5G: Challenges & Research

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***Abstract –***By 2020 the future mobile technology 5G is expected to be operational with some prime objectives such as increased capacity, improved data rate, lower latency, and better quality of service. To fulfil these demands, drastic and major improvements need to be made in cellular network architecture and the technology. It is important to understand the direction of research and developments which will be helpful in enabling 5G technology. This paper throws light on the challenges toward 5G provides few such developments such as network architecture, massive multiple input multiple output (MIMO) technology, and device-to-device (D2D) communication, millimetre wave solutions, cloud technologies for 5G radio access networks and software defined networks.

***Keywords- 5G, D2D, MIMO, mm – wave, SDN, Cloud, C-RAN.***

**INTRODUCTION**

We have seen the continuous and rapid growth in the evolution of the cellular network generations from 1G to 4G.It is expected that this digital world will have more than 50 billion connected devices by the end of the year 2020 [1], which would tremendously increase data traffic. Also there is tremendous demand for better quality of experience (QoE) and for high data rate. This encourages the development of future generation 5G mobile communication networks.

5G must address six challenges, not effectively addressed by earlier generation of mobile (4G) namely Ubiquitous connectivity, high capacity, high data rate, low End to End latency, connectivity support for massive device, reduced cost and consistent and better Quality of Experience provisioning [2],[3]. A few more expected features of 5G networks compared to the fourth generation (4G) networks, are as below [4, 5, 6]: (i) 10-100 times morenumber of connected devices, (ii) 1000 timeshigher volume of mobile data per area, (iii) 10-100 *times* higher data rate, (iv) latency of 1 millisecond (v) 99.99% availability, (vi) 100% coverage, (vii) *1/*10 energy consumption than the year 2010, (viii) real-time information processing and transmission, (ix) *5 times less*  network management operation expenses, and (x) seamless integration of the current wireless

technologies. In this paper, the key challenges encountered by future 5G wireless communication along with some technological directions that can be considered to fulfil these challenges are discussed.

CHALLENGES IN MIGRATION FROM 4G [7]

*A. User terminals with multi mode*

There is a need to design a mobile terminal that can operate in different wireless networks and overcome the design issues such as size of the device, its cost and power utilization.

*B. Selection of appropriate wireless systems.*

Every wireless system has its own distinctive characteristics and specific roles. Selecting appropriate technology for a specific service at right place & right time for better QoS (Quality of Service) requirements.

*C. Security*

Protection mechanisms for the data & content should be adaptive, easy to maintain & configure and lightweight. Also protection from jamming & snooping is necessary with the increase in mobile devices and cyber crime rate. Encryption must be strong.

*D. Network infrastructure*

Integration of non-IP and IP-based systems and

providing better QoS assurance .

*E. Billing*

Handling and storing consumer account information for proper billing is an important and difficult task.

*F. Attacks on Application Level*

Every now and then Software applications which offer an new feature are been targeted and commence new bugs.

**Developments toward 5G technologies**

Many technologies and schemes, such as modulation techniques, radio access techniques, or distributed computing, could be reused in 5G. With few alterations in some old technologies together with many other newly developed and evolved solutions will help to

fulfill the goals and overcome the challenges of future 5G communication network.

4.1. Millimeter wave communication & MIMO

Radio waves enables to cellular network communication. 5G use new spectrum above 6GHz so as to achieve very high data rates, low latency, energy efficiency, ultra- high reliability[8]. There is a substantial amount of spectrum available at very high frequencies, but the engineering challenges are also intense as this spectrum is vulnerable to shadowing effect. If line-of-sight link between the access point and the user device is not there, then the connectivity becomes zero – unless you have a reflection off a very flat wall nearby.

The current cellular licensed carrier is from the 750 MHz to 2600 MHz this spectrum is saturated now. Hence, the design of the under-utilized physical layers of the mm-wave spectrum is required. In addition, massive MIMO, beam forming, traffic offloading on to unlicensed spectra and cloudification of radio resources will provide faster data transfer and guaranteed availability.[9].

**MIMO is a scalable technology i.e. any number of BS antenna’s can be employed.** Massive MIMO can have arrays with dozens or 100 antennas. Simultaneously large number of users are served. It gives high spectral efficiency, high reliability and high energy efficiency. Directivity of massive MIMO helps to reduce mm- wave attenuation, multipath and multiuser interface. In turn mm waves helps to reduces the size of antenna array for MIMO. Due to size and weight they would be more likely, on the side of a building than on a cell tower.

4.2. Modulation technique better than OFDM

Spectral efficiency depends mainly on the multiple access technique and modulation scheme used. Orthogonal frequency division multiplexing (OFDM) and orthogonal frequency division multiple access (OFDMA) are used as the modulation scheme and multiple access strategy in LTE-Advanced (4G). OFDM’s applicability on wide band mm-wave with the required hardware setup is not certain. FBMC is robust to intrinsic asynchronicity between a transmitter and a receiver. The currently four waveforms, for 5G provide an efficient air-interface that is no longer dependent on stringent like orthogonality and synchronization requirements are GFDM, UFMC, FBMC, and BFDM.

4.3. Architecture

The 5G wireless cellular network architecture consists of two logical layers: a radio network and a network cloud. Radio network consist of different types

of components which perform different functions .. 5G is expected to have a well-connected core network and RAN. The backbone network may shift from optic fiber to mm-wave wireless connectivity, and the interconnected base stations. 5G should have an increase in the capacity of RAN, and should also an evolved core network, which is scalable, intelligent, easy to install and maintain, and low in cost. Recent development in cloud-based networking has opened new horizon of possibilities for virtualized core networks.[9] Hence a totally new application of cloud services, namely RAN deployment is the important element of 5G communication network which has sustainability and energy efficiency.

The main concept of the cloud-based RAN is to keep the RAN capacity in a centralized server and making it available on demand to the customer. In short, Cloud-RAN implement radio access network function in software and deploy them in the cloud. To achieve this, the base stations needs to be segregated into two parts, a radio access unit and baseband unit. There is a need to create a reserve pool of the baseband unit which will satisfy any cell that experiences high traffic. To reduce energy consumption, low power small cells should be deployed and the reserved capacity is made available to the cell that needs it in case of a sudden surge in traffic. The computational power requirement and energy efficiency will be further optimized with the availability of new cloud computing platforms and the development in data-center servers. Not only the RAN but also the core and backbone network may be virtualized

Along with C-RAN , two more concepts are thought to be part of 5G communication network development and they are SDN ( Software Define Network) and NFV (Network Function Virtualization) [SDN](https://www.sdxcentral.com/sdn/definitions/what-the-definition-of-software-defined-networking-sdn/) Separates the network’s control plane and forwarding planes and provides a centralized view of the distributed network so as to achieve more efficient orchestration and automation of network services. But this intelligence centralization technique has few drawbacks in terms of security, scalability and elasticity  and these are the main issue of SDN which needs to be considered. Whereas, [NFV](https://www.sdxcentral.com/nfv/definitions/whats-network-functions-virtualization-nfv/) has more focus on optimizing the network services. It decouples the network functions, such as DNS, router, firewall, caching, etc., from usual hardware appliances, so that these functions can run in software. These software packages can be then deployed and connected to cloud and accelerate the service innovation and provisioning, particularly within service provider environments. The network function virtualization (NFV) cloud consists of a User plane entity (UPE) and a Control plane entity (CPE) that perform functionalities those related to the User and Control plane, respectively.

4.4. Energy efficiency

Energy consumption is one of the major concern in the deployment of new networks in large scale. Currently, more than 0.5% of the world’s total energy is been consumed by the mobile networks. Therefore, one of the major aspects of 5G development is reduction in energy requirements for the environmental needs and also from the network maintenance perspective.

Tombaz and Sung [10] had made it clear that a network which is dense due to reduction in the size of cell has unavoidable network energy requirements. As the network will have a greater number of smaller cells, the major energy consumption component will be the idling and backhauling power. A 5G communication network framework with software defined MAC and network functional virtualization can be deployed. By integrating these solutions, a low latency and energy efficient 5G network can be deployed. In their research , they agreed that the logical separation of the control and data planes is a potential solution toward an energy efficient and flexible 5G architecture.

4.5. Protocol stack

Table 1: 5G Protocol stack [11]

|  |  |
| --- | --- |
| Application Layer | Application  ( Services ) |
| Presentation Layer |
| Session Layer | Open Transport Protocol  (OTP) |
| Transport Layer |
| Network Layer | Upper network layer |
| Lower network Layer |
| Data Link Layer | Open Wireless Architecture  (OWA) |
| Physical Layer |

Any communication system to performs well needs basis of a layered protocol stack. Gohil et al. [11], presented the general protocol stack for 5G end-to end mobile communication. The stack has provision for compatibility with other open source protocols. The physical layer & data link layer are combined and called as Open Wireless Architecture. While the Session and Transport layers are combined to the Open Transport protocol (OTP), which can be downloaded by any user equipment when required. User equipment may be connected to more than one base station (in fact, base stations may belong to different networks).The Network layer is divided into two where the Upper Network layer is for mobile terminal and the Lower Network Layer is for each interface. Also the Application and Presentation layer are included in one single Application Layer.

4.6. *D2D Communication* proximity services

Peer to Peer or direct device to device communication (D2D) eliminates IP based or Base station oriented connectivity. For increasing the cell capacity and for offering various proximity services D2D connectivity is essential in any cellular system. 3GPP itself has standardized LTE-Direct (LTE-D) which allows the discovery of “always-on” devices in a proximity of 500 m in an energy efficient and secured manner by using a licensed spectrum. Wi-Fi or Bluetooth technologies are the P2P proximity communication protocols which are widely used, but the energy consumption is an issue for them.

D2D communication in mm-wave is needed for 5G to reduce the traffic burden. Mm-wave D2D communication was presented in [12] where capable mobile devices were equipped with electronically steerable antennae and beam-forming technology. By virtue of highly directive antennae and beam forming technology, concurrent transmission among D2D users and the base station will not create much interference.

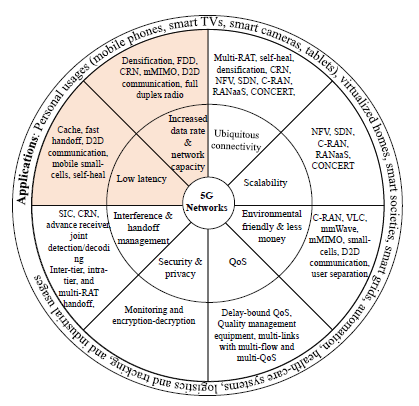
An overview of challenges, facilitators, and corresponding design fundamentals for 5G is shown below 

Figure 1: Requirements and proposed solutions for the development of 5G networks [13].

From the above figure we can see that the inner, middle, and outermost layers present requirements, solutions, and applications of 5G networks, respectively. Primary features of 5G networks is highlighted with two colored wedges [8].

**CONCLUSION**

This paper surveyed future 5G technology for mobile communication. The salient features (high speed, data transfer and ubiquitous connectivity, reliability), requirements, applications, and challenges involved in the development of 5G cellular mobile communication are discussed. 5G network technology will start a novel age in mobile communication. Device-to-Device (D2D) communication, and cloud-based radio access networks are been discussed. Along with the development of new architectures , other issues like interference , handoff management, QoS guarantee, channel accessing, and load balancing also needs to be focused on .

The design of 5G infrastructure is still under progress. The most prominent issues are enlisted below, which if resolved would contribute in early deployment and long run growth of 5G networks.

1. Huge number of devices will demand for better encryption, security and privacy of devices, infrastructures, communication, and data transfer.

2.The algorithms must be self-healing, self-configuring, and self-optimizing to preform dynamic operations such as dynamic load balancing, QoS guarantee, traffic management, and pooling of residual resources.

3. With C-RANs virtualization, backhaul data transfer,

inter-cloud communication, ubiquitous service guarantee, security and real-time performance guarantee with zero-latency are big question

4. The design, development, and usage of user devices, service-application models, and, especially, the network devices must be affordable to cater the needs of overwhelming users, service providers, and network providers.

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