From 5G to Beyond

Subjects: Telecommunications

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The histrionic growth of mobile subscribers, disruptive ecosystems such as IoT-based applications, and astounding channel capacity requirements to connect trillions of devices are massive challenges of the earlier mobile generations, 5G turned up the key solution.

mMIMO 5G augmented reality virtual reality

1. Introduction

The deployment of fourth-generation long-term evolution network (4G-LTE), and its extension long-term evolution-Advanced (LTE-A) in various countries have not only accomplished the International Mobile Telecommunications Advanced (IMT-A) constraint by utilizing IP envisioned for all services but also maintained up and around 1 Gb/s less mobility and 100 Mb/s data rate for large mobility. The histrionic growth of more mobile data subscribers in recent years is the result of people's craving for faster internet while on the go. The Wireless World Research Forum (WWRF) forecaste around 7 trillion mobile products will provide 7 billion individuals in 2017; which is about 1000 times the world's population [1]. While as per Ericsson's technical mobility report published in 2017, almost 29 billion devices are forecast by 2020 including 18 billion IoT related [2]. Furthermore, Rangan et al. [3] predicted 50 billion devices by 2020 and will keep up growing exponentially by around 5 zetta-bytes per month in 2030 [4]. IoT applications demand such as smart homes/cities/grids etc., sensors networks, explosive big data, and wearable artificial intelligent devices are increasing exponentially [5][6]. That has raised substantial attention to form new mobile standards in the telecommunication market.

Against these requirements, the massive data; peta-bytes (10,005 bytes), internet speed in Giga-bits per second (GB/s), and connection to trillions of devices definitely need next-generation wireless communication systems. To encounter these huge challenges, design and establish new standards for the next 5G communication, the academia, the standardization agencies, and the telecom industry are working in accordance [7][8]. Also, drastic enhancements and new innovations are essential to be made during network design both in physical and upper layers [9]. Emerging technologies such as disruptive ecosystems like IoT named as connected community and machine-to-machine (M2K) communications are also in consideration to be an important part and known as tactile Internet, a newly invented term [10]. METIS [11] and 5GNOW [12] are two main European ventures to address 5G networks. To reduce the firm orthogonality and synchronization criteria in present systems, particularly, 5GNOW explored new physical layer patterns by using non-orthogonal waveforms.

The key objective of the 5G network is not only to maintain a 1000-fold capacity gain and 10 Giga Bits per second delivered to a single user but also to assure quality-of-service, higher spectral efficiency (SE), the ultra-reliable and

improved battery life of devices, less expensive and massive machine-type communication as dissipated in **Figure 1**. Only 5G networks can tackle these challenges and it will contribute a true universal boundless mobile experience through upgraded terminals, low latency, and ultra-reliable connectivity. The major challenge of the 5G network is tremendous mobile traffic demand.

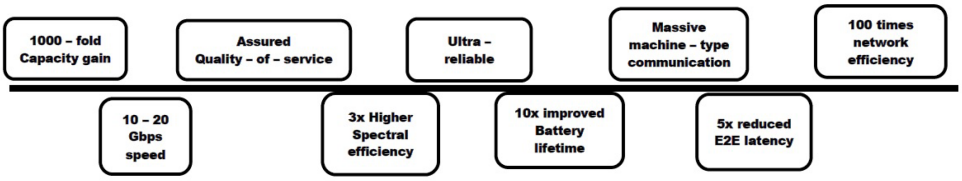

Figure 1. The prime objective of 5G.

This would certainly place a huge amount of traffic load at the edge and a huge amount of data will be processed in the cloud and consume a large number of resources which will not only affect the inadequate capacity of traditional cellular cells but also interrupt the admission and service of other subscribers. Another challenge for organizations is to process multiple repositories from multiple users using multiple applications in multiple environments simultaneously, producing a large amount of digital garbage and useless information. For example, data received from smart homes and health care are processed at the edge [13], processed at the fog to produce helpful information [14], and visualized in subscriber devices. Therefore, the edge, the fog, the cloud, and even the subscriber devices play an important role in the life process of the management of this data (i.e., smart cars, virtual reality, and health care). Therefore, it is a need to design, develop, and implement architectural models to produce on-demand and edge-fog-cloud processing systems to continuously handle big data.

The key problem with the ongoing development of mobile wireless systems is that it is thoroughly dependent upon network densifying to the cells or enhancing spectrum to attain the required throughput. The saturation point of these rare resources is almost reached. Moreover, cell densification and bandwidth increase also increases network latency and pay the cost of expensive hardware. Therefore, the throughput can effectively be increased by an untouched factor of SE without increasing cell densification and bandwidth to meet the current needs of wireless networks. Considering all these challenges, it also makes compulsory new means of channel capacity enhancements and SE techniques. Massive MIMO is an important part of the 5G key enabling technologies and is considered to be the solution to the above-discussed challenges.

The data rate that can be communicated by a certain bandwidth in a particular communication network is referred to as SE, measured in bits/Sec/HZ. Spectrum efficiency, spectral efficiency, or bandwidth efficiency is a technical quantity described as the data rate that can be communicated over a specified bandwidth and used to measure a frequency band. It can be enhanced through increasing modulation order.

2. 5G Evolution

The 5G cellular system offers an extremely expandable and flexible network scheme to connect everything and everybody, everywhere. Several industries, e.g., DOCOMO, Huawei, ZTE, Ericsson, Qualcomm, Samsung, Vodafone,

and Nokia Siemens Network have paid countless enthusiasm to develop 5G networks so far. Broadly, 5G is categorized into three domains:

- Ultra-Reliable Low Latency Communication (URLLC): fast and highly reliable with 100% coverage and uptime, applications to unmanned vehicles and smart factories
- enhanced Mobile Broadband (eMBB): whose goal to provide large data applications, massive device and user capacity for wireless broadband services
- Massive Machine Type Communication (mMTC): which permits a massive number of wireless devices connection density, energy efficiency, and reduced cost per device [15][16][17].

The early 5G spectrum in various countries is below 6 GHz but an additional wireless spectrum above 6 GHz and beyond is also proposed for enhanced capacity and SE [18]. The 3rd Generation Partnership Project was developed in 1998. It consists of seven regional/country telecommunications standards developing organizations whose aim is to regulate general policies and specifications, and produce reports that define 3GPP technologies. The 3rd Generation Partnership Project (3GPP) specifications are organized as releases that consist of several technical reports and specifications, each one of which may have concluded after various revisions [19]. A new release offers fresh radio access technology and/or improvements to an existing one and denoting to the achievement of certain milestones [20].

In Rel-13, mMTC and Narrow Band IoT (NB-IoT) were previously established by 3GPP to enable an extensive range of cellular devices, particularly designed for machine-to-machine, IoT applications and deployment scenarios [21]. In 2019, 3GPP has already initiated commercial deployment of Release 15 (Rel-15) focusing on eMBB and URLLC. The 5G networks are aimed to work with existing 4G networks by using a range of cells; macro cells for wide area coverage and small cells for in-building, homes, hospitals, schools, and smart forms as shown in [22]. During 5G connection formation, the user device will connect to both 4G for control signaling and 5G for fast data connection. The next phase of 5G is named Release 16 (Rel-16). Phase 2 of the 5G network will be presented in 2023 decided by the ITU World Radio-communication Conference in 2019 (WRC-19) to secure an additional mobile spectrum to meet consumers and business needs [21]. Rel-16 truly emphasizes industrial internet-of-thing (IIoT) related enhancements for Industry 4.0 as well as enhanced URLLC, the Time-Sensitive Communication (TSC), a platform for Non-Public Networks (NPN) wireless and wire-line convergence and complete system resiliency [19].

Rel-15 not only offers extraordinary performance for 5G standards but also provides extensive backward compatibility for new releases in coming years with additional features for ultra-high reliable communication, enhanced data rate, low latency, and improved security characteristics in Rel-16 and in discussion Rel-17 [23]. Release 17 (Rel-17) is an evolution to 5G-advanced systems and connects the community and provides an improved platform for multi-access edge computing, functioning in frequency bands beyond 52 GHz, aiding for reduced capability (RedCap) user equipment(UE), and proximity services, IIoT framework [24], virtual reality [25], smart homes automation [26], multi and broadcast architecture, Non-Terrestrial Networks (NTN), autonomous vehicles [27], and unmanned aerial systems (drones) [28][29][30][31] as shown in **Figure 2**. Furthermore, a physical uplink shared channel (PUSCH) and physical uplink control channel (PUCCH) will be used in Rel-17 for uplink. Release 18 (Rel-18) is officially the evolution of 5G-Advanced. It will bring improvements in the extended reality and field of artificial intelligence by employing machine-

learning-based techniques at multiple network levels, that will permit highly intelligent network solutions. This artificial intelligence (AI) based on machine learning (ML) solutions will use solve multi-dimensional optimization issues and intelligent network management with regard to non-real-time and real-time operations. Moreover, cyclic-prefix orthogonal frequency-division multiplexing (CP-OFDM) and discrete Fourier transform (DFT) spread OFDM (DFT-S-OFDM) in the uplink will be investigated. Ookla is a famous speed test provider to test the performance and internet speed of an internet connection [32]. As per Ookla 5G interactive map tracks, 5G roll-outs commercially in more than 132,031 locations across the globe by 216 operators including 220 pre-Release [33]. The world's first commercialization of 5G sub-6 GHz spectrum C-band aggregation by Qualcomm Technologies, Inc. and NTT DOCOMO, INC enabled in Japan [34].

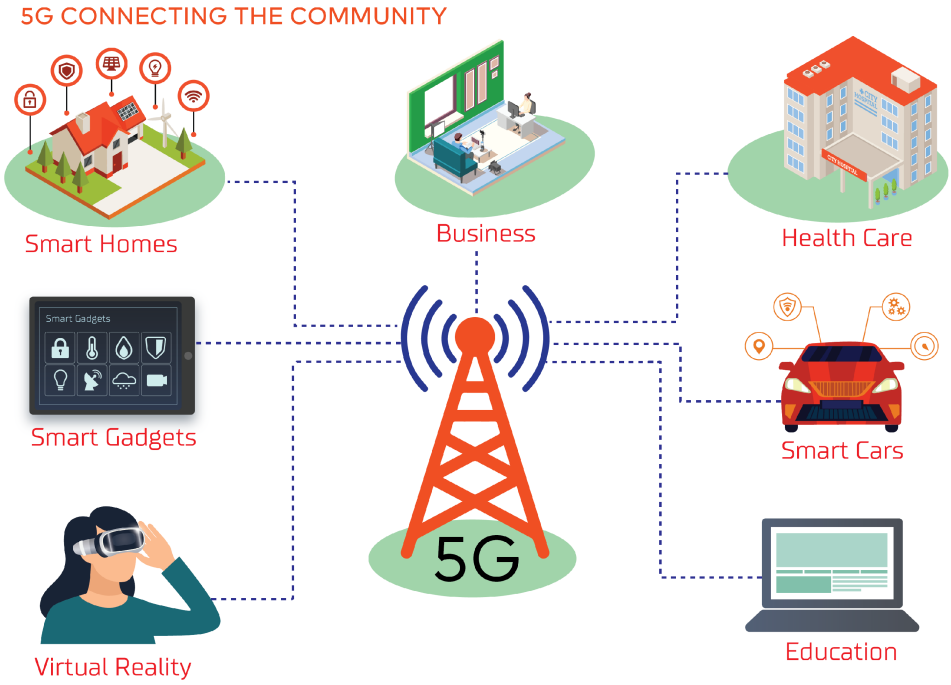

Figure 2. 5G, connecting the community.

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