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EVOLUTION OF 5G TECHNOLOGY FOR MODERN WIRELESS COMMUNICATION

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Abstract- The global bandwidth shortage facing wireless carriers has motivated the exploration of the underutilized millimeter wave (mm-wave) frequency spectrum for future broadband cellular communication networks. Beyond 4G, some of the prime objectives or demands that need to be addressed are increased capacity, improved data rate, decrease latency, better quality of service. There is, however, little knowledge about cellular mm-wave propagation in densely populated environments. Considering this information is vital for the design and operation of future fifth generation cellular networks that use the mm-wave spectrum. This paper presents the motivation for new mm-wave cellular systems, methodology, and hardware measurements and also used for implementing the new 3D printing technology for designing.

keywords- 5G, mm-wave, D2D, MIMO, C-RAN, HetNets, 3D Printing.

I.Introduction

Today and in the recent future, to fulfill the presumptions and challenges the wireless based networks of today will have to advance in various ways. Recent technology constituent like high-speed packet access (HSPA) and long-term evolution (LTE) will be launched as a segment of the advancement of current wireless based technologies. Nevertheless, auxiliary components may also constitute future new wireless based technologies, which may adjunct, the evolved technologies. Specimens of these new technology components are different ways of accessing spectrum and considerably higher frequency ranges, the instigation of massive antenna configurations, direct device-to-device communication, and ultra-dense deployments [1].

Since its initiation in the late 1970s, mobile wireless communication has come across from analog voice calls to current modern technologies adept of providing high quality mobile broadband services with end-user data rates of several megabits per second over wide areas and tens, or even hundreds, of megabits per second locally. The extensive improvements in terms of potentiality of mobile communication networks, along with the initiation of new types of mobile devices such as smart phones and tablets have produced an eruption of new applications, which will be used in cases for mobile connectivity and a resultant exponential growth in network traffic. This paper presents our view on the future of wireless communication for 2020 and beyond. In this we describe the key challenges that will be encountered by future wireless communication while enabling the networked society. Along with this, some technology routes that may be taken to fulfill these challenges [1].

The imagination of our future is a networked society with unbounded access to information and sharing of data that is accessible everywhere and every time for everyone and everything. To realize this imagination, new technology components need to be examined for the evolution of existing wireless based technologies. Present wireless based technologies, like the 3rd Generation Partnership Project (3GPP) LTE technology, HSPA and Wi-Fi, will be incorporating new technology components that will be helping to meet the needs of the future. Nevertheless, there may be certain scenarios that cannot be adequately addressed along with the evolution of ongoing existing technologies. The instigation of completely new wireless based technologies will complement the current technologies, which are needed for the long-term realization of the networked society [2].

A.Wireless Technology: Evolution

G. Marconi, an Italian inventor, unlocks the path of recent day wireless communications by communicating the letter 'S' along a distance of 3Km in the form of three dot Morse code with the help of electromagnetic waves. After this inception, wireless communications have become an important part of present day society. Since satellite communication, television and radio transmission has advanced to pervasive mobile telephone, wireless communications has transformed the style in which society runs. The evolution of wireless begins here [2] and is shown in Fig. 1. It shows the evolving generations of wireless technologies in terms of data rate, mobility, coverage and spectral efficiency. As the wireless technologies are growing, the data rate, mobility, coverage and spectral efficiency increases. It also shows that the 1G and 2G technologies use circuit switching while 2.5G and 3G uses both circuit and packet switching and the next generations from 3.5G to now i.e. 5G are using packet switching. Along with these factors, it also differentiates between licensed spectrum and unlicensed spectrum. All the evolving generations use the licensed spectrum while

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the WiFi, Bluetooth and WiMAX are using the unlicensed spectrum. An overview about the evolving wireless technologies is below:

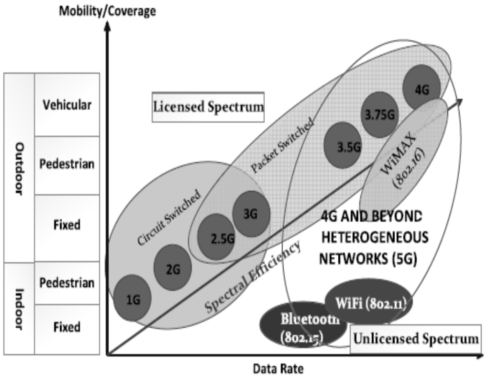

Fig.1. Evolution of Wireless technologies

1G

The 1st generation was announced in initial 1980's. It has a data rate up to 2.4kbps. Major subscribers were Advanced Mobile Phone System (AMPS), Nordic Mobile Telephone (NMT), and Total Access Communication System (TACS). It has a lot of disadvantages like below par capacity, reckless handoff, inferior voice associations, and with no security, since voice calls were stored and played in radio towers due to which vulnerability of these calls from unwanted eavesdropping by third party increases [7].

2G

The 2nd generation was introduced in late 1990's. Digital technology is used in 2nd generation mobile telephones. Global Systems for Mobile communications (GSM) was the first 2nd generation system, chiefly used for voice communication and having a data rate up to 64kbps. 2G mobile handset battery lasts longer because of the radio signals having low power. It also provides services like Short Message Service (SMS) and e-mail. Vital eminent technologies were GSM, Code Division Multiple Access (CDMA), and IS-95 [3], [7].

2.5G

It generally subscribes a 2nd generation cellular system merged with General Packet Radio Services (GPRS) and other amenities doesn't commonly endow in 2G or 1G networks. A 2.5G system generally uses 2G system frameworks, but it applies packet switching along with circuit switching. It can assist data rate up to 144kbps. The main 2.5G technologies were GPRS, Enhanced Data Rate for GSM Evolution (EDGE), and Code Division Multiple Access (CDMA) 2000 [3], [7].

3G

The 3rd generation was established in late 2000. It imparts transmission rate up to 2Mbps. Third generation (3G) systems merge high speed mobile access to services based on Internet Protocol (IP). Aside from transmission rate, unconventional improvement was made for maintaining QoS. Additional amenities like global roaming and improved voice quality made 3G as a remarkable generation. The major disadvantage for 3G handsets is that, they require more power than most 2G models. Along with this 3G network plans are more expensive than 2G . Since 3G involves the introduction and utilization of Wideband Code Division Multiple Access (WCDMA), Universal Mobile Telecommunications Systems (UMTS) and Code Division Multiple Access (CDMA) 2000 technologies, the evolving technologies like High Speed Uplink/Downlink Packet Access (HSUPA/HSDPA) and Evolution-Data Optimized (EVDO) has made an intermediate wireless generation between 3G and 4G named as 3.5G with improved data rate of 5-30 Mbps [3].

3.75G

Long-Term Evolution technology (LTE) and Fixed Worldwide Interoperability for Microwave Access (WIMAX) is the future of mobile data services. LTE and Fixed WIMAX has the potential to supplement the capacity of the network and provides a substantial number of users the facility to access a broad range of high speed services like on demand video, peer to peer file sharing and composite Web services. Along with this, a supplementary spectrum is accessible which accredit operators manage their network very compliantly and offers better coverage with improved performance for less cost [4]–[7].

4G

4G is generally referred as the descendant of the 3G and 2G standards. 3rd Generation Partnership Project (3GPP) is presently standardizing Long Term Evolution (LTE) Advanced as forthcoming 4G standard along with Mobile Worldwide Interoperability for Microwave Access (WIMAX). A 4G system improves the prevailing communication networks by imparting a complete and reliable solution based on IP. Amenities like voice, data and multimedia will be imparted to subscribers on every time and everywhere basis and at quite higher data rates as related to earlier generations. Applications that are being made to use a 4G network are Multimedia Messaging Service (MMS), Digital Video Broadcasting (DVB), and video chat, High Definition TV content and mobile TV [2], [4]–[6].

5G

With an exponential increase in the demand of the users, 4G will now be easily replaced with 5G with an advanced access technology named Beam Division

Multiple Access (BDMA) and Non- and quasi-orthogonal or Filter Bank multi carrier (FBMC) multiple access. The concept behind BDMA technique is explained by considering the case of the base station communicating with the mobile stations. In this communication, an orthogonal beam is allocated to each mobile station and BDMA technique will divide that antenna beam according to locations of the mobile stations for giving multiple accesses to the mobile stations, which correspondingly increase the capacity of the system [8]. An idea to shift towards 5G is based on current drifts, it is commonly assumed that 5G cellular networks must address six challenges that are not effectively addressed by 4G i.e. higher capacity, higher data rate, lower End to End latency, massive device connectivity, reduced cost and consistent Quality of Experience provisioning [22], [23]. These challenges are concisely shown in Fig. 2 [20] along with some potential facilitators to address them. An overview of the challenges, facilitators, and corresponding design fundamentals for 5G is shown in Fig. 2 [20]. Recently introduced IEEE 802.11ac, 802.11ad and 802.11af standards are very helpful and act as a building block in the road towards 5G [9]–[13].

B.Challenging Issues

As per the recent wireless network statistics, it revealed that global mobile traffic experienced around 70% growth [1] in 2014. Only 26% smartphones (of the total global mobile devices) are responsible for 88% of total mobile data traffic [1]. Cisco's Visual Networking Index (VNI) forecasts that mobile networks will have more than half of connected devices as smart devices by 2019. Increasing smartphone usage is resulting in an exponential growth in mobile video traffic. In fact, since 2012 video traffic is more than half of the global mobile traffic [1]. An average mobile user is expected to download around 1 terabyte of data annually by 2020 [2]. Moreover, researchers are exploring new applications in directions of augmented reality, Internet of Things (IoT), Internet of vehicles (IoV), Device-to-Device (D2D) communications, e-healthcare, Machine-to-Machine (M2M) communications and Financial Technology (FinTech). Supporting this enormous and rapid increase in data usage and connectivity is an extremely daunting task in present 4G LTE cellular systems. For example, with a theoretical 150 Mbps maximum downlink data rate, traditional LTE systems, with 2 × 2 MIMO can support only up to (150/4) simultaneous full HD (@ 4 Mbps rate) video streaming. Furthermore, while standard LTE networks were originally designed to support up to 600 RCC-connected users per cell [3], [4], M2M communications and IoT require supporting of tens of thousands of connected devices in a single cell. LTE cellular network is exploring avenues of different research and development like MIMO, small cells, Coordinated Multi-Point (CoMP) transmission, HetNets and multiple antennas to enhance capacity and data rates. However, it is unlikely to sustain this ongoing traffic explosion in the long run [2]. Hence, the primary concern is to satisfy the exponential rise in user and traffic capacity in mobile broadband communications.

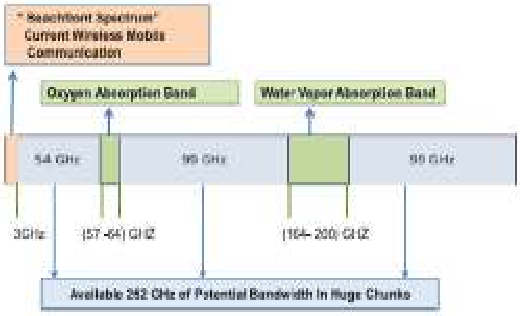

Fig. 2. Mm-wave Radio Spectrum Availability

Capacity for wireless communication depends on spectral efficiency and bandwidth. It is also related to cell size [5]. Cell sizes are becoming small and physical layer technology is already at the boundary of Shannon capacity [6]. Naturally, it is the system bandwidth that remains unexplored. Presently, almost all wireless communications use spectrum in 300 MHz to 3 GHz band, often termed as "sweet spot" or "beachfront spectrum" [2], [7]. This band derives benefits from its reliable propagation characteristics over several kilometers in different radio environments [8], [2]. The expectation from sub mm-wave band to accommodate the exploding mobile traffic and connectivity seems questionable [8]. Thus, for increasing capacity the wireless communications can not help, facing the new challenges of high frequency bandwidth. The key essence of next generation 5G wireless networks lies in exploring this unused, high frequency mm-wave band, ranging from 3 to 300 GHz. Historically, collision avoidance radars are the first to exploit this mm-wave spectrum [9]. The US Federal Communication Commission (FCC) opened the spectrum between 59 to 64 GHz and 81 to 86 GHz for unlicensed wireless and peer to peer communications respectively [9]. Radio astronomy, radars, airport communications and many military applications have already been using the mm-wave bands over the last few decades. Among the huge 3 to 300 GHz mm-wave spectrum, only 57 to 64 GHz and 164 to 200 GHz is un-suitable for communications. Even a small fraction of available mm-wave spectrum can support hundreds of times of more data rate and capacity over the current cellular spectrum [8]. Thus, the availability of a big chunk of mm-wave spectrum is opening up a new horizon for spectrum constrained future wireless communications [8], [9].

C.5G: Centralized Architecture – Cloud Ran

Cloud Radio Access Network (C-RAN) is one of the architecture, which resolves some of the major problems associated with increasing demands for high data rates. Wireless industry is working to enhance network capacity by adding more cells, implementing MIMO techniques, establishing complex structure of HetNets and small cell deployment. However, inter-cell interference, CAPital EXpenditure (CAPEX) and OPerating EXpenditure (OPEX) hinders these efforts. C-RAN offers to improve system architecture, mobility, coverage performance and energy efficiency while at the same time reducing the cost of network deployment and operation. C-RAN is based on fundamentals of centralization and virtualization. The baseband resources are pooled at Base Band Unit (BBU), situated at remote central office (not at the cell sites). In traditional cellular networks, the Internet Protocol, Multi-protocol functionality and Ethernet are extended all the way to remote cell sites. Fig.3 shows a typical C-RAN architecture, with BBUs from many remote sites centralized at a virtual BBU pool. This results in statistical multiplexing gains, energy efficient operations and resource savings. Virtual BBU pools further facilitate scalability, cost reduction, integration of different services and reduction in time consumption for field trials. Remote Radio Heads (RRH), comprising of transreciever components, amplifiers and duplexers enable digital processing, analog-digital conversions, power amplification and filtering. RRHs are connected to BBU pool by single mode fibre of data rate higher than 1 Gbps. This simplified BS architecture is covering the way for dense 5G deployment by making it affordable, flexible and efficient.

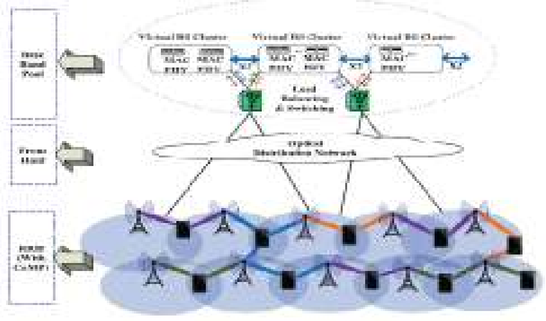

Fig. 3. Cloud-Radio Access Network(C-RAN) - Architecture

D.Heterogeneous Approach—HetNets

It is one of the way to handle the wireless traffic explosion, expected in 5G communication, is deployment of large number of small cells giving rise to Heterogeneous Networks (HetNets). HetNets are typically composed of small cells, having low transmission power, besides the legacy macro cells. By deploying low power small BSs, network capacity is improved and the coverage is extended to coverage holes. For enabling random HetNet deployment, Cooperative and distributed radio resource management algorithms are discussed in [10].

II. Motivation And Development

The combined effect of emerging mm-wave spectrum access, hyper-connected vision and new application-specific requirements is going to trigger the next major evolution in wireless communications - the 5G (fifth generation) [7], [10], [11].

Accordingly, eight major requirements identified by Group Special Mobile Association (GSMA) are:

1. **1 to 10 Gbps data rates in real networks:** This is almost 10 times increase from traditional LTE network's theoretical peak data rate of 150 Mbps.
2. **1 ms round trip latency:** Almost 10 times reduction from 4G's 10 ms round trip time.
3. **High bandwidth in unit area:** It is needed to enable large number of connected devices with higher bandwidths for longer durations in a specific area [10].
4. **Enormous number of connected devices:** In order to realize the vision of IoT, emerging 5G networks need to provide connectivity to thousands of devices [10].
5. **Perceived availability of 99.999%:** 5G envisions that network should practically be always available.
6. Almost**100% coverage for 'anytime anywhere' connectivity:** 5G wireless networks need to ensure complete coverage irrespective of users' locations [10].
7. Reduction in **energy usage by almost 90%:** Development of green technology is already being considered by standard bodies. This is going to be even more crucial with high data rates and massive connectivity of5G wireless [10].
8. **High battery life:** Reduction in power consumption by devices is fundamentally important in emerging 5G networks [10].

With these eight above-mentioned requirements, wireless industries, academia and research organizations have started collaborating in different aspects of 5G wireless systems.

III. 5G Antenna Designing

Thorough literature survey is being carried out to gain knowledge on developments in new generation 5G technology till date. For implementing this concept, 5G technology is demanding antennas with high data transmission capacity and low multi-path fading.

To cater this requirement, the 5G MIMO antenna technology has been studied for applying in wireless communication system such as WLAN or 4G LTE base stations [5-15].

In this proposed method, 3D printing technology, which can help to reduce time and cost, has been proposed to be applied in fabricating complicated structural microwave devices [16]. To implement this two typical 3D printing technologies have been usually observed to be used, they are

- Fused Deposition Modelling (FDM) technology that based on the extrusion of heated materials.
- Stereo lithography appearance (SLA) technology that based on the laser curing of photosensitive liquid polymer.

IV. Various Emerging Applications

A wide variety of new emerging applications is the major guiding force behind the commercial 5G wireless systems. 5G architecture is expected to provide network solutions for a wide range of public and private sectors, like energy, agriculture, city management, health care, manufacturing and transport, with improved software services [25]. Apart from the enormous number of connections, 5G networks also have to support diverse nature of devices and their associated service requirements [26]. Although research and development in some of these applications are already underway in 4G wireless, original 4G LTE standards, 3GPP LTE Release 8.0 [27] did not include support to any of these applications. Rather, these applications were spawned later, and started explosive increase in wireless data usage, thereby imposing additional burden on resource constrained 4G wireless networks. Naturally, later versions of 4G LTE networks often termed as “LTE Advanced” gradually started to include these applications. On the other hand, it is expected that massive bandwidth of 5G mm-wave communications will provide a native support for these emerging applications like, D2D communications, M2M communications, IoV, IoT and Healthcare.

Apart from the above-mentioned applications, the financial industry, with increasing businesses and customers, also requires strong computing and data processing [28]. Application of grid computing in financial industry is discussed in [28]. 5G based future mobile networks have a huge potential to transform different financial services [29], like banking, payments, personal finance management, social payments, peer to peer transaction and local commerce.

Sensing, communication and control increases efficiency and reliability of power grids, thereby modernizing them to Smart Grids (SGs). SGs use wireless networks for energy data collection, power line monitoring, protection and demand/response management [30]. Comparisons between smart and existing power grids are given in [31]. Smart information and smart communication subsystem are integral to smart grids [32]. Smart grids seamlessly link physical components and wireless communications representing large-scale cyber-physical systems [33]. Wireless technology is already being explored for efficient real time Demand Response (DR) management [34]. High bandwidth and low latency of proposed 5G are expected to resolve many challenges associated with SG demand response.

Similarly, smart homes, with roots in automation, embedded systems, entertainment, appliances, efficiency and security is an active technical research area [35]. Smart cities, with fundamentals of sustainability are gaining momentum. Major concepts of IoT, M2M, Cloud computing, integrated with 5G are very persuasive in these research areas [35].

V. Future Enhancement

Comparing to the existing 3G/4G cellular systems, next generation 5G wireless have significant different features with more stringent performance and QoS requirements.

Hence, there are a wide variety of opportunities for future research works in wireless cellular systems. Apart from these, many research works are focused on investigating the behaviour of mm-wave wireless channels, field trials, acquisitions, modeling, simulations and reasoning in different realistic environments should assist in channel extraction.

Despite variety of exciting research works to improve energy efficiency, it still remains an open challenge for 5G technology believing there is a huge scope for discussions on 5G networks. With myriad of BSs and enormous connectivity, the problem is more serious in 5G. One appealing possibility is renewable energy powered green BS. Finally, we think that it is almost impossible for any single technology to converge all the requirements simultaneously [10]. Thus, we believe successful commercial roll out of 5G requires cooperation between academia and industries to uncover a plethora of new research challenge.

VI. Conclusion

This paper concludes overall evolution of 5G wireless communication, Cloud RAN, HetNet architecture and also discussed various applications like D2D, M2M communications, IOT, Vehicular communications and Healthcare applications of 5G and identified major existing research challenges and future research directions.

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