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An Overview of 5G Technology and Recent Trends

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Abstract — *It is expected that 5G technology will be operational by 2020. Therefore it is important to know the direction of research and developments enabling 5G technology. This paper provides first a overview of 5G technology which is mainly includes a requirement and needs and second part provides a comprehensive analysis of recent developmental endeavors toward 5G in which mainly highlights are silent features such as flexibility, accessibility, and cloud-based service offerings, those are going to ensure the futuristic mobile communication technology as the dominant protocol for global communication.*

Keywords- *5G technology; Research groups; Energy-efficient; Modulation technique; Radio access network*

I. INTRODUCTION

The last few decades have observed tremendous changes in communication technologies. From 1G to 4G, the area of telecommunications has seen a number of improvements along with improved performance are developed. All previous generations are different from each other due to their improved specifications. 5G technology is on its way to change the whole telecommunication history in near future [1]. Looking back at the development of the wireless communication networks from 1G to 4G, which lead the communication history at high edge.

The evolution of wireless communication is stated as “generation”, started from early 1980’s known as first generation 1G mobile wireless communication system. This generation was based on analog technology known as Advance Mobile Phone Service (AMPS). 1G has channel capacity of 30 KHz and frequency band was 824- 894 MHz [2]. This generation uses circuit switching and totally designed for voice calls without data services. After 1G, in 1990’s the 2G second generation mobile communication system was the first digital cellular system launched. This generation uses two digital modulation schemes: TDMA (time division multiple access) and CDMA (code division multiple access). Three types of advancements in wireless communication system are 2G, 2.5G and 2.75G. These are family members of second generation [2]. 2G has speed of 64 kbps with bandwidth of 30 to 200 KHz. Next to 2G, 2.5G system uses packet switched and circuit switched domain and provide data rate up to 144 kbps [3].

The third generation 3G technology introduced in the year 2000, is seen more as pre 4G. Packet Switching is the technique for data sending in 3G networks. For video chatting and for high speed internet service, this network allows 15-20MHz bandwidth at a range of 2100MHz [3]. The evolution of GSM is also a part of this generation. 3G, 3.5G and 3.75G are also family member of this generation. High speed internet service, video chatting are main advantages of 3G. A very new service in this generation is GLOBAL ROAMING is launched [4].

In early 2011, fourth generation 4G technology is presented. 4G offers a downloading speed of 100Mbps to 1Gbps.This generation focuses on additional gaming services, HD mobile TV, video conferencing and 3D Television. This generation includes wireless broad band access, Multimedia Messaging Service (MMS) and Digital Video Broadcasting (DVB) [3]. The technologies under the 4G umbrella are; LTE (Long term evolution) and Wi-MAX (Worldwide Interoperability for Microwave Access)[2, 5]. Main advantage of 4G is that 4G systems are more cheaper than previous generations as it does not require to redesign and structure the scenario, there are already tools are present so 4G is built on the top of existing network [6]. 4G provides global mobility to support different services and devices [6]. In Figure 1, all wireless technologies and their evolutionary measures are shown which also presents a better picture of the advancements in the wireless technology.

5G is expected to enhance not only the data transfer speed of mobile networks but also the scalability, connectivity, and energy efficiency of the network. It is assumed that by 2020, 50 billion devices will be connected to the global IP network, which would appear to present a challenge [8]. In a true “networked society” remote controlled operation of appliances and critical commercial machines over a reliable 5G network will be possible with zero delay. Real-time control of machines by using mobile devices will be possible, making the Internet of things (IoT) more available to all. Finally, but not least important, less energy-hungry network nodes will be required toward a greener world. Therefore, the following are the most important elements in the description of 5G: high throughput, low-latency, high reliability, increased scalability, and energy efficient mobile communication technology.

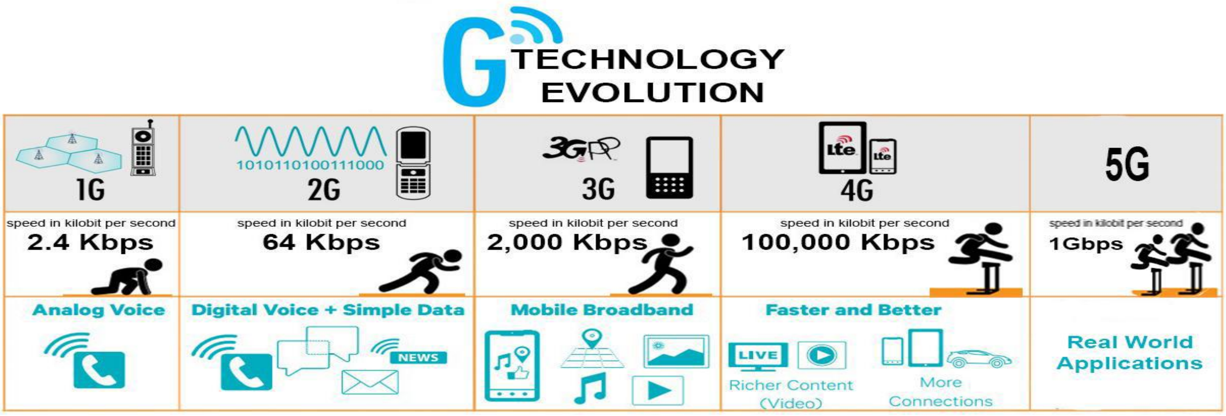

Figure 1. Wireless communication technologies

1.1. Requirements of 5G technologies

By accounting for the majority of wants, the following set of 5G requirements is gaining industry acceptance.

- 1-10Gbps connections to deadline points in the field (i.e. not theoretical maximum)
- 1 millisecond end-to-end round trip delay - latency
- 1000 x bandwidth per unit area
- 10-100 x number of connected devices
- Perception of 99.999% availability
- Perception of 100% coverage
- 90% decrease in network energy usage
- Up to ten year battery life for low power, machine-type devices

One of the key concerns with the 5G requirements is that there are many different interested parties involved, each wanting their own requirements to be met by the new 5G wireless system. This leads to the fact that not all the requirements form a consistent list. None of the technology is going to be able to meet all the needs together. As a result of these widely varying necessities for 5G, many anticipate that the new wireless system will be a umbrella that authorize a number of different radio access networks to work together, each meeting a set of needs. As very high data download and ultra low latency concerns do not easily sit with low data rate and long battery life times, it is likely that different radio access networks will be want for each of these requirements. Accordingly it is likely that various mixtures of a subset of the overall list of requirements will be supported when and where it matters for the 5G wireless system [7].

1.2. Why need of 5G?

- It provides a very high speed, high capacity, and low cost per bit.
- It supports interactive multimedia, voice, video, Internet and other broadband services, greater effective and more attractive, and has Bi- directional, accurate traffic statistics.
- It is supporting large broadcasting capacity up to Gigabit which supporting almost 65,000 connections at a time.
- 5G technology offers remote management that user can get better and fast solution.
- 5G technology offers Global access and service portability
- It provides the high quality services due to high error tolerance.
- 5G technologies provide high resolution for crazy cell phone user and bi-directional large bandwidth shaping.
- The uploading and downloading speed of 5G technology is very high.
- 5G technologies provide transporter class gateway with unparalleled consistency [7].

II. FUTURISTIC SCENARIOS AND 5G COMPLIANCE

The last few The society of 2020 will be a connected society. The IoT together with intelligent and integrated sensor systems and inhome sensor networks will change the way people lead their lives. “Smart living” people will require constant and ubiquitous mobile connectivity to the network to upload their activity data and IoT control commands, thus generating a “massive reporting” uplink data flow [8]. Massive machine to machine communication and critical machine to machine communication will play pivotal roles in service delivery and industry operations.

Vehicular ad-hoc networks (VANETs) are constantly advancing. By 2020, VANETs integrated with cellular networks will be in operation as VANET cloud, leading to a smarter and safer transportation system [8]. When the number of devices connected to the Internet passes tens or hundreds of billions in the coming decade, the offloading of networked data on unlicensed bands will play a critical role in network load balancing, providing guaranteed bit rate services and a reduction in control signaling. Hence, it is important that 5G will provide seamless compatibility with dense heterogeneous networks to satisfy the high demand of real-time traffic, so that end

III. RESEARCH GROUPS AND THEIR WORK

The Different research groups are working on 5G standards. A few examples are Mobile and Wireless Communications Enablers for the Twenty–twenty Information Society (METIS), 5th Generation Non-Orthogonal Waveforms for Asynchronous Signaling (5GNOW), Enhanced Multicarrier Technology for Professional Ad-Hoc and Cell-Based Communications (EMPhAtiC), 5G Infrastructure Public Private Partnership (5GPPP), Network of Excellence in Wireless Communications (NEWCOM#), 5G Innovation Center at the University of Surrey, NYU WIRELESS, and the Electronics and Telecommunications Research Institute (ETRI), Korea. These groups are researching different technical and probable standardization aspects of 5G. Among these, METIS is the largest framework program 7 (FP7) 5G project. FP7 is the European Union's research and innovation program [10]. METIS enlisted top telecommunication companies, such as NSN, Ericsson, T-Mobile, Docomo, and Orange, and academic institutions, such as the Royal Institute of Technology in Stockholm (KTH), Poznan University of Technology, Kaiserslautern University of Technology, Polytechnic University of Valencia, and University of Oulu, as its partners.

METIS recently published their final project report (Deliverable 8.4 on April 30, 2015) containing the main outcomes of their project: an architecture, high level architectural illustrations, a channel model, and over 140 technology components, and their testbed evaluations [11]. They showed the filter bank multi-carrier (FBMC) to be a successful enabler for designing flexible air interfaces. Their simulation report presents evaluations of 5G key performance indicators (KPIs), such as traffic volume per subscriber, traffic volume per area, average user data rate during busy hours, and actual user data rates. Interestingly, their simulation results showed a radio access network (RAN) latency under 1 ms. They also presented different RAN architectures and traffic flow in different scenarios, such as indoor offices, shopping malls, stadiums, and outdoor dense urban environments. They are now moving forward with the METIS-II project envisaging an overall 5G RAN design, collaborative evaluation of 5G RAN, and global consensus building among all standardization groups.

5GNOW researched unified frame structures, ultra-low latency, ultra-high reliability, and viable waveforms for 5G. Their most recent deliverable illustrates Gabor signaling, where the expanded signal is the sum of the scaled time–frequency shifts of a prototype window. The scaling factors are given by the Gabor expansion coefficients. It also discusses acquiring both time and frequency plane information of a signal by means of the short term Fourier transform (STFT) [8].

EMPhAtiC is exploring multiple-input multiple-output (MIMO) transmission, equalization, development of highly flexible filter-bank, and multi-hop- or relay-based communication techniques with asynchronicity. In the project's recent deliverable, different strategies for MIMO transreceiver schemes were proposed for FBMC under frequency selective channels [13].

NEWCOM# is working on high end possibilities, such as finding the tightest upper limits of wireless networks, opportunistic multi-hop communications, and energy and channel efficiency in wireless communications and networking. One of the project's latest deliverables contains exclusive research on Cloud-RAN, mobile broadcasting, 4G/5G coexistence using spectrum overlay, multi-hop coding, and localization with distributed antennae. The project's members have reached the conclusion that base band processing largely depends on the system bandwidth, the order of the modulation coding scheme (QAM), and the resource block used [14].

At NYU WIRELESS, Rappaport et al. are pioneering millimeter wave (mm-wave) experiments for 5G and have experimented with an mm-wave propagation model and path losses in two cities, New York and Austin [8]. 5GIC, UK's only research body dedicated to 5G research, recently achieved a remarkable breakthrough in wireless speed gain: a speed of 1 Tbps speed in a wireless point-to-point (P2P) communication. Its members are also considering ultralow latency-sensitive application services for futuristic purpose[15].

The Electronics and Telecommunications Research Institute (ETRI), Korea, in its GIGA 5G project, is focusing mainly on improving reliability, device-to-device (D2D) communication technologies, and the mobile hotspot network (MHN) protocol stack [16].

5Gforum, the Republic of Korea, is also seeking innovations and market research for the future standard. In another part of the world, 4G-Americas is the "voice of 5G" for the Americas. It has recently published (October 2015) its white papers on 5G evolution and recommendations, where information centric networking (ICN) is emphasized.

Other research bodies beyond those mentioned above also exist. In his survey, Pirinen briefly mentioned quite a few of them and their contributions [8]. The following section is dedicated to a detailed review of technological developments toward 5G.

IV. DEVELOPMENTS TOWARD 5G TECHNOLOGIES

Many well-known technologies or schemes, such as modulation techniques, radio access techniques, or distributed computing, could be reused in 5G with a few alterations together with many other newly developed and evolved solutions. Hence, we limited our literature review to very recent research papers, white papers, industry products, and market requirements. For example, Cisco Inc. publishes a white paper, the Visual Networking Index (VNI), annually. The Cisco VNI report forecasts global mobile data traffic, and the latest VNI report, published in February, 2015 showed interesting predictions: the monthly global mobile data traffic will pass 24.3 Exabytes (EB), which is ten times the current mobile traffic, by 2019, and the number of devices connected to networks will soon surpass the entire world population [17].

4.1. Architecture

5G will have a well-connected core network and RAN. The backbone network may even shift from fiber to mmwave wireless connectivity, and the interconnected base stations should use high bandwidth wired connections. As the number of connected devices increases, a typical macro-cell maybe heavily burdened with controlling overheads to maintain connectivity with a huge number of devices (around 10 k per cell). Therefore, the architecture must be less complex and evolved to accommodate an increased amount of signaling and payload overhead. The performance of such a futuristic 5G architecture, deploying mm-wave RAN, in the Giga KOREA 5G project has been reported [8]. The authors also elucidated graphical representations of the antenna array structures for 3D beam-forming in the report and described how the beam control mechanism facilitates fast handover among different beams.

3D beam-formation is achieved with the help of a 2D array of patch antennae. Highly directive beams of radio transmission signals formed in 3-dimensional spaces, emanating from the 2D array of patch antennae, help to achieve space division multiple access (SDMA). This essentially can be termed beam division multiple access (BDMA). In user equipment, they installed the patch antenna arrays consisting of a 2D NXM number of patch antennae. A quick handoff capability between different beams makes the radio access technique robust, secure, and highly reliable.

Moreover, to overcome the limited coverage of mm-wave RAN, “relay” transmission is used and the handoff process may no longer be controlled by the core node but rather by the base station. In 4G LTE, the base station or eNB performs this resource allocation task. Many scheduling algorithms have been proposed for achieving better QoS in LTE. Such an intelligent resource allocation scheme was proposed [8] for cognitive radio links, based on game-theoretic computations. 5G should use this type of optimal distributed resource allocation algorithm in case of macro cell-based operations, where beamforming may not be possible. Not only an increase in the capacity of RAN, but also an evolved core network, which is flexible, intelligent, easy to install, and low cost, are desirable. Moreover, recent development in cloud-based networking has triggered possibilities of virtualized core networks.

4.2. Modulation Technique

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). OFDMA succeeds code division multiple access (CDMA), which was used in 3G cellular telephony. Further improvements in OFDMA should be able to handle a high peak-to average- power ratio (PAPR) and its need of cyclic prefixes (CPs) to prevent inter-block interference. Moreover, OFDM’s applicability on wide band mm-wave with the required hardware setup is not certain. A comparative study of FBMC, universal filtered multi-carrier (UFMC), and OFDM modulation schemes in 5G was presented in [8].

In the FBMC scheme, the subcarriers are subjected to sidelobe suppression by passing them through a filter bank, which makes them capable of delivering higher spectral efficiency than OFDM. FBMC is robust to intrinsic asynchronicity between a transmitter and a receiver. The 5GNOW group is currently considering four waveforms, GFDM, UFMC, FBMC, and BFDM , for 5G to provide an efficient air-interface that is no longer dependent on stringent orthogonality and synchronization requirements [8].

4.3. Cloud: RAN-as-a-service

RAN can be viewed as the front-haul network segment. The air interface of 5G will have an interesting feature to carry high definition real-time video to very low bandwidth control signals for the IoT. Although important physical attributes, such as modulation, coding scheme, and a massive MIMO, are a direct part of RAN, this subsection focuses mainly on an emerging revolutionizing field called Cloud-RAN. The entirely new application of cloud services in RAN deployment is the most important anticipated element of 5G. Sabella et al. showed the benefits of RAN-as-a-service (RANaaS) in terms of network sustainability and energy efficiency. The idea behind the cloud-based RANaaS is keeping the RAN capacity in a centralized server and making it available to the customer on demand. To achieve this, the base stations need to be segregated into a radio access unit and baseband unit and a reserve pool of the baseband unit needs to be created to satisfy any cell that experiences high traffic. Low power small cells should be deployed to reduce energy consumption and make the reserved capacity available to the cell that needs it because of a sudden surge in traffic. They have also shown that computational power and energy efficiency will be further optimized with the availability of newer cloud computing platforms and the upcoming data-center servers. Not only the RAN but also the core and backbone network may be virtualized, as schematically shown in Figure 2, by means of cloud-based resource availability [8].

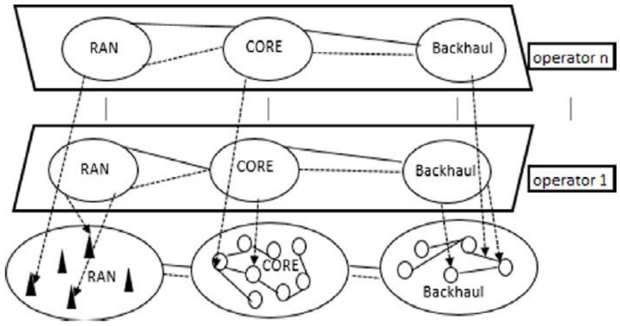

Figure 2. Schematic diagram of network cloudification

4.4. Energy efficiency

Energy consumption is a major factor in the large scale deployment of new networks. Currently, more than 0.5% of the world’s total energy is consumed by the mobile networks. Therefore, a reduction in energy requirements is one of the major aspects of 5G development not only from the environmental needs but also from the network maintenance perspective. Tombaz and Sung [8] numerically showed that a network densified by cell size reduction 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 candidate 5G framework with software defined MAC and network functional virtualization has been deployed [2]. The 5GrEEn project aims to introduce an energy-efficient and optimized heterogeneous network (HetNet) architecture for various traffic demands and scenarios to provide improved capacity. Cloud resources should also be allocated sensibly. “Anchor”, a versatile resource management framework in the cloud, has been proposed, implemented, and evaluated [8].

4.5. Protocol stack

Any communication system performs on the basis of a layered protocol stack. Gohil et al. , in their 5G survey, presented the general protocol stack for next-generation end-to-end mobile communication. Authors envisaged for a universal communication standard. The noticeable feature of the stack is its provision for compatibility with other open source protocols. They discussed 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).

4.6. 3GPP device-to-device proximity services

To increase the cell capacity and offer various proximity services (ProSe) (e.g., bus or cab availability, retail/restaurants advertisements in a locality, searching social networks in a large gathering, etc.) D2D connectivity is essential in a cellular system. 3GPP itself has standardized LTE-Direct (LTE-D) in its release-12. LTE-D is a new concept that 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. Although technologies such as Wi-Fi direct or Bluetooth are the P2P proximity communication protocols predominantly in use, they have disadvantages in terms of energy consumption. Hence, LTE-D is standardized and D2D communication in mm-wave is needed for 5G. Mm-wave D2D communication was presented in among capable mobile devices equipped with electronically steerable antennae and beam-forming technology. By virtue of highly directive antennae and beamforming technology, concurrent transmission among D2D users and the base station will not create much interference.

In the case of multimedia file sharing among a number of neighbors, a network can become congested. This type of case needs to be handled by crowd-sensing media retrieval frameworks, such as that proposed and prototyped by Abdelzaher, et al. MediaScope, the framework developed specifically for mobile devices, can provide timely retrieval of media files from a cloud. The important feature of this type of file sharing is that the contents are shared after a considerable time. Similarly in 5G, D2D multimedia sharing techniques may borrow this type of framework for sharing large multimedia content among nearby mobile neighbors.

An interesting extension of 5G is the provision of coverage in rural areas, at sea, or in the air routes 35 000 ft above ground level; these needs could be served by a satellite. A research initiative has reduced the latency of the non-GEO satellite constellation and power allocation in multi-beam satellite communication systems for onboard beam-forming. Domme, et al. envisaged the feasibility of reusing an FBMC scheme over satellite communication so that the hand-off between a terrestrial cellular infrastructure and satellite coverage becomes easier and seamless [8]

IV. CONCLUSION

This article provides basic information about 5G technology and a comprehensive review of some recent initiatives taken worldwide by different groups toward a green, flexible, and mostly dominant 5G mobile communication standard which is expected to operational by 2020. It also briefly described some important issues, from an improved substitute for OFDMA to energy efficient D2D communication.

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