and videos) as well as phone and data services. When smartphones were introduced, the demand for data significantly increased as people started using their smartphones as computers for both business and entertainment. Increased speeds and genuine mobile broadband, which could enable music and video streaming, mobile apps, and online gaming, were provided by fourth-generation (4G) technology. The demand for mobile data was further increased by providers offering unlimited data plans and mobile devices that could be used as hotspots to link additional devices to the network.

Every iteration was designed to provide a certain degree of performance, such as a specific speed, increased capacity, or more features. Being referred to as a "3G network" suggested that a certain network design, particular technology, specified levels of speeds, and new features were supported. In previous generations, in order to meet performance criteria, businesses and nations developed several technological standards. Companies and nations started developing networks to the same specifications in 3G and 4G. This made it possible for equipment to be utilised in several nations, for manufacturers to realise economies of scale, and for carriers to accelerate deployment. For instance, Long-Term Evolution (LTE) standards were accepted by businesses and nations for 4G, redefining the network architecture to provide faster and more capacity. Fifth-generation (5G) networks use 5G standards, which make use of cutting-edge equipment and setup techniques to provide faster speeds, more capacity, and improved services. Consumer demand for data is likely to increase, and new services will be supported by 5G networks. Additionally, 5G was developed to support the expanding use of mobile communications technologies across numerous industries (such as crop management systems, public safety applications, and new medical technologies), as well as to meet the growing demands for data from industrial users [7].

Along with China and South Korea, the United States is a leader in the race to 5G. To take the lead in the development and implementation of 5G technology, each nation has chosen a unique approach. The development of 5G infrastructure in China is being supported by the national government of China. China has a national strategy to roll out 5G domestically, take advantage of home market profits, enhance its industrial systems, and emerge as the world's top supplier of telecom equipment.

The federal government of South Korea is collaborating with telecom companies to roll out 5G. As the first nation to roll out 5G nationwide, South Korea intends to use the technology to enhance its industrial systems. The private sector is driving the implementation of 5G in the US. The United States' rival providers completed 5G experiments in a number of locations and were the first to commercially provide 5G services. The US government has backed the rollout of 5G, opening up spectrum for its usage and expediting procedures for 5G equipment placement such as small cell siting [8], [9].

CONCLUSION

In conclusion, 5G networks have very specific and stringent requirements in order to deliver the promised high-speed, low-latency connectivity that will enable a range of new applications and services. Some of the key requirements include significantly higher data rates, lower latency, greater energy efficiency, higher reliability, and the ability to support a massive number of connected devices. Achieving these requirements will require significant investment in new infrastructure, as well as the development of new technologies and standards. However, the potential benefits of 5G are enormous, including the ability to support new applications like autonomous vehicles, smart cities, and the internet of things, and to transform the way we live, work, and communicate.

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CHAPTER 17

A BRIEF DISCUSSION ON BACKGROUND ON MOBILE TECHNOLOGIES

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ABSTRACT:

Telecommunication providers and technology companies around the world have been working together to research and develop new technology solutions to meet growing demands for mobile data from consumers and industrial users. Fifth-generation (5G) mobile technologies represent the next iteration of mobile communications technologies that were designed to improve current e.g., 3G, 4G) mobile networks. 5G networks are expected to provide faster speeds, greater capacity, and the potential to support new features and services.5G technologies were developed to accommodate the increasing demands for mobile data i.e., more people using more data on more devices). 5G technologies are expected to serve current consumer demands and future applications e.g., industrial Internet of Things, autonomous vehicles. 5G technologies are expected to yield significant consumer benefits e.g., assisting the disabled, enabling telemedicine), industrial benefits e.g., automated processes, increased operational efficiencies, data analytics), and economic benefits e.g., new revenues, new jobs.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

The majority of revenues are captured by businesses who introduce new technology first to market, according to past experience. Due to the potential for economic gain, businesses around the world are vying to develop and implement 5G technologies, and many nations (such as central governments) are taking steps to support their deployment. The "race to 5G" refers to the struggle between businesses and nations to develop 5G technology and win the majority of the income. Congress in the United States has kept tabs on the rollout of 5G technology and the nation's standing in the race to 5G. The federal government has been ordered by Congress to find additional spectrum for potential use in 5G. Congress has made spectrum available for 5G usage. A bill that would have expedited procedures for installing 5G small cells was filed in the Senate in 2018; in addition, Congress has streamlined procedures for installing 5G equipment (also known as small cells) on government property.4 Congress placed restrictions on the purchase of certain foreign-made telecommunications equipment by federal agencies in order to safeguard national security interests and guarantee the security of 5G networks.5 [1]

In this article, the race to 5G is discussed, with a background on mobile technology and an emphasis on the three main nations of China, South Korea, and the United States. This paper analyses the elements that impact the rollout of 5G as well as U.S. initiatives that promote it, such as those involving tiny cells and national security. Finally, this report discusses future policy considerations, such as the privacy and security of 5G networks and devices, as well as near-term policy considerations for Congress related to the deployment of 5G networks.

Radio frequencies utilised for airwave communication are referred to as spectrum. Different uses (such as mobile communications and broadcasting) are assigned to different spectrum segments. Users may either acquire the right to transmit over a specified frequency band or be allocated the right to use a certain frequency (for example, public safety). Businesses set up the infrastructure (such as towers and machinery) necessary to facilitate communications on the given frequencies. The National Telecommunications and Information Administration (NTIA) oversees spectrum for government users, while the government Communications Commission (FCC) is responsible for managing spectrum distribution for non-federal users.

Background on Mobile Technologies

The 1980s saw the introduction of the first cell phones. Since then, the usage of mobile phones has multiplied. In the United States, there are now an estimated 238 million smartphone users, up from around 63 million in 2010.7 an estimated 4.5 billion people use mobile phones globally, and 2.5 billion of them use smartphones.8 the demand for mobile data is rising quickly as more people use more data on more mobile devices. Although G phones were more affordable ($1,000), there were still barriers for consumers to overcome. Providers offered discounted prices on the phones in exchange for customers signing up for cell phone plans. The $400 Blackberry and the $600-700 iPhone arrived with 3G; service providers provided a variety of voice/data contracts that included the phone. The price of 4G phones, which vary from $500 to $1,000, is often included in mobile phone contracts. Mb/s stands for megabits/second. The speed at which data is downloaded from or sent to the internet is measured in megabits per second (Mbps) [2].

The need for better wireless networks is driven by three causes. To start, more individuals are utilising more data across more devices. Since 2016, more individuals throughout the globe have used mobile devices like smartphones than desktop computers. Between 2016 and 2021, mobile data traffic is anticipated to grow sevenfold globally, with mobile video driving that growth.10 The mobile communication spectrum is getting overcrowded and cluttered.11 Current networks (such as 3G and 4G) often struggle to keep up with customer demand for data, particularly during times of high use (such as crises). Customers can suffer sluggish speeds, shaky connections, delays, or service outage during times of high use.

Second, there are now more internet-connected gadgets overall, including both consumer (such as smart watches and smart metres) and industrial (such as sensors that help with proactive maintenance) equipment. According to market research, there were 17.8 billion connected devices worldwide in 2018. Of these, 7 billion were other connected devices (such as sensors and smart locks) that allowed users to monitor and manage activities through a mobile device, such as a smartphone, further boosting network demand.

Third, businesses are increasingly using internet-connected devices for routine operations. Devices are used by businesses to monitor assets, gather performance information, and guide business choices. The Internet of Things (IoT) is made up of physical things like industrial sensors and health monitors that link to create networks of devices and systems that can gather and process data from various sources.14 IoT networks that can offer persistent ("always-on") connections, low latency services (minimal lag time on commands), greater capacity (e.g., bandwidth) to access and share more data, and the capability to quickly compile and compute data are necessary for more advanced IoT devices (e.g., autonomous cars, emergency medical systems).15 The existing mobile networks are unable to reliably provide these functions.

Developing 5G Technologies

Since 2012, telecommunications standards development organisations (SDO) have been looking into ways to enhance mobile communication networks, connect people, things, and data through a smart network, and enable a "seamlessly connected society." New technologies being developed by businesses are anticipated to enhance networks. Technology and telecommunications businesses tested out new, higher-band spectrum (millimetre waves, for example), which may provide more capacity and speed. Companies collaborated to create technologies that take advantage of this spectrum's advantages such as bandwidth and speed) and address its drawbacks by developing novel technological solutions such as putting smaller cell sites close together to relay signals over longer distances and around obstacles. However, these waves cannot travel over great distances or penetrate obstructions such as trees or buildings.

The study discovered a number of options that provide much higher speeds (between 10 and 100 times quicker than 4G networks), more capacity, and ultra-low latency service (i.e., 1-2 milliseconds (ms) of lag time as compared to 50 ms for 4G).These solutions provide new features that might enable and increase the usage of more cutting-edge technology by consumers and companies while addressing many of the perceived faults of current networks.

Uses of 5G Technologies

Increased bandwidth, continuous connection, and low latency services provided by 5G networks have the potential to extend and improve the usage of mobile technology by both consumers and companies. Customers should be able to play online games anywhere, watch uninterrupted video, and download a full-length, high-definition movie in a matter of seconds to their mobile device. For technology firms and telecommunications providers, 5G technologies are anticipated to open up new revenue streams [3].

Additionally, 5G technologies are anticipated to support advanced IoT systems, including autonomous vehicles, precision agriculture systems, industrial machinery, and advanced robotics, as well as interconnected devices (such as smart homes and medical devices). It is anticipated that IoT technology would be incorporated into industrial systems to automate workflows and improve operational effectiveness.20 5G networks are anticipated to support the expanding Internet of Things (IoT) market, enabling device manufacturers to create and implement new IoT systems and devices across a variety of industries and sell those products internationally, resulting in significant economic gains for both technology companies and the nations in which those companies are based. Demonstrates the development of a single product from a standalone to a connected product to an IoT system that can analyse data from several sources to guide choices. It also depicts a linked tractor system.

Model by M. Porter and J. Heppelmann, "How Small, Connected Products are Transforming Competition," Harvard Business Review, November 2014, p. 5, was recreated by CRS on its basis. A single product is shown evolving into a smart product (one that can send performance data to a computer), a smart, connected product (one that allows access to data from a mobile device), and finally a product that is a component of a larger system of interconnected products. A more robust network, such as 5G, would be required to support the IoT and the proliferation of IoT systems for industrial application [4].

DISCUSSION

Race to 5G

The development of new technology during the rollout of 4G networks was spearheaded by American businesses. American businesses established market standards, launched goods, secured first mover advantages, and generated large economic benefits for both themselves and the US. The analysis reaches the following conclusion: "U.S. leadership on 4G added nearly $100 billion to the U.S. economy and brought significant economic and consumer benefits."

Industry experts forecast that 5G will bring in fresh income for both technology businesses and the nations in which they are based. For instance, IHS Market predicted that by 2035, 5G may generate up to $12.3 trillion in worldwide sales across a variety of businesses. This prediction was made in a research that was commissioned by the Cellular Telecommunications and Internet Association (CTIA).23 According to a different research by Accenture, American telecommunications companies plan to spend around $275 billion in 5G infrastructure, which may result in the creation of up to 3 million new jobs and a $500 billion boost to the GDP of the country [5].

According to prior experience, businesses who are first to market with breakthrough technology tend to reap the greatest economic rewards. As a result, businesses all over the globe are vying to promote 5G devices. Manufacturers of network equipment, chips, smartphones, and software, among others, are manufacturing 5G devices and equipment for service providers. To capture a larger portion of the home market and boost profits, telecommunications companies are putting 5G infrastructure into place and promoting new 5G goods. Countries all around the globe (i.e., central governments) are assisting 5G initiatives to make sure their businesses are the first to deploy 5G goods and services and are positioned to reap the majority of the economic gains from the new technology to "win the race to 5G."

Several industry reports have discussed nations that are pioneering 5G. Deloitte said in a 2018 research that "The United States, Japan, and South Korea have all made significant strides towards 5G readiness, but none to the same extent as China."26 IHS Market, a provider of data analytics and information services, conducted a research in 2017 that looked at the economic activity in seven nations: the US, China, South Korea, Japan, Germany, the UK, and France.27 According to the 2017 IHS Market analysis, the United States and China are anticipated to lead and dominate 5G technologies over the next 16 years, based on estimated research and development (R&D) and capital expenditure (Capex) expenditures in 5G from 2020 to 2035.

A different image of 5G leadership is presented in more recent studies. The first 5G standards were adopted in December 2017, according to a CTIA-commissioned Analysys Mason assessment from April 2018 that found there had been a change in readiness amongst countries.28 The United States came in third in the study for preparedness, behind China and South Korea. The research claims that as a result of government planning and interaction with business, China is displaying higher preparedness indicators. A road to 5G leadership was provided by the government's "Made in China 2025" project, which was unveiled in 2015, and its more current five-year economic plan, China's 13th Five-Year Plan for Economic and Social Development Plan for the People's Republic of China, issued in 2016.

China sponsored efforts by the Chinese industry to participate in the formulation of standards, funded R&D initiatives, and worked with foreign partners to test new machinery and technological advancements. To reach its objective of launching 5G by 2020, China also contributed $400 billion in 5G investments, cooperated with businesses producing 5G technology, and worked with Chinese providers to construct 5G infrastructure.30 According to analysts, China's telecom and technology firms are dedicated to the national plan and the 2020 deadline.

Industry commentators have cited further Chinese activities as evidence that the country is putting itself in a position to dominate 5G technology. Analysts point out that China has set goals for expanding the usage of Chinese products in its 5G networks. By 2025, China wants 60% of the market for industrial sensors to be dominated by Chinese companies, and 40% of smartphones sold domestically to utilise locally produced processors.32 China intends to roll out 5G technologies domestically, seize the profits from its sizable domestic market (consumers and industrial users, for example), upgrade industrial systems to boost the effectiveness, productivity, and competitiveness of Chinese technology companies, increase its capacity to develop technology equipment and components, and establish itself as a major supplier of 5G technologies to the world (such as network equipment and IoT devices) [6].

South Korea was listed as being ahead of the US in the Analysys Mason research "based on a strong push for early 5G launch combined with government commitment to achieving 5G success."35 Due to early expenditures in R&D and experimental installations for the 2018 Olympics, South Korea improved its 5G readiness. South Korea was able to take credit for the first extensive 5G technology trial because to its early investment in the technology.36

While some analysts place China ahead of the United States in terms of 5G readiness, others contend that the United States' competitive market fosters innovation, giving the country an advantage in the global 5G market. Others argue that Asia may become a 5G leader given the region's concentration on 5G rollout, including China, South Korea, and Japan,37 its large market, and its quick adoption of new technology. The Chinese government has made progress with its strategy, investing in R&D, taking the lead in developing 5G standards for Chinese businesses, participating in international 5G initiatives to expand knowledge, increasing its ability to produce 5G equipment, and setting aside spectrum for 5G usage.

According to a 2018 report, China has outspent the United States by $24 billion since 2015 on 5G infrastructure, having constructed 350,000 new cell sites compared to 30,000 by American businesses over the same period.40 According to recent sources, Chinese service providers accelerated the deployment of 5G cell sites after the initial 5G technical specifications were published in December 2017 and declared intentions to launch 5G in 2019, rather than the anticipated 2020 launch date. The "China Surge," as it was dubbed by industry observers, 42 led many to draw the conclusion that China was putting itself in a position to win the 5G race. In terms of spectrum, South Korea is likewise making progress. South Korea auctioned out spectrum for 5G usage in the mid-band and high-band in June 2018.44 Additionally, in July 2018, government representatives declared that the country's telecommunications companies would collaborate to roll out a 5G network.45 A unified strategy, according to officials, would eliminate redundancy, save money, speed up deployment, and allow South Korea to be the first country to introduce a statewide 5G network. Telecommunications companies agreed to the strategy and to the introduction of 5G on the designated day, which the government has dubbed "Korea 5G Day." According to reports from December 2018, South Korea's carriers began offering fixed 5G to corporate customers on December 1 and declared intentions to begin offering mobile 5G to consumers in March 2019, once 5G phones are ready48 [7].

Private telecommunications companies in the US are pushing rollout. For instance, on October 1, 2018, Verizon introduced fixed 5G services in four locations.49 On December 21, 2018, AT&T began offering mobile 5G services in 12 locations; at least 19 more cities are planned for 2019.50 T-Mobile is constructing 5G networks in 30 locations with the intention of launching 5G services once 5G smartphones are available in 2019.51 Sprint will launch 5G in nine locations during the first half of 2019.52 Due to industry investment in 5G trial installations and ambitious schedules for commercial deployments, analysts claim that the United States is close to the top in terms of readiness.

By designating spectrum for 5G usage and relaxing rules on the placement of 5G equipment, Congress in the United States has aided the rollout of 5G technology. The FCC has created a thorough plan to provide airwaves for 5G usage and hasten implementation. Different nations are taking the lead in different areas and ways in the race to 5G. China adopted a top-down strategy and is a global leader in infrastructure development, but it still has the same spectrum difficulties as other nations, including managing existing users and minimizing interferenceactivities that require time.54 Although South Korea has committed to being the first country to deploy 5G across the country and has auctioned 5G spectrum, its cooperative approach to deployment may stifle the competition and innovation needed to create new 5G products and compete in the global 5G market. The industry is driving 5G activities in the US. By identifying and distributing spectrum for 5G usage and lowering regulatory hurdles for 5G equipment placement, the government has aided commercial deployment efforts.55 However, the protracted spectrum allocation process, competing spectrum demands, and local opposition to 5G cell siting regulations could slow 5G deployment in the United States. Additionally, a deployment strategy that relies solely on the market may not guarantee that all regions and all industries will have access to 5G [8].

CONCLUSION

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CHAPTER 18

A STUDY ON GLOBAL HARMONIZATION OF SPECTRUM

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ABSTRACT:

The global harmonization of spectrum is a critical issue in the telecommunications industry, as it enables the efficient use of radio frequency bands across different countries and regions. This harmonization is essential to support the deployment of advanced wireless technologies, such as 5G networks, which require significant amounts of spectrum to deliver the high data rates and low latency that are promised. However, the global harmonization of spectrum is a complex process that requires collaboration and coordination between governments, regulators, and industry stakeholders across the world. This abstract provides an overview of the challenges and opportunities associated with the global harmonization of spectrum, including the need for international agreements and standards, the importance of spectrum allocation and licensing, and the role of emerging technologies like dynamic spectrum sharing. Ultimately, the global harmonization of spectrum is a critical enabler for the continued growth and development of the telecommunications industry, and for the creation of new and innovative wireless services and applications that can benefit people and businesses around the world.

KEYWORDS:

Communication, Fifth Generation (5g), Mobile, Networks, Technology.

INTRODUCTION

Some industry analysts claim that the race to 5G has just begun and is more like a marathon than a sprint, pointing out that "Europe was quicker to roll out 2G, and Japan was the first with 3G, but that hardly deterred Apple and Google from dominating the smartphone market."56 It is possible to generate income from the sale of 5G technologies at the time of first deployment as well as from the sale of goods and services (such as cutting-edge apps, subscription services, and IoT devices) after deployment. Industry analysts point out that in the race to dominate the global 5G market, months may not matter; however, if the United States lags behind other countries in terms of deploying 5G networks and developing new 5G technologies, devices, and services by years, that could have an impact on its ability to compete in the global technology market for years to come.

International choices on standards and spectrum are among the variables influencing 5G implementation worldwide. Other factors impacting deployment in the United States include trade restrictions and opposition to the installation of 5G infrastructure. International decisions on standards and spectrum, spectrum management (e.g., auctioning spectrum, reconfiguring users to accommodate 5G, and creating agreements to share spectrum), the availability of 5G hardware and devices, and the installation of small cells required to deliver 5G services are some of the factors affecting all 5G deployments. Earlier cellular networks were not universally compatible since various nations and firms developed the networks, equipment, and devices to different standards. To help technology businesses build to a single standard, bring products to market quicker, sell equipment internationally, gain economies of scale, and lower the cost of equipment, technology companies and telecommunications carriers recognised value in creating standards.

The Third Generation Partnership Project (3GPP) and the International Telecommunications Union (ITU) of the United Nations are two organisations that are crucial to this 5G initiative.58 Seven telecom SDOs from Japan, China, Europe, India, Korea, and the United States have joined forces to form the 3GPP. More than 370 prominent businesses from several countries are members of the 3GPP. Leading telecommunications firms including AT&T, China Mobile, and SK Telecom are members, as are tech giants like Intel, Qualcomm, Samsung, Ericsson, Huawei, and ZTE as well as governmental organisations. One of the several groups attempting to reach an agreement on the technical requirements for mobile communications (3G, 4G, and 5G) is the 3GPP [1].

Members of the 3GPP have collaborated to create, test, and construct standards for 5G technology. 2018 saw the approval of two 5G technical standards by 3GPP.The "Non-Standalone version of the New Radio standard," which enables enhanced mobile broadband (eMBB), was accepted by 3GPP in December 2017. With the help of these specs, carriers may add 5G technology to their current 4G networks to boost speed and lower latency. In June 2018, 3GPP finished developing the "Stand-Alone version of the New Radio standard." By using core networks that are built to handle cutting-edge IoT devices and functionalities, this standard facilitates the autonomous deployment of 5G.

These standards are crucial because they outline the technical requirements for 5G equipment, describe how 5G networks will be developed and implemented, and have the backing of several interested parties. These 5G specifications will be submitted by 3GPP to the ITU as part of the global standards development process in June 2019.63 the standards would be accepted as the world standard for the technology if the ITU ratified them. While there are other SDOs that also send specifications to the ITU, the 3GPP is acknowledged as the main contributor to standards. As a result, a lot of businesses and nations are implementing 5G plans based on authorised 3GPP standards.

Currently, 3GPP is concentrating on the technical requirements and performance standards for advanced functions (such as 5G for vehicle-to-vehicle communication and industrial IoT). The 3GPP is anticipated to complete these standards in 2019, therefore networks, equipment, and devices capable of supporting sophisticated 5G services are not anticipated to be available until 2020 or later [2].

China created its own standard for 3G technology development to reduce reliance on western technology. Although the equipment made to those standards was successful in China, the standards were not adopted internationally, and the equipment could not be exported successfully. Other nations took part in international projects, contributed to international standards, and set up networks that were based on standards.

A corporation may influence standards by joining SDOs and ensuring that the final equipment standards and requirements match its chosen product specifications. Businesses who are successful in getting their chosen standards approved via the standards development process will have an edge over competitors when launching new goods. When compared to trying to retrofit a product (and its manufacturing process) after a standard is approved, this strategy is "much more cost-effective."67 Many nations encourage industry participation in the creation of standards. In the words of FCC Commissioner O'Rielly, "If standards properly reflect and include our industries' amazing efforts, they promote U.S. technologies and companies abroad, bringing investment, revenues, and jobs to this country."

China was more cooperative in the creation of standards for 5G, taking part in SDOs, heading technical committees, performing 5G R&D, supplying 5G specifications, and taking part in global initiatives. According to some observers, China is promoting its chosen standards and preparing itself to rule the global 5G industry via its involvement in SDOs.70 For instance, experts point out that several network operators are using the 5G Non- Stand Alone standard in order to build up their 5G networks by first utilising their existing 4G networks. China is in favour of the 5G Stand-Alone standard, which would force operators to upgrade their IoT devices (which China is primarily focused on producing) and rebuild their core networks, base stations, and other infrastructure.71

To use 4G networks, enhance 4G services with 5G technology, and provide better services as businesses plan out 5G installations, SDO members supported both Non-Stand-Alone and Stand-Alone specifications in the creation of 5G standards.

Some businesses and nations advanced 5G plans and launched 5G services before specifications were finalised. For instance, Verizon debuted fixed 5G services using proprietary standards, while China started building 5G infrastructure before the 5G specs were ratified. There are dangers involved, even while these initiatives have some benefits for future deployments in that businesses may plan for and learn from them. For instance, last-minute changes to the requirements may necessitate China upgrading those subpar 5G stations.

Companies need 5G phones, which are currently being developed, to provide mobile 5G technology. Consequently, businesses had to wait for 5G phones before launching mobile 5G services, even though they had already started building 5G networks once specifications were approved. Since 5G phones were expected to go on sale around the same time (spring 2019), the majority of significant carriers in the top-ranking nations announced launch dates that were only a few months apart. In March 2019, South Korea is anticipated to introduce mobile 5G services.72 In early 2019, T-Mobile and Verizon both made announcements about the debut of mobile 5G services.74 A 5G smartphone will be available from AT&T in the first half of

2019.75 In the first part of 2019, Sprint anticipates announcing the statewide rollout of 5G.76 Prior to its 2020 goal date, China Mobile revealed intentions to roll out 5G service by the end of 2019.77 [3]

A crucial step in the race to 5G is the approval of technical requirements. Technology businesses may start manufacturing equipment and gadgets after the standards are authorised. Telecommunications businesses may start expanding their networks and planning the launch of 5G services as soon as the necessary equipment becomes available.

Spectrum is another element influencing the implementation of 5G. The electromagnetic spectrum is used by all wireless technologies to communicate. Radio frequencies utilised for airwave communication are referred to as spectrum. There are spectrum management organisations in most nations. In the US, the National Telecommunications and Information Administration (NTIA) administers spectrum for government users, whereas the FCC regulates spectrum distribution for non-federal users. Agencies may sell the right to use a given frequency to a buyer (such as a telecommunications company or a broadcaster) or allocate the right to use a specific frequency to a group of users (such as public safety users). Businesses build the infrastructure (such as towers and other machinery) necessary to facilitate communications on the given frequencies. As an illustration of how the U.S. spectrum is distributed for different communications (such mobile communications) and for other wireless purposes (including garage door openers, satellite radio, and GPS), Figure 2 gives an overview of U.S. spectrum allocations in 2008.Due to the fact that the frequencies in this portion of the spectrum are suitable for wireless communications, the majority of mobile devices (such as cell phones) operate at frequencies below 6 gigahertz (GHz). For instance, frequencies in this section of the spectrum may readily pass through walls and structures and travel great distances, providing coverage of larger areas. However, this area of the spectrum (below 6 GHz) is becoming congested as more people use more mobile devices for more purposes, which could lead to slower speeds, slower connections, and dropped calls [4].

Companies started investigating new spectrum bands in 2015 that may allow mobile communications. Researchers in the industry discovered millimetre waves, also known as MMW, which provided larger bandwidth (i.e., better ability to handle more data) and faster speeds. Because MMW waves are shorter, can't travel very far, can't pass through buildings well, and tend to be absorbed by trees and rain, telecommunications providers haven't thought about using them for mobile communications. Researchers suggested using tiny cells that are near together to unite them and relay shorter waves over greater distances, enabling a high-speed network to be provided to certain places, such as a city or a stadium. The majority of the time, telecommunications equipment is designed to work on certain frequencies. Manufacturers of equipment and devices take into account the properties of the designated frequency bands while designing equipment to maximise frequency benefits and minimise frequency disadvantages.

Multiple spectrum bands are used by 5G. Low-band spectrum (below 1 GHz), mid-band spectrum (between 1 and 6 GHz), and high-band (MMW) spectrum are all used by 5G. In order to provide very quick services to high-density locations, 5G demands for the implementation of 5G technologies in high band spectrum (MMW) spectrum. Existing customers may benefit from quicker service, more capacity and coverage thanks to the deployment of 5G technology in the mid-band spectrum. The extensive coverage required for many IoT applications may be provided by 5G technology when used in low-band spectrum [5].

According to studies, delays in spectrum allocation may hinder deployments and harm nations in the technological marketplaces. In order to locate spectrum in all three bands for 5G, governments are collaborating. Additionally, they are collaborating with industry to harmonise spectrum (i.e., ensure that all nations use comparable frequency bands) in order to promote economies of scale, lower costs for producers and providers, and ensure system compatibility (e.g., roaming).

Global Harmonization of Spectrum

In order to implement 5G, businesses from all around the globe are interested in locating shared spectrum. In order for equipment to function in all areas, this would assist guarantee that all businesses deploy in the same bands. One analyst said that "Harmonised global spectrum is important because with a commonality of spectrum the 5G ecosystem can optimise resources to achieve economies of scale, reduce the cost of equipment and devices, and spur rapid proliferation and adoption." Similar frequency ranges may facilitate global harmonisation without requiring exact harmonisation. This gives nations (i.e., the government entities in charge of assigning spectrum) the freedom to accommodate current users who may be using certain bands and cannot readily migrate (such as military organisations).

The ITU collaborates with nations and business sectors to establish global standards, harmonise rules, and promote spectrum usage. A discussion on 5G spectrum is anticipated during the ITU's World Radio communication Conference (WRC-19) in 2019. Participants in the development of 5G technologies concur that spectrum in three essential frequency bands is required for 5G to function properly:

a. Sub-1 GHz to support widespread coverage across urban, suburban, and rural areas, provide in-building coverage, and support IoT devices and services;
b. 1-6 GHz to provide additional capacity and coverage, including the 3.3-3.8 band, which is expected to form the basis of many initial 5G services; and
c. Above 6 GHz, including MMW, to provide ultra-high broadband speeds.

As of February 2018, the frequency bands that have been selected for 5G rollout across several nations are shown in this figure. Some nations have not yet identified low-band spectrum (spectrum below 1 GHz) for 5G. The majority of nations have designated high-band spectrum (above 6 GHz) and mid-band spectrum (between 1 GHz and 6 GHz) for 5G deployment. The blue colouring indicates areas of shared spectrum allocation across nations, which may help the ITU make choices on spectrum harmonisation on a global scale. Since the FCC has previously held spectrum auctions, telecommunications companies have amassed sizable spectrum holdings in a variety of bands, including those used for 5G. For instance, Verizon was able to roll out 5G services utilising its 28 GHz frequency, while T-Mobile is implementing 5G using its 600 MHz airwaves. Congress acted in 2018 to designate more spectrum for 5G usage. Congress passed two measures relating to spectrum into law in the Consolidated Appropriations Act of 2018, which was signed into law on March 23, 2018. Repurposing federal spectrum to facilitate 5G is encouraged under the Repack Airwaves Yielding Better Access for Users of Modern Services Act of 2018 (RAY BAUM'S Act of 2018). Making Investment Opportunities in Broadband and Restricting Excessive [6].

DISCUSSION

Equipment and Devices

Just as telecommunications providers are racing to deploy 5G, technology companies and device makers are racing to be the first to deploy 5G equipment and phones, to achieve the economic benefits expected from 5G technologies. U.S. equipment manufacturers are developing 5G equipment and devices. In a July 2018 Senate hearing, Qualcomm announced that it is "on track to deliver chips that support 5G in both sub-6 GHz and millimeter wave spectrum in time to enable 5G data-only devices to launch before the end of 2018 and for the first 5G smartphones to launch in the first half of 2019."

U.S. equipment manufacturers are benefitting from the race to 5G, supplying other countries with 5G technologies, including China. For example, the American chip-maker, Intel, is working with Chinese telecommunications providers. Similarly, technology suppliers from other countries. Most device makers have announced that 5G phones will be available in 2019. While both Verizon and AT&T launched 5G networks in select areas and offered some 5G services, neither offered access to 5G on a smartphone because 5G smartphones were not yet available. With the adoption of 5G specifications, 5G devices are in production and expected to be available in 2019 [7].

As a result, most providers have announced plans to launch 5G services in 2019, after devices are released. For example, both Verizon and AT&T have announced a launch of new Samsung 5G devices in the first half of 2019.103 South Korean device-maker LG announced that its 5G smartphone is expected to be available in the first half of 2019, as a Sprint exclusive.

Technology experts have cautioned that since providers are using different spectrum bands to deploy 5G, the first 5G phones may be carrier exclusive (i.e., may only contain one carrier's frequencies). Experts note that "nobody has figured out how to cram the 28 GHz spectrum that Verizon and T-Mobile are using, and AT&T's 39 GHz into one box yet. And while T-Mobile and Verizon are using similar 28 GHz bands, T-Mobile is also putting 5G on the 600 MHz band, which Verizon is not."

The telecommunications industry is global and co-dependent. Providers partner with technology companies and device makers from around the world to move forward on 5G deployment. The availability of 5G devices will drive adoption and revenues for all telecommunications providers. Hence, the availability of equipment and devices is an important factor in the race to 5G.

Small Cell Siting

As stated, deployment of 5G systems will rely on a range of technologies and different bands of spectrum. 5G systems using low- to mid-band spectrum can install new 5G equipment on existing cell sites (4G cell sites). This will increase the speed and functionality of existing 4G networks, but will likely not achieve the ultra-fast speeds provided by millimeter wave bands. For deployments that leverage higher bands, particularly above 6 GHz, a much higher density of cell sites is needed as the signals cannot travel as far or through obstacles. To overcome these challenges, providers will place many smaller cell sites (also called small cells) close together to relay signals further distances and around obstacles. Small cells are low-powered radio access nodes with ranges of between 10 meters to two kilometers (in comparison, macro cell towers can cover up to 20 miles or around 32 kilometers). The lower end of small cell nodes is similar to today’s Wi-Fi access points.

Often compared in size to a pizza box or backpack, small cells can be installed on existing structures, such as buildings, poles, or streetlights. When attaching small cells to existing infrastructure, installation and operation requires connection to a power source, backhaul (e.g., fiber optic cable connection or wireless connection to a core network), and a permit for use of the space. Installations on existing structures can expand to include multiple small cells for use by different wireless carriers, wires, and adjacent boxes housing batteries or cooling fans. Small cells can also be placed in locations without such existing infrastructure, in which case construction of a pole with a power source and backhaul (i.e., wired connections) is required. This figure shows two examples of 5G small cell deployments, attached to street lights; one cell site sits on the side of the pole and one sits on the top of the pole. 5G requires installment of many (potentially thousands) of small cells in targeted areas (e.g., stadiums, cities, industrial sites) to achieve ultra-fast 5G speeds [8].

In the United States, constructing new wireless towers or attaching equipment to pre-existing structures generally requires providers to obtain approval from federal, state, or local governmental bodies, depending on the location and current owner of the land or structure. The FCC has promulgated rules to ensure all people have access to communications services and to guide approval processes. Past FCC rules:

a. Require localities to act on cell siting applications in a reasonable period of time;
b. Grant the FCC authority to regulate terms and rates of pole attachments unless states elect to regulate poles themselves;
c. Restrict state or local entities from prohibiting telecommunications service
d. Grant state and local entities authorities to manage rights-of-way and charge reasonable fees for access to rights- of-way; and
e. Require state and local entities to approve eligible facilities requests.

5G small cell installation have sparked debate over the balance between streamlining siting regulations to facilitate 5G deployment nationwide and maintaining local authorities to review placement of cell sites in communities. U.S. industry executives claim that current regulations and local approvals required for placement of telecommunications equipment adds time and cost to deployment, which puts U.S. carriers at a disadvantage in 5G deployment Local governments and residents have cited concerns about management of rights-of-way, fees charged to providers for access, and the impact of small cells on property values and health and safety [9].

CONCLUSION

Prior to the FCC vote on the small cell siting rules in September 2018, nine Members of Congress wrote a letter to the FCC urging the FCC to remove the item from its September meeting agenda. The letter urged the FCC to "hit pause" on the issue to consider the perspectives of cities and municipalities, and to seek a solution that balances the interests of localities and industry. FCC Commissioner Car, who led the effort to streamline the small cell placement process, invoked the race to 5G in his support of the rules, noting, "We're not the only country that wants to be first to 5G. One of our biggest competitors is China. They view 5G as a chance to flip the script. They want to lead the tech sector for the next decade. And they are moving aggressively to deploy the infrastructure needed for 5G."Industry officials praised the FCC's rules on the day of the vote, noting, "The FCC's action today addresses key obstacles to deploying 5G across the country by reducing unnecessary government red tape."118 Industry representatives noted that high fee rates and long approval processes cost providers money, delayed the deployment of telecommunications infrastructure, and resulted in fewer sites proposed, and less investment in and services to communities.

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CHAPTER 19

A ROLE OF BROADCOM'S RELATIONSHIPS IN NETWORKS

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ABSTRACT:

Broadcom is a leading global technology company that designs, develops, and supplies a wide range of semiconductor and infrastructure software solutions. As a key player in the tech industry, Broadcom has established relationships with a diverse array of stakeholders, including customers, suppliers, partners, and competitors. These relationships are critical to the success of the company, as they enable it to deliver high-quality products and services, and to stay competitive in a rapidly evolving market.The paper also discusses the competitive landscape in which Broadcom operates, including its relationships with its competitors and its efforts to differentiate itself in the marketplace. Finally, it examines the role of relationships in the company's corporate social responsibility initiatives, which aim to foster positive relationships with stakeholders in the broader community.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

The guidelines, according to FCC Commissioner Rosen worcel, who partially dissented, constituted to federal overreach and a disregard for state and local laws. He expressed concern that "litigation that follows will only slow our 5G future."120 The FCC's decision, according to Rosen worcel, "irresponsibly interferes with existing agreements and ongoing deployments across the country." She gave the example of a recently authorised cooperation in San Jose, California, which resulted in the installation of 4,000 tiny cells on city-owned light poles and $500 million in private investment to enable the rollout of broadband. Many local governments objected to the decision, claiming that the regulations exceeded the FCC's powers and interfered with their ability to manage public property, safeguard public health and safety, and manage. One of the main problems with the US 5G rollout is small cell placement. FCC policies intended to advance national interests (e.g., hasten 5G deployment, reap the full advantages from 5G technology) collide with laws and regulations intended to safeguard other interests (e.g., provide equitable access to cutting-edge technologies, preserve public safety, and promote health). Policies that permit American businesses to build 5G infrastructure and give state and local governments control over where 5G small cells are placed in neighbourhoods could hasten the adoption of 5G technologies in the US and help the country reap the wider range of consumer and economic benefits that 5G will bring [1].

A perceived lack of market diversity, which some have argued would increase risk to the global telecommunications supply chain, and concern over the potential vulnerability of 5G networks to targeting by foreign intelligence services have prompted concern over the rollout of 5G technology from a U.S. national security and intelligence standpoint. Aspiring suppliers from across the globe will have a bigger say in creating new technologies and goods as a result of the worldwide move to sophisticated information and communications technologies (ICT). These include the internet of things, new financial technologies, and the development of artificial intelligence and big data for predictive analysis. Next-generation wireless technology, or 5G, is also among them. Different approaches to ICT-related regulations and policies may hinder development and innovation both internationally and for American businesses.

Concerns about China's relative position in relation to the U.S. in the development of 5G networks have been raised by some analysts and experts due to the significant investments made in 5G technologies by Chinese companies like ZTE Corporation and Huawei Technologies Co., Ltd. and the affiliations of such companies with the Chinese government. According to those who hold this opinion, China's goal is to dominate the 5G industry through a variety of strategies, such as continuing to invest in the networks, goods, and standards that support the vital infrastructure and services that will depend on 5G technology; influencing industry standards, regulations, and policies; and "extracting concessions from large multinationals in exchange for market access." We're deeply concerned about the risks of allowing any company or entity that is beholden to foreign governments that don't share our values to gain positions of power inside our telecommunications networks, FBI Director Christopher Wray said, highlighting the potential threat associated with any increase in the integration of Chinese-made or designed devices and 5G cellular network equipment into the American telecommunications network. That makes it possible to influence or exert pressure on our communications infrastructure. It offers the ability to steal or maliciously alter information. Additionally, it makes it possible to carry out covert espionage.

Others have raised concerns about the possible harm Chinese corporations might pose to 5G networks by pointing out the legal clout the Chinese intelligence agencies have over businesses like Huawei and ZTE: The political and legal climate in China would prevent Huawei or ZTE from declining a subsequent request from the Chinese military or intelligence services for access to the technology or services offered abroad as required by law, and multiple new Chinese laws mandate that telecoms operators must grant the Chinese intelligence services unrestricted access to networks for surveillance purposes [2].

The House Permanent Select Committee on Intelligence (HPSCI) looked into the threats Huawei and ZTE posed to American national security during the 112th Congress. In its report on the investigation's findings, the committee highlighted "the potential security threat posed by Chinese telecommunications companies with potential ties to the Chinese government or military." According to its findings, "the opportunity exists for further economic and foreign espionage by a foreign nation-state already known to be a major perpetrator of cyber espionage" and other types of state-sponsored and corporate espionage "in particular, to the extent these companies are influenced by the state, or provide Chinese intelligence services access to telecommunication networks." A number of suggestions are made at the conclusion of the HPSCI report. The Committee on Foreign Investment in the United States (CFIUS) should prevent mergers that involve the Chinese firms Huawei and ZTE, and the intelligence community should continue to concentrate on the threat of Chinese companies entering the American telecommunications market.

The acquisition of Qualcomm Inc., a pioneer in 5G research and development financing, by Singapore-based Broadcom was thwarted by CFIUS in March 2018. A March letter from the U.S. Treasury Department outlining this choice said that a Broadcom acquisition of Qualcomm "could pose a risk to the national security of the United States." Although specifics of the national security concerns are classified, they relate to Broadcom's relationships with foreign third parties and the implications of its business plans for Qualcomm for national security. Given the well-known U.S. national security concerns about Huawei and other Chinese telecommunications firms, a shift towards Chinese dominance in 5G would have grave consequences for American national security. Many observers are worried about how easily foreign intelligence services could exploit the vulnerabilities of 5G networks. The fact that people can utilise 5G-enabled networks and systems for good indicates that the same technology may also be used by foreign intelligence to influence people's views and behaviour [3].

This manipulation will probably take many different forms, including attempts to mislead and perplex individuals about what is really occurring and what the reality is. Overloading our senses with unimportant or irrelevant information makes it difficult for us to accurately understand what our enemies are up to or what is important. We can also be presented with false information in order to mistakenly confirm our prejudices, misperceive reality, and make the wrong decisions. They'll also aim to incite long-standing resentments and anxieties so that Americans quarrel and seem silly to the rest of the world.140

With the advent of 5G technology, the quantity of personal data that may be exploited will increase dramatically, coupled with concerns about the networks' security. Advocates for privacy and experts in national security are concerned about this. For the U.S. intelligence, military, and diplomatic services to communicate freely and discretely with foreign persons who could be discouraged by the potential of an aggressive counterintelligence posture, there will be substantial obstacles, according to national security experts.

Some analysts contend that measures intended to discourage Chinese investment in the United States run counter to the country's long-standing policy of promoting China's participation in international standard-setting processes and may even be harmful. They contend that seeing China's influence on the creation of 5G standards and technologies as a possible national security issue may push China to adopt national standards that might serve as trade barriers that, in and of themselves, endanger U.S. national security. They contend that collaboration between the United States and China is essential for technological innovation in the private sector, including 5G.These opponents also point out that the Trump Administration's trade policy, which includes tariffs on Chinese telecom equipment, poses a serious risk of driving up the price of 5G infrastructure and delaying its rollout [4].

They claim that isolating the U.S. technology sector from one-sixth of the world's population will only cause it to lose market share to Chinese rivals, increase consumer costs, and weaken the competitiveness of the nation's top technology firms while also cutting it off from the hubs of innovation.

Policy Considerations for Congress

Congress and other U.S. authorities must decide how to balance the desire to increase American competitiveness in the global 5G race with the need for a successful domestic 5G deployment. Congress may take into account the federal government's involvement in industrial policy and promotion as well as the domestic rollout of 5G technology. U.S. telecommunications businesses made research and development investments, took part in global programmes to test the technologies, contributed to standards, and developed business plans throughout the spread of earlier technologies. This market-based strategy sparked competition and innovation, giving the US an advantage over other countries in earlier technologies. In order to gain an advantage in the race to 5G, other nations (i.e., central governments) have engaged in centralised planning and cooperation with industry. Congress may keep an eye on American developments in 5G deployment and technology, decide if greater planning and industry cooperation are required, and determine whether further government participation will support or impede American businesses' efforts in the race to 5G globally.

Congress can be requested to take the advantages and hazards of 5G deployment into account for domestic deployment. Nationwide, 5G technologies are anticipated to provide new income and employment opportunities. Additionally, 5G technologies have sparked concerns about personal privacy, national security, and how to evaluate the security of equipment made abroad [5].

Congress may take into account measures to safeguard domestic telecom networks, such as trade sanctions or economic penalties against foreign tech companies or limitations on foreign involvement in 5G rollouts. Congress may examine the effectiveness of different policy stances in addressing risks to the nation's security, such as those to vital infrastructure, telecommunications networks, industrial systems, and government networks, as well as dangers to cybersecurity and privacy. Congress may also take into account how trade regulations would affect American businesses' capacity to build networks locally and to buy and sell equipment overseas.

Additionally, 5G technologies are anticipated to provide consumers with new services (such as telehealth in rural areas and new services for the disabled). Local governments have expressed concerns about where to locate 5G small cells, including how to decide on fees, public rights-of-way, assuring rural access, and health and safety. While some stakeholders want the U.S. government to speed up the deployment of 5G, others want it to first evaluate the risks and issues related to the technology. Congress may think about how to balance these conflicting interests and concerns [6].

Congress may take into account regulations that allot more spectrum for potential 5G applications. In order to guarantee that crucial users will have appropriate access to the country's spectrum, Congress may compare the spectrum requirements for 5G with those of other users (such as other commercial, governmental, and educational users). When formulating spectrum policies, Congress may also take into account future spectrum requirements, such as spectrum required for advanced 5G technologies and industrial IoT systems.

The usage of 5G and IoT devices in the future may be covered by legislation from Congress. Congress may take into account new regulations regarding the privacy and security of data being transferred across millions of IoT devices and across 5G networks as 5G and IoT technologies are incorporated into numerous sectors and used in day-to-day life. To safeguard the security of data, Congress may take into account rules adopting security measures (i.e., best practises) in devices, systems, and networks.

Congress may think about boosting or supporting spending on the research and development of new telecommunications technologies (such IoT applications and 6G technologies) in order to maintain American leadership in the field. The problem with new technologies is that although an unrestricted flow of information (as in the international standards process) fosters innovation, there are also hazards involved, such the sharing of intellectual property. Companies all across the globe may utilise equipment and component components from different nations as global standards develop and equipment is constructed to a common standard. The security of American telecommunications networks may be improved by policies and procedures that evaluate and handle security threats with 5G supply chains.

DISCUSSION

The introduction of 5G technology is only getting started. To reap the majority of the economic advantages from this new technology, nations all over the globe are competing to be the first to market with 5G technologies and services. Private enterprise is driving deployment efforts in the US. By identifying and assigning spectrum for 5G usage and simplifying regulations pertaining to the site of 5G small cells, the U.S. government is assisting the implementation of 5G technology. Deployment of 5G, however, might be hampered by a number of problems, such as the convoluted spectrum allocation procedure, local opposition to small cell regulations, and trade restrictions that could limit the supply of 5G devices and equipment [7].

Up to 2035, 5G technology development and adoption are anticipated. The 116th Congress may be requested to take into account both concerns about the immediate deployment of 5G networks and concerns about the potential usage of 5G devices in the future, including Internet of Things devices. Decisions taken today, at the beginning of the deployment, may have an impact on the U.S. position in the race to 5G and the country's future usage of 5.

Congressional Actions Related to 5G

The 115th Congress considered several policies related to 5G technologies. Congress enacted two pieces of legislation related to 5G spectrum:

The Consolidated Appropriations Act, 2018, which was passed on March 23, 2018, included the Repack Airwaves Yielding Better Access for Users of Modern Services Act of 2018 (RAY BAUM'S Act of 2018) (P.L. 115-141, Division P). The spectrum auction process will be sped up and improved by the provisions in this legislation.The Making Opportunities for Broadband Investment and Limiting Excessive and Needless Obstacles to Wireless (MOBILE NOW) Act, which was also incorporated into the Consolidated Appropriations Act, 2018 (enacted on March 23, 2018), requires federal agencies to make decisions on applications and permit requests for placing wireless infrastructure on federal property in a timely and reasonable manner. This act also directs the federal government to [8].

A national pipeline of spectrum for commercial usage would have been established under the Advancing Innovation and Reinvigorating Widespread Access to Viable Electromagnetic Spectrum (AIRWAVES) Act (S. 1682) that was proposed in the Senate on August 1, 2017, with the goal of encouraging business to increase cellular services. If the measure had been enacted, the federal government would have been compelled to designate extra spectrum for commercial licenced and unlicensed usage (including 5G) and to set aside 10% of the earnings for the expansion of wireless infrastructure in rural regions. There was no more action taken on the measure after it was sent to the Committee on Commerce, Science, and Transportation. On February 6, 2018, a similar measure (H.R. 4953) was submitted in the House. It was sent to the Committee on Energy and Commerce's Subcommittee on Communications and Technology, but no further action was taken. The resolutions would have affirmed the belief that the US should make a commitment to modernising infrastructure policies in order to meet the demand for wireless broadband services, to improve broadband service access, quality, and affordability, and to support national economic growth and digital innovation. The resolutions' adoption would have shown legislative support for the introduction of 5G technology in the United States.

In order to solve the difficulties of small site deployment, legislation was introduced: On June 28, 2018, the Streamlining the Rapid Evolution and Modernization of Leading-edge Infrastructure Necessary to Enhance (STREAMLINE) Small Cell Deployment Act (S. 3157) was introduced. It would have established standards for state and local government review of cell siting applications, deadlines for approvals of applications, and limitations on the fees that state and local governments may impose. There was no more action taken on the measure after it was sent to the Committee on Commerce, Science, and Transportation.

Four bills were introduced that addressed cybersecurity issues:

a. The Securing the Internet of Things Act of 2017 (H.R. 1324), proposed on March 2, 2017, would have mandated that devices utilising certain frequencies adhere to new cybersecurity standards established by the Federal Communications Commission and the National Institute of Standards and Technology.
b. On June 7, 2018, the SMART IoT Act (H.R. 6032), also known as the State of Modern Application, Research, and Trends of IoT Act, was introduced. The measure would have mandated that the Department of Commerce examine the US market for Internet-connected products. This measure was approved by the House

on November 28, 2018, and it was sent to the Committee on Commerce, Science, and Transportation in the Senate on November 29, where it remained inactive.

c. The FCC was obliged to establish a new interagency committee to go through security reports pertaining to telecommunications and provide suggestions for avoiding and mitigating assaults under the Interagency Cybersecurity Cooperation Act (H.R. 1340), which was introduced on March 2, 2017. Additionally, it would have classified communications networks as "critical infrastructure," subject to restrictions for national security. There was no more action taken on this measure after it was sent to the Committee on Energy and Commerce, Subcommittee on Communications and Technology, and the Committee on Oversight and Government Reform.
d. The FCC would have been required by the Cyber Security Responsibility Act (H.R. 1335) to establish regulations for protecting communications networks and define those networks as "critical infrastructure." There was no further action taken on the measure after it was sent to the Committee on Energy and Commerce's Subcommittee on Communications and Technology.

Congress also addressed national security concerns related to telecommunications:

a. The John S. McCain National Defence Authorization Act (NDAA) for Fiscal Year (FY) 2019 (P.L. 115-232), passed on August 13, 2018, forbade the heads of federal agencies from acquiring telecommunications gear or services from Huawei, ZTE Corporation, and other businesses associated with the Chinese government that might pose a threat to American national security and counterintelligence.
b. "Race to 5G: Exploring Spectrum Needs to Maintain U.S. Global Leadership," Senate Committee on Commerce, Science, and Transportation, July 25, 2018. Among the hearings conducted during the 115th Congress that covered 5G and related subjects.
c. House Committee on Energy and Commerce, Subcommittee on Communications and Technology, "Realising the Benefits of Rural Broadband: Challenges and Solutions," July 17, 2018.
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CONCLUSION

The company's partnerships with other technology companies are also key to its success, as they enable it to drive innovation and bring new products and services to market. These partnerships are built on shared values and complementary strengths, and are essential for pushing the boundaries of what is possible in the technology industry. Broadcom's relationships with its suppliers are equally important, as they ensure the quality and reliability of its products and services.

The company is committed to maintaining strong and mutually beneficial relationships with its suppliers, and works closely with them to ensure that its products meet the highest standards of quality and performance. In conclusion, Broadcom recognizes the importance of relationships in the success of its business, and is committed to maintaining strong and mutually beneficial relationships with its various stakeholders.

Through its continued focus on innovation, quality, and collaboration, the company is well positioned to maintain its leadership position in the technology industry for years to come.

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CHAPTER 20

A STUDY ON CELLULAR TECHNOLOGY

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ABSTRACT:

This paper provides an overview of cellular technology, including its history, evolution, and the current state of the art. It examines the key features and benefits of 4G LTE networks, which provide high-speed connectivity and support a range of advanced services and applications. It also discusses the emerging trends and challenges in the cellular industry, including the need for increased network capacity and the transition to 5G technology.The paper also highlights the importance of cellular technology in the digital economy, and the potential of 5G to enable new and innovative applications in areas such as autonomous vehicles, smart cities, and the internet of things (IoT). Finally, it examines the role of standardization and collaboration in the development and deployment of cellular technology, and the need for global harmonization of spectrum to support the growth of the industry.Overall, the abstract underscores the critical importance of cellular technology in modern society, and the ongoing evolution and innovation in this field that will continue to shape the way we communicate and interact with the world around us.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

One of the most active industries is telecom. In fact, things keep growing better as a result of the introduction of new technologies and technical developments, whether it be in the areas of user experience, spectrum utilisation, the creation of new services, etc. Over the past two decades, the telecom industry has experienced rapid growth, bringing with it numerous innovations that have benefited the economy as a whole and other related industries. The most recent advancement in telecom technology, 5G, will improve connection for everyone while also aiding in the digitalization of several industrial sectors. By the end of 2019 or the beginning of 2020, full-scale 5G network deployment is anticipated to begin; pilots have already started. India is not far behind either. By 2020, India's 5G High Level Forum and the rest of the globe want to have 5G installed[1], [2].

TRAI has developed a White Paper in order to foster the conditions necessary for the timely deployment of 5G in India. This White Paper discusses the 5G technology's specifications, potential use cases, and network architecture. It also deliberates the investment-required areas for 5G deployment, discusses the spectrum needs for 5G networks, and attempts to pinpoint regulatory issues that must be resolved before 5G can be deployed in India. This White Paper's goal is to highlight potential obstacles to the deployment of 5G networks in India and to start a conversation with all interested parties about feasible solutions. I have no doubt that by eliminating obstacles to the successful introduction of 5G technology in India, this White Paper will inspire the business community and technologists to think differently and bring about revolution. The potential advantages of 5G are discussed in this TRAI White Paper, which also aims to pinpoint the regulatory issues that must be resolved before 5G can be deployed in India. No implication, assertion, or thesis contained in this text ought to be interpreted as TRAI recommendations or support.

With seamless coverage, high data rates, minimal latency, and very dependable connections, 5G is the most recent version of cellular technology. It will improve other systems' efficiency as well as the efficiency of networks, spectrum, and other systems. In addition to offering quicker and more reliable access, it will link billions of Internet of Things (IoT) devices by acting as a conduit for information. New mobile communication network capabilities made possible by 5G technology will allow for higher-quality video services with mobility at high speeds, business automation delivered by billions of connected devices, delivery of crucial services like tele-surgery and autonomous vehicles assured by low latency and ultra-reliable networks, and improved productivity assisted by high-quality, real-time data analytics. The needs for each of these many use cases may be tailored inside the same network, unlike current mobile communication networks [3].

Prior predictions placed the commercial rollout of 5G in 2020. The first 5G New Radio (5G NR) standard was completed for a Non-Standalone (NSA) solution in December 2017 and for a Standalone (SA) standard in June 2018, though, and this has prepared the way for the global mobile industry to begin full-scale development of 5G NR for large-scale trials and commercial deployments as early as in 2019. It has been noted in the past that India's technical development has not kept pace with that of the world's most advanced nations. However, India is carefully planning to launch 5G in line with the rest of the world.

Government’s initiatives

The Government established a 5G High Level Forum (5G HLF) in September 2017 to describe the 5G vision for India and to provide policy actions and action plans to realise this goal. "Making India 5G ready" is the title of a report2 published by the 5G HLF in August 2018 that suggests actions in the areas of spectrum policy, regulatory policy, education and awareness promotion programme, application & use case labs, development of application layer standards, major trials and technology demonstration, and participation in international standards.

To boost innovation and research in 5G, the government has started a program3 called "Building an End-to-End 5G Test Bed"4. The funding for this three-year programme was authorised at Rs 2,240 million, and it started in March 2018. IIT Madras, IIT Hyderabad, IIT Delhi, IIT Kanpur, the Centre of Excellence in Wireless Technology (CEWIT), the Society for Applied Microwave

Electronics Engineering & Research (SAMEER), and the Indian Institute of Science (IISc) Bangalore have all received the program's award. The programme calls for tight cooperation between small technology enterprises and colleges. The program's objective is to create 5G proof-of-concept prototypes that largely adhere to 3GPP specifications. The Department of Science and Technology (DST) and Ministry of Electronics and Information Technology (MEITY) have also financed many university R&D projects with 5G topics.

The International Mobile Telecommunications-2020 (IMT-2020) requirements now include the Low Mobility Large Cell (LMLC) use case, thanks to the Department of Telecommunications (DoT) and Telecommunication Standards Development Society, India (TSDSI) working together with the IITs. The demands of rural India and other nations in a similar situation are reflected in LMLC. In order to incorporate standards in Release 15 that enable the LMLC use case, TSDSI is now collaborating with 3GPP.

In order to create applications for broadband and low latency locations, Ericsson established the first public access 5G test bed at IIT Delhi in July 2018. The company also granted access to the industry and universities so they could work on use scenarios and applications that were relevant to India [4].

From 39 Petabytes in June 2016 to 4178 Petabytes in September 2018, India's mobile data use per month5 has surged significantly. India is becoming one of the nations with the greatest mobile data use due to the exponential development in data usage. By 2025, 208 million new users will connect in India, making up 25% of all new subscribers globally and 50% of those in the area of Asia-Pacific (APAC) between 2017 and 2025, according to GSMA intelligence (GSMAi) 6. By then, smartphone connections will make up 75 percent of all connections in the nation.

The increased demand for high-speed internet will be met in part by 5G. Additionally, it will open up new business opportunities and have a significant positive socioeconomic impact through increased productivity, better service delivery, efficient use of limited resources, and the creation of new jobs. By 2035, 5G is anticipated to have a cumulative economic effect of USD 1 trillion in India, according to 5G HLF7, which anticipates its deployment in India by 2020. By 2026, India's potential for digitalization-enabled income would exceed USD 27 billion, predicts Ericsson. Following its initial launch in 2020, 5G connections in India are expected to reach almost 70 million by 2025, or about 5% of all connections (cellular IoT connections excluded).

1. The National Digital Communication Policy-2018 (NDCP-2018), which was unveiled on September 26th, 20188, aims to support India's transition to a digitally empowered economy and society by meeting the information and communications needs of individuals and businesses through the establishment of a pervasive, dependable, and reasonably priced Digital Communications Infrastructure and Services. In terms of the implementation of 5G services, the NDCP-2018 envisions:
2. Using 5G technology to provide high-speed internet, the Internet of Things, and M2M:
3. Executing a plan of action for the implementation of 5G services and applications

4. Increasing backhaul capacity to assist the construction of 5G and other next-generation networks
5. Ensuring 6 GHz band spectrum is available for 5G.
6. Examining market norms for traffic prioritisation in order to provide 5Gen-enabled apps and services
7. Creating a framework for rapid M2M service deployment while protecting device security and interception.

Defining the EMF radiation policy for M2M devices and the institutional architecture to coordinate government-funded and India-specific research in this area In India, the timely deployment of 5G is crucial for fulfilling the goals set out in the NDCP-2018. The Digital India programme will be advanced by 5G, and it will aid in making public digital services accessible to everybody. The initiative for Smart cities will also need 5G capabilities [5].

As the country's telecom and broadcasting regulator, TRAI must work with the government, business, and other stakeholders to create an environment that will support the deployment of 5G in India. In light of this, this white paper explores the potential advantages of 5G while attempting to pinpoint the regulatory issues that must be resolved before 5G can be deployed in India.To ensure that this white paper was balanced and thorough, it was drafted using information from a number of publicly available documents, including those produced by government departments and agencies, international organisations, academic institutions, telecom vendors, and operators. This white paper also contains excerpts from a few papers that were pertinent to the subject matter.

There are eight chapters in the white paper. The specs of the 5G technology are highlighted in Chapter II. The architecture of the 5G network is covered in chapter three. The spectrum needs for 5G networks are covered in Chapter-IV. The deployment of tiny cells is covered in Chapter-V. The requirements for 5G backhaul are discussed in Chapter VI. The regulatory difficulties are discussed in Chapter-VII.

The International Telecommunication Union (ITU-R) standard M.2083 established specifications for IMT-2020, and the 5G network is created to satisfy those criteria. IMT-2020 (5G) aims to provide significantly improved capabilities compared to IMT Advanced (4G). It is anticipated to provide much better throughput, significantly reduced latency, ultra-high dependability, significantly larger connection density, and significantly longer mobility range. The comparison of design goals for 4G and 5G is shown in Figure 2.1.A flexible, scalable, agile, and programmable network platform is what the 5G networks are intended to provide, allowing for the provisioning and management of various services with various needs while adhering to rigorous performance constraints. The primary performance criteria connected to the IMT-2020 (5G) minimum technical performance. Three alternative use case classifications, including enhanced Mobile Broadband (eMBB), massive Machine-Type Communication (mMTC), and Ultra-Reliable Low-Latency Communications (UR-LLC), may be used to group 5G use cases. The use cases within each use case class and the criteria for each use case class differ greatly. Demonstrates the critical performance requirements in various use situations. eMBB: It solves the data-driven, human-centric use cases for accessing multimedia data, services, and content.

Along with the already existing Mobile Broadband applications, this usage scenario also includes new application areas like virtual reality, video monitoring, mobile cloud computing, 360-degree Ultra-High-Definition (UHD) video streaming, real-time gaming, etc..

UR-LLC: The throughput, latency, and availability requirements for this use case are quite strict. It will aid in the transmission of crucial messages. Examples include the use of wireless technology to manage industrial manufacturing or production processes, remote medical procedures, automation of the distribution system in a smart grid, transportation security, driverless automobiles, etc [6].

mMTC: A very high number of linked devices that normally send a little amount of non-delay-sensitive data are what define this use case. Devices must be reasonably priced and have a lengthy battery life. IoT applications are covered under this use case. Wearable health monitors, smart grid-enabled cities, intelligent transportation systems, and smart homes are a few examples.

5G will have impact on many sectors: A report12 by 5G Americas titled "5G services and use cases" was released in 2017 and highlighted prospective 5G use cases across several industries.

Networks built on Software Defined Networking (SDN) and Network Function Virtualization (NFV) offer virtual "network slices" for various vertical markets, providing specialised Quality of Service (QoS) and functional needs. Cloud Radio Access Network (Cloud RAN) facilitates effective resource allocation while lowering operators' Total Cost of Ownership (TCO). Small cell deployment boosts network capacity and spectrum reuse. Both classic and dispersed RAN network implementations are supported by new backhaul technologies. Users get quicker, higher-quality experiences with constantly-improving visual, audio, and maybe haptic interfaces when edge computing is used for local data analysis and processing. By dynamically delivering data as highly-focused beams and using multipath propagation and spatial multiplexing, Massive Multiple Input Multiple Output (MIMO)13 solutions boost user data rates and system capacity to meet 5G specifications.

Technologies like massive MIMO, super-dense meshed cells, and macro-assisted small cells work well in high frequency bands. Additionally, high frequency bands have significantly more bandwidth than bands below 1GHz, which is advantageous for offering much wider channels and faster speeds. Utilising spectrum in three different frequency ranges—sub 1 GHz, 1-6 GHz, and above 6 GHz—can support various use cases' varying needs. Spectrum utilisation is improved via spectrum sharing methods like Licenced Shared Access (LSA). Additionally, the capacity of the access network is increased by combining licenced and unlicensed spectrum, which also enhances the wireless experience for users.

The Global System for Mobile Communications (GSM) was created to provide circuit switched voice services. Circuit switched modem connections might also be used for data services, although at extremely low data speeds. The transition from GSM to GPRS, which uses the same air interface and access technique, was the first step towards an Internet Protocol (IP) based packet switched solution. Wideband Code Division Multiple Access, or WCDMA, is a new access method that was created to help the Universal Mobile Terrestrial System (UMTS) achieve faster data speeds. For phone and data services, the UMTS access network simulates circuit switched and packet switched connections, respectively. Paging for incoming data services in UMTS still required the circuit switched core. The Evolved Packet System (EPS), which is entirely IP-based, was created to address this weakness. Voice and data services are both handled using the IP protocol in the EPS system. To achieve high data rates, a novel access method called Long Term Evolution (LTE), which is based on Orthogonal Frequency Division Multiple Access (OFDMA), is utilised. Without a centralised intelligent controller, the LTE access network is just a collection of evolving NodeB smart base stations, resulting in a flat architecture. The length of time needed to establish the connection and to switch over was decreased by sharing information among the base stations in LTE [7].

DISCUSSION

5G has demanding service and network requirements that will require a fundamental change to the core architecture. Simply upgrading the existing LTE core won't be able to support the varied requirements of all envisaged 5G use cases. The 5G NG core will have the following characteristics:

a. Virtualization and NF modularization;
b. Service based architecture and interface;
c. Control plane and user plane separation;
d. Mobility management and session management function decoupling;
e. New QOS architecture for introducing the new services;
f. Network slicing for supporting the new business domains.

NF modularization and virtualization the underlying physical infrastructure is supported by software-defined networking (SDN) and network functions virtualization (NFV), and 5G fully codifies access, transport, and core networks. SDN focuses on the separation of user-specific traffic from network control traffic (control plane/user plane). It is built on the idea of centralising configuration and management while maintaining a straightforward data plane design. In NFV, network tasks that may be executed on a variety of common hardware are virtualized (by being implemented in software). Platforms based on the cloud and virtualization enable the construction, configuration, connectivity, and deployment of several distinct tasks at the scale required at the moment. It allows for flexible resource orchestration and effectively manages the network.

Adoption of the cloud enables the critical technologies of end-to-end network slicing, on-demand deployment of service anchors, and component-based network functions and improves support for a variety of 5G services. Scaling and managing the network infrastructure are also made simpler. Additionally, it provides an expanding range of feature-rich "Platforms as a Service (PaaS)" to make the development of new applications simple.

Point-to-point (P2P) and service-based (SBA) are the two 5GC architectural representations that are identified by 3GPP. In 2G, 3G, and 4G, the P2P architecture has been used. Because P2P architecture contains numerous unique interfaces between functional elements, it is challenging to modify a deployed system. Numerous adjacent functions must be rearranged when a new element is added or an existing element is upgraded. The SBA separates the platform and network infrastructure from the end-user service. As a result, both functional and service agility are enabled. Separating the control and user planes allows for decoupled technological progress and independent scaling. Additionally, it will enable flexible deployments at centralised and edge locations. It may also be used with the 4G EPC. With this improvement, the EPC is better equipped to handle rising traffic needs at a cheaper cost-per-bit and to support edge-hosted low-latency applications. Additionally, it offers a crucial transition route from 4G to 5G [8].

Business clients may take advantage of network slicing to get connection and data processing that are specifically customised to their needs and that comply to a Service Level Agreement (SLA) established with the operator. Data speed, quality of service, latency, dependability, security, services, and billing are just a few of the network's adaptable features. Under order to satisfy certain service needs, an operator under this idea build create several virtual slices of the RAN, core, and transport networks on top of the same physical infrastructure. The operators might implement either a single network slice type that meets the demands of many distinct verticals or a number of network slices of various sorts that are bundled together as a single product and marketed to business clients with a variety of requirements.

Network Slicing offers a platform that is industry vertically optimised and efficiently satisfies the unique demands and commercial requirements of each vertical. Government, utilities, media & entertainment, financial, smart cities, consumer, automotive, logistic, industry internet, and health & welfare are the industry sectors, according to GSMA, that have the most potential for using network slicing.

Network slicing may be used for a variety of things, including a fully private network, a duplicate of a public network to test a new service, or a network that is only utilised for that service. The network exposes a set of capabilities in terms of bandwidth, latency, availability, etc. while setting up a private network in the form of a network slice, which may be an end-to-end virtually isolated component of the public network. The slice owner will then be able to operate a freshly constructed slice locally since they will see the network slice as their own network, replete with transport nodes, processing, and storage. A slice may receive a combination of dispersed and centrally hosted resources. Applications are simply executed and data is stored, either centrally, in a distributed management system, or a mix of both, by the slice owner from his or her management centre.

Mobile network capabilities are developing swiftly as a result of increasing demands for latency, traffic volume, data speeds, and the necessity for dependable connection. The LTE RAN design will need to provide better resource pooling, capacity scaling, layer interworking, and spectrum efficiency across a variety of transport network topologies in order to effectively meet future needs. Utilising NFV techniques, data centre processing power, and improved radio coordination for both distributed and centralised RAN deployments, cloud RAN architectures meet these needs.

Distributed RAN18 (DRAN): In the DRAN design, the radio site serves as the interface between the RAN and core network. Today, only a distributed baseband deployment is used by the majority of LTE networks. DRAN design provides rapid adoption, simplicity in implementation, and IP-based networking as a standard. **Centralised RAN (CRAN):** In a CRAN design, a single location acts as the hub for all baseband processing, including RAN L1, L2, and L3 protocol layers. The transmission lines utilise Common Public Radio Interface (CPRI) fronthaul via dedicated fibre or microwave links to connect the central baseband units and dispersed radio units. The CPRI fronthaul demands high bandwidths and low latency. Its primary use is to improve performance in very congested urban environments.

Virtualized RAN (VRAN): This architecture for mobile networks provides coordination and centralization by using NFV methods and data centre processing capabilities. By virtualizing portions of the baseband process, it provides resource pooling, scalability, layer interworking, and resilient mobility of the network, making it simpler to increase capacity, deploy new services, and adopt the network. The improved adaptability of this split architecture would enable the operators to implement a wider variety of deployments, with the ability to customise the networks to cater to client demands ranging from automated manufacturing machine management to dense urban, high eMBB bandwidth applications. Both DRAN and CRAN networks may use VRAN [9].

New interfaces have been standardised for the new 5G RAN architecture, including the split architecture. In order to increase bandwidth efficiency and facilitate deployment, the CPRI has been replaced with the new fronthaul interface eCPRI, which is packetized. Similar to the conventional S1 backhaul link, the new IP-based interface between the Centralised Unit (CU) and Distributed Unit (DU) processing nodes in VRAN requires reduced latency for maximum performance. The majority of the features of the present S1 backhaul will be retained by S1/NG backhaul, but with more capacity. The transport domain provides communication between equipment and devices at distant locations. Fronthaul is the term used when the BS antennas are linked to a distant integrated Radio Frequency (RF) unit, or to a centrally placed baseband (BB) unit. Backhaul serves both ends of the transmission, for example, to connect a Base Station (BS) to an access network or a central office. The transport domain may provide several kinds of customer-facing connection services, including a Layer 2 or Layer 3 VPN, in addition to providing bulk connectivity for the operator's mobile network fronthaul and backhaul.

The bandwidth and latency of transport networks must now meet new standards due to 5G RAN technology. As a result, extensive automation and coordination both inside and across network domains will be needed. The radio, transport, and packet core layers of a mobile operator's network are coordinated via a concept called RAN Transport Interaction (RTI), which offers network-wide optimisation and service assurance. Support for diverse businesses and extending network resource distinction into the transport network are a few examples of this cooperation. To enhance user Quality of Experience (QoE) and ensure fairness amongst radio technologies inside the transport network, proactive congestion management is enabled, allowing RAN load balancing with consideration for transport. Advanced antenna systems (AAS) are now a practical alternative for extensive deployments in current 4G and upcoming 5G mobile networks because to recent technological advancements. Modern beamforming and MIMO methods, which are effective tools for enhancing end-user experience, capacity, and coverage, are made possible by

AAS. Both the uplink and the downlink network performance are greatly improved. Beamforming is the capacity to focus radio energy on a particular receiver by directing it via the radio channel. Constructive addition of the relevant signals at the UE receiver may be accomplished by altering the phase and amplitude of the broadcast signals, which boosts the received signal strength and, therefore, the throughput for end users. Because more radio chains, also known as Massive MIMO, provide more degrees of freedom, adding AAS features to an AAS radio boosts performance significantly.

CONCLUSION

In conclusion, cellular technology has revolutionized the way people communicate and access information, enabling unprecedented levels of mobility and connectivity. The development of cellular technology has evolved rapidly over the years, from the early days of analog cellular systems to the advanced 4G LTE networks that are widely used today. As the demand for mobile connectivity continues to grow, the emergence of 5G technology promises even faster data rates, lower latency, and greater capacity. Cellular technology is a critical enabler of the digital economy, supporting a wide range of applications and services that are essential for modern life. The benefits of 4G LTE networks include high-speed connectivity and support for advanced services and applications, such as video streaming, online gaming, and remote working. The potential of 5G technology is even greater, with the ability to enable new and innovative applications in areas such as autonomous vehicles, smart cities, and the internet of things (IoT). The ongoing evolution and innovation in cellular technology are driven by the need for increased network capacity, improved performance, and the ability to support new applications and services. Achieving these goals requires standardization and collaboration among industry stakeholders, as well as global harmonization of spectrum to support the growth of the industry. Overall, cellular technology is a critical driver of the digital economy, and the continued evolution and innovation in this field will continue to shape the way people communicate and interact with the world around them. As the demand for mobile connectivity continues to grow, the emergence of 5G technology promises to unlock new opportunities and transform the way we live, work, and play.

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CHAPTER 21

STUDY ON SMALL CELL DEPLOYMENT

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ABSTRACT:

Small cell deployment is a critical aspect of modern wireless network infrastructure. With the proliferation of mobile devices and the growing demand for high-speed connectivity, small cells are becoming an increasingly important tool for delivering reliable, high-quality wireless service to users in a variety of settings. Small cells are low-powered radio access nodes that are designed to provide wireless coverage and capacity over a small area, such as a neighborhood, campus, or shopping center.This paper provides an overview of small cell deployment, including its benefits, challenges, and emerging trends. It examines the key features of small cells, including their low power consumption, flexibility, and ability to support a range of wireless technologies and services. It also discusses the challenges associated with small cell deployment, including the need for access to suitable sites, power, and backhaul.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

Large frequencies are necessary for 5G to provide large data speeds, however these frequencies have unfriendly propagation. The use of cutting-edge antennas is crucial in overcoming the difficult propagation circumstances at these frequencies. There is a feature to include Wi-Fi access within the 5G core in the IMT-2020 specs. A non-3GPP Inter-Working Function (N3IWF) Interface connects non-3GPP access networks (such as WiFi networks) to the 5G core network. The N2 interface and N3 interface are how the N3IWF connects to the control plane and user-plane functionalities of the 5G core network, respectively. The traffic (calls and data) is offloaded to the WiFi network whenever the User Equipment (UE) is at a location with WiFi capability. However, since UE and N3IWF have set up a secure tunnel, there is no security compromise when using the non-3GPP access. This will contribute to easing the strain on the IMT spectrum [1].

(NSA) Non-Standalone and (SA) Standalone. In NSA, Dual Connectivity (DC) is used towards the terminal and NR and LTE are seamlessly integrated. They connect to either the current EPC or the 5G NG Core. While in SA, the 5G NG Core is connected via either NR or LTE. The 5G network will first be installed alongside LTE in order to hasten its adoption. NSA networks will gradually transition to SA networks with 5G NR and 5G Core as soon as the technology develops and all 3GPP standards are locked. A Master Node (MN) and a Secondary Node (SN) simultaneously deliver radio resources to the terminal for increased end-user bit rates in a Dual Connectivity architecture.

Any wireless communication needs spectrum to function. Low frequencies (less than 1 GHz) facilitate IoT for low data rate applications and provide broad area and deep indoor coverage in urban, suburban, and rural locations. High speeds and adequate coverage are provided by medium frequencies (1-6 GHz). For the provision of extremely high data rates and great system capacity in dense installations, high frequencies (over 6 GHz) show considerable potential. Based on their physical characteristics, the frequency bands in the figure are compared. Technically speaking, any spectrum band may be utilised for the deployment of any technology since spectrum is technology neutral. However, in addition to technical considerations, the development of the eco-system is important when deciding whether to deploy a technology [2].

A new technology called 5G is expected to employ low frequencies (f1GHz), high frequencies (1GHzf6GHz), and extremely high frequencies (f>6GHz), also known as "millimetre wave" frequencies, for the first time ever in consumer networks. The promises of 5G's expanded coverage (low frequencies), ultra-high speeds (extremely big channels in very high frequency bands), and low power consumption are guaranteed by this spectrum's diversity. The 3GPP has conducted research to find the best bands for 5G. The following 5G NR frequency bands are mentioned by 3GPP in its Release 15 specifications. The pioneer bands for 5G are 700 MHz, 3.5 GHz, and 26/28 GHz.

Eleven possible frequency bands, including 24.25-27.5 GHz (26 GHz), are being evaluated in the higher frequency bands as part of the World Radio Conference 2019 (WRC-19) to see whether 5G can coexist with existing services in the same and nearby frequencies. With the Asia-Pacific region's important position in mind, the Asia Pacific Telecomm unity (APT) Wireless Group (AWG) is also undertaking sharing and compatibility studies for IMT above 24 GHz frequencies.

Countries like the US, Canada, South Korea, Japan, Hong Kong, New Zealand, Singapore, Brazil, Taiwan, Colombia, and Slovakia have either allocated or are in the process of allocating portions of 26.5-29.5GHz (28 GHz band) for 5G, which is outside the purview of WRC-19. This is based on the availability of spectrum and the readiness of equipment from the mobile industry. The telecom industry has begun building a robust ecosystem of equipment for the 28 GHz frequency. In this band, there have been over 50 trials. With the strong backing of the mobile sector, 3GPP has also produced the standard to enable the 28 GHz band for 5G, anticipating becoming the first global mmWave ecosystem. Additionally, organisations representing the global mobile industry like GSMA and GSA fully support the 28 GHz band as the 5G Frontier band. The current method of allocating spectrum in India is via an auction, and the spectrum sold is liberalised (technology agnostic), meaning that the service provider is free to choose the technology to be used in the specified frequency band. Over time, various spectrum bands have been designated for IMT services in India. MHz band (3400 MHz - 3425 MHz) has been designated for ISRO's usage in the Indian Regional Navigation Satellite System (IRNSS) [3]:

(i) TDD Duplexing scheme

(ii) The full spectrum from 3300 MHz to 3600 MHz should be made accessible for access services, with the exception of the particular sites where ISRO is utilising the 25 MHz of spectrum.

However, one of the key determining factors for the use of any technology in a specific spectrum band is the development of the ecosystem. Spectrum harmonisation is crucial in order to quickly realise this future vision of high-speed mobile broadband communications since ecosystem growth is driven by worldwide deployments. Spectrum harmonisation increases economies of scale, lowers cross-border interference problems, and permits roaming, which in turn increases user adoption of services. Spectrum availability is one of the most crucial concerns in the 5G concept. The right frequency bands must have enough spectrum made accessible in order for 5G to reach its full potential. The 5G HLF has suggested three levels of access spectrum release for 5G depending on availability and readiness in recognition of this reality.

The 700 MHz, 3.5 GHz, and 26 GHz–28 GHz bands are all included in the Announce Tier, as can be seen in Paragraph 4.11. Additionally, HLF has recommended that the government name these bands as potential 5G candidate bands and permit research trials on them. The previous time the 700 MHz spectrum was put up for auction, nothing was bought. IMT services may still use the 35 MHz (713-748 MHz for uplink and 768-803 MHz for downlink) paired frequency [4].

Recently, India designated the 3.5 GHz (3300-3400 MHz and 3400-3600 MHz) range for IMT services. Out of 200 MHz in the 3400-3600 MHz band, 175 MHz (3425 MHz - 3600 MHz) is available for access services, and 25 MHz (3400 MHz - 3425 MHz) is reserved for ISRO's use in the Indian Regional Navigation Satellite System (IRNSS). 100 MHz of spectrum between 3300 and 3400 MHz is available on a pan-India basis. Since only a few locations would be used by ISRO for this 25 MHz spectrum, reserving the entire 25 MHz on a pan-India basis would result in the waste of this priceless spectrum. Therefore, TRAI has advised that the entire 200 MHz should be made available for access services through recommendations dated August 1st, 2018, with the exception of the particular areas or districts where ISRO is using this spectrum. Time Division Duplexing (TDD) should be used in the range between 3300 MHz and 3600 MHz, according to TRAI's further recommendation [5].

For MOBILE, FIXED, Fixed Satellite System (FSS), etc., GHz has already been designated. At the moment, it is also being taken into account for a brand-new service at WRC called Earth Station in Motion (ESIM), whereby tiny terminals with satellite connection capabilities are put on aeroplanes, ships, and land vehicles. Some governments around the world recognise 28 GHz as one of the most important bands for early 5G deployments. In the Asia Pacific Telecommunity (APT) meeting of APT Wireless Group 24, India has also proposed a coexistence study for the 28 GHz band.

The research findings in the AWG Report will assist not just the Indian government but also those of other Asia Pacific nations in deciding whether to allocate 28 GHz for 5G and other services. The conduct of sharing studies for the 3GPP Band n257 (26.5-29.5 GHz) by AWG received strong support from all nations (S. Korea, Japan, New Zealand, Singapore, Hong Kong, Bangladesh, Australia, Indonesia, and others) at the AWG#24 summit, with the exception of

China. Large contiguous spectrum blocks per operator are generally needed for 5G to be able to deliver multi-gigabit mobile broadband services (MBB). According to the results of various recent global.GHz band auctions, an operator purchased between 40 and 100 MHz. However, some of the country's regulators set the block size at just 5 MHz.

Smaller block size offers more flexibility while bigger block size improves the networks' spectrum efficiency and mobile broadband experience. The latter, however, increases the likelihood of fragmentation. Therefore, in its recommendations to the Government dated 1st August 2018, TRAI suggested a block size of 20 MHz with a cap of 100 MHz to provide flexibility, increase efficiency, and prevent band fragmentation. The 20 MHz block size would provide bidders options, and a 100 MHz cap per bidder would aid in preventing monopolisation of this spectrum. It has also been suggested that, if a Telecom Service Provider (TSP) is successful in winning more than two blocks of spectrum, it should be given spectrum in continuous blocks to prevent spectrum fragmentation [6].

5G has the potential to work as a catalyst in achieving larger overall economic growth of the country. Investment in mobile network infrastructure will be a key enabler of growth and competitiveness in national economies worldwide for the foreseeable future. Therefore, for spectrum pricing and allocations, the administrations are needed to be focused on maximizing long-term welfare benefits, not on short term revenue benefits, by simulating competition and investment. Keeping in mind, the massive impact 5G will have on different industry verticals, and hence on the overall economy, effective spectrum pricing will play a vital role in promoting healthy investment in the networks.

Spectrum sharing and unlicensed spectrum

Wider coverage regions and improved quality of service assurances are made possible by licenced spectrum. Unlicensed spectrum 21, however, may serve as a supplementary technology that enables operators to improve the 5G user experience by combining licenced and unlicensed bands. By enhancing capacity, boosting spectrum utilisation, and introducing novel deployment scenarios, access to shared and unlicensed spectrum will broaden the scope of 5G in many ways. Mobile carriers with licenced spectrum will gain, but it will also make it possible for those without licenced spectrum to use 5G technology.

Through 3GPP Release 13, the 3GPP introduced Licence Assisted Access (LAA), a feature that uses the 5 GHz unlicensed band in conjunction with licenced spectrum, as part of LTE Advanced Pro. In order to mix LTE in the licenced band with LTE in the unlicensed 5 GHz spectrum, carrier aggregation is used in the downlink. A bigger conduit with quicker data rates and a more responsive user experience is made possible by this spectrum aggregation. The smooth and dependable user experience is made possible by keeping a constant anchor in the licenced spectrum that contains all of the control and signalling data [7].

Until recently, the only unlicensed bands in India for indoor and outdoor usage of low power devices were 2.400-2.4835 GHz and 5.825-5.875 GHz. Recently, it was decided to include the frequency bands 5150-5250 MHz, 5250-5350 MHz, 5470-5725 MHz, and 5725-5875 MHz as unlicensed for usage in both indoor and outdoor environments. The growth of the 5G ecosystem will be facilitated by the availability of new unlicensed frequencies.

Although unlicensed bands are used, the term "unlicensed" does not imply consent to operate these devices at will. The use of type-approved equipment is required, and the operation must closely adhere to the established power restrictions. Interference also affects any transmission in unlicensed spectrum. Quality of Service must still be guaranteed, however.

If spectrum is not used effectively and optimally, it not only costs the government money but also impedes the economic and social development of the nation. The idea of LSA is to dynamically share a spectrum band whenever and wherever the current users aren't using it. Only those with a specific permission (i.e., a licence) are permitted to utilise the spectrum in a shared manner. Administrative spectrum allocation is done for all Indian government organisations. The detection of unused or ineffectively used spectrum will be made possible via a spectrum audit. LSA may be employed for the best spectrum utilisation after identification. Wider coverage regions and improved quality of service assurances are made possible by licenced spectrum. Unlicensed spectrum 21, however, may serve as a supplementary technology that enables operators to improve the 5G user experience by combining licenced and unlicensed bands. By enhancing capacity, boosting spectrum utilisation, and introducing novel deployment scenarios, access to shared and unlicensed spectrum will broaden the scope of 5G in many ways. Mobile carriers with licenced spectrum will gain, but it will also make it possible for those without licenced spectrum to use 5G technology.

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The growth of the network towards an integrated network dubbed HetNet (Heterogeneous Network) made up of macro cells, micro/small cells, and WiFi access points is being pushed by both technological breakthroughs and capacity limitations. The promised benefits of 5G include a 100-fold increase in traffic capacity, a 20Gbps peak data rate, and a 100Mbps user experience data rate. A 100-fold increase in site capacity is not practical, however. Additionally, because high frequencies are used, each site's coverage area is only a few metres wide. Future network needs will necessitate network densification, which entails increasing the number of small and macro cells in the network. Operators will be able to provide much more capacity in crowded regions and increased coverage in places where building obstruction would normally impair signal strength by installing tiny cells.

For operators, small cells represent a technological revolution that is resulting in the birth of a new "as-a-service" business model. For firms who provide infrastructure in our nation, this may provide a new opportunity. Operators may reduce costs via multi-operator deployments and avoid most of the Capex associated with large-scale small-cell roll-outs thanks to small-cell-as-a-service (SCaaS) models. In order to save operators money, SCaaS providers could try to make use of their current asset ownership of sites, backhaul connections, etc.

DISCUSSION

Since 5G capabilities depend on hyper dense network, small cells will be required to be deployed at every 200-250 meters on many types of infrastructure such as electric utility poles, street light poles, bus stands, roof tops, traditional cell towers, etc. However, telecom operators are experiencing significant challenges in the deployment of small cells. For deploying a macro cell/ small cell, a TSP has to contact varied authorities/institutions for obtaining necessary approvals/clearances such as site acquisition, municipal clearance, RF compliance certification, environment clearance, power supply management, etc. All these processes are time consuming and impose excessive administrative & financial obligations on operators [9].

Many efforts are being made to address the problems with small cell deployment and promote the growth of 5G internationally. A report22 titled "Small cell siting: regulatory and deployment considerations" was released in February 2017 by the Small Cell Forum (SCF) and 5G Americas with the goal of laying out ways to improve collaboration between a large number of stakeholders (regulators, administrations, municipal authorities, site owners, operators, and vendors) for the successful delivery of dense HetNets.

In order to hasten the deployment of small cells throughout the United States (US), the Federal Communications Commission (FCC, the US Telecom Regulatory Authority) has announced guidelines23 that place time restrictions on local authorities' ability to make judgements on small cell deployments in localities. The regulations also place restrictions on how much operators may be charged by cities to install tiny cells. The 28 Member States of the European Union are preparing to incorporate the new European Electronic Communication Code24, which is being approved by the European Parliament and Council, into the new telecommunications legislation. The Code specifies "small-area wireless access points" and establishes nationally defined guidelines for the streaming deployment of upcoming 5G networks, noting the changes in the network architecture.

A TSP used to need to get consent from several organisations in order to install a BTS in India in the past. All of those procedures took a lot of time and placed administrative and financial burdens on TSPs. The Department of Transportation (DoT) released the Indian Telegraph Right of Way (RoW) 25 Rules-2016 in November 2016 to provide a uniform framework throughout the country and expedite all the procedures associated in rolling out telecom infrastructure. The RoW guidelines provide a framework for granting permissions, resolving disputes in a timely way, and enhancing collaboration between businesses and public agencies. These rules require the State Governments to create a single electronic application procedure for all applicable agencies under their control within a year of the rules' effective date in order to reduce administrative burdens.

The regulations further limit the one-time fee levied by the local government to cover administrative costs for reviewing each application to 10,000 rupees. The Standing Advisory Committee for Frequency Allocation (SACFA) site clearance application procedure may now be completed online thanks to a portal set up by the Wireless Planning & Coordination (WPC) Wing of the Department of Transportation (DoT). With the use of the Bharat kosh site, it is now possible to get online receipts for the "SACFA siting application registration fee." The online application procedure is not entirely paperless, however. In this regard, TRAI has advised making the whole SACFA approval procedure paperless and conducting it end-to-end via an online platform in its Recommendations on "Ease of Doing Telecom Business" dated 30th November 2017. This would increase its effectiveness, timeliness, and transparency.

Concern about potential negative health consequences from electro-magnetic field (EMF) radiation from mobile towers has long been in India. People are against building telecom towers in densely populated areas and on the rooftops of homes for this reason. In order to dispel the public's misperception about the emissions from mobile towers, the DoT launched 26 Tarang Sanchar in May 2017. It is a website platform for the exchange of information on mobile tower compliance and EMF emissions. The compound annual growth rate (CAGR) of new small cell deployments in India is expected to be 33% in enterprise environments and 90% in outdoor urban areas between 2016 and 2021, according to a report by the Small Cell Forum titled "Small Cell Forum Densification Summit: Asia Market Requirements" published27 in December 2017.

Although precise data on the number of small cells deployed in India is not yet available, Tower Xchange reports that the country ranks second among the major Asian markets in terms of the number of telecom towers. The growth of tiny cells in India has been hindered by lengthy and complicated procedures, high fees, and out-of-date rules. Many of the advantages that the Indian government, regulator, and cities hope to obtain from 5G, such as smart city platforms, improved access to healthcare, education, and banking, and the Industrial IoT, will be seriously jeopardised if the difficulties in deploying small cells are not resolved in a timely manner.

Indian TSPs will need to increase the density and speed of the deployment of small cells if they want to begin the commercial roll-out of 5G services by 2020. Due to their density, public infrastructure like street lights, traffic lights, metro pillars, electricity poles, and public buildings/rooftops make excellent locations for the deployment of small cells; therefore, it is crucial to ensure that local and national authorities grant operators easy access to such public infrastructure for the installation of small cells on a non-discriminatory basis. For this, strong coordination and cooperation amongst several players.

In order to expedite the approval process, further approval from municipal companies and local bodies are not required for site sites where power authorities, metro rail corporations, or other governmental organisations are allowing the construction of small cells and telecom equipment. Batch processing for a group of small cells will be essential since it will speed up approval times and ease the administrative strain on local authorities as more small cells must be deployed. Administrative fees for obtaining permissions or clearances also need to be taken into account in order to make the deployment of a large number of tiny cells economically feasible. Despite the fact that thorough RoW regulations 2016 have been announced, the state governments must be contacted in order to ensure that RoW rules 2016 are effectively applied. Additionally, a suitable modification to the RoW rules in accordance with the needs of the deployment of small cells will be advantageous.

CONCLUSION

In conclusion, small cell deployment is a critical aspect of modern wireless network infrastructure, offering a range of benefits including improved coverage and capacity, enhanced user experience, and reduced network congestion. As the demand for high-speed wireless connectivity continues to grow, small cells are becoming an increasingly important tool for delivering reliable and high-quality wireless service in a variety of settings.

Small cells are low-powered radio access nodes that can be deployed in a variety of environments, including urban areas, campuses, and shopping centers. They offer a range of benefits, including low power consumption, flexibility, and the ability to support a range of wireless technologies and services. However, small cell deployment also presents a number of challenges, including the need for access to suitable sites, power, and backhaul. Regulatory and policy issues also need to be considered to ensure that small cell deployment is carried out in a safe, efficient, and respectful manner.

Emerging trends in small cell deployment include the use of small cells to support 5G networks, the deployment of small cells in outdoor environments, and the use of innovative technologies such as virtualization and automation to simplify small cell deployment and management.

Overall, small cell deployment is a critical driver of modern wireless network infrastructure, and the continued evolution and innovation in this field will continue to shape the way people communicate and interact with the world around them. The success of small cell deployment depends on collaboration among industry stakeholders, streamlined permitting processes, and access to suitable sites, power, and backhaul.

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CHAPTER 22

WIRELESS BACKHAULING REQUIREMENTS IN 5G

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ABSTRACT:

Wireless backhauling is a critical component of modern wireless networks, providing the necessary connectivity between base stations and the core network. With the emergence of 5G technology, the demands on wireless backhauling infrastructure are increasing significantly. This abstract provides an overview of the wireless backhauling requirements for 5G networks, including the key technical challenges and emerging trends in this field.The paper first outlines the technical requirements of 5G networks, including the need for high bandwidth, low latency, and high reliability. It then discusses the key technical challenges associated with wireless backhauling in 5G networks, including the need to support multiple radio access technologies, the requirement for high capacity and low latency, and the need for efficient management of network resources.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

As the Internet of Things (IoT) takes off and billions of devices utilise mobile networks to interact with one another, mobile data traffic has increased significantly over the last few years and is expected to continue to expand. The use of smartphones will rise quickly in order to exploit IoT, and each new smartphone user will transmit and receive far more data than they did with their prior device. Backhaul nowadays uses microwave radio connections or optical fibre. Fibre has virtually infinite capacity, however it is practically impossible to draw fibre to every cell site owing to the cost, time, and logistical difficulties. Microwave can be rapidly installed, is more affordable than fibre, and is scalable. In addition, microwave connection capacity has continuously increased over time to suit the needs of the newest networks. Microwave backhaul throughputs of 1–10 Gbps are already a reality. Backhaul in 5G has developed into a more complicated network made up of front haul, mid haul, and classic backhaul with the introduction of Cloud RAN architecture. Fibre optics is the only front haul technology that works with speeds above 10 Gbps and latency in the hundreds of microsecond range. However, installing fibre to connect the envisioned Remote Radio Head (RRH) to the core may be difficult or even impossible in some circumstances [1].

The decision between fibre and microwave for backhaul networks comes down to fibre availability and Total Cost of Ownership (TCO), not capacity. When it comes to cost-effective high capacity backhaul, microwave technology is better suited to operations in urban areas and challenging terrain where laying fibre is impractical. These factors have caused the worldwide mobile backhaul network to change and include a combination of microwave and fibre.Microwave plays a crucial part in delivering strong mobile network performance since it is the primary backhaul medium in modern networks. But the ongoing pressure to raise performance standards necessitates the need for more bandwidth for microwave backhaul.

Historically, microwave backhaul has operated at frequencies between 6GHz and 42GHz. To meet the high-capacity backhaul needs of future networks, regulators throughout the globe are opening higher frequency bands, such as V-band (60GHz) and E-band (70/80GHz). Ericsson32 asserts that E-band will meet the high-capacity requirements of current networks. Additionally, it will be appropriate for the rollout of 5G in the upcoming years. Long term, nevertheless, additional spectrum will be required. Wireless communications research is focused on frequencies over 100GHz in order to meet future demand.

The W-band (92-114.25GHz) and D-band (130-174.8GHz) are still being standardised and prototyped. E-band was founded in the US more than ten years ago. Since then, E-band has consistently expanded. E-band is already available in more than 85 nations. Low spectrum fees and large capacity are the key proponents of E-band.India now has 1.5 million km of fibre installed. Less than 25%34 of telecom locations, however, are fiber-connected. Microwave lines are used for backhauling at the majority of telecom facilities. The biggest installed base of microwave lines in the conventional bands6GHz to 42GHzis in India [2].

Even with the greatest modulation methods, the anticipated traffic increase, especially in 4G/LTE and 5G networks, would be challenging to handle over current microwave backhauls. The backhaul portfolio will need mmWave spectrum to meet the demand created by congestion in these bands and the need for greater capacity. The bandwidth is greater in the bands above 43 GHz. Greater frequency reuse efficiency is also supported by the short connections associated with V-band and E-band. For the implementation of 5G, a swift policy decision on carrier allocation in these bands is essential. E-band should be on light-licensing and assigned at extremely low prices on a "link to link basis," according to TRAI's recommendations in its Recommendations dated August 29, 2014 on "Allocation and pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF carriers." WPC creates the required provisions for an online registration procedure by creating an appropriate web portal in order to simplify link registration. Industry experts predict that India will surpass all other countries as the world's biggest E-band market if E-band is made available there with a low-fee approach, as it is in the majority of other nations [3].

New services are launching and new use cases are proliferating quickly across several business sectors as a result of technological advancements. It's possible that the current licencing and regulatory rules do not clearly allow or enable these new services or use cases. Future network upgrades or gradual elimination of older technologies like 2G and 3G will accompany the deployment of cutting-edge technologies like 5G owing to the difficulties of non-capabilities and increased maintenance costs. The adoption and spread of 5G networks are anticipated to soar in the first years of the next decade (after 2020). Less physical installations will be needed as a result of technological convergence and the accumulation of resources like spectrum. The cell/Node (gNB) will also be able to use a variety of fundamental network features, which enables the Node to operate intelligently and effectively in 5G, something that was not feasible in prior technologies. The main responsibility for regulators and licensees is to determine the modifications that must be made to the licencing and regulatory framework in order to not only authorise or promote the emergence of new services but also to make it easier for them to be used in new ways. The adoption of newer, better technologies shouldn't be hindered by any regulatory or licencing requirements; rather, the framework for regulation and licencing should be supportive to the development of newer technologies. New capabilities and use cases made possible by 5G are expected to have an impact on consumer services as well as many other industries that are starting their digital transformations. For the services to launch on schedule, industry participants and regulators must work together to coordinate on a number of relevant issues, including standards, technology, spectrum, security, and RoW.

By establishing universal access to voice, video, and data connection, the government hopes to promote socioeconomic growth all the way to the base of the socioeconomic pyramid via its National Digital Communication Policy (NDCP) 2018 objectives. By harmonising regulatory and licencing frameworks affecting the telecom sector, it aims to provide dependable and secured connectivity with assured quality of service, facilitate the development of infrastructure and services for new technologies including 5G and IoT, encourage innovation and manufacturing, and develop a large pool of digitally skilled manpower.The primary topics of the strategy, according to the government, would include adoption of new technologies like 5G and IoT as well as connection for everyone, quality services, ease of doing business, and regulatory and licencing framework influencing the telecom industry [4].

The current Core network deployment policy. The telecom industry as a whole has changed from a "voice-centric" to a "data-centric" business with the advent of 4G. Media and technology are coming together to make content sharing more effective. The 'flat' radio and core network architecture are key components of LTE. The fact that all services, including voice, are offered over the IP packet network utilising IP protocols is a crucial component of the 'flat' LTE design. LTE envisions only a single evolved packet-switched core, the EPC, over which all services are supported, in contrast to earlier systems that had a separate circuit-switched subnetwork for supporting voice with their own Mobile Switching Centres (MSC) and transport networks. This could result in significant operational and infrastructure cost savings.

The aforementioned considerations suggest that the network design of the 4G LTE network differs significantly from that of the 2G and 3G networks. Major hardwired switching functions have been transformed into logical and virtual functions thanks to network function virtualization (NFV). Without physical expansion, a soft switch or comparable server can handle millions of jobs at once. The actual location of the servers has gradually lost significance for operational purposes as newer technologies, including LTE, have evolved and replaced key network components. Additionally, virtualization of a number of functions has made it possible for telecom operators to host servers in the cloud [5].

Due to the architectural modifications made to cellular networks, the DoT amended the UL and UASL licences' terms for the "Location of Switches and Other Network Elements" clause under the "Technical and Operating Conditions" section on June 23, 2017. The licensee is now permitted to host any of its equipment anywhere in India as long as the interconnection points are situated and run in the appropriate service area for inter-operator, inter-service area, NLD, and ILD calls and comply with the license's security requirements. In the end, DoT eliminated the requirements for hosting the Media Gateway Controller/Soft switch and other common systems in a licence service area.

Network component deployment on the cloud. As people's functioning in the real world and the virtual world shifts to web-based services on the cloud, cloud computing is becoming an increasingly important part of people's everyday lives. Wide-ranging advantages of cloud computing include improved availability, higher scalability, and a more secure environment. These advantages have changed business capabilities for companies and sped up economic, commercial, and social advancements. Cloud-based services boost collaboration, provide flexibility (work from anywhere), provide backup and recovery solutions, and lower the cost of infrastructure—all of which increase productivity and availability.

The Service Based Architecture (SBA) is anticipated to serve as a major foundation for 5G. High expectations will be placed on service providers to enable quick development of new services and extendibility without compromising quality. With the use of SDN and NFV technology, 5G networks may leverage network slicing to address a variety of consumer, business, and industrial use case needs on the same physical infrastructure. The infrastructure and apps' programmability and agility are also made possible by these technologies [6].

It may be projected that NFVs and SDNs alone cannot satisfy the goal unless they are advanced given the size and functional needs of the future networks. In order to increase the needed capabilities of future networks, fault tolerance and scalability difficulties in the current virtualized environment need to be addressed. A cloud-based Network Function Virtualization (NFV) framework will essentially be helpful in removing or overcoming the infrastructure limitations of the core networks by enabling tenants to transparently attach stateless, container-based network functions to their services hosted in network of cloud.

Despite its many benefits, cross-border data flow, data privacy, and data security are some of the major issues that cloud computing must address. When a TSP's data or network function is housed over the cloud, these factors become increasingly important. In the service-based architecture, there may be more than just TSP involved in offering services and support to the end user or to a service aggregator.

Adoption of cloud-based services depends on cloud security. No cloud service could be properly provided without security. Users in particular need to feel confident knowing that their data is safe in the cloud. Security is required for both data and services and applications in order to prevent their use outside of agreed-upon parameters. There are issues with data transfer, information exchange, and the usage of third-party systems [7].

In addition to network tasks like security, firewalls, load balancing, software-defined WANs, and big data analytics, the Cloud firms and technological start-ups now provide network infrastructure resources for computing, storage, and processing. On August 16, 2017, TRAI released recommendations about cloud services. It has been emphasised via the suggestions to take a light-handed approach to regulating cloud services and to provide a wide framework for DoT registration of an industry organisation of cloud service providers (CSPs). After accepting the suggestions, the DoT requested from TRAI proposals on further parameters, such as eligibility requirements, entrance cost, registration period, governance structure, etc.

Also regarding the legal framework for data protection, TRAI published its recommendations on "Privacy, Security, and Ownership of the Data in the Telecom Sector" on July 16, 2018, which address the following issues:

Adequate protection to sensitive personal information:

adopt the principles of data protection reaffirmed by the 2012 Report of the Group of Experts on Privacy of the Planning Commission; regulations for international data transfers. To address the problem of law enforcement agencies' access to data maintained by CSPs in various jurisdictions: In order to provide law enforcement authorities access to data, robust Mutual Legal Assistance Treaties (MLATs) need be drafted with the nations where CSPs often host their services. Existing MLATs should be changed to include clauses that allow for legal interceptions or access to cloud-based data.

To guarantee that the mission-critical services are not disrupted, the cloud service provider must enforce and agree to a specific Service Level Agreement on the cloud service side. As statutory, regulatory, and legal requirements differ by market, sector, and jurisdiction, the issue must be addressed in the future by policy makers while taking into account the need for rules and framework specific to each industry or service.

Policy for sharing of active and passive infrastructure

Sharing infrastructure creates a healthier atmosphere for competition in the telecom business. Additionally, it enhances economies of scale by preventing network duplication where it is unnecessary. A speedier roll-out of next-generation networks and services has been made feasible as a result of increased infrastructure sharing in the telecom industry. This is because both active and passive infrastructure may be shared. In addition to reducing total Capex and Opex costs, which are shared by TSPs, the sharing of towers and equipment results in a transfer of knowledge between telecom firms.

The Body of European Regulators for Electronic Communications (BEREC) paper on infrastructure sharing offers a preliminary examination of the infrastructure sharing agreements that are presently in existence in several specific European markets. The research covers a number of possibilities for sharing agreements, their advantages and disadvantages, as well as how sharing arrangements may change in the future as a result of 5G. Any policy decisions could be deemed to benefit from the analysis. It has been noted that commercially driven network-sharing agreements are often chosen and seem to have achieved market momentum for infrastructure sharing. According to the degrees of market development and the nations involved, the business motivations for infrastructure sharing and the sorts of agreements governing it are likely to vary [8].

A helpful feature for transitioning from 4G to 5G is dynamic spectrum sharing (DSA), which allows for the deployment of 5G in the same spectrum as 4G. By using 1800 MHz for both 4G and 5G, for instance, TSP might enable a gradual transition of resources from 4G to 5G over time. New radio installations or the installation of new software may do this. By using spectrum sharing between LTE and 5G, many networks may be quickly updated to enable 5G services in the current LTE frequency bands, for instance in the low to mid-bands. All of the current LTE bands are taken into consideration as potential candidates for 5G installations in the bands below 6GHz. This form of deployment is comparable to current LTE installations in terms of coverage. Future network slicing, hosting virtual network operators, and spectrum sharing between two organisations should all be made more simpler by the fact that the equipment, in particular base stations and cells, is built to accommodate the multiband scenario. The sharing of active infrastructure by TSPs in the 5G scenario will also be pushed by the densification of cells and Right of Way (RoW) difficulties.

Future use cases must be accommodated by the licencing architecture. The demand for a wired Local Area Network (LAN) will be replaced by the gigabit rate speed provided by 5G networks. For their own internal needs, such as plant operation or internal office communication, the businesses are building up LAN.

These businesses often do not route their traffic over the Internet or any other kind of Wide Area Network (WAN). Future use cases of platforms and services for LAN and industrial automation are anticipated with 5G. In the near future, "Network-as-a-service" is thought to be one of the services provided by telecom companies, allowing medium and large businesses to find a replacement for LAN and reduce defects and other issues with no or minimal investments in their IT networks. These use cases must be covered by the licencing framework's coverage requirements in order for the industry to benefit from 5G. To allow the orderly development and migration to Industry 4.0, the licencing and regulatory framework must make provision for Network as a Service (NaaS).

According to their needs, telecom operators may create, implement, and manage an integrated solution for the sector, with the majority of the computation being done at the edge. Low latency and low bandwidth use will result from less data entering the control plane and most user plane processing occurring at the edge.

This could call for TSP to set up a 5G network for a particular industrial unit and provide the services directly, or as a backup, to lease the network with the industrial organisation having authority over the edge devices. After receiving the necessary resources from the connection providers, the M2M Service Provider (supposed to be registered with DoT) may also provide the services to other Industries [9].

DISCUSSION

Numerous services based on network slicing may be offered, with telecom operators allocating network resources (slices) in accordance with the complexity of client requirements. The network slicing technology and standards will allow new income sources for telecom operators. Stringent Quality of Service (QoS) requirements must be satisfied for use cases using network slicing in order for the telecom operator to align the necessary resources to provide the services.

Regulations for certain industries. eMBB, uRLLC, and mMTC capabilities will be used to apply 5G use cases across industrial verticals. At this point, it is difficult to determine which use case will lead to an increase in 5G demand. The traditional offerings based on connection speed and usage volume may change as a result of the variety of 5G use cases across industry verticals that call for various characteristics, such as high data throughput requirements for augmented reality use cases and low latency and high reliability applications for robotics in the manufacturing and automotive sectors. The use cases will have distinct service applications depending on the particular industry vertical they want to serve, appropriate rates to fulfil the demands of the customers, and the ability to satisfy any applicable sectoral regulations.

Coordinated efforts would be needed to manage the 5G ecosystem with cross-sectoral engagement for the cross-sectoral use cases. DoT 36 has proactively established the M2M Apex Body, M2M Review Committee, and M2M Consultative Committee to address regulatory bottlenecks and concerns from the M2M industry for cross-sectoral M2M/IoT instances. To solve the issues and serve as advisors to the government's policy-making agencies, domain experts from every industry that has been identified as a potential M2M/IoT market must come together [10].

To bring M2M industry concerns and regulatory bottlenecks to the attention of Apex body, M2M Consultative Committee has been established, with representatives from Standardising bodies including Bureau of Indian Standards (BIS) and Telecom Standards Development Society of India (TSDSI) and sectoral industry representative bodies. Additionally, the M2M Review Committee has been established under DoT to support the implementation of the actionable points developed from the National Telecom M2M Roadmap. All 5G use cases may be included by broadening or expanding the purview of the current committees.

As was previously said in prior chapters, 5G will impact and transform our lives in ways we have never seen. Using 5G for healthcare (tele-surgery), driverless cars, automated manufacturing, and other applications will be feasible because to its core characteristics of extremely high speed and ultra-low latency. There will be direct and indirect advantages from 5G. It has the ability to act as a catalyst for greater national economic development. Rolling out 5G services in India will need a large investment, however, in order to make this a reality. While the investment for 5G would grow gradually as improvements on the current 4G/LTE technology, it is anticipated that industry may need an additional investment of USD 60-70 billion to successfully implement 5G networks. This is according to the Deloitte report "5G: The catalyst to Digital Revolution in India"37. According to an estimate by Ernst & Young, India will need to spend $60–$70 billion on 5G.

In the process of making industries more digital, 5G is anticipated to be crucial. 5G will improve telecom networks' performance and features, allowing new services and fostering new ecosystems. As operators go beyond being only connectivity and infrastructure suppliers to become service facilitators and service creators, new income sources will become available to them. According to research from Ericsson, India's potential earnings from digitalization would exceed USD 27 billion by 2026? The High-Level Forum research estimates that by 2035, 5G would have a cumulative economic effect of $1 trillion.

Network diversity, which in turn will rely on network infrastructure, including spectrum, Radio Access Network (RAN) infrastructure, and core network, is crucial for the success of 5G speed and coverage. The investment locations for the implementation of 5G are shown in Figure 8.1.

Operators with current 4G coverage areas will be able to use the 4G infrastructure to provide 5G services, reducing the amount of investment necessary. A Greenfield operator, on the other hand, would need to spend heavily in order to build the network from the bottom up. According to a Nokia estimate, the difference between 4G and 5G coverage utilising the 1800 MHz radio range would be roughly 60%. Through the concept of dual connectivity/UL-sharing, operators with existing 5G footprints will be able to use 4G UL coverage and thereby cover larger areas with the same number of sites. To make up for penetration losses, a Greenfield 5G operator will need to install around 66% more stations.

Ultra-low latency and significantly faster data speeds will be supported by 5G. Consequently, more spectrum will be needed for 5G than for 4G, with larger blocks being needed. In comparison to LTE systems in the low and mid bands, "deploying the 3.5 GHz and 26 GHz band on existing macro sites can provide a capacity improvement of approximately 10 times," according to an analysis by Ericson.

Sub-1 GHz, 1-6 GHz, and over 6 GHz are the three main frequency regions where spectrum is needed for the 5G network. The capacity and coverage needs of the area will determine which spectrum is best among these ranges. The GHz frequency band is most likely to be the first band to be deployed worldwide for 5G. The DoT has not yet held a spectrum auction in the 3300-3600 MHz range. Due to the expense of spectrum, the TSPs would probably need to make an initial extra expenditure when providing 5G services. Increasing Network Density: Small and Large Cell Deployments The deployment of tiny cells, particularly in crowded metropolitan areas, will be the main focus of investment in the race to bring out 5G services globally. Small Cell Forum predicts that the worldwide compound annual growth rate for the deployment of small cells will be 14% and reach at least

Operators just need to improve their current network to handle the additional traffic in urban and rural locations. The need for operators to use small cells to densify their network, on the other hand, is less important for those with greater spectrum allocations. Small cell equipment often has a lower marginal cost than setting up a macro base station location. However, because many small cells would need to be installed in order to add capacity in densely populated areas, the overall cost would be high.

Small cell adoption is predicted to expand significantly in India and soon surpass global standards40. Increased infrastructure sharing among telecom operators is likely as a result of the increasing investment requirements for network densification as well as the challenges in site identification and related permissions. In addition, demand and cost will play a role in TSPs' decision to roll out 5G, which was one of the factors that led them to advocate against imposing roll-out responsibilities for the 3.5 GHz frequency band. As a result, it is anticipated that the investment in network densification will be made in stages.

A key component of the implementation of 5G is the digital transformation of network infrastructure using Software-Defined Networking (SDN) and Network Functions Virtualization (NFV). All elements become more efficient thanks to NFV and SDN-based network architecture, which also lowers operational (OPEX) and capital (CAPEX) costs. With virtualization, resource over-provisioning can be avoided and existing resources can be used more effectively, lowering operational costs on a daily basis. Additionally, it lowers the amount that must be invested in real estate and environmental resources like cooling and power. The implementation of NFV would need the initial one-time expense. Virtualization reduces the total cost of ownership (TCO) for telecom operators after it has been introduced. These technologies will eventually improve the network's capacity to provide new income sources for

The amount of traffic on backhaul networks will rise as a result of network densification caused by an increase in the number of tiny cells. In the past, wireless backhaul was utilised by 2G and 3G networks to distribute data points across the network. The need for fibre backhauling has risen somewhat with the introduction of 4G.

The International Telecommunication Union (ITU) predicts that worldwide investments in fibre backhaul would exceed $144.2 billion between 2014 and 2019. Since fibre backhaul offers virtually unlimited bandwidth, its use is steadily growing to accommodate the rising data traffic. It is crucial to invest in fibre since fibre investments generally depreciate over 25 years, compared to 5-8 years for microwave.

A significant backhaul upgrade will be required for the 5G network design, which enables the deployment of both conventional and dispersed RAN networks. 30% of locations in India are linked through fibre, with the other 70% via microwave connections. While microwave frequencies available in India can only deliver backhaul capacity of 250 to 500 Mbps, fiber-based backhaul can provide unlimited capacity and low latency, which are prerequisites for 5G applications.

Therefore, the backhaul solutions with operators that are currently available will not suffice. Although fiberization is the best option, it is expensive to lay and maintain, so it might not be possible to lay fibre everywhere. E-band (71-76 GHz combined with 81-86 GHz) is a significant band that may be utilised to swiftly and affordably install backhaul in congested metropolitan areas to support the fast expansion of wireless services. The development of the 5G network will need a substantial investment in the radio network, core, and spectrum. However, in addition to improved mobile broadband solutions, the 5G services will also create a number of new revenue streams as they will cater to a variety of solutions for new verticals.

CONCLUSION

In conclusion, wireless backhauling is a critical component of modern wireless networks, providing the necessary connectivity between base stations and the core network. With the emergence of 5G technology, the demands on wireless backhauling infrastructure are increasing significantly. Meeting the requirements of 5G networks demands advanced wireless technologies such as millimeter-wave (mmWave) and massive multiple-input, multiple-output (MIMO) to increase capacity and performance, the use of virtualization and automation to simplify management and deployment, and the need for greater collaboration among industry stakeholders to ensure the interoperability and standardization of backhaul solutions. Wireless backhauling for 5G networks must support multiple radio access technologies, provide high capacity and low latency, and efficient management of network resources.

Regulatory and policy issues associated with wireless backhauling in 5G networks are critical to the success of the infrastructure and include access to suitable spectrum, streamlined permitting processes, access to suitable sites, and ensuring that backhaul infrastructure is deployed in a safe and efficient manner. Overall, the success of 5G networks depends on the ability of wireless backhaul infrastructure to meet the demands of the latest wireless technologies. Innovation and collaboration among industry stakeholders are essential to achieve this, and it is important to continue to develop and evolve wireless backhauling solutions to meet the evolving needs of 5G networks.

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CHAPTER 23

INDIA DRIVING GROWTH IN THE GLOBAL MOBILE INDUSTRY

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ABSTRACT:

India has become one of the fastest-growing markets for mobile technology in the world. With a population of over 1.3 billion people, India represents a significant opportunity for growth in the global mobile industry. This abstract provides an overview of the key drivers of growth in the Indian mobile market, including the rise of affordable smartphones, the expansion of mobile networks, and the increasing adoption of mobile payment solutions.The abstract begins by examining the rise of affordable smartphones in India, which has led to a significant increase in the number of people using mobile devices to access the internet. As a result, the demand for data services has increased, leading to the expansion of mobile networks and the deployment of new technologies such as 4G and 5G.The abstract also discusses the increasing adoption of mobile payment solutions in India, which has been driven by the government's push towards a cashless economy. Mobile payment solutions such as Paytm and Google Pay have become popular in India, enabling people to make digital payments and access financial services using their mobile devices.Finally, the abstract explores the role of the Indian government in driving growth in the mobile industry, including the Digital India initiative, which aims to increase internet connectivity and promote the adoption of digital technologies across the country.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

Making India 5G Ready, a report by the 5G High Level Forum published in August 2018 and overseen by the Department of Telecommunications. Members of the Ministry of Electronics and Information Technology and the Department of Science and Technology, as well as representatives from business (such as Reliance Jio, Bharti Airtel, and BSNL), academia, and other governmental departments, attended the meeting. Many of the GSMA's own positions are broadly supported by the report's insights and recommendations. The Telecom Regulatory Authority of India (TRAI) published a White Paper on enabling 5G in India in February 2019; this contained thorough insights into facilitating 5G implementation in India [1].

An ambitious National Digital Communications Policy released by the Department of Telecommunications in 2018 serves as the foundation for these publications. The Policy's three primary objectives, "Connect India," "Propel India," and "Secure India," are pertinent to the early implementation of 5G. It will need large investments in new infrastructure, a stable investment environment, a competitive market structure, and an appropriate framework for privacy and data protection to realise these objectives. The GSMA thanks the relevant Indian institutions for their thoroughness and comprehension and provides the following analysis and advice to make sure that the deployment of 5G in India is long-lasting and produces the desired outcomes within the allotted timeframe.

The GSMA's 'Intelligent Connectivity' vision demonstrates how the fusion of 5G, AI, smart platforms, and the Internet of Things can benefit consumers, businesses, and society as a whole. The 5G High Level Forum succinctly stated the agreed future vision of the Indian government and policymakers: By allowing a fast growth of the role of information technology across industrial, educational, healthcare, agricultural, financial, and social sectors, 5G technology has the potential to usher in a significant societal shift in India.

With the aim of building the digital infrastructure that supports the next generation of digital services and enables India to realise the full potential of the digital economy, India's new National Digital Communications Policy (NDCP) similarly presents a positive vision for the industry and nation. Mobile has already been crucial to achieving the objectives of the Digital India programme, and it will continue to be crucial to achieving the Connect India, Propel India, and Secure India goals of the NDCP. To fully exploit the benefits of 5G and attract the significant investments from mobile carriers that this would need, India must overcome a number of obstacles [2].

With about 750 million unique customers at the end of 2018, India is now firmly entrenched as a behemoth in the global mobile market. Up until 2025, India alone is expected to add over a quarter of all new mobile customers worldwide, and the industry is rapidly moving towards smartphones and 4G-capable devices. With approximately 1 billion smartphones deployed, India will firmly establish itself as the second-largest smartphone market in the world by 2025.The mobile industry is already working to increase financial access, enhance information flows, and boost economic production. As mobile technology works to empower everyone and establish itself as the primary access technology for a wide range of public services, efforts are being made to close the digital divide by providing inclusive internet access to every Indian.

Even if the Indian mobile market has recently achieved notable milestones, the industry's overall financial health is still poor. The Department of Telecommunications (DoT) and the Telecom Regulatory Authority of India (TRAI) acknowledge that the industry needs to invest in order to transition to 5G, but it is still unclear whether the sector is currently on a sustainable footing or even if it has the financial capacity to do so [3].

Given the distinctiveness of India's telecoms infrastructure and industry, as well as the potential of mobile technology to address some of the challenges the country still faces, it is crucial that mobile broadband remains at the centre of the country's policy vision as India moves towards 5G and aims to fulfil its digital goals and ambitions. Three essential components are needed for the 5G era to succeed: a large investment in digital infrastructure, which should mostly come from private sources; a trust-inspiring digital environment; and a modernised legislative and regulatory framework that makes this possible.The NDCP calls for initiatives to lessen regulatory burden and impediments that impede investment, as well as for efforts to spur innovation and boost consumer interest in the area of digital communications and infrastructure, which is a good development in terms of the overall regulatory approach. To build a favourable regulatory framework that enables the mobile sector and larger digital ecosystem to fulfil its full potential, the Indian government and policymakers must, however, shift from plans to action.

The NDCP should be put into practise in a way that fosters a long-term investment climate and enables operators to receive a decent return on their investments. Key issues that directly affect the industry's viability should be addressed by policymakers, such as more reasonable pricing of scarce spectrum resources, a workable network deployment policy for digital infrastructure (covering issues like rights of way and tower sharing), and the simplification of definitions and procedures under licence terms [4].To overcome the rising issues of network densification, policymakers must encourage simplified network deployment laws to hasten the adoption of 5G. We advocate for collaboration between central and local authorities on this matter, particularly in the context of the Indian market.

The importance of spectrum to 5G

Harmonised 5G bands should make sufficient, reasonably priced, exclusively licenced, contiguous spectrum across the three important frequency bands accessible. Spectrum in India is often distributed via an auction. The competitive nature of the downstream market is often considered by authorities when allocating spectrum, creating auctions, and packing lots. Spectrum caps are a tool that may be used to stop spectrum concentration from harming the downstream market. Spectrum limits may be beneficial, but their implementation must be done carefully to prevent unforeseen repercussions and, ultimately, negative consumer results. Adopting spectrum policy measures that encourage investment in 5G is necessary. The Indian government and regulators can secure the long-term survival of the business and its capacity to finance the enormous investment necessary for 5G network installations by taking a long-term view, establishing moderate reserve pricing, and giving spectrum allocation first priority.

Modernising Legacy Regulatory Structures

Regulators should promote flexibility to support emerging 5G services (e.g. through a pragmatic interpretation of the Open Internet principle) and should modernise regulatory frameworks. India has been at the forefront of the adoption of a coordinated approach under the banner of Digital India. This needs to be maintained and developed further as the cross-sectoral use cases require coordinated efforts in managing the 5G ecosystem across the relevant players. On the ‘level playing field’ issue, the GSMA has contributed to TRAI’s consultation on the best way to ensure that digital services are subject to the same rules as equivalent telecoms services. The need for a supportive investment and taxation policy. Reducing taxation and regulatory fees on revenues could contribute to further evolution of the tax framework. The GSMA suggests that as the industry is a key enabler of socioeconomic growth, there is a strong case to lower the GST rate from 18% to 5% as prescribed for other essential services [5].

The complexity of the mobile taxation structure in terms of, for example, the interpretation of the basis on which licence fee and spectrum usage charges are levied results in disputes between the sector and the government agencies. To foster an environment that encourages investment in mobile service provision, the mobile taxation framework should be simplified. Since the launch of mobile services in India in 1995, mobile networks have been an engine for social and economic transformation. As highlighted by the TRAI3, a number of policy developments have facilitated the liberalisation of the telecoms sector and helped boost the competitiveness of the Indian mobile market. The New Industrial Policy of 1991 initiated the process of liberalisation in India, which was then followed by the pro-competition stance of the National Telecom Policies of 1994 and 1999.

These moves led to the opening up of basic telecoms services to the private sector, now widely recognised as an inflection point for the subsequent tremendous growth of the telecoms sector in the country. The National Telecom Policy 2012 saw the delinking of spectrum awards from telecoms licences, with spectrum allocated through market-based processes. More recently, a key development has been the accelerating migration to 4G services and smartphones. This has proved to be a catalyst for the rapid growth of mobile data as well as new apps and services, helping to lay the foundations for the development of a modern digital economy in India.

India is now a giant in the global mobile industry, with close to 750 million unique subscribers at the end of 2018 a figure that will grow significantly over the coming years to reach almost 920 million by 2025. India alone will generate almost a quarter of the world's new mobile subscribers over this period. In absolute terms, India will remain the second largest mobile market in the world, behind only China. Seven countries will account for half of new subscribers to 2025 [6]. India is seeing rapid migration to mobile broadband, particularly 4G-capable devices. At the end of 2017, almost two-thirds of the connections base in India were running over 2G networks, yet 4G will account for more than half of all connections before the end of 2019. The entry in 2016 of a Greenfield competitor with an LTE-only network and focus on stimulating data traffic growth has been a major catalyst.

4G represented just 9% of total connections in India at the end of 2016. At that time, LTE was a relatively mature technology with networks launched in around166 countries around the world. However, a number of developing markets had seen only limited adoption and coverage was a key issue, suggesting that India was far from unique in terms of its adoption rate. All the main Indian operators are now focused on growing their 4G subscriber bases and building out coverage and capacity. The ongoing shift to 4G reflects the rapid adoption of smartphones in India. By the end of 2018, smartphones accounted for just over half the connections base, a figure that will increase to more than three quarters by the end of 2025.

Adoption has been fuelled by the global trend towards lower cost devices and the emergence of a new wave of device vendors. A number of local manufacturers have grown rapidly in India, including Micromax, Intex, Lava and Karbonn. In addition, Chinese and Korean brands such as Samsung, Vivo, Oppo and Xiaomi have captured the imagination of consumers. Samsung and Xiaomi, as well as contract manufacturers such as Foxconn, have also opened plants in the country. Jio launched its branded Jio Phone in 2017, an LTE-capable feature phone that was initially manufactured in China, though production has recently moved to India [7].The size of the Indian market and the rapid adoption of smartphones means that by 2025 it will have cemented its place as the second largest smartphone market, with an installed base of almost 1 billion devices. According to the GSMA Intelligence Consumer Survey, smartphone users in India are already highly engaged in the digital world and use their smartphones frequently to access and consume a range of digital services and content. In a number of areas, particularly in terms of consuming paid-for digital content (both music and video), Indian smartphone users score well above the global average. While the number of users is significantly lower, there is a clear appetite in India to access government services through apps and online. In the area of digital commerce, India is broadly in line with global averages but lags significantly behind leading markets such as China.

These scores reflect surging data volumes a trend that will continue both with the ongoing shift to 4G networks and in time with the uptake of new 5G devices and services. Higher speed networks and the growing base of smartphones have fuelled rapid growth in data volumes in the Indian market; the increased viewing of video content is an important factor in India, as in many other markets. The TRAI has highlighted that mobile data usage per month in India increased from 39 petabytes in June 2016 to 4,178 petabytes in September 2018.

Ericsson estimates that in 2018 India generated more traffic than the whole of Western Europe, with total data volumes set to increase four-fold by 2024.Operators are using a combination of their own apps and premium content partnerships to defend market share and to help monetise the strong growth in data traffic. Content partnerships include those with international players such as Amazon and Netflix, and domestic players including Voot, Eros Now, ALT Balaji and ZEE5.

Financial Outlook: Still Subdued

The sector's financial performance has remained muted despite recent years of significant subscriber growth and a quick transition to a more technologically sophisticated market driven by faster networks and smartphones. Since the end of 2016, revenues have been falling on a quarterly basis year over year. Over the period, India's total mobile revenues have decreased by more than 20%. Despite a large increase in data volume, ARPU levels have dramatically declined in recent years and are now at levels that are probably unsustainable. However, recent quarters have indicated a stabilisation in market trends, with a marked easing in the rate of revenue decline:

a. Market shares are now stabilising, with Reliance Jio gaining scale following a period of rapid market share gains: the company is close to achieving a 25% share of the total connections base at the end of 2018, which translates to close to 30% share of the market in revenue terms.
b. Recent consolidation moves (which have transformed the once highly fragmented industry and seen the emergence of three private sector players and one public sector player) will potentially present a more sustainable market structure, allowing the remaining operators to realise scale benefits.

c. The two incumbent operators (Vodafone Idea and Bharti Airtel) are investing heavily in their 4G networks to close the coverage gap with Reliance Jio, as well as improve capacity in areas of high demand. Operators are also investing to deploy more fibre, densify their networks and roll out new technologies such as massive MIMO.

Reliance Jio may already have a dominant position in the Indian mobile industry, according to certain calculations of market shares using a variety of different criteria. Based on AGR5, the adjusted gross revenue.

DISCUSSION

Reliance Jio has a market share of up to 37% at the end of 2018, whereas Jio's headline gross revenues and AGR plus national long distance both placed the company around the 30% mark. The degree to which Jio maintains its emphasis on gaining market share or changes more towards a focus on investment returns will be a critical factor in the market forecast. Gross receipts modified to reflect certain standard deductions. The AGR value serves as the foundation for operators' payments to the government for licence fees and spectrum use. Other revenues, including as fixed line and other non-core revenues, are included in the gross revenues and AGR provided by TRAI.

Because of intense competition and initiatives by operators to spread their services to lower income demographic groups, ARPU is already quite low in India. According to the GSMA's Mobile Connectivity Index, which analyses nations' advancements in key factors that allow mobile internet access and usage, India had the biggest percentage-point rise of any nation between 2014 and 2017 in terms of the affordability of mobile internet. India ranked first among the 230 nations examined in the fourth quarter of 2018 in a new study of global mobile data pricing. During this time, the average cost per gigabyte was INR18.5 ($0.26), versus an international average of $8.53.

Reduced rates and higher ARPU levels contribute to affordability and are crucial components in closing the digital divide. Low levels, however, can have an impact on the industry's financial stability and the capacity of operators to retain viable business models while making investments in networks and new services. India's ARPU per unique subscriber for 2018 was much lower than those of other Asia Pacific markets. India really ranks second lowest globally among emerging markets, just behind Ethiopia.

In recent months, there have been indications that the strains of competition are lessening. In India, minimum ARPU bundle plans were introduced by Bharti and Vodafone Idea. These deals are expected to decrease the use of multiple SIM cards while also stabilising ARPU levels. The growing adoption of 4G and smartphones, as well as the bundling of premium content services that will push customers towards higher ARPU plans, will continue this trend.

Longer-term possibilities exist for operators to increase the number of subscribers they have, transition consumers away from feature phones and other less advanced devices, and encourage them to adopt mobile data services. Additionally, there is still a sizable population in the nation who is still unconnected. Although many of these will come from rural areas and lower income groups, this is not always the case. The degree to which operators are able to take advantage of these chances to raise ARPU levels will depend on a variety of variables, most notably the intensity of market competition.

The Indian mobile market is expected to resume revenue growth in the second half of 2019 and maintain a moderate rate of growth for the balance of the projection period, according to GSMA Intelligence predictions. Market restoration will be a sluggish and difficult process, however, since market revenues in 2025 will still be lower than they were in 2016. Both Vodafone Idea and Bharti Airtel have made significant investments in recent years, with capex amounting to around $18 billion over a five-year period as the two businesses increased the capacity and coverage of their 4G networks [8].

In the Asia Pacific area, India now has one of the highest capex-to-sales ratios as a consequence of a combination of significant investments in boosting 4G network capacity and coverage and revenue declines brought on by competitive pressures. The capex/sales ratio for India is expected to level out around 20% of revenues in the following years after rising to a high of over 35% in 2018. A number of factors, including the overall financial health of the industry and the pace of 5G deployment, will affect how much money operators will spend over the next years. Thanks to a flurry of consolidation transactions over the past two years, the Indian industry, which was once among the most fragmented in the world, has now become a four-player market, albeit one with three bigger operators and one smaller operator. In several markets throughout the world, similar trends towards consolidation have been linked to periods of market healing and a more optimistic view for overall market performance.

The Herfindahl-Hirschman Index (HHI) is a metric used in competitive economics to assess market concentration. A 10,000-index score denotes a monopoly. A market that is not concentrated is indicated by a figure under 1,500. The numbers in between show how consolidated the market is and how intensely competitive it is. Due to consolidation efforts over the last several years, India's HHI score increased from 1,483 in 2014 to 2,717 in 2018. Previous studies revealed that in India historically, competition was considerably greater at the individual circle level, and HHI values were below 1,000.8, India, where the HHI index in 2018 was 3,854, is still more competitive than the average for the larger Asia Pacific area despite consolidation.

In recent years, both mature and emerging markets for mobile have seen an increase in mobile mergers. India is now, without a doubt, closer to other emerging economies throughout the globe, where there are normally three or four national providers. According to investment and customer benefit considerations, there is no magic number of operators that would provide the best market structure. The effect of regulation is one such aspect that affects an operator's capacity to invest in addition to the number of participants in a market.

According to GSMA analysis of the situation in Central America, operator spending is not always greater in markets with more operators.9 It reaffirmed the results of competitive economics, specifically the existence of an inverted 'U': operators' investment is maximised when operators have an EBITDA margin between 32 and 38%. Similar studies conducted in

Europe indicated that the degree of competitive intensity at which operator capital expenditures are maximised is at an EBITDA margin of 38%.10 These evaluations highlight the necessity for operators to obtain sustainable profits if they are to maximise network investment, even if some care should be applied when extrapolating outcomes from other areas.

Market structure improved but leverage remains a concern

Improvements in the industry's financial performance in India have not yet been seen as a result of consolidation. The sector is heavily in debt due to high levels of network investment, large spectrum fees, and the expense of consolidation agreements. Indian mobile providers have higher debt levels than their international counterparts, with the recently combined Vodafone Idea having net debt/EBITDA of around 29 at the end of 2018.Operators are taking action to alleviate these high levels of debt. For instance:

1. A large capital infusion of INR250 billion ($3.5 billion) is planned for Vodafone Idea. The two major owners of the corporation have declared their desire to back this with up to INR182.5 billion. Additionally, the company intends to recoup its estimated INR0.5 billion investment by selling its 11.5% stake in the tower company Indus Towers.
2. Debt reduction is a priority for Bharti Airtel at the parent company level. In addition to the planned IPO of the African business and the transfer of Airtel's Indian fibre assets into a separate company, management recently authorised a rights issue of INR250 billion, which might pave the way for a partial sell down.

A significant amount of the about $90 billion in total capital utilised by private companies in 201811, or 27% of the total, pertains to delayed spectrum obligations owed to the government. Of the declared net debt of INR1, 147.6 billion for Vodafone Idea as of the end of 2018, INR914.8 billion was attributable to delayed spectrum payments to the government. By extending the payback periods for these fees from 10 to 16 years, the government has already taken steps to ease the strain on operators' cash flow. However, given the size of these debts, they will continue to have a major negative impact on the sector's free cash flow in the years to come. As mentioned in the report's concluding section, several further measures could still be necessary to establish a more sustainable investment climate.

A variety of characteristics, including the fact that India was for a number of years a highly fragmented market with a big number of operators, have resulted in substantial competitive pressures on the Indian market in recent years. Profitability was put under strain as a result of the introduction of a green field operator with an aggressive pricing approach, which added to the difficulties. Over the past two years, margins have generally decreased by about 640 basis points, and they now lag far behind the regional average.

It is interesting to note that India did not also enjoy the high margins that were common in many developing economies during their first boom phases, when margins may regularly reach around 40%.The industry-level returns in India have fallen significantly as a result of high investment levels (in both physical network assets and intangibles like spectrum licences) and declining EBITDA margins. As a consequence, returns on capital are often negative and well below the regional telecommunications industry average.

CONCLUSION

In conclusion, India has become one of the fastest-growing markets for mobile technology in the world, driven by the rise of affordable smartphones, the expansion of mobile networks, and the increasing adoption of mobile payment solutions. The Indian government's push towards a cashless economy has also played a significant role in driving the growth of mobile payments and digital financial services in the country. The growth of the Indian mobile market presents significant opportunities for industry stakeholders, including mobile network operators, smartphone manufacturers, and mobile payment solution providers. However, continued investment in infrastructure, innovation, and collaboration will be essential to realizing the full potential of the Indian mobile market.

The Digital India initiative, which aims to increase internet connectivity and promote the adoption of digital technologies across the country, is a crucial element in driving the growth of the Indian mobile industry. The success of the initiative will depend on the continued support of the government and industry stakeholders, as well as a regulatory environment that fosters growth and innovation. Overall, the growth of the Indian mobile industry is a positive development for the global mobile industry, providing significant opportunities for growth and innovation in the years ahead. As the Indian mobile market continues to evolve, it will be important for industry stakeholders to remain adaptable and innovative, building on the momentum of the current growth trajectory to drive further innovation and growth.

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CHAPTER 24

THE GSMA GLOBAL 5G POLICY FRAMEWORK

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ABSTRACT:

Governments and regulators must take into account market mechanisms that will promote an environment that is supportive of investment and innovation for the mobile ecosystem if they want to hasten the adoption of 5G for commercial usage. The current legislative and regulatory framework places major barriers in the way of investment, spectrum availability, network management flexibility, and infrastructure development for mobile operators in many areas. It is crucial to remember that the industry's stance on a wide variety of policy and regulatory concerns in a 5G future is the same as it was for previous generations of mobile network technology. The opinions expressed in the GSMA Mobile Policy Handbook17, which include topics like spectrum, infrastructure sharing, and taxes, to mention just a few, are still valid and pertinent today.

KEYWORDS:

Communication, Fifth Generation (5G), Mobile, Networks, Technology.

INTRODUCTION

As ardent supporters of mobile network evolution and technology-led economic development, policymakers should take the lead in advancing 5G by establishing the prerequisites for an effective and timely mobile network rollout and lowering the regulatory burden on operators. To make 5G a reality, they should concentrate on four crucial areas: network deployment, network flexibility, spectrum access, and regulatory costs. The cost of spectrum is still expensive. Due to their significant debt loads and poor levels of profitability, India's mobile operators' overall financial situation continues to be precarious. In addition to market competition, a number of additional problems, including as the unequal cost of spectrum, expensive rights-of-way fees, regulatory levies/taxes, and spectrum use fees, all play a role in this predicament[1].

High spectrum pricing are a serious problem in emerging nations, according to a GSMA paper titled Spectrum Pricing in emerging Markets. Once income levels are taken into account, final spectrum prices in developing markets were typically more than three times higher between 2010 and 2017 than they were in developed markets. There may be major negative impacts for the mobile industry notwithstanding the large earnings from spectrum assignments increasing public cash to aid in easing short-term public sector budgetary difficulties. LTE network rollouts are taking longer, and more costly, lower-quality mobile broadband services are also included[2].

The paper emphasises that a variety of factors contributed to both unusually high spectrum pricing and unsold spectrum in India in the time after the Indian 3G auction in 2010. Between 2010 and 2016, a total of six auctions were held in the nation. Seven bands and a substantially larger amount of spectrum than prior awards were offered in the auction held in October 2016. Only 41% of the spectrum that was available was sold, though. Across 850, 1800, 2100, 2300, and 2600 MHz, the average price was $0.33/MHz/pop, which was nearly 33% more expensive than the median price in developing countries between 2015 and 2017. For comparison, throughout the years 2010 to 2017, India's ARPU values were, on average, roughly 35% lower than those of the developing nations in Asia Pacific as a whole[3], [4]. This shows that government and regulatory policy choices, rather than local mobile market realities, were responsible for the high spectrum prices achieved in the auction. By MHz/pop/year, spectrum prices have been aggregated by nation, band, generation, and assignment and have been adjusted for inflation, GDP per capita, and licence length. This graphic includes all spectrum bands for which relevant data were available. Outliers were not included in the study. Three-period moving averages are the foundation of the study. The increase between 2014 and 2016 is mostly attributable to many pricey missions in countries including Afghanistan, Iraq, Pakistan, Niger, and India. Prices returned to the range between 2010 and 2013 in 2017.

The DoT seems to be contemplating spectrum auctions for the second half of 2019, according to the TRAI's recommendations on spectrum pricing. These might include bands like 700 MHz and 3.3-3.6 GHz that are relevant to 5G. Pricing will be a crucial factor in determining the outcome of these auctions, particularly in light of the industry's high debt levels, low ARPU levels, and low profitability. The huge delayed spectrum payments that many operators now face will also be a key element.Some of the operators have expressed concern about the planned auction's timing, pointing out that large deferred spectrum payments already made will have a negative impact on cash flows. They have also questioned the longer-term necessity of additional spectrum in India at a time when the 5G ecosystem is still in its infancy.

The sector's detrimental effects of general taxes and regulatory fees. In many places throughout the globe, mobile users and operators are subject to significant taxes and regulatory levies, which are increasingly driven by sector-specific taxes and levies. According to a recent analysis by the GSMA, consumer and operator taxes made about 22% on average of industry revenues in 2017.This limits the generally accepted social and economic advantages connected with mobile technology and presents a serious danger to the spread of mobile services among people [5].

India is one of the top 20 countries with the greatest incidence of sector-specific taxes and levies, with a sector-specific tax burden of around 11% of revenues. According to the general situation in the nation, the health of the mobile industry is significantly impacted by a mix of taxes and spectrum fees. Digital inclusion and mobile sector taxation in India, a GSMA report released in December 2015, highlighted the important role mobile networks and the ecosystem played in India's socioeconomic success but also the fact that investment in infrastructure is restricted by an excessive tax burden on the sector. Taxes and fees on revenue tend to influence production and consumption behaviour by directly altering pricing, which may restrict the usage of digital services by posing a financial barrier to the poor's access to the internet. Revenue-based taxes and levies make it more difficult for cell carriers to fund investments in digital infrastructure, which may eventually result in lower tax collections for the government. The research suggested lowering the spectrum charge from 3-8% to 1% and the licencing fee, which was then 8% to 6%. According to the assessment, India might increase investments and total tax income for the country's economy as a whole by following these measures.

Indian market: 5G policy ideas from a local standpoint

There has never been a more pressing need for pro-investment policies and modernised regulatory frameworks than now, as the mobile sector turns to 5G to fulfil the expectations of a digitised future. Taking network performance to a new level and offering a foundation for the emergence of new digital services and business models, 5G promises limitless connection and intelligent automation.

Three essential components are needed to fully realise the benefits of the 5G era for consumers and business: a sizable investment in digital infrastructure, which should primarily come from private sources; a digital environment that fosters trust; and a modernised policy and regulatory framework that makes this possible. The National Digital Communications Policy (NDCP), launched in India in 2018, includes the elements needed to promote 5G adoption:

1. The NDCP recognises the significance of high-quality, long-lasting network investments. The policy specifically states that it "aims to attract long-term, high quality, and sustainable investments" given the sector's capital-intensive nature.
2. It is necessary to evaluate legacy rules and eliminate or modify them in light of the new economy in order to reduce regulatory impediments to investments, sustainability, and innovation. It will be crucial to concentrate on projects related to fibre deployment and rights-of-way clearances, for both overground and subterranean infrastructure, since they will be requirements for the implementation of 5G networks, as acknowledged in the NDCP.
3. It is encouraging that the NDCP emphasises the goals of obtaining "universal coverage rather than revenue maximisation," with a clear reference to the "optimal pricing of spectrum," given the industry's continued financial difficulties.
4. A review of "levies and fees, including licence fees, spectrum usage charges, and the definition of adjusted gross revenue, as well as rationalisation of the universal service levy" is also requested in the policy paper.

The NDCP identified essential policy levers to usher in the developing digital future, which the GSMA emphasised in its response to the Consultation. The High-Level Forum Paper offered further clarification on the possible barriers to 5G adoption in India. The TRAI White Paper lists some of the most significant concerns that have already been resolved and gives a summary of the steps that must be taken for 5G to be implemented in India.

The 5G High Level Forum acknowledged that for the densification of infrastructure, the proper policies and procedures for rights of permits and clearances are essential. The DoT should establish tight criteria for the State and Local Governments for giving clearances, according to the recommendation. Additionally, they ought to be distributed uniformly across the country. Enabling online applications, cost reductions, single window clearing, and deadline-driven permit determinations are some significant advancements in permitting. Now, it's crucial to start achieving the policy objectives set forth by the NDCP and other pertinent Indian policy-makers.

DISCUSSION

In order to ease the rollout of 5G services in India and realise the promise of that country's digital economy, the GSMA provides a number of suggestions. Enabling the expansion and densification of networks.

The GSMA concurs with the suggestions made by the 5G High Level Forum regarding permissions for rights-of-way outlined in the preceding section and takes notice of the jurisdictional challenges resulting from India's federal and state government structure. The GSMA released a study on allowing rural coverage, however even though the report's main emphasis was on rural coverage, several of the suggestions still hold true today, like the need for having the proper permission and right-of-way laws. In particular, national and local authorities should work together. The function of central government is crucial in [6]:

a. Establishing uniform notification, health and safety, and visual integration processes and standards for permits
b. Establishing a single source of data for issuing licences
c. Offering a free appeals mechanism that prevents arbitrary restrictions of mobile network antennas
d. Requiring prior notice of civil works for the deployment of infrastructure (such as roads, sewage, electricity, and telecommunications);
e. Supporting programmes to map infrastructure.

For the purpose of issuing permits, local governments must adopt effective processes that are in line with the national framework and adhere to national health and safety standards.

The importance of spectrum to 5G

- Spectrum in India is often distributed via an auction. The competitive nature of the downstream market is often considered by authorities when allocating spectrum, creating auctions, and packing lots. Spectrum caps are a tool that may be used to stop spectrum concentration from harming the downstream market. Spectrum limits may be useful, but their implementation must be done carefully to prevent unforeseen repercussions and, ultimately, negative consumer results. The 5G High Level Forum is aware of the need to guarantee that spectrum is auctioned at a fair price. The reserve prices for spectrum in future auctions should be established at acceptable levels so that price determination is via fair market price discovery. This will be a particular area of concern moving ahead. The Indian government and regulators can ensure the long-term sustainability of the industry, its competitiveness, and its ability to fund the sizable investment required for 5G network deployments by adopting a long-term perspective, setting modest reserve prices, and prioritising spectrum allocation.

- The GSMA thinks that in order to enable coverage and capacity for 5G, there has to be a large quantity of additional harmonised mobile spectrum in the three important frequency bands. In order to support 5G, regulators should strive to provide each operator with 80–100 MHz of continuous spectrum in the prime mid-bands (e.g., 3.5 GHz) and around 1 GHz in the millimetre wave bands (above 24 GHz). In order to provide comprehensive coverage and enable all use cases, 5G also needs spectrum in the three important frequency bands of sub-1 GHz, 1-6 GHz, and over 6 GHz.
- The main goal of spectrum policy should be to encourage significant investment in 5G networks. Support for long-term, exclusive, technology-neutral spectrum licences with a transparent renewal procedure should be part of this. A spectrum roadmap should be published so that operators can plan and value spectrum appropriately [7].
- The TRAI has proposed that spectrum in the 57-71 GHz band, as well as 71-76 GHz and 81-86 GHz, be released as unlicensed spectrum for use in backhaul.22 When fibre links are not available, these bands could be used as last-mile solutions in urban areas with higher population densities. The WRC-19 Agenda item 1.13 identifies the 66-71, 71-81, and 81-86 GHz bands as potential candidates for 5G/IMT. The TRAI's suggestion to keep the bands 71-76 and 81-86 GHz for backhaul is one that the GSMA supports. According to the GSMA, depending on the circumstances in a particular geographic location, the 66-71 GHz band might be utilised for both licenced and unlicensed technologies for last-mile solutions and/or for backhaul. You may get complete information on the GSMA's 5G spectrum positions on its website.

Legacy regulatory structures and the need for a new, whole of government paradigm

a. The High-Level Forum report and the White Paper both identify problems with old regulatory frameworks. The differing treatment of mobile carriers and other participants (which is often subject to separate regulation and the authority of a sector-specific regulator) is significant to the GSMA.
b. The entire ecosystem, decision-makers, and conventional industries have all been compelled by the digital age to adopt new ways of thinking and work more collaboratively. India has been in the fore in implementing a coordinated strategy that includes governance. Structure that falls under the Digital India umbrella and reports directly to the Prime Minister's office. Since the cross-sectoral use cases demand coordinated efforts in managing the 5G ecosystem with cross-sectoral involvement, this approach needs to be maintained and developed further.
c. There are already several committees with members from diverse businesses. The GSMA has discussed the best course of action with Indian policymakers in order to determine the best overall government strategy to 5G.
d. The GSMA participated in the TRAI consultation on how to best guarantee that digital services are governed by the same regulations as comparable telecom

services. The competitive restriction OTTs presently placing on mobile carriers by operating under various regulations is something that policy-makers may address by creating a framework of policies centred around the same rules for the same service can create a competitive environment that is fair, sustainable, and supports consumer interests and economic growth.

The need for a supportive investment and taxation policy

All pertinent papers released in the last few months on becoming India 5G-ready acknowledge the necessity for investment in 5G rollout. A crucial factor is that India's tax system should be compatible with advanced countries. Taxes and other levies on income are uncommon in these economies. Reducing taxes and regulatory fees on revenue may help the tax system continue to develop.The GSMA supports a taxation structure that treats all actors in the same situation equally. In contrast, mobile services countrywide were subject to an 18% tax when India implemented the Goods and Service Tax (GST) in 2017. The GSMA contends that as the sector plays a significant role in enabling socioeconomic progress, there is a compelling rationale for reducing the GST rate to 5%, as is the case for other important services. Conflicts between the industry and the government agencies occur from the complexity of the mobile taxation system, for example, on the interpretation of the grounds on which licencing fees and spectrum use charges are paid. The mobile taxation structure has to be made simpler in order to promote an environment that stimulates investment in mobile service offering [8].

Compared to universal service charges in other nations, India's present level of mobile coverage does not justify the 5% USOF fee. The GSMA suggests that the current charge be scaled down or eliminated entirely. This may be accomplished by lowering the USOF charges beginning in 2019.The same standards for comparable digital services should be established by policymakers, giving carriers and internet/OTT businesses a level playing field. As OTT services gain in popularity, a variety of rules intended to alleviate perceived network bottlenecks become less and less justifiable. According to the principle of the same rules for the same service, all equivalent services should be subject to the same regulatory and fiscal obligations where regulation is deemed to be necessary, regardless of the underlying technology, geographic origin, or whether they are delivered by a mobile operator or OTT service provider. Clear policy requirements on consumer protection, innovation, investment, and competition must guide this framework.

The Fourth Industrial Revolution offers an opportunity for diverse sectors to enhance their competitiveness and contribution to regional economies, while supporting the United Nations Sustainable Development Goals. This industrial revolution is powered by both established and emerging technologies, including the internet of things, artificial intelligence, advanced data analytics, robotic process automation, robotics, cloud computing, virtual and augmented reality, 3D printing and drones. One key enabler that allows these technologies to realize their full potential is connectivity.

Industrial revolutions have been characterized by the transformation of physical infrastructure networks. Electricity powered the Second and Third Industrial Revolutions, as networks achieved economies of scale by connecting large plants over high-voltage transmission grids to local distribution networks reaching many users. The Fourth Industrial Revolution's full potential will be fully realized through the wide-scale deployment of 5G communication networks [9].

With its five core functional driversultrafast broadband, ultra-reliable low latency communication, large machine-type communications, high reliability/availability, and efficient energy use5G will be crucial for enabling previously unheard-of levels of connection and upgrading 4G networks. Numerous industries, including manufacturing, transportation, public services, and health, will undergo significant change as a result of these distinguishing characteristics taken together.

Key stakeholders need to overcome significant issues in order to enable the broad deployment of 5G networks. Government regulators and city managers must determine whether and when to invest in 5G infrastructure, while mobile and telecommunications providers must assess appropriate business models. Finally, citizens must find ways to take advantage of all the advantages that this technology can offer while preserving the rights of the community. Only with the cooperation of all parties involved, including the public, business, and government, can the switch to 5G networks be successful. The insights and suggestions in this White Paper are intended to pave the way for a faster, more sustainable, and more equitable switch to 5G networks worldwide, generating substantial economic and social benefit.

By widely implementing 5G communication networks together with other connection options, the benefits of the Fourth Industrial Revolution and its associated new technologies will be completely realised.A wide variety of options will become available as a result of 5G's major functional drivers, including improvements in service delivery, decision-making, and end-user experience.Enabling use cases driven by 5G has the potential to provide significant commercial and societal benefit. By 2035, it is predicted by an IHS Markit study1 that $13.2 trillion in global economic value would be achievable, creating 22.3 million employment in the 5G global value chain alone.

The components, players, and interdependencies of the 5G ecosystem were identified, as well as the steps required to hasten 5G adoption and fully realise its promise, in order to better comprehend it. Each component (spectrum, infrastructure, devices, services, impact, and security) was given a set of difficulties to overcome. Strong stakeholder engagement is required to guarantee that all measures to hasten 5G rollout are coordinated and the interdependencies are acknowledged. The measurement of the potential social value that may be generated is one important area for cooperation that needs input from all stakeholders. This will improve the commercial case for 5G. The functional drivers of 5G have made many of the present use cases technically possible, and these use cases have been activated via multistakeholder cooperation and collaboration.

The preparation of this White Paper included the research of 40 use cases, which helped to pinpoint significant technological advancements, societal effect areas, as well as the primary functional drivers of 5G and the necessary maturity levels of these characteristics. The following major conclusions were drawn as a consequence of this study, together with information from stakeholder interviews and multiple cross-industry workshops:

The widespread installation of 5G networks has the potential to provide significant economic and social benefits. Technological applications will support industry advancements, boosting their bottom line, and improve municipal and citizen experiences. This is made possible by a number of essential functional elements. Clear approaches and new stakeholder cooperation models are required to hasten the introduction of 5G [10].

By 2035, the worldwide 5G value chain alone is projected to provide 22.3 million employment, $3.6 trillion in economic production, and fast, intelligent internet connection.2 A total of $13.2 trillion will be generated globally across all sectors as a result, with manufacturing accounting for almost a third of overall production. The remaining third will be split between information and communications, wholesale and retail, public services, and construction.3 But for that to occur, trillions of dollars must first be invested to introduce global. Companies have the chance to be first to market with 5G, but more collaboration is required to hasten rollout.We in the IT and telecom sectors were more and more enthusiastic about the promise of 5G during the previous decade as it was first envisaged, then created, and finally released. We anticipated that 5G would make digitization more affordable, enabling small firms, government agencies, and even private families to benefit from smart goods and services. However, we were unsure of the precise nature of those goods and services. We are aware at this time. This study, to which we made significant contributions, demonstrates how 5G's speed, dependability, and scalability have already made significant contributions to society and the economy. This is the future, and Nokia is excited to be a part of it.

Even while a number of nations have started their 5G rollout roadmaps, some are lagging behind because of a variety of issues that call for an unprecedented degree of cooperation between the private and governmental sectors as well as other socially significant groups. These have an impact on various ecosystem components, such as developing new business models, encouraging innovation, defining investment models for digital infrastructure, preparing for cybersecurity scenarios, and, more generally, guaranteeing sustainability and having a positive social impact.

A 5G-Next Generation Networks Programme has been launched by the World Economic Forum to assist businesses across sectors in transforming while establishing an equitable and sustainable transition to the next generation of networks in order to better grasp these systemic difficulties. This initiative is a component of the Digital Economy and New Value Creation Platform, whose goal is to create new, digitally-driven economic and business models that will provide lasting value for a society that values inclusion.

This White Paper's goal is to, using a bottom-up, use-case-driven strategy and research, illuminate approaches to realise the substantial anticipated economic production potential. The examination of 40 representative use cases in a range of sectors identifies connections between economic and social effects and considers how the functional drivers of 5G might improve the outcomes of these use cases as 5G networks advance. This document also proposes a set of stakeholder activities to expedite the deployment of 5G in order to realise the full promise of the technology. It also summarises critical difficulties based on observations from various stakeholders. The fifth generation of cellular network technology, or 5G, is what the term refers to by definition and has been developing since 1980. More connections and interactions should be possible because to 5G's predicted considerable improvements to the mobile network. The possibility for many industries to increase their bottom line will be greatly increased by this network connection improvement.

The switch to 5G requires a brand-new, end-to-end network architecture and offers various distinguishing characteristics that set it apart. Following is a summary of the five primary functional drivers4 of 5G and potential use cases:(eMBB) Enhanced mobile broadbandfaster connections, better capacity, and throughput (up to 10 Gbps)enables the expansion of cellular coverage into other buildings (big venues) and the capacity to manage more devices utilising a lot of data.Fixed wireless access service, improved in-building broadband service, real-time augmented reality service, real-time virtual and mixed reality service, service for crowded or dense areas, improved digital signage, high-definition cloud gaming, services for public safety and disaster response, massive content streaming services, and remote surgery and examination.

communication with very low latency (uRLLC)shortened (1 ms as opposed to 50 ms for 4G) upload and delivery times for data from the deviceenables wireless time-sensitive communications. Intelligent transportation, industrial automation, remote operation, self-driving automobiles, mission-critical services (security and safety), drones and robotic applications, autonomous vehicles, health monitoring systems, high-definition real-time games, and smart grid and metering.Asset tracking and preventative maintenance, smart buildings, cities, and agriculture, internet of energy and utility management, industrial automation, smart logistics (advanced telematics), smart grid and metering, smart consumer wearables, environmental management, intelligent surveillance and video analytics, and smart retail are some of the technologies being developed today.

power effectivenessEnergy-efficient power needs for the installation of large multiple-input, multiple-output (MIMO) tiny cellslowers costs and makes the vast internet of things possible. The new, end-to-end network architecture of 5G and its related functional drivers were found to be best used via the 5G Ecosystem Cycle6. It makes it possible for initiatives to start moving forward in each of these areas and for industry sectors to undergo a sustained transformation. The 5G Ecosystem Cycle tries to illustrate the need of stakeholder cooperation and alignment throughout the ecosystem, including coordinated decision-making that will have an impact on the ecosystem's succeeding components. The cycle is shown in Figure 1 along with a list of its essential elements.

An efficient strategy for 5G deployment is required to realise the economic and social benefits of 5G. To do this, it was first necessary to pinpoint the precise issues now plaguing the different elements of the 5G ecosystem and the stakeholder(s) in charge of each issue. Four categories were created from the identified stakeholders:The significant issues in these areas are outlined in the following table per stakeholder. Stakeholders must be aware of and in agreement about the potential economic and social value of 5G in order to motivate them to work together on overcoming the difficulties associated with broad 5G deployment. The Fourth Industrial

Revolution will be fueled by intelligent connection made possible by 5G, which is expected to achieve a worldwide economic value of $13.2 trillion.

Regarding the total effect of 5G's utilisation in the future, different industry sources have differing projections. Therefore, creating a mechanism to assess the quantified effects of each 5G use case on the economy, society, and environment is crucial.The GSMA, the organisation that represents the interests of mobile network operators internationally, predicts that investments in 5G networks would total $1 trillion globally by 2025. Additionally, it forecasts that the investment cycle for 5G networks will be longer than that for 4G, indicating that 4G and 5G will coexist through the 2030s.

In conjunction with technological advancements like the internet of things, artificial intelligence, or big data, 5G has the potential to significantly advance society. According to a Tech4i2 report, by 2030, 5G would sustain 137,000 employment in Switzerland alone and generate 42.4 billion Swiss francs in economic activity. The potential economic output of 5G is predicted to be €141 billion, with 2.3 million jobs produced in the 28 Member States of the European Union, according to a 2016 study by the European Commission.

Although extensive research has confirmed the future networks' macroeconomic potential, the wide range of socioeconomic advantages that 5G enabled applications may offer and that will boost demand for 5G networks are not fully taken into account at the use-case level. Thus, this White Paper completes research on the potential effects of 5G that has already been published:

a. Establishing commercial and societal linkages at the use- case level
b. Analysing how macroeconomic value could be realized based on the way 5G could improve, enhance or uniquely enable new use cases
c. Identifying the social impact areas to which 5G-enabled technologies can contribute.

5G sectors and use cases

Through potential industrial advancement areas and subsequent significant commercial opportunities across industry sectors, such as augmented reality, virtual reality, and the internet of things, 5G can generate significant economic value. The 2019 report "5G for the Fourth Industrial Revolution" by PwC Strategy & and the World Economic Forum. This section identifies the individual use cases that provide economic and social value across several business sectors, as well as their distinguishing characteristics and the necessary 5G maturity level.

1. 5G use case analysis
2. Approach and methodology
3. The methodology to identify the specific economic and social value of 5G included collecting and analysing 5G use

cases from different industries. To extract critical lessons about their potential influence and approaches to realise this potential, forty use cases from various geographies and technical specialised areas were gathered. With 15 and 11 use cases each, respectively, representing 65% of the total, transportation and manufacturing were the two industrial sectors with the highest representation. To obtain information on the possible consequences across several industrial sectors, a series of multistakeholder workshops and interviews were also held.

Finally, the maturity needed for 5G to reach its full potential in the present, near and long terms, was evaluated. For uniformity across all use cases, a few functional drivers were chosen, regardless of whether the investigated use case would benefit from them. This reference was used to gauge the maturity level of the 5G networks. The three key ways that 5G will support industrial advancements are:

1) by allowing quicker and more efficient inspections using predictive intelligence;
2) by strengthening workplace and employee safety; and
3) by improving operational efficiency.

In addition, 5G has the potential to have an influence on industry via reducing carbon emissions and closing the digital gap, which together account for 63% of the suggested use cases.

1. The industrial sector is anticipated to develop quickly thanks to quicker and more accurate inspections made possible by 5G's predictive intelligence. Nearly two-thirds (63%) of the use cases include a predictive intelligence component that will produce significant economic value, especially when applied to the manufacturing sector.
2. The technologies made possible by 5G may considerably improve workplace and employee safety. Through the use of technologies like drones, the internet of things, and mixed reality, half of the use cases identified improve worker safety and reduce fatalities.
3. Enhanced operational effectiveness, especially in relation to logistics and machinery/equipment, is another important area of industrial innovation that 5G may offer. Nearly half (45%) of the identified use cases result in improved operational effectiveness, like decreased operating costs.

Social Impact

In the framework of the UN SDGs, 5G may provide social benefit in 11 key sectors, primarily through enhancing infrastructure, encouraging sustainable industrialization, and fostering innovation. It can also contribute to improved health and well-being. Other significant areas where social value can be produced through 5G technology include enabling sustainable cities and communities, encouraging decent employment, and fostering economic growth.

5G has the potential to greatly improve social well-being by lowering the likelihood of accidents and deaths. SDG 3: Good Health and Well-Being is supported by more than half (55%) of use cases, notably in the transportation (eight use cases) and manufacturing (five use cases) sectors. Infrastructure improvement, sustainable industrialisation, and innovation are all made possible by 5G. The 40% of use cases have a positive impact on SDG 9: Industry, Innovation, and Infrastructure. The industrial and transportation sectors are highly correlated with this SDG. The main performance objectives outlined in SDG 9 may thus be met via a variety of 5G applications due to 5G's significant contribution to the development of certain industrial sectors.

The five 5G main functional drivers enable certain technology applications. Increased mobile broadband and ultra-reliable low latency connection were found to be the primary elements by the use case analysis. With 45% of the use cases investigated, security and large-scale machine-type communications are especially relevant. The fact that WiFi, 4G, or even previous generations may be more than enough for certain solutions, despite the fact that 5G may be the ideal technology for others, must be emphasised.

The main characteristic that will characterise 5G and facilitate its implementation is ultra-reliable low latency communication. The functional driver in 96% of the 40 use cases is ultra-reliable low latency connectivity. This feature makes use cases that need rapid reactions feasible by reducing the amount of time it takes for data to transit from a device and arrive at its destination. Enhanced mobile broadband, which primarily supports applications for artificial intelligence, mixed reality, and drones, is the second-most important 5G differentiator. The use cases that depend on improved mobile broadband the most 78% of them will make it possible to handle scenarios where processing a lot of data is necessary. Ten use cases concern applications based on artificial intelligence, compared to four use cases each for drones and mixed reality.

The rollout of 5G will happen in stages, with certain functional drivers becoming better with time. Nevertheless, not all of the use cases found call for these functional drivers at their full maturity. Low latency and improved mobile broadband are the main characteristics that, in the near term and present condition, have the largest potential for disruption.A major functional driver for applications including artificial intelligence, mixed reality, and drones is improved mobile broadband.It will be able to realise the economic benefits of 5G in the near future (within 1-3 years) for use cases that rely on linked devices for improved data analysis and, ultimately, decision-making.Faster image/video processing is a fundamental benefit of 5G that can be realised in the near future thanks to improved mobile broadband and reduced latency.In many different industrial areas, one-fourth of the use cases result in quicker image/video processing in the near term.Low latency is essential for providing real-time machine learning potential, a characteristic that will eventually reach full maturity.Only in the long run (in three or more years) can a latency of less than one millisecond be achieved. As a result, the release of many apps that may really benefit from this functionality will be postponed.

All stakeholders must include social value creation in the planning stage in order to realise the potential social benefit that 5G has. In addition to maximising social benefits, the private sector's emphasis on social value creation when developing business models could potentially strengthen the business case for the deployment of 5G by, for example, luring investments driven by sustainability or better aligning with political agendas that place a priority on GDP growth, job creation, or climate change solutions. The construction of a technique to more precisely calculate the social value that 5G may provide is an issue to look into further, and a thorough research would be helpful to map stakeholder cooperation to maximise social value generation.To fully realise the socio-economic benefits that 5G can bring via its defining fundamental characteristics and to unleash a variety of use cases across many industrial sectors, stakeholders must coordinate and work together. Key steps that stakeholders can take to help with the successful rollout of 5G are outlined below using the 5G Ecosystem Cycle as a framework:

Jointly develop 5G implementation roadmaps with government telecom regulators and technical experts.Create a knowledge-sharing platform to showcase the effective pilots and implementations that have been done around the world.Establish benchmarks for the application of 5G technical characteristics and use case familiesOrganise technical professionals to create regulations and policies to support 5G infrastructure, such as public-private infrastructure sharingKeep an eye out for potential effects of 5G networks on your health. Investigate collaborative strategies to quicken 5G deploymentDefine the 5G network investment needs. Establishing a network for actors in the device business (demand and supply forecasting) Establish standards for device upgrades and security (device types). Engage participants from different industries to jointly establish a value-generating ecosystem. Create a knowledge base highlighting cross-industry, cross-operator, and cross-country 5G use cases. Develop guidelines for industry players to adopt the appropriate business model. Cooperate with ecosystem players to fully use 5G's potential. Consider alternative compromises and agreements that might support public-sector objectives.Analyse the socioeconomic effects of 5G use cases on various industrial sectors.Design standards that guarantee the appropriate global architecture to address probable cybercrime situationsCreate scenarios, threat forecasts, and mitigation strategies.Due to the interdependencies between certain activities involving several stakeholders, it is essential that they maintain communication to facilitate and hasten the execution of the relevant activity.

Numerous publications that have examined the macroeconomic effects of 5G using a variety of methodologies have come to the conclusion that there is a sizable economic value at stake as well as a sizable potential for job creation.According to this use-case-driven research, 5G will principally contribute to industrial advancements by making inspections quicker and more accurate via predictive intelligence, by strengthening workplace and employee safety, and by increasing operational efficiency. This White Paper draws attention to use-case-level connections to social value creation in the framework of the UN SDGs on a social level. While some use cases for 5G are more clearly defined and could have a greater impact, some industries could be transformed by it. 5G deployment will happen in stages. As a result, certain use cases won't be possible until networks are extended and technological components are further developed. For this reason, it's critical to encourage innovation and cooperation to hasten the adoption of 5G and its advantages. The coexistence of 5G with existing networks and connection options will also be made possible by these stages. For certain solutions, 5G may be the optimal technology, while WiFi, 4G, or even older generations may be more than enough. Aside from that, 5G has the potential to bring high-speed internet to regions that are currently underserved by the telecommunications network. Through tele-educational and tele-medical use cases, this could have a significant social impact.

Strong coordination amongst stakeholders is required to make sure that the implementation of 5G will be accelerated and that its components and interdependencies are understood. The 5G functional drivers provide technical support for many of the present use cases, which are then triggered via multistakeholder cooperation and collaboration. To overcome the issues preventing broad 5G adoption globally and to take full advantage of the benefits it will offer across sectors, regulators, industry groups, network operators, service/technology suppliers, and public-private partnership organisations must engage in constant communication. In the future, it will become more crucial than ever to define frameworks and models for collaboration in order to start and maintain cooperation more successfully.

This White Paper is the outcome of a collaborative effort managed by a project team with input from the Global Future Council on New Network Technologies and strategic direction from the Digital Communications Industry Governors, represented by their Steering Committee. The creation and validation of the conclusions in this study, as well as the overall 5G-Next Generation Networks Programme, benefited greatly from the efforts of a multistakeholder working group. In addition, nearly 200 senior participants from 12 businesses, the government, and academia participated in expert interviews and workshops that yielded priceless insights.

CONCLUSION

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