A Robust Method of Workload Allocation Between Smallcells and Macrocells of H-CRAN.

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Electronics and Telecommunication Engineering
(BSc in ETE)

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APPROVAL

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DECLARATION

I hereby declare that this thesis Report has been done by me under the supervision of Engr. **Md. Zahirul Islam**, Assistant Professor, Department of ETE, and Daffodil International University. I also declare that neither this report nor any part of it has been submitted elsewhere for award of any degree or diploma.

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Abdullah Al Jobaer
Priyanka Roy
Afsar Uddin

DEDICATION

THIS THESIS IS DEDICATED

TO

MY PARENTS

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Abstract

Cloud-radio access Network (C-RAN) develops as an answer for fulfill the interest for an assorted scope of utilizations, enormous availability, and system heterogeneity. C-RAN utilizes focal cloud arrange for handling client demands. Effective administration of cloud assets (e.g., calculation and transmission assets) is one of the significant difficulties in C-RAN. In this work, noble approach is been proposed of workload allocation between small cell and microcell of H-CRAN (Heterogeneous Cloud-Radio Access Network). This proposal is been verified by the simulation model designed in INET 4.2 under OMNET ++ 5.5.1. The simulation results show that proposed method illustrate better result than existing method in terms of Access Point Power (AP Power), Diversity Gain and End-to-End Delay (E2E Delay).

Chapter 1

Introduction

1.1 General Introduction

The mobile network has seen huge growth in data traffic, customer capacity, the number of apps, and the polymorphism of operation scenarios. From 2016 to 2021, Cisco expected a seven-fold increase in global mobile data traffic, with the vast majority generated by mobile devices. Mobile network operators (MDOs) need to find efficient Quality of Service (QoS), enhance spectrum efficiency and maintain good revenue, whilst reducing both Capital Expenditure (CAPEX) and Operational Expenditure (OPEX), to meet end-user demands beyond 2020 and optimize legacy networks on future demand.

The main expectations from 5G are high data rate up-to 20Gbps, low transmission delay between 1 to 10ms, and million device connectivity per square kilometer [1].

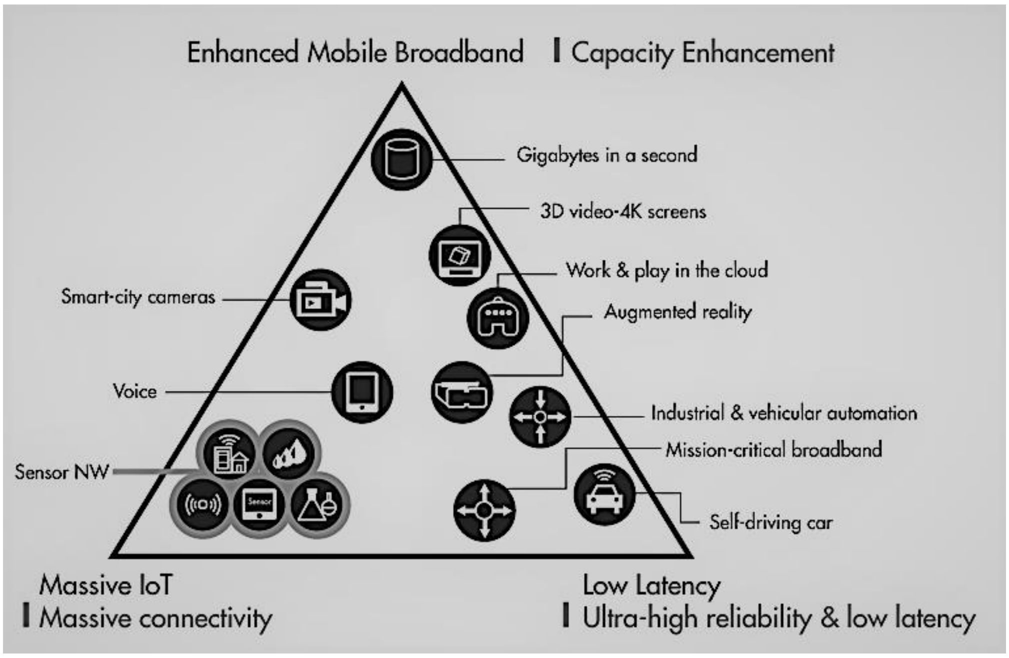

Figure 1. 5G expectations.

Numerous technologies and strategies have been introduced for mobile networks of the fifth generation (5G), especially for the Radio Access Network (RAN) domain, in order to counter traffic development, create cost-effective networks and provide better quality for large end-users [2]. Some of them can be categorized into the following:

- Implementing innovative transmission technologies to improve the bandwidth performance for higher data ability such as Beamforming, Millimeter Wave Transmission (mmWave), and Massive Multi-Input Multi-Output (massive-MIMO). Design and application of these systems has advanced significantly, but they still face major technical challenges, including the difficulty of installation, interaction with the radio frequency (RF), environmental obstacles and antenna correlation.
- Combining Small Cells (micro, pico, and femto cells) and Macrocells and deploying them over current existing network infrastructure. This network is also known as heterogeneous network. LTE also uses this network, but in contrast with the old RAN model, the heterogeneity in 5G RAN is far more complex than legacy network. However, the use of small cells increases energy consumption, CAPEX / OPEX, a number of interference and the frequency of handover.
- Use new software-defined network (SDN) and network virtualization (NFV) technology in order to automate the networks. However, there are wide shortcomings of the implementation of NFV and SDN in terms of safety, control, orchestration, isolation, allocation of resources, complexity, stability and scalability.
- Modifying and rebuilding of network infrastructure. RAN architecture in specific, through linking networking, connectivity, transmission and storage equipment to the network edge, end-users can access the low-latency and high-performance data and services.

Of the four categories listed above, we will focus on surveying state-of-the-art of various 5G RAN and Heterogeneous Cloud Radio Access Network (H-CRAN), small cells, and improved workload sharing between small cells and macro cells.

1.2 Motivation

5G wireless networks of the next generation will be operating devices that will demand high data rates. The densification of the network by using small cells is one solution to solve the data rate requirement. This densification improves the spectral efficiency and can also minimize power usage through contact with neighboring pico-cells. This approach increases network coverage considerably.

Small Cell networks are seen as a viable alternative which can meet the demands of high-speed voice and indoor traffic. It uses existing broadband connection services to connect to the core network of the service provider. Using the Network Function Virtualization (NFV) platform, multiple small cells can be integrated with the 5G network at no signalling cost. The implementation of a VNF as a multi-access edge computing (MEC) in the cloud can cause many small cells working as one. The other possible scenarios for smaller cells can either be seen and managed by the 5G core, or by directly connecting all small cells to the 5G Core via the NG interface, or adopt dual connectivity mode. The use of VNFs significantly reduces signalling in contrast with other potential design scenarios.

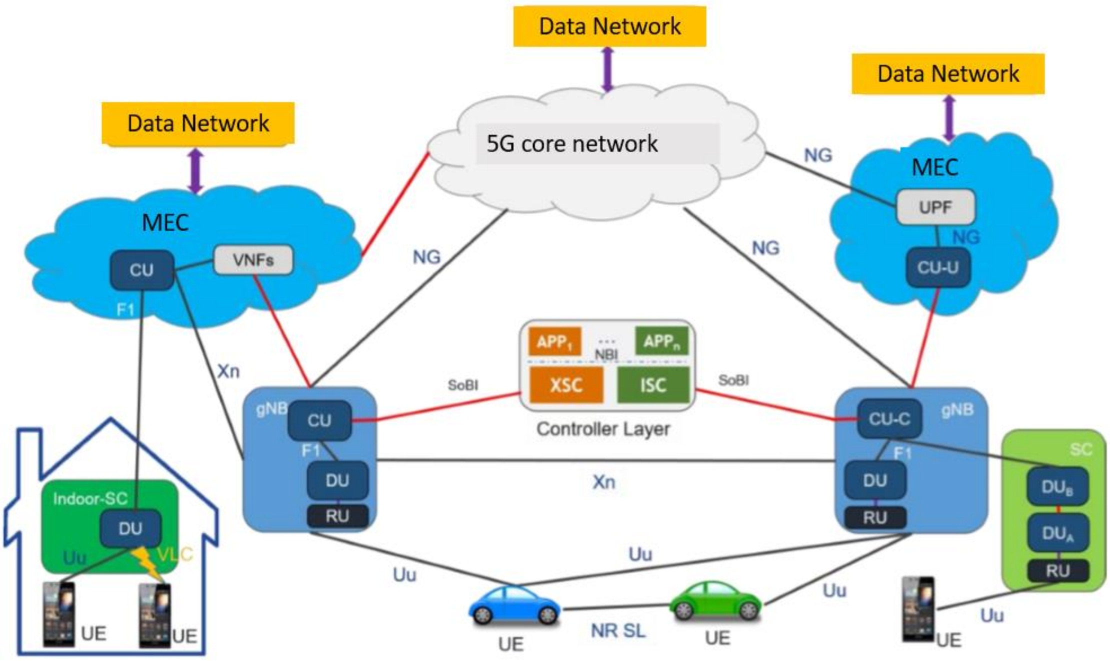

Figure 2. Overall 5G architecture.

Mobile network providers must adjust the current single tier macrocell network to provide smallcell coverage to their customers. Recent market surveys show that up to 80% of wireless communication use appears to take place at indoor. Of this, 50% is due to telephone calls and 70% is due to data services and the statistic relates especially for indoor environments [3]. The demand for high-speed data networks by end users is constantly increasing. Between 2018 to 2020, it is projected that mobile data traffic would rise by 10 to 30-fold!

Demand for multimedia traffic is high and the existing mobile network system cannot meet the demands required, given that it does not have sufficient coverage and capacity. Small cells should mitigate the problems faced by indoor mobile users. The Remote Radio Head (RRH) and small cells are commonly used indoors and in hot-traffic areas to provide the end users of H-CRAN with improved quality and efficient connectivity. The data transmission between the RRHs / small cells and the macrocells will thus be increased. Therefore, it is important to explore an effective mechanism for allocating the workload between RRHs/smallcells and macrocells to take large amounts of traffic requirements into account.

1.3 Outline Methodology

By contrast with the RAN systems of the existing LTE networks, the RAN design in the 5G mobile network is more heterogeneous. BSs density in the 5G RAN is expected to rise to 40–50 per square kilometer. So, heterogeneous network is one of the best solutions to satisfy 5G expectations and needs beyond 2020. We need an effective architecture where small cells and macrocells can co-exist and cooperate together.

In this paper we've proposed a cognitive small cell network architecture that can balance the workload between small cells and macrocells by connecting them to the core via broadband network. In cognitive small cell network, the Remote Radio Head (RRH) allocates different number of channels to its adjacent small cells based on their user capacity and load. If the user load changes, the number of canals assigned to a small cell can be changed dynamically. The result is a dynamic and balanced cell network which extracts loads from macrocells and creates a cooperative network.

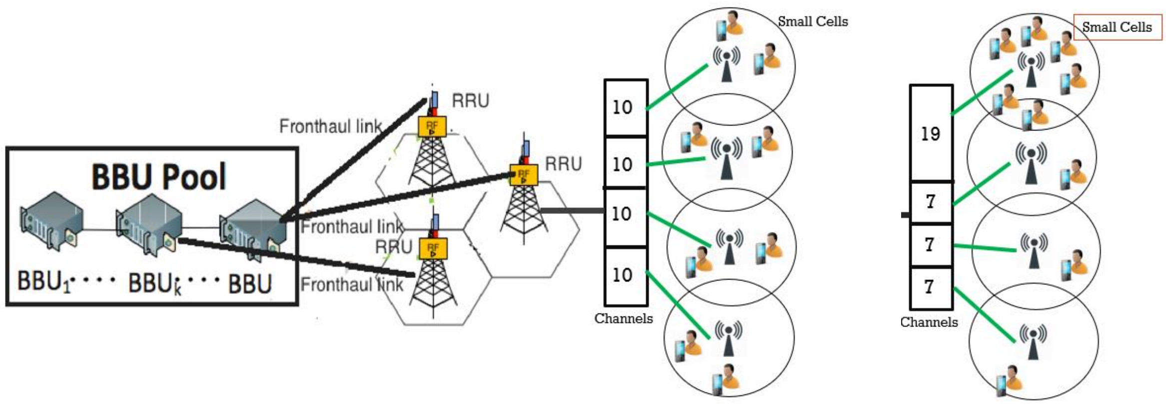

Figure 3. A cognitive Small Cell Network.

The small cells are needed to be deployed at the edge of the macrocell network to improve the overall network efficiency. We've also proposed frequency reuse models for macro and small cell networks based on fractional frequency reuse and soft frequency reuse. In both cases, small cells share workloads with macrocells with minimum interference.

1.4 Literature Review

Basically, our proposed architecture is to balance the workload between macrocells and small cells. There has been extensive study of small cells and heterogeneous cell structures in the literature. A detailed survey and deployment of small cells in LTE and UMTS network have been studied in [4]. The authors in [5] provides an overview of the key drivers and major challenges for small cell deployment and demonstrate how densification can be complemented by advanced MIMO and small cells to accommodate the anticipated traffic demand. The architecture of small cell network combined with LTE wireless network has been reviewed in [6] along with performance evaluation and future deployment scopes with 5G network. Cambridge University Press published an excellent source for understanding small cells in 5G mobile network [7]. The book includes the architecture, configuration and application of all facets of the small cell network. It also discusses emerging trends, priorities for research resource management, energy efficiency, performance analysis, implementation approaches, standardization practices, environmental concerns, and maintaining mobility in heterogeneous small cell networks. In [8] The authors talked about the development and deployment of small cells as well as the technical challenges associated with small cell network design, deployment and optimization. They also discussed main operational aspects such as bandwidth availability, mobility management, interruption control, energy efficiency, backhaul, deployment planning, frequency allocation / access method and heterogeneous network management. Numerous studies have been carried out on the use of small cells. Most of these studies are operations, administration, network control, intrusion management, LIPA (Local IP Access), connectivity and design [9] [10]. Minimum OPEX / CAPEX is one of the main drivers of small cell deployment as discussed in [11].

1.5 Organization of Thesis

This thesis is divided into five chapters. The chapters contain as follows:

Chapter 1 introduces brief introduction to 5G network and its objectives. The motivation of the paper, research methodology, and literature review.

Chapter 2 contains an overview of 5G network.

Chapter 3 describes the evolution of RAN architecture from 2G to latest 5G and comparison between various RANs. It also contains depth study of Heterogeneous Cloud RAN (H-CRAN) and HetNets network.

Chapter 4 presents a robust solution for allocating workloads between small cells and macrocells.

Chapter 5 contains conclusion and future research challenges.

Chapter 2

Overview of 5G Network

2.1 Introduction

Second generation (2G) of mobile communication systems were based on voice service, while internet and mobile broadband infrastructure were the focus of the third generations (3G) and fourth generation (4G) technologies. The use of 5 G networks to serve a range of new needs that may include an extremely high level of data traffic, massive numbers of connections and high user accessibility will further improve the mobile broadband infrastructure. The 5G systems are expected to meet future service and business requirements beyond 2020, play an important role in promoting new innovations, and a big boost to the economic output.

1G	2G	3G	4G	5G
The analog telecommunications standards introduced in the 1980s.	Replaced 1G. The radio signals used by 2G were digital. Provided small data services like SMS and MMS.	Introduced in 2000. Based on wide band wireless network. Offers faster data transfer rates and is the first to enable services such as Web browsing, e-mail, TV streaming, video calls.	Introduced in 2010. Provides high speed wireless network that can transmit multimedia.	Has speeds beyond what the current 4G can offer. Allows a much higher number of mobile broadband users per area unit. Aims to improve IoT support, lower costs and battery consumption and provide lower latency than 4G.
Data bandwidth: 2 Kbps	**Data bandwidth:** 150 - 384 Kbps	**Data bandwidth:** 125 Kbps - 2 Mbps	**Data bandwidth:** 100 Mbps peak rates in full-mobility wide area coverage and 1Gbps in low-mobility local area coverage.	**Data bandwidth:** 1 – 10 Gbps

Figure 4. Evolution of Mobile Networks.

In the next decade, a growing number of countries and nations, like the United States, the EU, China, Japan, the United Kingdom, and South Korea are taking part aggressively in the 5G market to develop their technical and economic leadership. For example, in 2018, Korea Telecom introduced a 5G-based mmWave communication system in South Korea, while in 2020, in the Tokyo Summer Olympics, Japanese operators plan to demonstrate their 5G network.

Through two schemes for innovation and research funding, the European Commission (EC) has also funded many 5G R&D projects, the Seventh Framework Program (FP7) and Horizon 2020 (H2020) in particular. Standardization bodies globally have already started standardizing the worldwide 5G network platform. A well-known organisation, the 3rd Generation Partnership Project (3GPP), has been involved since the end of the last century in the standardization of communication systems. The 3GPP 5G standards for commercial deployment and service demand are expected to be available between 2020 and 2030.

2.2 5G Aim and Ambition

5G is expected to make significant progress on all performance levels, including 1000-fold network capability growth, an improved connectivity to 100 billion or more devices, max 10 Gbps and average user experience of 100 Mbps, extensive battery life with 1000 times lower per bit energy consumption, network capacity consumption loss of 90%, support for high speed (i.e. high-speed trains) 500 km/h mobility, a 3-fold rise bandwidth performance, 99.99 percent accessibility perception, coverage of 100%, and 1-10 msec latency.

To meet these targets and satisfy end-user and market standards after 2020, the current nature of mobile network infrastructure requires substantial enhancements and interruptive technologies, both on upper/physical layer. In addition to increasing system level capacity, this enhancement and redesign of the network architecture often increases energy efficiency and reduces CAPEX and OPEX.

Improvement of energy efficiency is a crucial sustainability element, implementation and standardization 5G mobile communication network. With complete wireless 5 G network launch, millions of Bases (BSs) and billions of connected devices will be distributed around the world that need efficient operations and systems. As of now, The ICT business and applications responsible for five per cent of the world's production of carbon dioxide (CO_2). This pollution trend is growing globally, with connected devices, networks and Data/VoIP traffic rising. ICT sector energy consumption is deemed one of the world's major environmental concerns. New approaches to wireless communication networks are needed to reduce energy consumption and to minimize CO_2 emissions worldwide.

Each of the 5G technology impacts the mobile operator's CAPEX and OPEX. Some of the innovations are reducing expense such as network virtualization by about 30%. Some will increase costs, for example the minimal transmission capabilities of the high frequency spectrum. 60–80% of CAPEX is spent by mobile operators on RAN technologies. While the China Mobile Research Institute (CMRI) estimates that C-RAN will minimize CAPEX by 15% and OPEX by 50%. It is therefore important to consider the correct implementation of each of the consumer cases to minimize an operator's total ownership costs (TCO).

2.3 5G Service Categories

The implementation of 5 G communication systems focuses on three key issues: capability expansion, broad accessibility and a range of services. All 5G networking services listed by the International Telecommunications Union (ITU) has been categorized into three categories: Enhanced Broadband Mobile (eMBB), Massive Machine-Type Networking (mMTC) and Ultra-Reliable Low-Latency Communication (URLLC).

The eMBB is expected to meet common end users' requirements, i.e. increased web access bandwidth suitable for web navigation, virtual reality, high definition (HD) video streaming, etc. The mMTC provides services for a wide variety of connected devices and appliances, such as smart environment, smart agriculture, sensor networks, smart meters, etc. The URLLC tends to be used for autonomous driving, factory automation and remote surgery applications that generally require submillisecond latency at the rate of loss of packets below 10^{-5}.

The 5G services categories listed above shall also support a number of vertical industries, including medical, manufacturing, automobile, transportation, electricity, climate, housing, etc. Such sectors require different usage cases and various QoS specifications. Which eliminates traditional fixed QoS network architecture. In order to provide services to these various sectors, 5G needs technological enhancement and renovation of the current network architecture. The network is logically split into multiple virtual networks a.k.a. Network Slices to meet complex service requirements and to help the growing application scenarios effectively and efficiently. Furthermore, Network Slicing technology allows operators to structurize their networks in an elastic, scalable, and automated manner.

2.4 Key-Enabling 5G Technologies

5G Communication System's key technologies include wireless as well as networking technologies. The key innovations that allow 5G to work in the field of networking are MEC, SDN, NFV and network slicing. In the field of wireless technologies, 5G has interest in massive MIMO, Ultra- Dense Networking (UDN), unique multiple access, and all-spectrum access. Furthermore, the 5G key technologies that are capable of adopting include innovations like device- to device connectivity (D2D), flexible duplexes, full duplex, mmWave, device-centric architectures, etc.

2.5 5G Spectrum

The 5G Mobile Communications Network needs access to new spectrum (both approved and non-licensed) to meet the requirements of broadband and vertical subscribers. Extremely high frequency spectrum is one of the leading candidates for 5G spectrum. 5G frequency range is split into three parts: high-band, mid-band and low-band. The range of the low-band is under 1 GHz, the mid-band spectrum ranges from 1 GHz to 6 GHz, and high-band spectrum spans above 24GHz. Each band has its unique features that are ideal for certain deployment scenarios. In particular, the low band offers good propagation properties that are useful for a large area. However, its bandwidth is limited hence capacity is short. The medium band has an effective range for metropolitan use with increased capacity. The high-band has the least coverage and its richness of available spectrum provides a high capacity.

2.6 5G Mobile Network Architecture

A new architecture is necessary to complete a total network transformation to satisfy 5G specifications. 5G network architecture comprises a simplified yet effective central network with control and forwarding functions, and highly effective access network. The logical design of the 5G network comprises of access plane, control plane, and routing plane.

The access plane comprises of a variety of BSs and control systems. There is enhanced interaction between BSs and wireless devices and a rich networking topology leading to flexible access control and increased utilization of resources. The control plan is responsible for generating a global control policy for the network as a whole. The forwarding plane is responsible for the transfer of data from all network devices and services. Efficiency and reliability of data transmission can be accomplished by preparing policies created by a centralized control plan. Figure 5 shows three logical planes of 5G network architecture. The control features can be divided into central network management features and network control access functions. The core network control functions are primarily used in the metropolitan and backbone networks, while network access control functions at the edge of the mobile network are deployed or integrated into the BS to provide support for low latency and high reliability services.

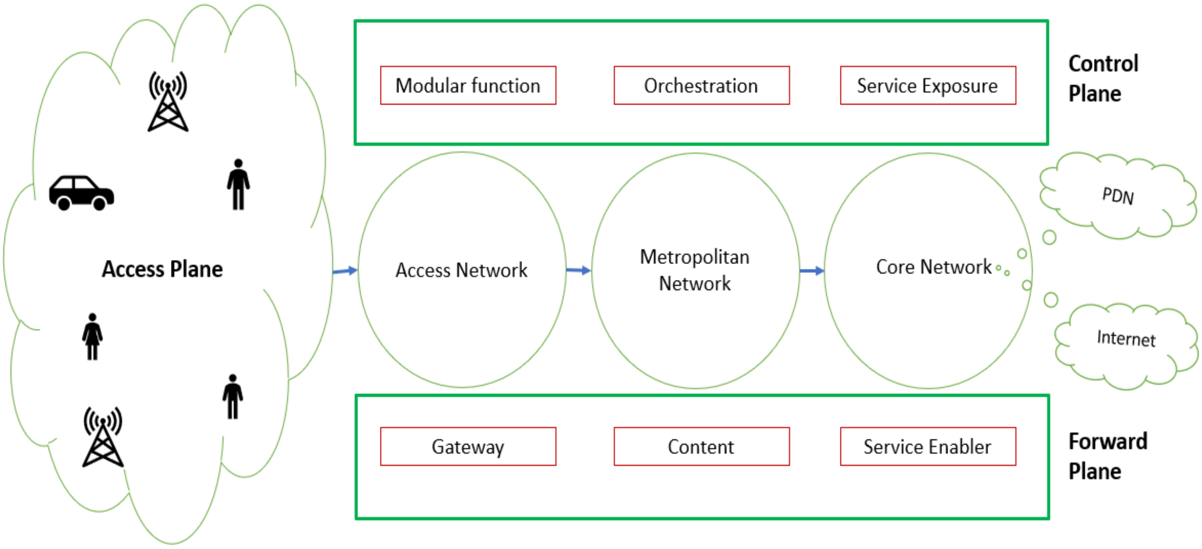

Figure 5. 5G logical design.

2.7 5G Radio Access Technologies

mmWave:

While demand for a higher rate of data is steadily increasing, mmWave wireless connectivity is perceived to be one of the potential approaches to mitigate the emerging infrastructure shortage for future communication systems. The current spectrum bottleneck can be solved with higher bandwidth in conventional LTE systems by the deployment of the mmWave communication networks. In addition, due to the small wavelength, multiple antenna arrays at mmWave transceivers can be equipped in limited space. This can be used to increase signal strength and minimize interferences by using directed beamforming techniques. A coverage of 100-200 m is available in the mmWave communications cell, it is thus known as a small cell that typically occupies a wavelength between one and ten millimeters between 30GHz and 300GHz.

High transmission loss is one of the key challenges of mmWave communications relative to other communication systems (which uses lower carrier frequencies). The spectrum of mmWave communications reduces by rain and atmospheric/molecular absorption. mmWave Communications are typically used for short/indoor communications like small cells/backhaul on an order of 200 meter. Because atmospheric absorption and rain attenuation create no major path loss for indoor communication of short range.

Massive MIMO:

Since almost a decade MIMO is known as a core technology in wireless systems. It offers significant capacity increase and a large multiplexing gain. There are two major category MIMO systems: point to point and multi-user system. All end users and BS are equipped with multiple antennas in the point-to-point MIMO, but only one user is supported at a time. By comparison, in the Multi-user MIMO a BS has an antenna array, and many end users are required to be supported. The idea of large MIMO was adopted in order to further improve the data throughput and to maximize the multiplexing gain. Massive MIMO works with Time-Division Duplex (TDD), though, the uplink data transmission and download data transmission takes place in the same frequency range, but in different time domains. Massive MIMO concept is planned to fit the BS with many antennas which then is used to transmit gigabit level of wireless traffic to serve many active users at the same time. The installation of a large number of antennas in one BS produces challenges of significant gains, high complexity and expensive signal processing equipment.

One of the main advantages of large MIMO is that the received signal can be focused in short range areas, this improves system capacity performance. Massive MIMO also enhances energy efficiency, because tens of BS antennas help to focus energy on small areas with a particularly narrow signal, which are found in hundreds of end users. Another one of the main benefits of MIMO is the convergence with other 5G essential RATs like mmWave, Non-Orthogonal Multiple-Access (NOMA), HetNets (Heterogeneous Networks), and Device-to-Device (D2D) communication.

Device-to-Device (D2D) Communication:

D2D connectivity explicitly routes the data traffic of close-lying devices directly to the internet and is not necessarily needed to cross through RAN/CN. Recent studies have found that D2D connectivity is expected to improve reliability, boost energy efficiency and decrease mobile network delays due to the short distance between the two mobile devices and direct communication. The D2D is split into internal and external bands. Direct communication between devices takes place in the D2D internal band mode, with a permitted spectrum allocated to cellular operators. Internal band D2D users can use two modes to enter the permitted spectrum, the dedicated mode (overlay or orthogonal) and the common mode (underlay or an orthogonal mode). Direct connectivity between devices is carried out in external band D2D communications in a permitted network followed by other wireless technologies such as Wi-Fi or Bluetooth.

Massive Machine Type Communication (mMTC):

The mMTC case applies to new technologies like sensor networks and IoT, which involve an extremely high density of traffic and a large number of connections. Furthermore, with the introduction of 5G, network technologies are being rolled in with various devices around us such as smart watches, smart sunglasses, etc. In existing telecommunication networks, network systems are limited to smart phones only. The 5G is also characterized by full linkage of everything, and the mMTC is widely recognized as an essential part of 5G. The 5GPP is expecting that the 5G network can connect up to trillions of IP-based devices and appliances by 2020 via the Internet of Everything (IoE) concept. For example, 5 G will become a systemic component of the smart cities that will have a significant impact on energy management, water management, smart residences, mobile / smart cars, smart farmhouses, telemedicine, public safety, healthcare, traffic management, time critical applications that requires immediate response. This would make it expensive and difficult to design, manage and maintain next-generation telecoms networks. The mMTC compared to traditional handheld human-type communications (HTC) networks exhibits: unusual features of a wide number of devices, a minor size of data-packets (possibly up to few bytes), uplink-domain transmissions, lower user data speeds, intermittent user operation (like daily and/or synced transmission), heavy restrictions in device flexibility and power consumption.

Multi-Access Edge Computing (MEC):

A modern architecture Multi-access Edge Computing (MEC) was introduced to tackle the explosive growth in data traffic associated with a large number of digital applications and services. MEC is a new paradigm that offers cloud computing infrastructure at the edge of the radio access network (RAN), providing ultra-low latency environment with a high bandwidth and real-time access to the radio and analytics. MEC promotes customer satisfaction, increases QoS and makes more effective use of cellular backhaul and core networks, and helps end users with compute-intensive and low-latency applications in close proximity. MEC introduces a flexible and multi-lease environment from a business point of view, enabling authorized third parties to take advantage of storage and processing capabilities.

SDN, NFV, ICN and network slicing are key technologies that allow edge computing. Various exceptional scenarios and applications such as cloud offloading, IoT, content delivery and storage, AR and VR, video streaming and analysis, smart car, and massive mobile data are exciting possibilities and case studies within 5G communications systems can gain benefit from edge computing. Computing offloads are considered a major case for MEC, improving energy efficiency and accelerating the computing process – particularly for the time-sensitive applications. In IoT applications and services, the MEC can be used by enabling storage and associated computing infrastructure close to data sources. Throughout the digitization of automobile industry including self-driving and autonomous vehicles, MEC plays a significant role. It may also be used for connectivity between vehicle-to-vehicle (V2V) and vehicle to Infrastructure Cars (V2I) to provide services for the ultra-low-latency applications.

Network Function Virtualization (NFV):

Most traditional mobile networks have a large number and dedicated hardware-based network functions. This process provides the network with many problems such as service delivery issues and maintenance of the network. In comparison, the implementation and construction of specialized hardware protocols is costly and time consuming. The NFV is regarded as an important enabler for disconnecting network functions from specific hardware and making them available under the name Virtual Network Functions (VNFs) software. The NFV offers several benefits to telecoms networks, including simplifying network management, lowering CAPEX/OPEX, reducing power consumption, increasing coverage efficiency, and much more.

In October 2012, the first industry standard group (ISG) within ETSI was formed to describe the NFV in telecommunications networks, among some of the biggest telecommunication operators and providers are American Telecommunications and Telegraphs (AT&T), British Telecom (BT), Deutsche Telekom (DT), NTT, DOCOMO, Telecom Italia and Telephonica. The number of ETSI member organizations has increased to over 300, including over 40 of the largest providers of telecom service in the world ever since the establishment of ISG. All of them work closely together to deploy NFV in telecommunication networks and to develop NFV standards.

There are three parts to the NFV architectural framework: Network-functions of virtualization structure (NFVI), Virtualized Networking Function (VNF), and Network Function Virtualization Management and Orchestration (NFVM&O). The NFVI is a data plane used for providing simulated services for the execution of the VNFs. The VNF is the network device implementation and is capable of running over the NFVI. The VNF corresponds to the application plane and consists of several VNF type applications. The

M&O part of the NFV architecture corresponds to the control plane. The NFV Architecture is guided by a set of metadata which include specifications of service and VNFs, and infrastructure, to ensure that NFV M&O runs in compliance with these regulations which are delivered by various parties [12].

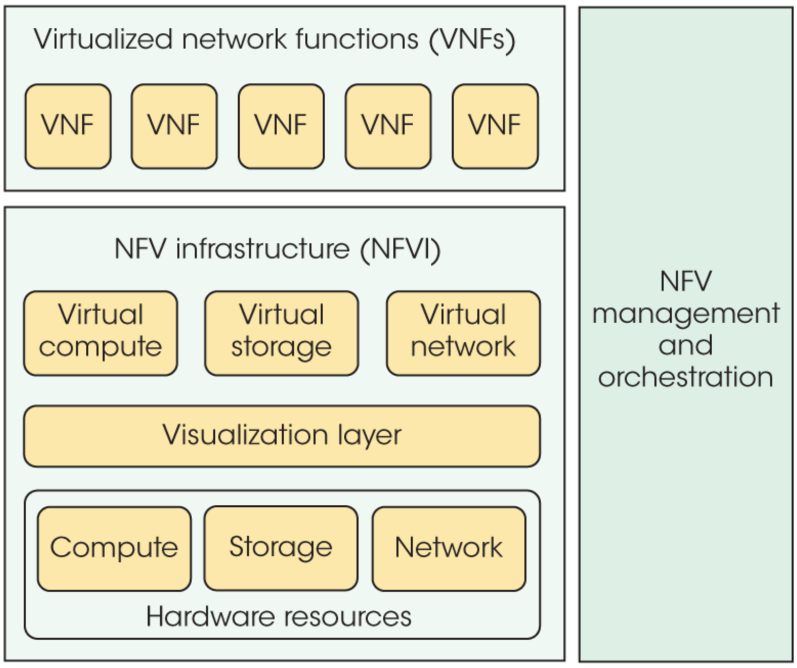

Figure 6. Architectural framework of NFV.

There are many functionalities in the 5G communication network. All these tasks pose technical and practical problems. The NFV is one of the most important tools to achieve this goal to easily manage and implement these features into the 5G network architecture. NFV offers high versatility in the implementation of 5G as well as other communication technologies in different scenarios, specifications and implementations. There are several user-plane and control-plane features in the 5 G RAN architecture, which are required for virtualization. Virtualization of functions in 5G, RAN in particular, reduces the power consumption and reduces footprint by allocating dynamic infrastructure resources and balancing traffic.

Software Defined Network (SDN):

Vertical convergence of the existing telephone networks is carried out where the control plane and data stage are merged. The current method of convergence with conventional IP networks is difficult to manage, and difficult to customize. The SDN is considered a key enabler for 5G and beyond communication technologies, which replaces the conventional telecommunications network convergence strategy and splits the control plane from data plane. SDN is capable of dynamically partitioning the network, adjusting the traffic flow and delivering service quality implementation level. The separation between data and control systems provides the communication network with a range of benefits, including rebalancing of network management, service management, system management, and simple programming of software. However, many telecoms operators are not able to deploy SDN to the full due to certain obstacles, such as financial limitations, fear of downtimes and so on, instead they are willing to selectively deploy SDN to build their networks. The primary objective behind partly SDN implementation is to bring a limited number of SDN-related equipment into existing network infrastructure, which is also known as hybrid SDN networks.

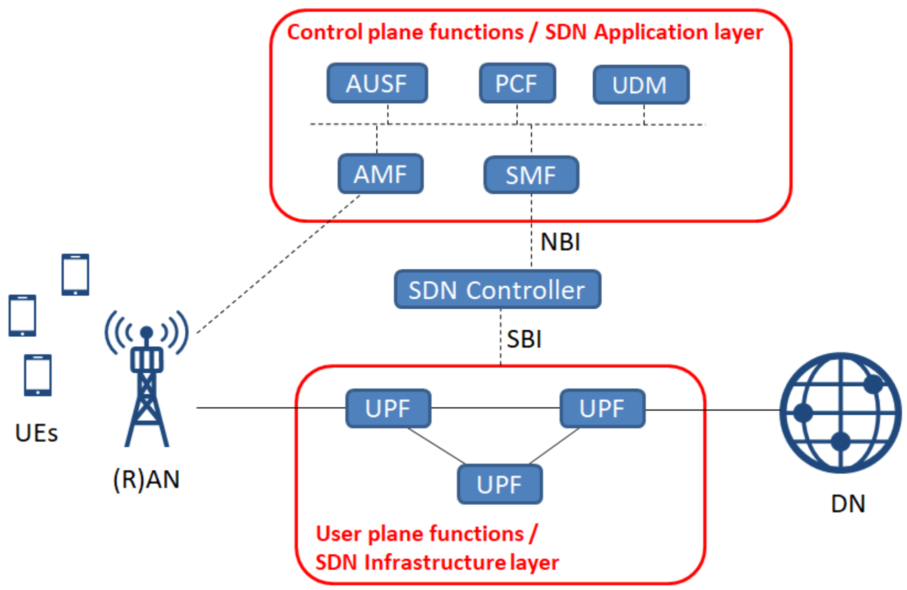

Figure 7. Separation of control plane from user plane in SDN.

There are three layers of the SDN architecture: infrastructure layer, control layer and application layer. The infrastructure layer is the lowest tier consisting of all network equipment and hardware. Like traditional networks, SDN nodes do not have technical control over its functions and behave just as forwarding devices. The Infrastructure layer uses the data plane controller to communicate with the control layer. The control layer consists of several SDN controllers. In this layer all network intelligence is theoretically clustered. Both virtual and physical network services are handled by the SDN Controllers. The Application Programming Interface (API) provides direct control to the SDN controllers over all data plane components. The application layer is the top layer in where the network is managed primarily by service providers, network operators, and app developers to satisfy their business requirements such as bandwidth, traffic, access control, QoS, energy consumption etc.

The architecture of the 5G mobile network is focused on SDN that must be operated seamlessly and in real time. It allows operators to provide communication effectively between applications, cloud services and end-users. In addition, the introduction of SDN in the 5G mobile network increases efficiency with respect to spectrum distribution by centralizing and seamless connectivity through various radio access technologies.

Network Slicing:

The 5G communication system will offer services to different vertical sectors, including medical, industrial and automobile facilities, etc. Network slicing is one of 5G's relevant technologies for meeting vertical market requirements. This allows the operator to organize the network in an elastic, flexible and automated manner. Each application requires its own network segment consisting of individual functions, requirements and features. For instance, a slice may serve for vital machine communication, such as remote surgery, distinguished usually by high reliability, ultra-low latency and high performance. There can be another network slice for the calculation of water level reading of an IoT appliance, which requires a simple radio connection, low workload and low mobility process. In addition, eMBB services may require a separate bandwidth slice to support high data rate services such as HD video streaming.

Network slicing allows multiple logical networks to run across a single shared physical infrastructure with SDN / NFV, reducing overall costs, reducing energy use and simplifying network operations relative to a network with various usage / business scenarios. Each slice in a slice-based network has its own special properties and work as a single logical network. This will improve capacity and cost-effectiveness compared to traditional network use and capital distribution.

The deployment of network slicing over 5G communications system poses several technical challenges to be addressed. There are also other economic and business problems, such as total expenses, revenues etc., that require considerable optimization and restructuring in order to meet the evolving network architecture. On the other hand, there was an enormous increase in demand for broadband multidimensional networks. With the ongoing trend, CAPEX and OPEX needed to run the network would soon be higher than MNO’s revenues. One of the main purposes of network reduction is to refine the economic analysis of traditional telecom networks, to increase overall profits and reduce total network investment.

Chapter 3

Evolution of Radio Access Network (RAN) Architectures

Introduction

Each technological breakthrough throughout the history of Mobile Network growth is motivated by new demands for mobile communication services which cannot be met by legacy systems with dated infrastructure that have inherited shortages. It is important to track the progress of new and past RANs to address the RAN architecture for 5G mobile communication. In this chapter, we will discuss RAN's concept and architectural development throughout different historical times.

3.1 The Base Station Subsystem (BSS)

The BSS is the cornerstone of the 2 G RAN architecture, standardized in the context of the Global System for Mobile Communication (GSM). BSS's main objectives are to provide network coverage for a desired area and to fulfill the roles of radio and mobility functions. The coverage area of all BSS extends across several small areas called cells. At least one fixed transceiver or Base Transceiver Station (BTS) serves each cell. Cell size, shape, capacity and network coverage depend on the density and the topography of the users in one area. A cellular system allows a wide range of Mobile Stations (MSs) to connect with each other and with other mobile operator's MSs and fixed-line phones in its coverage area.

The principle of frequency reuse has been developed in order to accommodate a large number of MSs within a limited spectrum. In this model, multiple BSs with enough distance (geographically / physically) will reuse the same frequency. Radio channels are scattered across the cells so that the presence of co-channel interference is negligible. Figure 8 shows the idea of frequency reuse where same frequency can be reused by BSs that have significant distance between them.

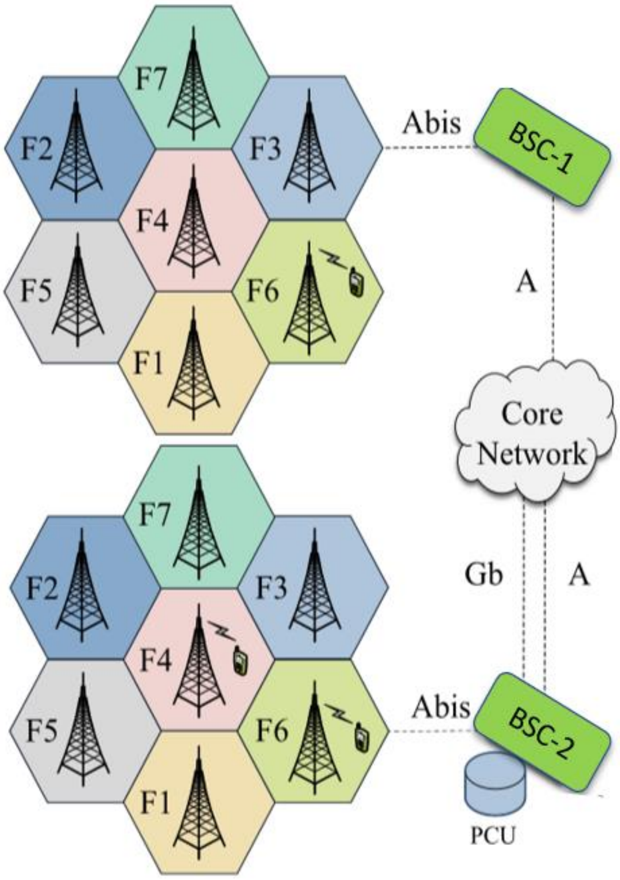

Figure 8. Frequency reuse planning in 2G.

As shown in figure 8, the BSS is comprised of the BTS, the Air-Interface, the A-interface, the BSC, and the Abis-interface. BTS is the first component to connect directly to MSs wirelessly. It consists of antennas and mobile unit to communicate via radio link with MSs. The BSC handles the mobility and radio assets of all BTSs and their related MSs. A standard BSS consists of tens of BSCs and hundreds of BTSs. These nodes and all of the BSS infrastructure bridge the gap between the GSM core network (CN) and millions of MSs. The MSs connect with the BTS through Air-interface which makes it possible for MSs to connect with other MSs. The Abis-interface is used to connect BTSs to the BSC (usually an E1 connection). Which uses channelized Time Division Multiplexing (TDM) link where users receive 16/8 kbps connection, depending on the modulation scheme used for multiplexing. BSC is connected to the CN using the A-interface (multiple E1 link combination).

3.2 General Packet Radio Service (GPRS)

In the mid-1990s, the demand for internet for mobile devices grew. In 1997 the European Telecommunications Standards Institute (ETSI) approved the standards for GPRS, which had been fully completed in 1999. GPRS technology was initiated in 1999, but was made commercially available in 2001 and was integrated into cellular networking. Through implementing GPRS functionality on the GSM network, modifications in the network architecture were actually necessary, especially in the BSS. The GPRS uses packet switching (PCU, refer to figure 8) where many users share the available capacity to reduce bandwidth loss to a small level. The packet switching is more effective than the circuit switching with bandwidth utilization. The packet switching is seen as a turning point in mobile communication's history which opened the door to 3G and beyond technological research and development. The GPRS and GSM work side by side using the same BSS architecture. GPRS needs an update of the BSS architecture as it transfers to packet switching. As shown in figure, a new element PCU was added to the BSS (figure 8). In the meantime, there were also changes to existing systems and interfaces. GPRS/GSM specifications allow the PCU to be installed at different network locations, i.e. near BTS, BSC or CN. The most typical PCU installation is near the BSC. In order to support GPRS services, for example web browsing, and file transfer, at least one separate E1 connection from the BSC to BTS is required in addition to a PCU. The connection does not modify the BTS fundamental architecture or the specifications of E1 link protocol.

3.3 GSM EDGE Radio Access Network (GERAN)

The Radio Access Network for EDGE is GERAN, which was modified and implemented in GSM Phase 2+ Rel. 98. The 3GPP Rel.5 and Rel.6 further modified and improved the system. The Rel.5 introduced a new interface called Iu, which connects 3G core network with GERAN. This leads to a new GERAN architecture and major changes to its radio protocols as shown in figure 9.

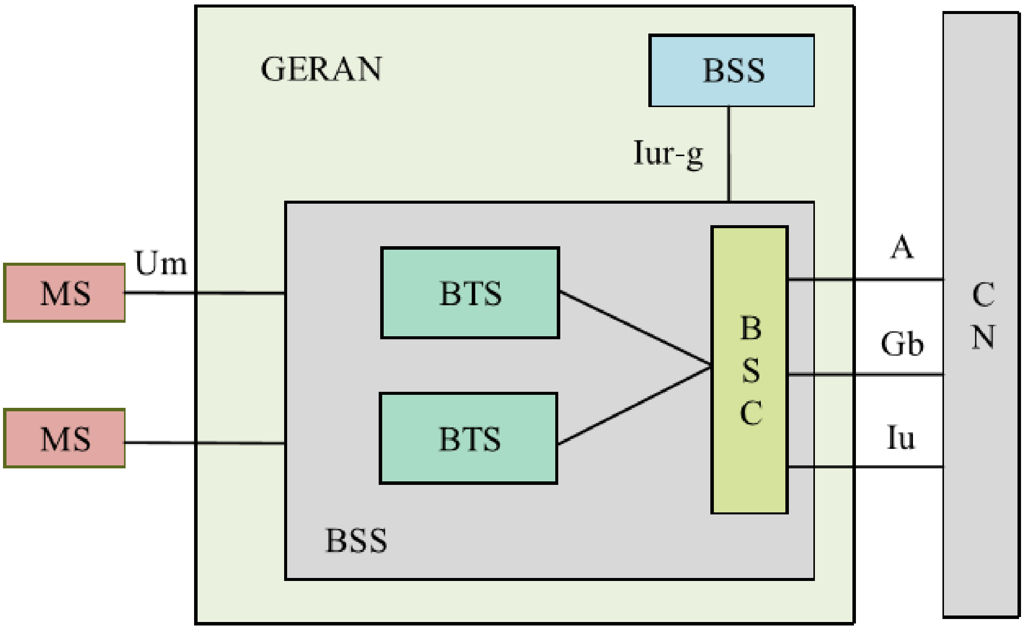

Figure 9. GERAN architecture in GRRS network.

The Rel.6 introduces some major changes in the physical layer of GERAN. GERAN's main motive is to boost the GSM / EDGE data rates and to improve the experience of the end-users. The EDGE aims specifically to increase radio time slot transmission through the Gaussian Minimum-Shift Keying (GMSK) modulation used in the GSM/GPRS networks. GERAN radio interface uses 8-PSK (Phase Shift Keying) GMSK, which has a transmission rate of 3 symbols/bit instead of 1 symbol/bit as in GSM/GPRS. This development of the modulation system raises the average bit rate from about 20Kbps to about 60Kbps per slot.

The general structure of GERAN is shown in figure 9. The Um interface serves to link the MS with GERAN BTS, the Gb interface in GSM/GPRS serves to connect Serving GPRS Support Node (SGSN) and BSS, while A-interface connects BSS and 2G Mobile Switching Center (MSC). In GERAN, the Iu and the Iur-g are two new interfaces. The Iu connects GERAN to the CN. The Iur-g binds GERANs to RANs of other networks such as GSM/GPRS or the Universal Mobile Telecommunications System (UMTS) RAN.

3.4 UMTS Terrestrial Radio Access Network (UTRAN)

The UTRAN for UMTS network was released first in Rel.99 by the end of 1999. The UTRAN is based on existing standards and is therefore inspired heavily by existing RAN architectures. The UTRAN consists of one or more radio network subsystems (RNSs), each consisting of at least one Radio Network Controller RNC and some BSs. In UTRAN the BS and the air interfaces are known as Node-B and Uu interface.

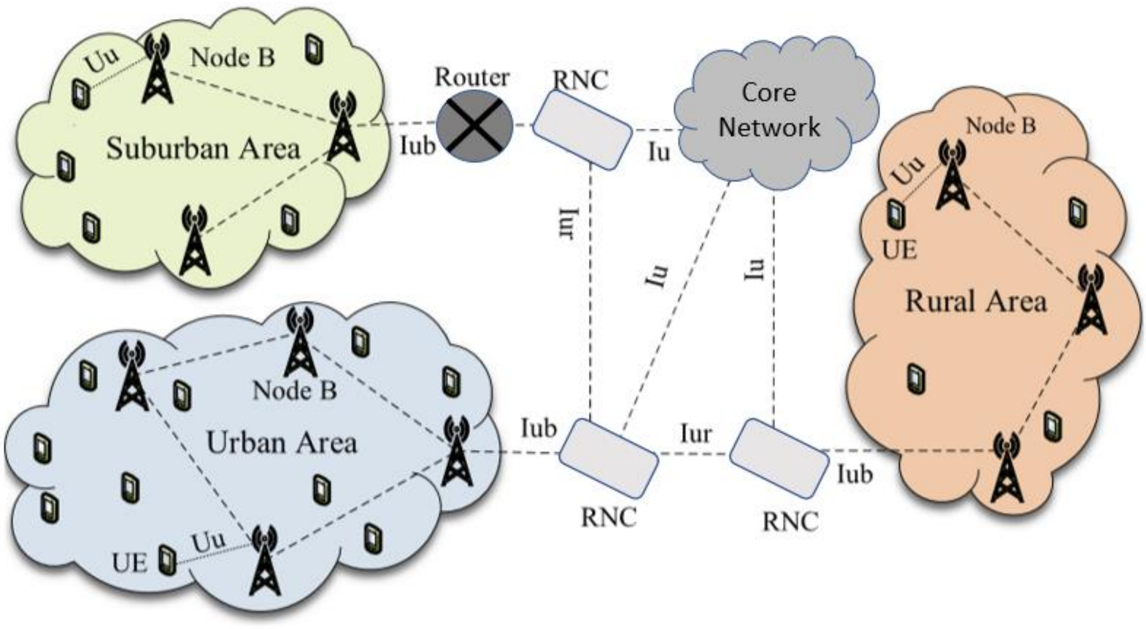

Figure 10. UTRAN architecture.

The Uu interface is based on Wideband Code-Division Multiple-Access (WCDMA), which is comprised of Code-Division Multiple-Access (CDMA) and Direct-Sequence Spread-Spectrum (DSSS). To achieve greater speed and support more device communication simultaneously compared with Time-Division Multiple-Access (TDMA) and Frequency-Division Multiple-Access (FDMA). The RNC communicates with Node B and the CN via two communication links called the Iub interface and the Iu interface respectively. Two types of Iu interfaces exist: one for circuit-change CNs and the other for packet-change CNs. The RNC is the core element of UTRAN and is responsible for mobility control of UEs and radio resources management (RRM) for all linked cells. It is also the RNC that is responsible for Radio Barriers (RBs) deployment, release and management.

3.5 Evolved UTRAN (E-UTRAN)

In E-UTRAN, there is no centralized control but only base stations known as eNode-B. Hence, E-UTRAN is also known as flat RAN. The eNode-Bs are interconnected by X2 interface, and through S1 interface to the Evolved Packet Core (EPC). All eNode-Bs are linked to the Mobility Management Entity (MME) and the Serving-Gateway (S-GW), via S1-MME and S1-U interfaces. LTE-Uu is the interface between eNode-B and the UEs.

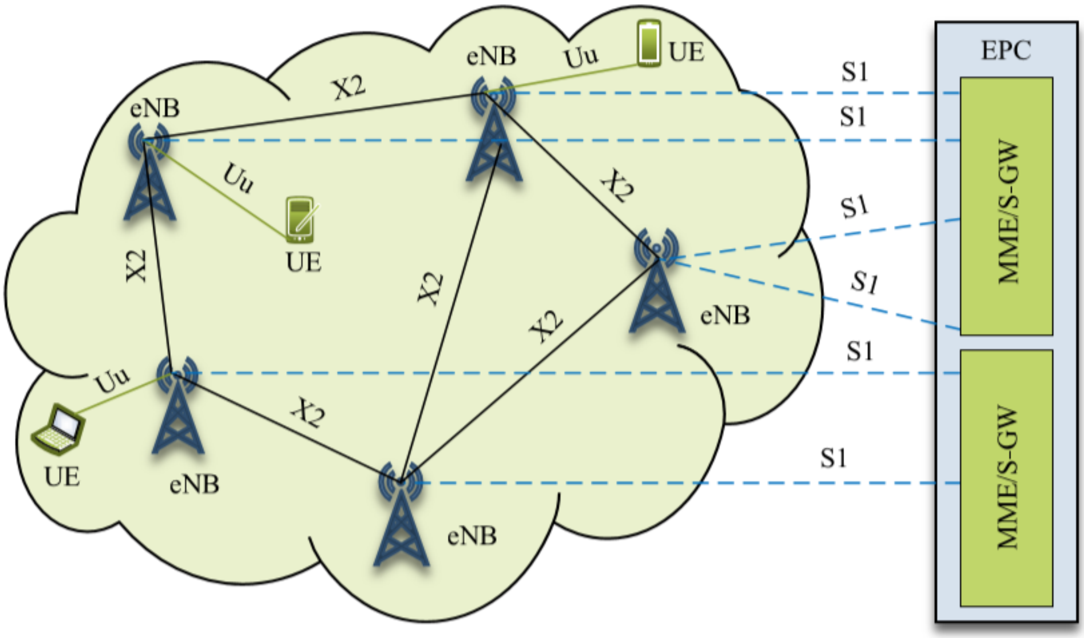

Figure 11. E-UTRAN architecture.

Unlike the previous RANs, the E-UTRAN incorporates all functions including RRM, header correlation, stability etc. into eNode-Bs, which results in reduced latency and improved efficiency. In LTE, many nodes of the EPC, e.g. MME/S-GW serve a single eNode-B via S1 link. This system offers the opportunity for load sharing and eliminates the risk of EPC nodes malfunction at a point. The Uu framework uses two different methods to enhance mobile data communications user experience, the downlink operates with Orthogonal Frequency-Division Multiplexing (OFDM) wave-form and the uplink operates with Single-Carrier Frequency Division Multiplexing (SC-FDM) wave-form. The S1 interface is divided into a control and user plane. The X2 link is used to extract two kinds of information, mobility and load/interference.

3.6 Distributed Radio Access Network (D-RAN)

In a conventional macro BS, radio and signal processing units are isolated from one another in UTRAN and E-UTRAN. Remote Radio Head (RRH) or Remote Radio Unit (RRU) is the radio unit that is positioned next to 3G/4G macro BS. The baseband signal processing unit is called the Baseband Unit (BBU) or Data-Unit (DU), which is conveniently and situated in an easily accessible location. In terms of network specifications, BBU allocates network resources dynamically to their respective RRHs. The RRH interacts explicitly with the end user and is limited to RF functions only. This architecture is known as D-RAN. Each RRH is connected via the Common Protocol Radio Interface (CPRI) transport network to their respective BBU, to transmit in-phase and IQ signals. For the connection between RRH and BBU, which is known as the fronthaul, both optical and microwave can be used.

3.7 Cloud Radio Access Network (C-RAN)

In C-RAN, all network services are integrated in a central BBU pool. The main concept behind C-RAN is to detach all BBUs into a central, unified, shared, cloud based, and virtualized BBU pool from their respective RRHs. Each RRH is connected to its corresponding BBU pool via a fronthaul link as shown in figure 12.

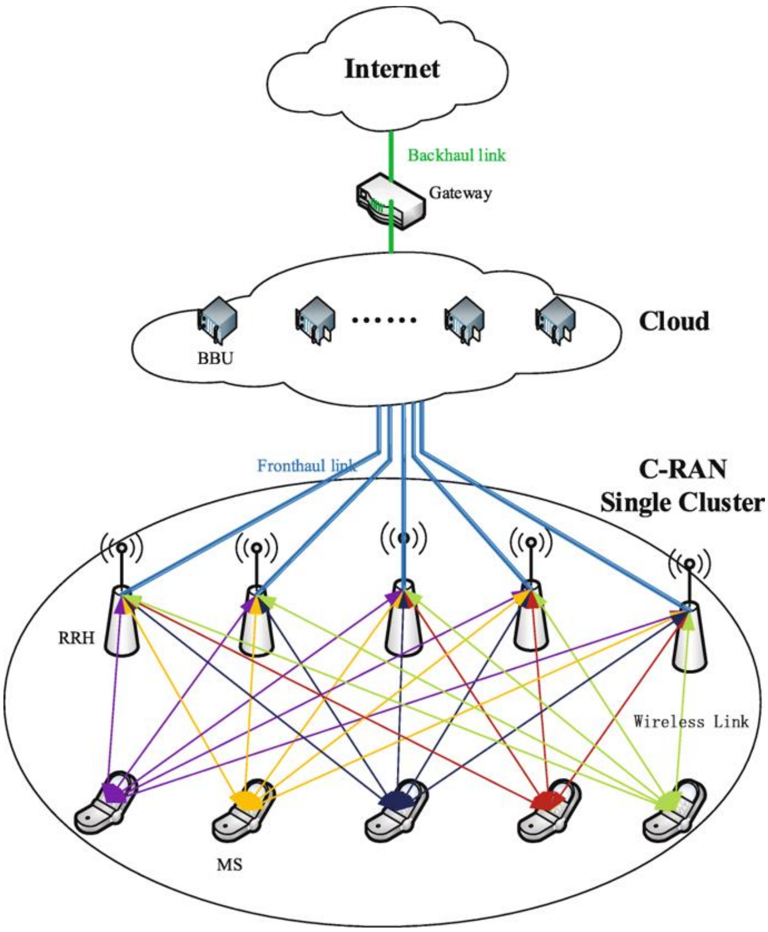

Figure 12. C-RAN architecture.

Each BBU pool can support up to ten RRHs and can be linked back to the central network via a backhaul link. The C-RAN architecture lowers MNO's CAPEX and OPEX, eliminates power usage, increases scalability for network, simplifies network management and maintenance, boosts spectral efficiency and network performance and promotes load balance. The C-RAN integrates cloud computing into the 5G RAN system. There are two kinds of C-RAN: fully centralized and partially centralized C-RAN.

In a fully centralized C-RAN, all the operations relating to Layer-1 (such as sampling, modulation and demodulation, resource blocking, antenna mapping, data quantization etc.), Layer-2 (such as transport access control), and Layer 3 (such as radio-link resource control) are found in the virtualized BBU pool. Some of the major achievements of a fully centralized C-RAN to 5G cellular network includes easy network coverage extension, easy network capacity improvements, support for multi-standard activities, network aggregation, and support for shared signal processing in multi-cell networks. However, two major challenges are faced by fully integrated C-RAN are: high standards for bandwidth and the propagation of the I/Q signal from the baseband to the BBU.

In a partially centralized C-RAN radio and baseband management functions are implemented into the RRH, and all high layer tasks are merged into the BBU. Partially centralized C-RAN demands low bandwidth between RRH and BBU, as the baseband signal processing is transferred from the BBU to the RRH. Partially centralized C-RAN also faces some challenges such as poor efficiency in network upgrades and less accessibility of collaborative signal processing for multi-cell.

3.8 Heterogeneous Cloud Radio Access Network (H-CRAN)

Recently, propositions were made to decouple control and user plane functions to increase the functions and performance of C-RAN architecture where control plane functions are only integrated into the macro BSs. This new RAN is called Heterogeneous Cloud RAN. In H-CRAN, full benefits have been obtained from the heterogeneous and C-RANs, which increase spectral and energy efficiency while at the same time improving the data rate. The cellular architectures of H-CRAN architecture are divided into two parts: the BS macro cell structure (high power node) and the small BSs or the RRH layout. The main purpose of high-power nodes (HPNs) is to improve network coverage and also to control network signals. Nevertheless, the small cells and RRHs guarantee increased network capacity and meet different end-user QoS needs.

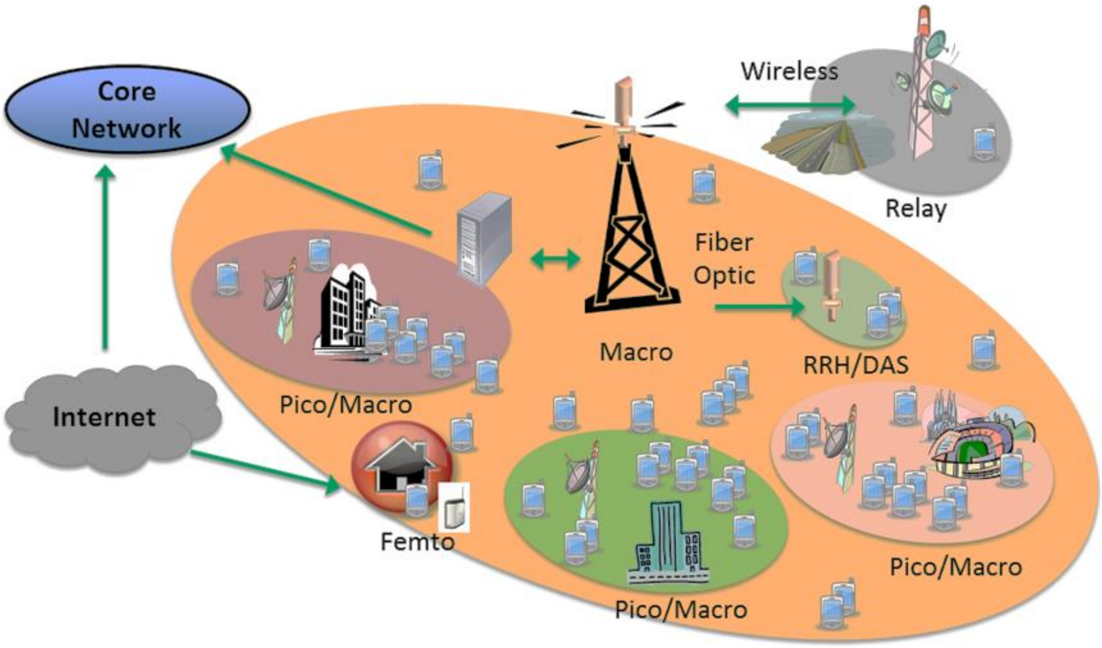

Figure 13. Heterogeneous C-RAN architecture.

The H-CRAN Architecture consist of three primary operating modules:

- Real-Time and Upgraded-Cloud Virtualized BBU Pool: All BBUs distributed into multiple cells are combined in the BBU pool in this operational module. The BBU pool is based on efficient virtualization technologies and cloud computing. In addition, the BBU pool is connected to HPNs in order to coordinate HPN-RRH interfaces.
- Ultra-Reliable Transport Network: All RRHs are connected to their BBUs in the BBU poll. RRHs and BBUs are connected via high-bandwidth fronthaul connections like optical fiber. The S1 and X2 are the interfaces of data and control between the BBU and MBS (HPNs).
- Large Number of Macro-BSs, Small BSs, and RRHs: Different cell types, including macro base-stations, small base-stations and RRH coexist in H-CRAN architecture. The macro base stations monitor the network and handle mobility. The small cells and RRH increase the capacity of the network and decrease the transmitting energy. The RRHs customize the symbol processing and radiofrequency functionality, all other physical baseband signal processing functions of the top layers are processed in the BBU array. All functions from the physical layer to the network layer are given to the high-powered nodes.

In H-CRAN, enhanced cloud computing, centralized convergence of all BBUs, function separation between RRHs and BBUs and disengagement of the control plane and data plane lead to efficient mobile network management. Therefore, mobile operators only need to install new RRHs close to the user in scenarios such as increasing network coverage and increasing system capacity and connecting them to the BBU pool. In fact, it is also quite easy to implement flexible software solutions. For example, if a network operator is keen in improving RANs and promoting multi-standard services, then it can be possible by upgrading software via SDR.

Chapter 4

Workload Allocation Between Smallcells and Macrocells in 5G HetNet

4.1 Introduction

Small cells that are deployed in Heterogeneous Network (HetNet) are low-powered wireless Base Stations (BS) operating within the range of 10 meters to a few kilometers, and uses licensed and unlicensed frequency spectrum. Compared with a mobile Macrocell they are "small" because of their shorter range and also because they normally have lesser simultaneous calls or sessions. Small cells are usually used in homes and in small office/businesses. Small cells connect their users to the central network through broadband connections (such as DSL cable). Small cells allow network coverage in places where macrocell signal cannot reach or too weak. Furthermore, small cells take off some load pressures from macrocells which in turn, increases macrocell capacity and efficiency.

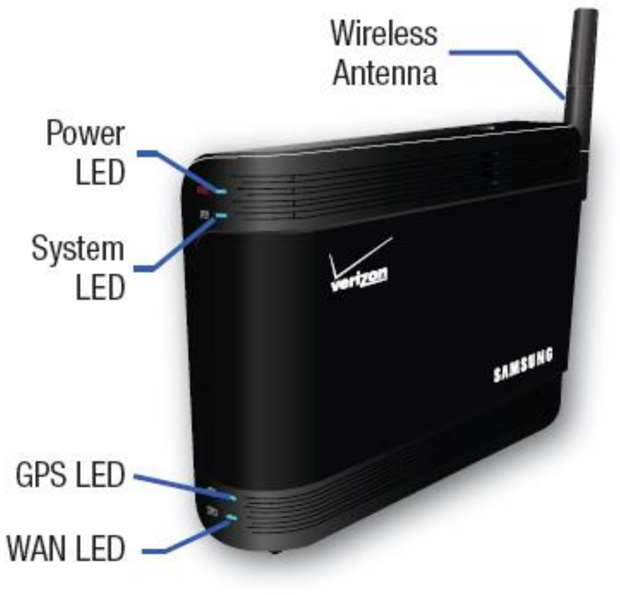

Figure 14. Small cells launched by Verizon.

Home users and small office/business owners' profits most from the small cell network deployment. As being close to the cell means much less power consumption by User Equipments which in turn, greatly prolongs battery life. Small cell users may also be offered by operators with discounted call rates or cheaper data-plans. Small cells that are deployed indoor can be configured in restricted/unrestricted mode. There are three possible access method configurations in small cells.

- Open Access: In open access configuration, any user can connect to the small cell network without any restriction. These cells are also called open Heterogeneous eNode-B (Open HeNB). This setup is suitable for public use cases such as shopping mall, stadium, bus stations etc.
- Closed Access: The closed access configured small cells allows only specific users to access to the small cell network. These cells are called Closed Heterogeneous eNode-B (Closed HeNB). This is suitable for private uses such as home/office users.
- Hybrid Access: In hybrid access configured small cells, unsubscribed can get access to the network. However, these unsubscribed users are restricted with a limit to resource usage. This setup is suitable for use cases such as coffee shop/restaurants, or academic buildings etc.

4.2 Small Cell Deployment Architecture

The operators need to specify the architecture for a small cell Base Station in order to provide connectivity to end-users with a smallcell. In general, a mobile phone user may connect to the core network by either connecting to the small cell, or macrocell. The small cells are connected to the core via RAN or through broadband cable. The macrocells are connected with the BBU pool and core through CPRI and backhaul connection. The small cells provide services to users that are stationary or less mobile. There are two kind of layout in heterogeneous network architecture, High Power Nodes (HPN) or macrocells, and small cells or RRH cellular layout. HPNs are deployed primarily for greater network coverage and control signalling. And the small cells ensure the enhanced network capacity and various QoS for end users.

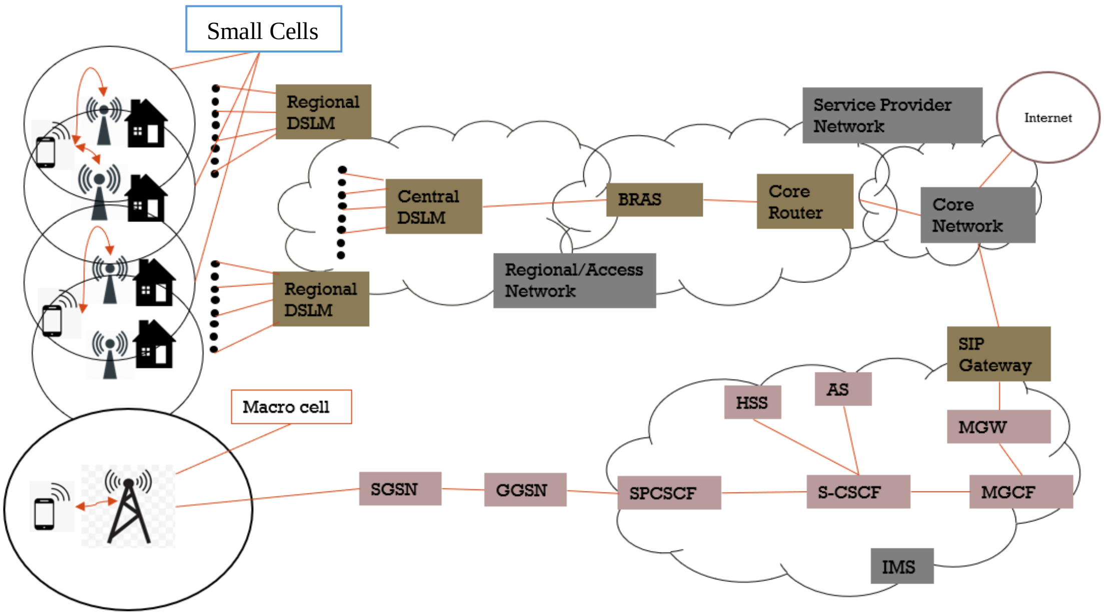

Figure 15. A general architecture for small cell deployment on current cellular architecture.

As shown in figure 15, small cells are designed in such a way so that user data traffic moves through the public internet while voice traffic passes through the IP Multimedia Subsystem (IMS) network. Figure 15 shows a Session Initiation Protocol (SIP) and IP Multimedia Subsystem (IMS) network based small cell structure. IMSs are used because they converted through the SIP gateway. After the IMS passes through Media Gateway (MGW) and Media Gateway Controller Function (MGCF), it is connected with Public Switched Telephone Network (PSTN). The architecture guarantees end-to-end QoS call flow connection in small cell network. It important to remember that IMS can be used only for voice connections. Since data traffic does not go through the IMS network, the small cell customers can enjoy various voice services at lower cost. Hence, in this architecture, users are able to get the best of voice communication by using IMS and SIP, and data service by using broadband connection.

The small cell integrated cellular architecture can be divided into two types:

- The Legacy Mode, where the small cells are connected to the Radio Access Network (RAN).
- The Flat Mode, where small cells are directly connected to the central network.

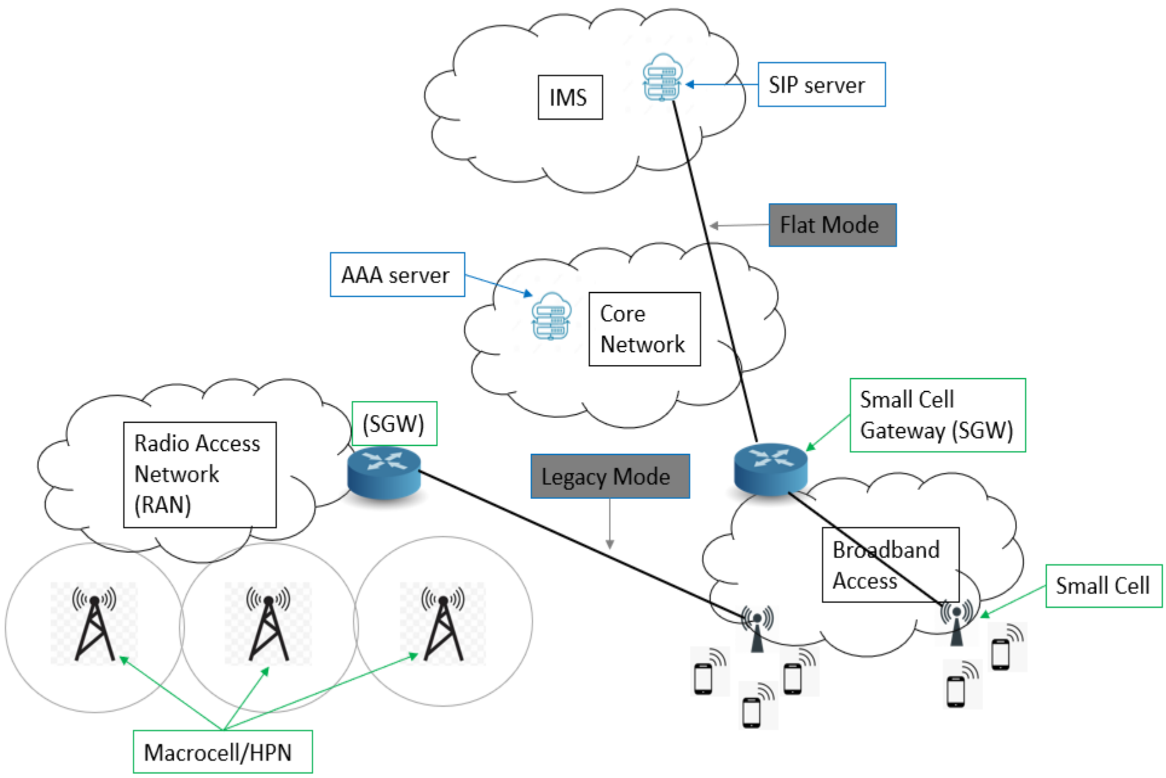

Figure 16. Two types of small cell integration.

Small-Cell Gateway (SGW) are used in small cell for security purpose, IPSec is enabled in it by default. The flat mode reduces load pressure on RAN. Small cell integrated 5G architecture based on broadband connection and macrocell layout are discussed on [13].

4.3 Workload Allocation Between Small Cells and Macrocell

Deployment of small cells is advantageous for Mobile Network Operators (MNOs), because they increase network coverage, capacity, scalability, data rate, spectral and energy efficiency. By deploying small cells at the edge of macrocell MNOs can provide better coverage, connectivity and improved network performance to end-users along with high data rates while reducing loads from macrocells. In a heterogeneous network, expending the network coverage or capacity is easy since control plane is decoupled from data plane, the MNOs only have to deploy new RRHs and connect them to the BBU pool.

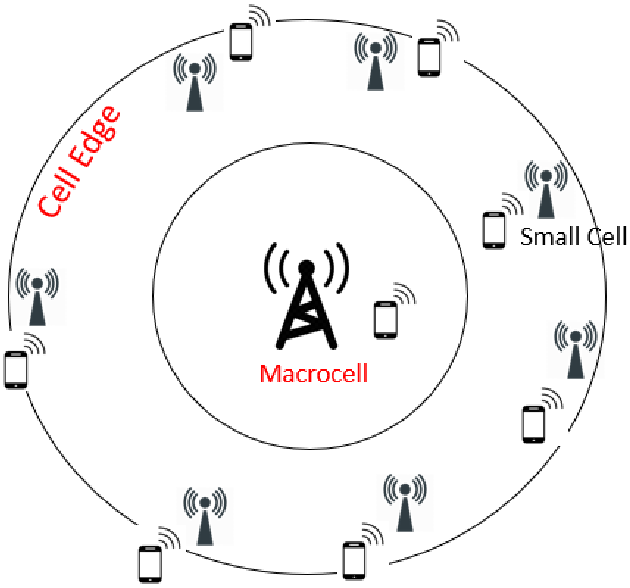

Figure 17. Deployment of Small Cells at Macrocell Edges.

In figure 17, macrocell region is divided into two regions, central region and edge region. At the central region, users can attain maximum quality cellular services while at the edge region the macrocell connection is poor and User Equipments (UEs) require more power to communicate with macrocell. This problem is solved by deploying small cells at the macrocell edges so that users can get maximum cellular services with minimum power consumption. These small cells work as independent cells but are integrated into macrocells. A cell needs to provide sub-channels to its users so that the users can communicate with that cell using the provided sub-channels. If two neighboring cells uses the same frequency for allocating sub-channels then interference will occur and in result, no users will be able to communicate with the cell because of the interference. Hence, comes the idea of frequency reuse. The frequency reuse method is adopted to eliminate neighboring cell frequency interference. In frequency reuse method, multiple adjacent cells in an area uses different frequency ranges so that frequency interference is at minimum. However, same frequency range can be used by multiple cells if they have significant distance from each other.

In HetNet, multiple small cells are connected to a Remote Radio Head (RRH) through fronthaul connection. Fronthaul connection may include fiber link or direct microwave link. The RRH is connected to a virtualized BBU pool via Common Public Radio Interface (CPRI) which is connected to backbone network via backhaul link.

We’ve proposed a cognitive method for inter-cell channel allocation between small cells and macrocell. The RRH that connects the small cells and macrocell allocates frequency-channels to each cell based on their user load and capacity. The total number of channels is divided into a number of small groups, each of these groups contains several numbers of sub-channels.

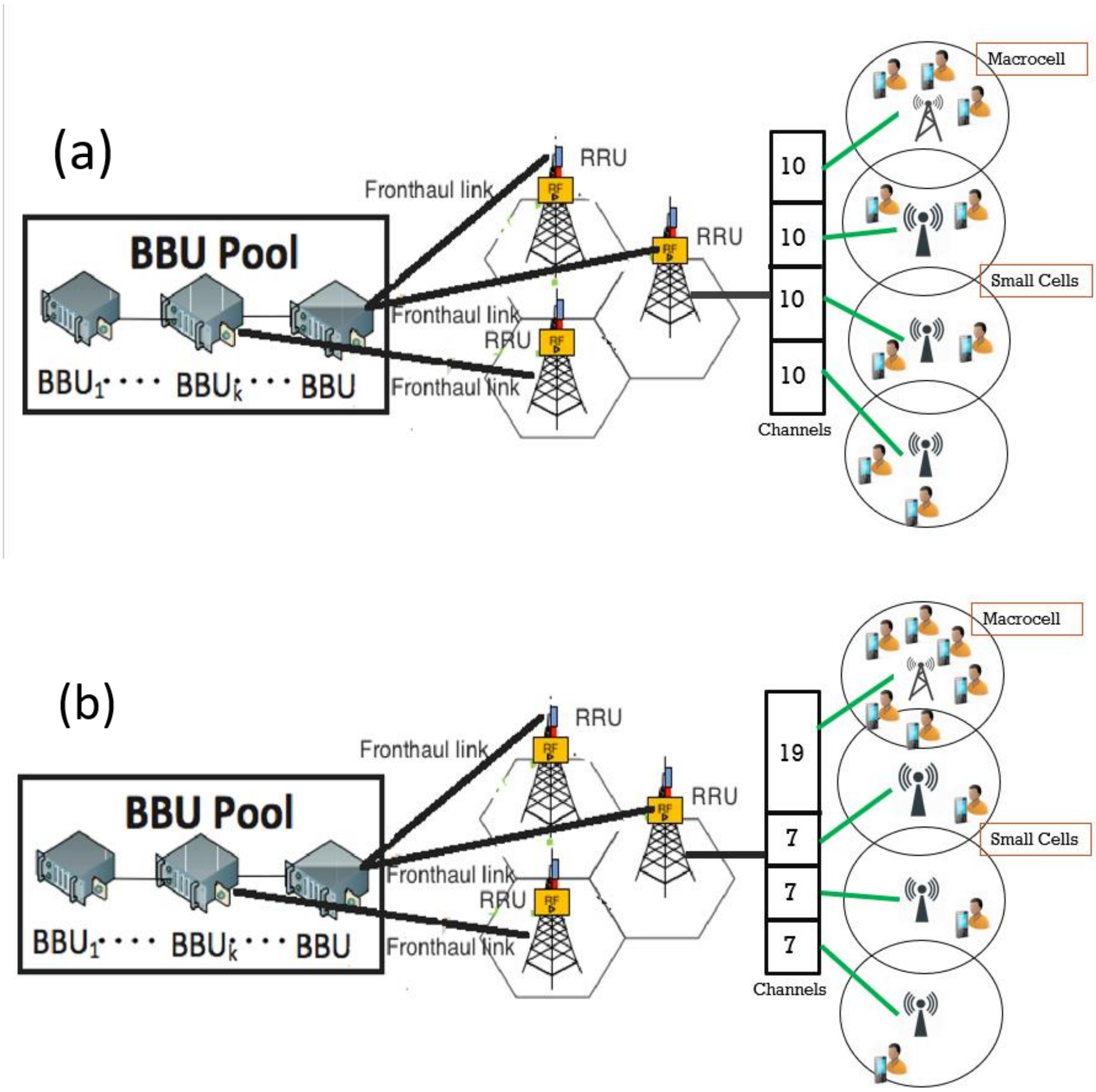

Figure 18. Cognitive channel allocation between small cells and macrocell.

The RRH has the ability of sensing user loads on different cells through Spectral Sensing Method. Then based on the requirement, the RRH can dynamically allocate channels to different cells based on their load. In figure 18(a), the RRH allocates channels to each connected cell based their user load. However, in figure 18(b), when RRH senses increased user load through spectrum sensing, it dynamically allocates more channels to that cell.

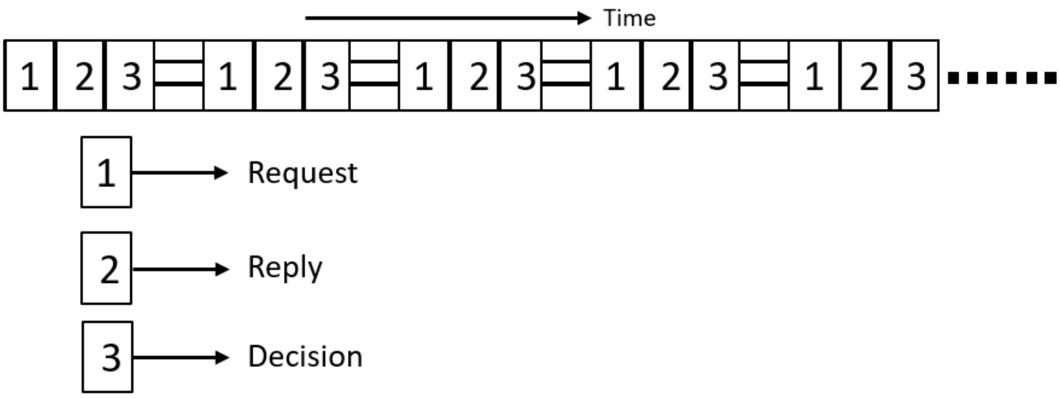

Figure 19. RRH spectrum sensing mode.

The process is done through request-reply process as shown in figure 19. After periodic times, the RRH sends a request enquiry to the cells. The cells reply with current user information. Then based on the reply, the RRH may change the number to allocated channels assigned to a cell.

Chapter 5

Simulation and Result

5.1 Experimental Description

In order to validate the proposed method, a simulation model is been developed and tested using INET 4.2 which is installed in OMNET++ 5.5.1. OMNeT++ itself is not a simulator of anything concrete, but rather provides infrastructure and tools for *writing* simulations. One of the fundamental ingredients of this infrastructure is a component architecture for simulation models. OMNeT++ simulations can be run under various user interfaces. Graphical, animating user interfaces are highly useful for demonstration and debugging purposes, and command-line user interfaces are best for batch execution.

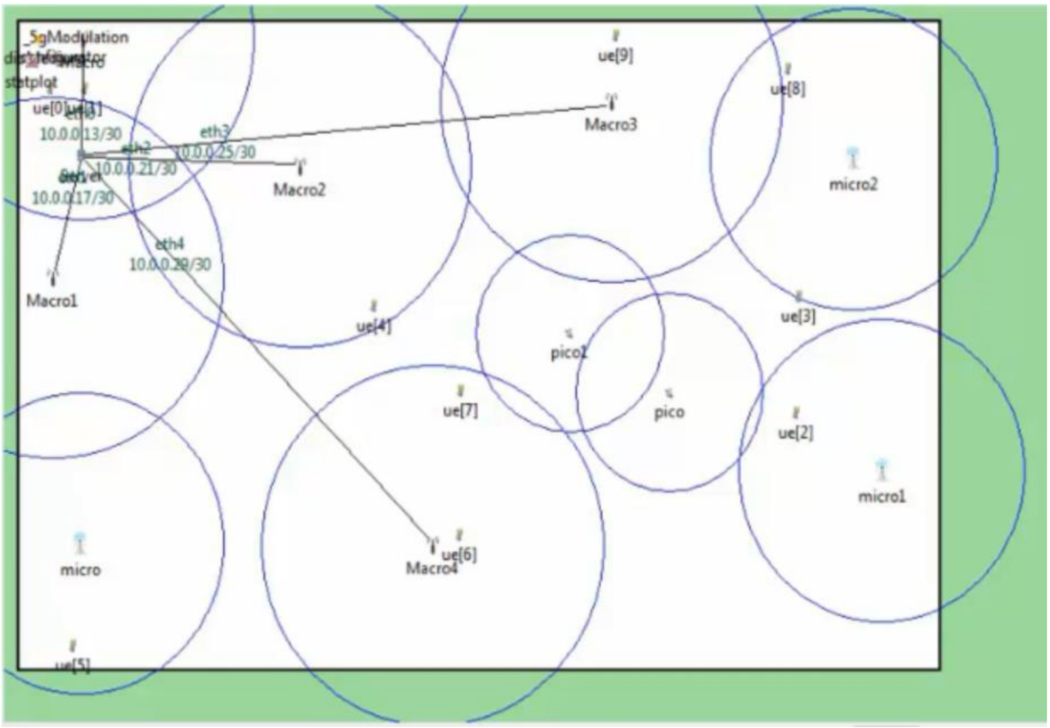

Figure 5.1: Topology Framework

Figure 5.1 illustrate the topology of the simulation model which is designed in INET 4.2. Two similar topology is been designed, where one topology denoted without the proposed method and another topology is been applied the proposed method. In these circumstances the simulation work entitled as proposed method and existing method. In this topology 5 macro, 3 micro and 2 pico cells are designed under 1 HCRAN for both topology. This simulation is been verified for both 24GHz and 60GHz frequency of 5G network.

5.2 Access Point Power (AP Power) Comparison:

Comparison between proposed and existing method in terms of Access Point Power (AP Power) is been illustrated in Figure 5.2 (a), (b). The X-axis denotes the Frequency in GHz whereas Y-axis denoted Average Peak power in mW. In existing method AP Power for 24GHz band is 380mW and 60GHz band is 480mW (in figure 5.2 (a)), whereas 580mW for 24GHz band and 600mW for 60GHz band (in figure 5.2 (b)) is found in proposed method.

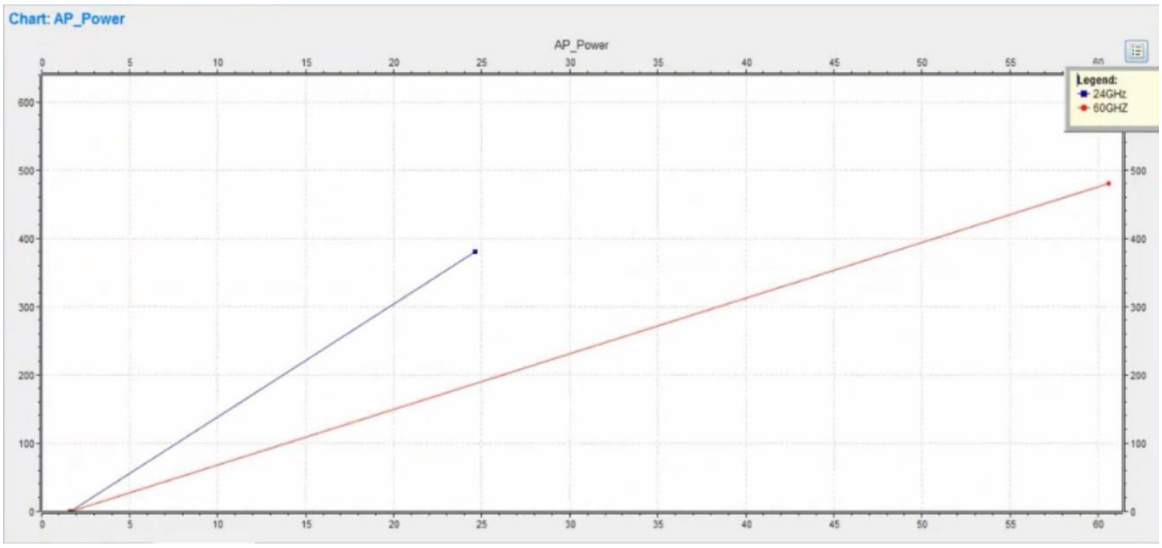

Figure 5.2 (a): AP Power (Existing Method)

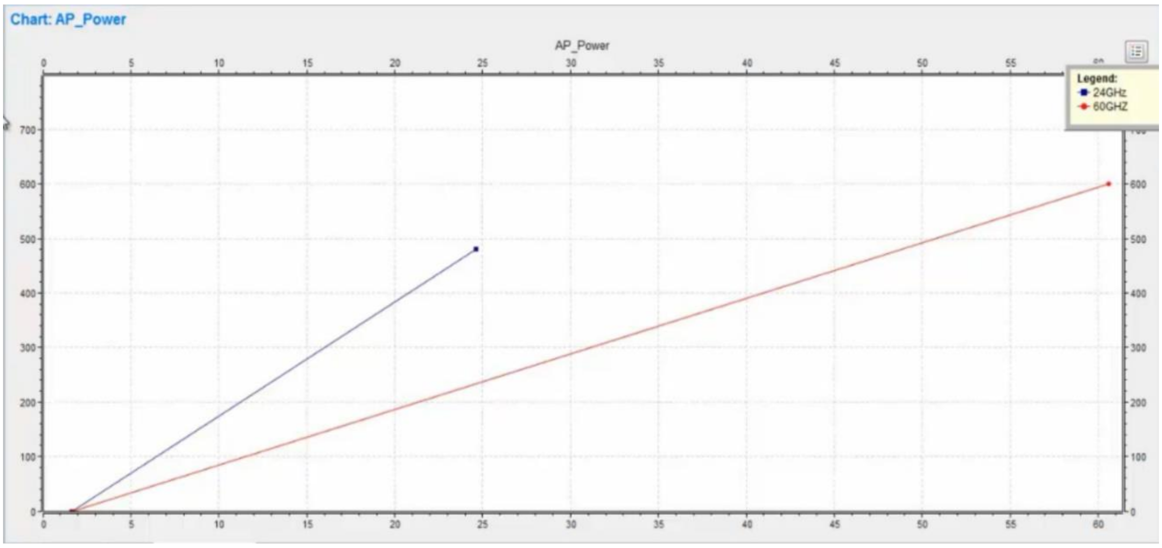

Figure 5.2 (b): AP Power (Proposed Method)

5.3 Diversity Gain Comparison:

Comparison between proposed and existing method in terms of Diversity Gain is been illustrated in Figure 5.3 (a), (b). The X-axis denotes the Frequency in GHz whereas Y-axis denoted Diversity Gain. In existing method Gain for 24GHz band is 8 and 60GHz band is 14 (in figure 5.3 (a)), whereas 12 for 24GHz band and 18 for 60GHz band (in figure 5.3 (b)) is found in proposed method.

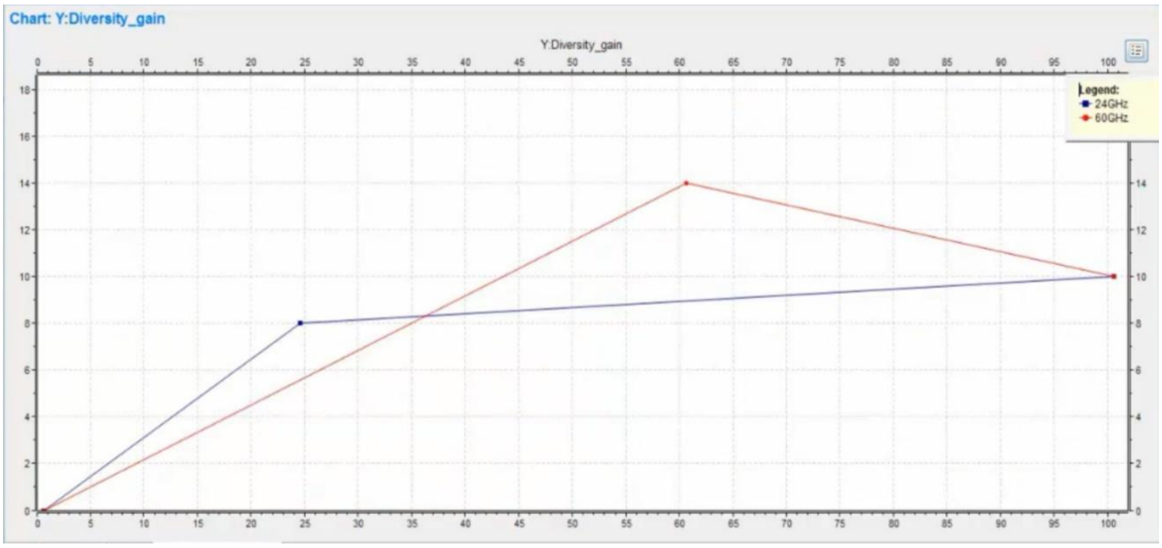

Figure 5.3(a): Diversity Gain (Existing Method)

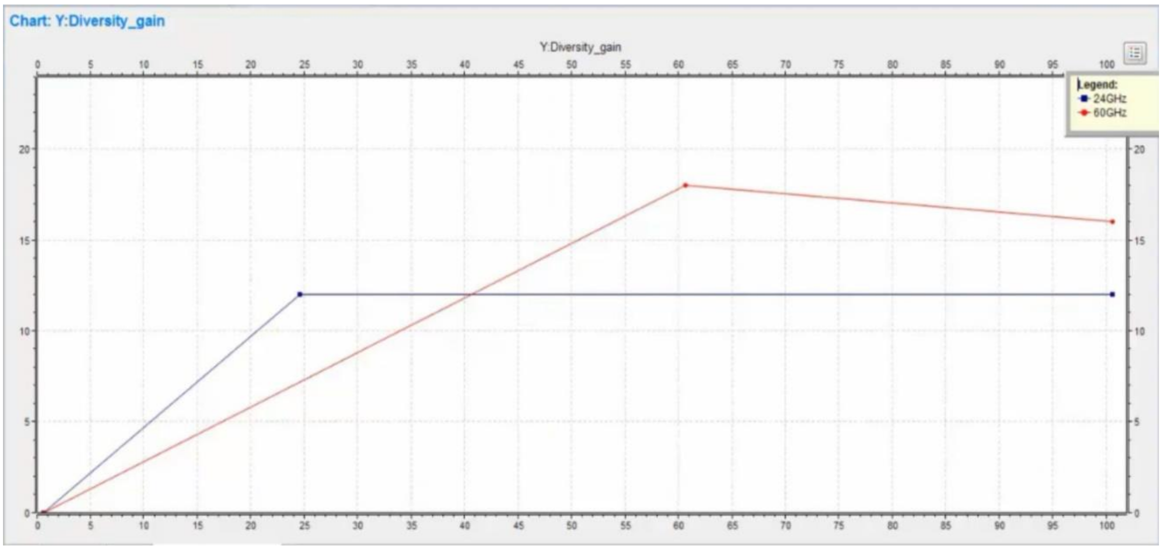

Figure 5.3(b): Diversity Gain (Proposed Method)

5.4 End to End Delay Comparison:

Comparison between proposed and existing method in terms of End to End (E2E) is been illustrated in Figure 5.4 (a), (b). The X-axis denotes the Frequency in GHz whereas Y-axis denoted E2E delay in ms. In existing method E2E delay for 24GHz band is 600 ms and 60GHz band is 1000 ms (in figure 5.4 (a)), whereas 300 ms for 24GHz band and 800 ms for 60GHz band (in figure 5.4 (b)) is found in proposed method.

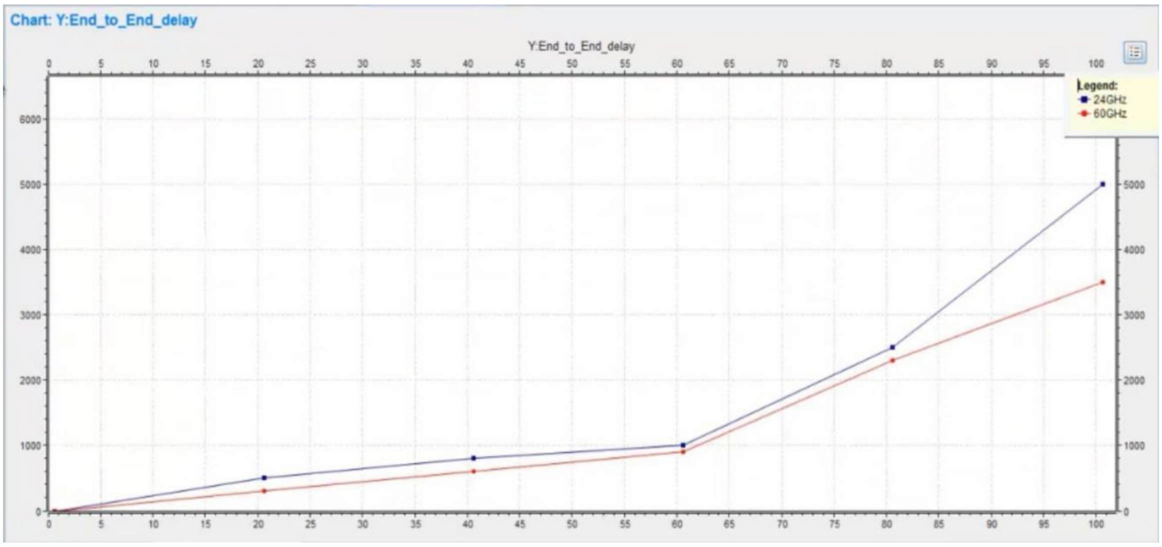

Figure 5.4(a): End to End delay (Existing Method)

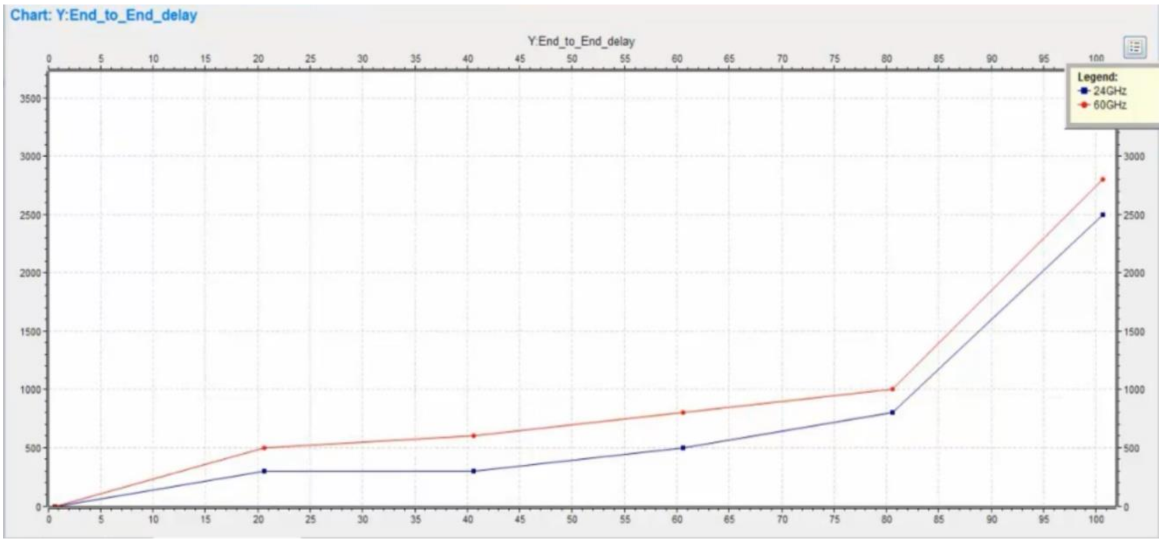

Figure 5.4(b): End to End delay (Proposed Method)

5.5 Summary:

	AP Power		**Diversity Gain**		**E2E Delay**	
	24GHz	**60GHz**	**24GHz**	**60GHz**	**24GHz**	**60GHz**
Existing Method	**380mW**	**480mW**	**8**	**14**	**600ms**	**1000ms**
Proposed Method	**480mW**	**600mW**	**12**	**18**	**300ms**	**800ms**

Chapter 6

Conclusion

6.1 Conclusion

In this research work, a noble approach in order to make the workload distribution between small cell and microcell of the HC-RAN is been proposed. Radio Access Network (RAN) is one of the most prominent part of 5GPP. This proposal is been verified and validated by the simulation work using INET 4.2 under OMNET++ 5.5.1. The results are verified in terms of Access Point Power, Diversity Gain and End to End delay. The simulated results shows that proposed method perform better if it is applied in the existing method.

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