Proceedings of the Pakistan Academy of Sciences: A. Physical and Computational Sciences 55 (3): 11–20 (2018)

ISSN: 2518-4245 (print), 2518-4253 (online)

Pakistan Academy of Sciences

Research Article

5G – The Expectations and Enablers

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Abstract: 5G the fifth generation of mobile communication technology relies on a new network architecture that will be used to overcome the challenges faced in 4G technology. The current 4G Network architecture is unable to cater the increasing data traffic demand with very low latency rate. It is also not able to provide 100% network coverage. 5G technology will enable mobile users to experience the network with almost 100X better network capacity and coverage, very low latency and increased data traffic rates with new multiple radio access technology, improved radio network optimization and resource sharing. This paper provides an overview of key technology enablers that are imperative to ensure the promises of 5G.

Keywords: 5G mobile communication, Wireless communications, Massive MIMO, Heterogeneous networks.

1. INTRODUCTION

While the time is passing at the fastest stride, the newly introduced technologies in recent era have driven a developing consensus that information technologies are affecting the way humans live, work, connect, and establish the routine life together with the working culture [1]. Numerous technologies have modernized the lifestyle of humans in the past decades. The technologies including the manual hand tools, mechanical devices, powered machineries, and automated robotic maneuvers have indeed made the standard of living much on ease. However, among these developments, wireless communications stand out as vital contribution in the global transformation [2]. As the telecom network is evolving rapidly due to the rising needs of data rates, capacity and bandwidth, the continuous evolution in number of customers and data traffic is also increasing worldwide. Considering all this, 5G network is designed to provide splendid features including, high data rates, high capacity, compatibility with different data types, support of third-party applications energy efficient and flexible to spectrum utilization.

Small cells have turned 5G to be one of the feasible options to cater the increased traffic, i.e. inclusion of small cells leads to the increased capacity [3, 4]. Thus, the future deployment of wireless mobile networks includes small cells in conjunction with traditional macro-cells to increase the capacity and coverage in future generation networks. To Cope with the random deployment of small cells into the heterogeneous network architecture, dynamic on-off of cells and flat system architecture have been proposed [5, 6]. These requirements pose many challenges for the wireless communication industry to comply with the requirements of future mobile users.

IoT is another main segment for 5G networks and it will be prerequisite for industry 4.0 [7]. Industrial IoT (IIoT) [8] is envisioned to work in a way that the data is obtained from sensors and feedback systems and automatically transferred to cloud-based data centers for processing and ultimately updating the configuration of industry system based on the result of processed data. Wireless sensor networks are the core part of IIoT and a research area is focused for virtual WSN to bring the discussed advantages of virtualization in IIoT.

Received: August 2016; Accepted: September 2018
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The emerging 5G wireless standard is expected to provide great advancements to the society and consumers. The benefits of the 5G technology include lower battery consumption, multiple paths for duplex data transmissions, data of multiple Gbps, software defined processing, greater system level spectral efficiency, no harming effects for human health, intelligent wearable devices cheaper charges as a result to less costs in infrastructure development, antenna systems with smart beams, and many more [9,10]. 5G is predicted to connect the globe as never before, using a communication infrastructure with ultra-reliable links, much lower latencies, massive traffic, instant information and greater spectrum [11]. The major developments that 5G will bring using various techniques are described in the Table 1 [12].

Thus, the key enabling technologies of 5G will include network cooperation along with a greater interference mitigation among the neighboring cells, massive MIMO, context awareness, both transmission and reception at the same time and use of various technologies to provide high speed connections that were never expected before [13].

This paper aims to address the expectations from 5G and the key enablers of 5G technology. The paper is organized as follows: Section 1 Introduction about 5G. Section 2 explains the enablers of 5G networks in terms of requirements of 5G technology, architecture of 5G networks, details of network challenges in 5G, and explicates the network slicing in 5G technology; the section 3 finally concludes the paper.

2. ENABLERS OF 5G NETWORKS

The requirement of upcoming 5G mobile networks is to achieve a higher spectral efficiency. The three major factors that may lead to higher spectral efficiency are: Interference reduction, addition of small cells to densify the network and massive multiple-input multiple-output (MIMO), which refers to a great increase in the number of antennas at base stations as well as the mobile stations [2]. The fifth generation of Mobile networks is anticipated to provide a better area spectral and energy efficiency alongside improved and uniform user experience. Moreover, a peak data rate of more than 10Gb/s is predicted [14]. A capacity growth through network densification comes with a great challenge of severe inter-cell interference [15]. In order to meet the network requirements of 5G, the networks over 5G slices, NFV and SDN technologies are broadly considered as the key enablers in network architecture and design. The trailing sections explain about these enablers.

2.1 Network Architecture for 5G

In a heterogeneous network scenario, the channel and traffic variations will be rapid and there is no central node to perform the radio resource allocation, thus the system architecture becomes flat. Thus, as a result of random deployment and flat system architecture, it is critical to develop efficient algorithms based on cooperation and self-organization networks for load distribution synchronization, inter-cell power control, and so on [3, 14]. Due to the challenge of random deployment,

Table 1. The Key aims of 5G and the methods to achieve them

The aims of 5G	Technologies to provide these developments
20 times increased data rate	Using Massive MIMO and Millimeter Wave Spectrum
A triple times spectral efficiency in the downlink	Device to Device Communication(D2D), full duplex systems and massive MIMO
Data processing increased to 100 times in a given radius	Using Radio-access network, D2D, small cells and Millimeter wavelength
Per square KM, about 900 000 more devices will be connected	Small cells and D2D
Increase the mobile devices speed from about 350km/h to 500km/h	Heterogeneous network architecture
Reduce the latency to one tenth	D2D, and content catching close to the users
Provide 100 times greater efficiency	Massive MIMO

dynamic on-off and flat system architecture, there is a need for cooperative algorithms that can enable random deployment and improve the performance in next generation hyper-dense small cell networks. The 5G networks is enabled through Network slicing technology which works with Network Function Virtualization (NFV) and Software Defined Networking. These technologies are briefly discussed in the following sections.

2.1.1 Network Slicing in 5G Technology

It is a concept in which a physical network allows to open several logical self-contained networks for the requirement of several specific services on its physical infrastructure. These network slices are given on lease for a specific period and the lessee has access to physical, service and virtualization layers of 5G networks and this concept integrate the network vertically. Using slicing concept different network services specific to requirement may be offered using virtual network functions using a single network infrastructure making it cost effective and using network efficiently [16]. As network slicing is a recent concept [17] so it needs to be standardized. 3GPP is working on requirement definition [18], and NGMN identified network sharing among slices as one of the key 5G issues [19]. A network slice is set of network function and resources required to run the function as per NGMN, it contains three layers:

i) Service instance layer, which represent the operator or 3rd party service provider
ii) Network slice instance provides network functions with the help of resource layer
iii) Resource layer contains physical resources such as computers, storage and memory etc.

Network slicing will make 5G network architecture more complex and challenging as different slices are deployed and managed at each level and data and traffic management will be more complex. To overcome these challenges some rules may be defined which are as follows:

i) Flexible and seamless management of resources (physical and virtual) across all three layers.
ii) End to end service management for each network slice.
iii) End-to-end programmable connectivity for each service.

Network function virtualization (NFV) and Software Defined Networking (SDN), are the key technologies that can overcome the above-mentioned requirements. NFV is designed to cater the flexibility and scalability requirements where SDN can make the networking requirement programmable in 5G networks. But there are still many challenges in making these two technologies deployable [20].

2.1.2 Software Defined Networking

SDN is used as a reference model for an extended version of SDN which is Software Defined Mobile Network (SDMN) and there are many integration issues in SDMN which needs to be discussed [21].

Architecture Issues: Since SDMN is an extension to SDN as SDMN will work in wireless domain which is more challenging due to complexity of mobile radio networks, Radio link reliability and quality is a challenge while designing SDMN.

Controller Placement: is an issue in addition to deciding the optimal number of controllers, as it will affect network performance [22]. Network controller optimal placement and optimal quantity van minimize the latency and improve the reliability and SDMN architecture will introduce additional constraints and requirements in the controller placement problem.

Cognitive radio integration to SDMN: Cognitive radio can monitor and dynamically reconfigure physical radio characteristics based on the environment variability and we can have centralized intelligence of network by integrating cognitive radio to SDMN [23].

Mobility Management: It ensures reliable data delivery without and disruptions while the user is moving. Future mobile networks will complicate things more as we can have extremely fast-moving users or apps (e.g. high speed trains) [24].

2.1.3 Network and function virtualization

In C-RAN BBU is shifted from physical to virtual machine, but virtual machine is using the same physical resource, there are following challenges that needs to be addressed to minimize overhead and improve performance:

2.1.3.1 Optimized Performance
Due to increase in overhead network performance is facing degradation. Some means needs to be explored to minimize latency and overhead.

2.1.3.2 Isolated Network
Virtual networks should be isolated from each other; this requirement in mobile networks is a major challenge due to the broadcast nature of wireless medium [25].

2.1.3.3 Resource Allocation
It is also a major challenge in wireless medium due to wide availability of spectrum, mobile nature of devices and separate uplink and downlink channel.

2.1.3.4 Slice Management
Network slices should be scalable as per requirement and dynamic nature of 5G network makes it a challenging task [26].

2.2. Enabling Interoperability to Deploy Flat Network for 5G

The current communication networks rely on the traditional IP based protocol stack, which cannot be completely isolated to attain flat architectures, however the cross-layer approach enables information exchange to attain the flat architecture since it allows direct access between all the layers.

The traditional OSI and TCP/IP support only upward approach because of physical and networks constraints. This causes difficulty in catering the downward user demands. Thus, there is a disagreement of opinion about the layered architectures suitability for the wireless access networks. A protocol which is designed by violating reference layered communication architecture is called cross-layer protocol.

A cross-layer design can help capture these concerns by arranging a uniform framework at different semantic levels. Moreover, the layered architecture makes the information dependent on other layers and may produce delays in the information exchange. On the contrary, the cross-layer approach allows different layers of protocol stack to communicate with each other directly. In this approach, one layer may access data from another, thus enabling information exchange between various layers. Hence, a cross-layer approach has a vital role in the next-generation of Mobile networks which are featured by IP-based protocol stack [27, 28, 29].

A further study at the University of Surrey has envisaged some important requirements for 5G architecture [30]. The primarily requirement of flat architecture is to provide distributed cloud based services and architecture flexibility on time. The architecture must also provide content centric networking and support Internet of Things and various kinds of nodes involved in these services. The network resources should be optimally used providing context aware networking to both user and network. A low latency must be achieved through direct interactions, supporting cloud computing and quick access to the nodes and devices associated with the Internet of Things. Flat network architecture is based on the distributed mobility management whereas the previous generations had been working on centralized mobility management. The section below provides a brief discussion on both types of network architectures to comprehend the transition from centralized to the distributed/flat network.

2.2.1 Flat Network architecture VS Centralized Mobility Management

The Mobile Network Operators (MNO's) are attracted towards complete IP-based networks to provide maximum capacity for voice data as well as video data. There are various standard mobility management protocols including MIPv6 and PMIPv6. These protocols are implemented through a central anchor node, and are known as Centralized Mobility Management (CMM) protocols. The problem with centralized mobility architecture is that they include single point of failure, they require redundant mobility functions and they suffer with traffic congestion [31, 32]. Therefore, a re-design of network architecture is required that must consider the following features:

i) Flexibility: The new architecture must enable the network to upgrade the software's, provide new services whenever required and allow variations in traffic management systems and strategies.

ii) Performance: The architecture should be scalable and should ease the traffic management

iii) Complexity: Must be simple and easy to deploy, implement and manage the costs [33].

The above concerns can be sought by the flat architecture that is based on distributed mobility management. The systems that are built on a centralized/hierarchical structure, connect multiple access networks to a central core. The important network functionalities such as controlling charging and managing traffic all take place at the mobility anchors. These problems may be solved by the Distributed Mobility Management (DMM) architecture, where the centralized anchor is removed [34]. Figure 1 depicts a typical CMM architecture.

2.2.2 Distributed Mobility Management

The purpose of DMM architecture is to realize such a network that communicates without a centralized entity. This allows the IP flows to be routed in a more flexible way. The key entities in a DMM are mobility-enabled access routers that are located at the edge of the operator's network, i.e. in the vicinity of the users, and they are enabled to communicate with the external IP networks. The Figure 2 provides a diagram of DMM approach [35]. A cloud based and virtualization concept new RAN architecture is being introduced that will minimize operators CAPEX and OPEX by minimizing the needs of base stations deployment requirement. [36, 37, 38]. Cloud computing will enable the user to access shared resources for computing and virtualization will enable the network to be programmable through SDN and all network functions to be virtualized through network function virtualization (NFV) [39, 40, 41, 42]. Cloud-RAN (C-RAN) can be deployed on the same infrastructure with reduced cost of deployment and also reduced OPEX [43, 44, 45]. The Technologies that Complement C-RAN include C-RAN, SDN, NFV, Network virtualization and slicing, and Common public radio interface CPRI [46].

2.3 The 5G Radio Perspective

The promise of higher data rates and anytime anywhere connectivity by 5G has to be kept while also knowing that the limited radio spectrum has to be fully and intelligently utilized to deliver the promise. The following subsections provide important discussion about 5G radio.

2.3.1 Massive MIMO Antenna

To provide Gigabits of speed to end users, it is imperative to use the massive MIMO antennas. Some of the drawbacks faced by this technology include: High costs, difficult installation in high-rise sights and very High Complexity.

2.3.2 Better Signal to Noise Ratio

5G systems also require better SNR to guarantee the quality of service. Some of the practical methods to achieve an improved SNR include: Cell densification through addition of micro, pico and femto cells, usage of steerable beam antennas and application of Interference reduction techniques.

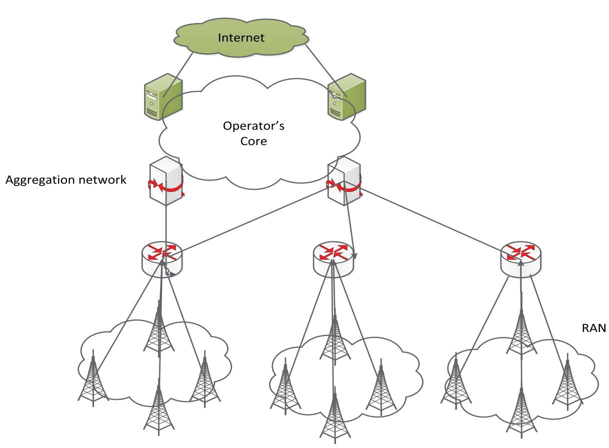

Fig. 1. Centralized Mobility Management Architecture

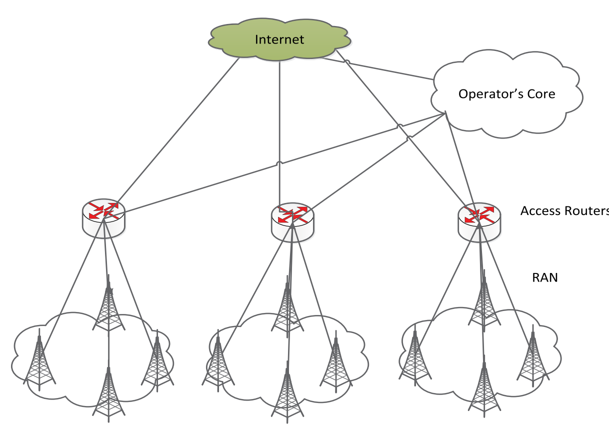

Fig. 2. Distributed Mobility Management Architecture/Flat Architecture

2.3.3 Spectrum for 5G

The spectrum scarcity of frequency bands currently utilized has resulted in discovery of new spectrum spaces that can be used to 5G. It is vital to identify the spectrum range that than enable the vision of 5G. The Millimeter wave spectrum is being considered for communication. It has the range of frequencies starting at 30 GHz to 300 GHz and correspondingly have a wavelength between 10 mm and 1 mm. Millimeter-wave bands offer substantially wider bandwidth and Provide dramatically higher data capacity than the current cellular bands. Thus, they are suitable to equip the 5G systems with the core requirements. The initial experimentation on 28GHz frequency has acceded that these frequencies can be used for 5G coverage. However, the initial stage of 5G deployment is believed to start with 3300-4200 MHz, 4400-5000 MHz and 700 MHz. These bands are particularly suitable for machine type applications in 5G. Whereas, the usage of higher mmWave frequencies with an extensive RF range is anticipated to help global ecosystems and deployments below building rooftops in urban/ suburban environments with directional beams towards targeted coverage areas [47, 48, 49, 50].

2.3.4 Capacity VS Spectrum Crunch

The ever-growing demand in network capacity is inevitable due to increasing user demands and inventions of vast range of mobile applications. However, the dilemma is that there is only a fixed amount of spectrum that may be used by wireless communications. The section *1)* give details on the developments and concerns regarding network capacity and followed by that, section *2)* describes the problem of having fixed spectrum availability and proposes few potential solutions.

2.3.5 Network Capacity

During recent years, a sudden shift of mobile subscribers to the smart phone devices has resulted in a great increase of mobile data usage. Subscribers need high speed connectivity at every instant and location. A well-known quote by Plato is that, necessity is the mother of invention. This applies to the network capacity too. Cooper's Law establishes that "Capacity has doubled every two-and-a-half year for last 104 years. This has resulted in a cumulative improvement of spectrum utilization to one million times! Thus, it may be inferred that the need for mobile data have led to the significant increase in the wireless network capacity, which is witnessed today. There are various reasons that have directed towards this development. Some of the reasons include: increase in the number of wireless nodes, increased use of radio spectrum and improvement in the link efficiency [15]. Fig.3 shows the rate of improvement in the spectrum utilization, owing to various technological techniques during past 45 years [51].

According to Fig.3, a five times increase is experienced because of using various frequency division schemes as well as modulations and spread spectrum techniques. A 25x rise is a result of being able to use greater amount of spectrum. Finally, a huge increase of 1600x is obtained by spectrum re-use, which is achieved using small cells.

2.3.6 Addition of Small Cells

In order to support 1000 times mobile data traffic increases by 2020, the new generation 5G network technologies are under development to provide high data rates and increased network capacity. A number of industry activities and organizations have been established to define and develop 5G standards, one of the solutions to cater the need higher capacity and network densification is the deployment of small cells. Small cell for residential is saturated but keep growth for enterprise and public area scenario and the main purpose is shifted from coverage extension to capacity improvement.

In future it is anticipated that the small cells such as micro cells, picocells and femtocells will be compactly integrated to the macrocell networks creating cooperation based heterogeneous networks. Deployment of such access points provides additional benefits other than providing extra capacity to the current marcrocell infrastructure. They have lower transmitter powers. Further, the co-ordination with the small cells is quicker for the reason that they are mostly not directly linked to the macro base stations. The mobile operators have also been attracted towards small cells to improve indoor and local area system capacity along with service coverage [52]. However, reception of high power macrocells yields most of user devices staying connected to them, which results in the under-

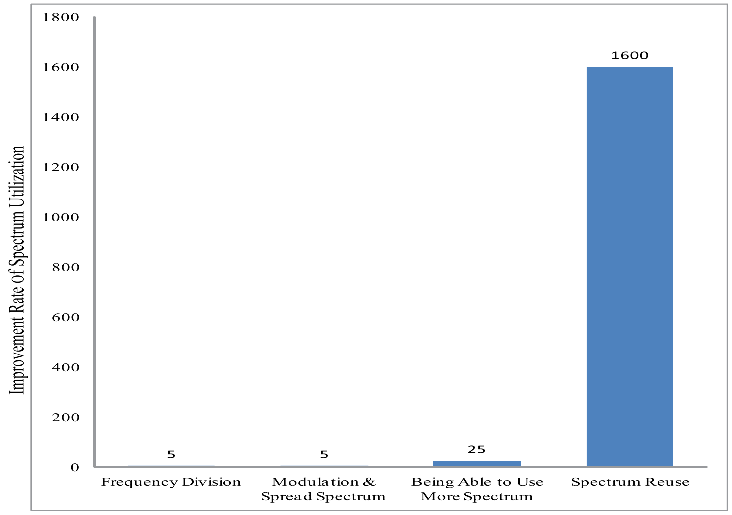

Fig. 3. Rate of improvement in the spectrum utilization in last 45 years

utilization of small cells

2.3.7 Carrier Aggregation

To increase capacity carrier aggregation is the key factor for doing this, some types of carrier aggregation include LTE and WiFi aggregation, LTE and licensed and unlicensed bands.

2.3.8 Multi-cell Coordination

The resource and management allocation will be a challenge in densely deploying small cell for 5G network. Multi cell joint transmission, channel prediction technique, channel reciprocity, channel state info feedback scheme, multi cell synchronization are the challenges [53]. Multi cell will require multiple antennas, distributed antenna or massive antenna arrays, for this some kind of pre-coding or post-coding techniques will be required to manage antenna beams. For switching of transmission modes adaptive algorithm will be required. This multi-cell coordination also known as network MIMO will play a key factor in 5G network.

Spectrum efficiency can improve the system capacity by using massive MIMO i.e. by deploying large number of antennas which will serve more users in parallel with low interference. Higher order modulation scheme and new multiple access schemes will be required to increase system capacity.

It is suggested by most of the researchers and from the statistics that the key method to achieve requirements of 5G networks will be network densification. However, serious concerns have been raised on the limit of densification of wireless network in [54]. It is argued that there are some fundamental limits to the amount of densification that may be done to increase network capacity.

3. CONCLUSION

It is expected that cellular communications industry will facilitate multiples of user demands expected in coming decades. This work has explored the methods that are expected to provide a platform for competing with the needs of fifth generation of mobile networks. As discussed in preceding sections, the emerging 5G wireless standard is expected to provide great advancements to the society and consumers. The benefits of the 5G technology include lower battery consumption, multiple paths for duplex data transmissions, data of multiple Gbps, software defined processing, greater system level spectral efficiency, no harming effects for human health, intelligent wearable devices cheaper charges as a result to less costs in infrastructure development, antenna systems with smart beams, and many more. The challenges faced by the wireless industry currently have also been explored in this work. To achieve a higher spectral with affordable complexity, some of the solutions have been envisaged. These include advanced interference mitigation techniques, massive MIMO and network densification. It is observed that a diversity of methods has been suggested and will be deployed to increase the many-fold network capacity. In the light of discussion carried out in preceding sections, it is concluded that 5G although is a very heavy investment but it opens many prospects for the betterment of the society, may it be any social class, the people can take advantage of automated facilities, given that the government and industries collaborate to provide these services to the public at easily affordable rates for all social categories including the upper, middle and lower classes.

The current architecture will be modified extensively as the need for high speed data traffic and low latency mobile network is arising and with the advent of 5G concepts such as SDN and NFV as well as advancements in optical and wireless technologies are shaping the way mobile networks are designed and deployed, ultimately enabling operators to provide more diverse, flexible, and cost-effective services to users.

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