5G Emerging Technology: What is the big deal?

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Abstract

This report provides research overview for the 5G technology, which is the fifth-generation technology standard for broadband mobile and cellular devices. As 5G technology begins its journey, many scholars have put 5G technology in check and seek to answer the most basic question "what is the big deal of the 5G technology"? Though a simple question, it is quite challenging to get a straightforward and convincing answer. This report provides an overview of the development of the 5G technology with detailed findings and identification of the process used in each finding. Then the report predicts future work of the potential improvement and impact 5G can bring us. In the end, the report attempts to answer the question "what is the big deal of the 5G technology".

1 Introduction

1.1 Trends

It is well known that mobile data consumption is rising at an exploding rate, driven by increased penetration of smart devices (smartphones and tablets), better hardware (e.g., better screens), better user interface design, compelling services (e.g., video streaming), and the desire for anywhere, anytime high-speed connectivity. More end users are using multiple devices with different capabilities to access a mix of best effort services and services with quality of experience expectations. The Internet of Things (IoT), which adds "anything" as an additional dimension to connectivity (in addition to anywhere and anytime), is also becoming a reality. Smart wearable devices such as bracelets, watches, glasses), smart home appliances (e.g., televisions, fridges, thermostats), sensors, autonomous cars, and cognitive mobile objects (e.g. robots, drones) promise a hyper-connected smart world that could usher in many interesting opportunities in many sectors of life such as healthcare, agriculture, transportation, manufacturing, logistics, safety, education, and many more.

1.2 Overview

In the past decade, the world has experienced an exploding amount of hardware and software advancements in the information technology. Amongst them, the 5G technology is one important milestone that dominates today's information and technology sector. The 5G technology is the fifth-generation technology standard for broadband mobile and cellular networks. The 5G technology can provide higher speed, lower latency and greater capacity than its predecessor, 4G LTE. These advancements can imply faster downloading speeding, much lower lag and a higher and more significant impact on how we live our lives.

To better understand the concept of the 5G technology, it would be extremely helpful to understand the many predecessors before it. In general terms, the first generation or 1G focuses

on voices and sounds, which gave us the ability to make cellular calls in a moving var. The second generation or 2G proposed a short-texting feature, of which we still see traces of this technology today. The third generation of 3G provided the essential technology in both sound and video platforms which allowed us to launch smartphones. The fourth generation or 4G provides advanced upgrades on 3G and allowed us to stream videos with a few buffering and established the foundation for connected devices between different users. Next, a detailed list is provided to cover the historical development and their sources of the first four generations.

This section summarizes the generations of mobile wireless communication from 1st generation to 5th generation and compares the different technologies. It is advantageous to describe previous generations of wireless mobile communications. With 5G technology still now researching and developing, it is another revolution by providing high data speed rate adapt to modern technologies.

1. The first generation mobile systems or 1G were analogue LeBeane et al. (2016). The representation that was put in operation was in 1978 by Nippon Telephone and Telegraph (NTT) in Tokyo LeBeane et al. (2016). It uses analog radio signal which has frequency 150 MHz. Another famous representation amongst the first generation analogue cellular and mobile systems were Nordic Mobile Telephones (NMT), Total Access Communication Systems (TACS), and Advanced Mobile Phone System (AMPS). The frequency modulation technique for the radio transmission was the same between AMPS and TACS. This was a good source to start with, but it has a decided disadvantage: though these systems rendered handover and roaming capabilities the networks needed, the cellular and mobile networks were actually not able to interoperate among different countries LeBeane et al. (2016). In order for communications to happen amongst different users, a technology called Frequency-division multiple access (FDMA) is required. FDMA provides the capabilities such that multiple users can send data through a unified communication channel. During this process, the bandwidth is divided and allocated into sub-channels to be accessed by separate users. Hence, multiplexed traffic is carried over and can sometimes cause conflicts Ramjee (1998).This generation is unreliable, without security. In any case, 1G innovation experienced various disadvantages Salih et al. (2020) which used the AMPS (Advanced Mobile Phone System) and TACS (Total Access and Communications System) that can speed up to 2.4Kbps.

2. The second generation mobile network systems (2G) are based on the standard Global System for Mobile Communications (GSM) LeBeane et al. (2016). The 2nd generation calls could be scrambled and computerized voice calls were altogether clearer. Some of its significant features included send text messages (SMS), picture messages, then voice and image messages (MMS) Salih et al. (2020). It implemented the concept of CDMA Code Division Multiple Access, which gives every client with an uncommon code to convey ended multiple physical channels. CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimizing the use of available bandwidth. The technology is used in ultra-high-frequency (UHF) cellular phone systems in the 800 megahertz (MHz) and 1.9 gigahertz (GHz) bands. It also employs analog-to-digital conversion (ADC) in combination with spread spectrum technology. Audio input is the first digitized into binary elements. The frequency of the transmitted signal is then made to vary according to a defined pattern code. This enables the signal to be intercepted only by a receiver whose frequency response is programmed with the same code, following along with the transmitter frequency. The core structure of the wireless CDMA networks composes of cell clusters. Each cell in a cell cluster has a transceiver with the necessary transmitting power and mobile units distributed around the cell's coverage area. The CDMA channel is nomially 1.23 MHz wide. CDMA networks uses a scheme called soft handoff, which minimizes signal breakup as a handset passes from one cell to another. GSM made its first appearance in 1901 and they are digital cellular systems, which enabled advanced source coding techniques to be implemented thus allowing the spectrum to be used

much more efficiently LeBeane et al. (2016). However, this also reduces the bandwidth required for voice and video Ramjee (1998); Prasad et al. (2000). Though 2G has major upgrades from 2G, the main disadvantage with GSM is that it could handle a maximum data rate of 9.6 kbps, which is so slow that is insufficient for efficient internet-related services. The 2G technology eventually had improvements and was superseded by 2.5G and 2.7G. The 2.5G systems are developed based on the General Packet Radio Service (GPRS) standard, which supports Wireless Application Protocol, Multimedia Message Service, Short Message Service, mobile games, and search and directory mobile services LeBeane et al. (2016). The 2.75G systems are evolved using standard Enhanced Data rate for GSM Evolution (EDGE) and is an extension of GSM. This was when we saw some increase in data transfer rate especially comparing to GPRS.

3. The third generation mobile systems (3G) systems was a major upgrade and it provided very high speed Internet access, which is about 384 kbps in burst mode). Burst mode, a generic term for electronics, is referring to a situation that a device is transmitting data repeatedly without going through all the steps required to transmit each piece of data in a separate transaction. There is a main advantage of burst mode, which is over single mode. The burst mode typically increases the throughput of data transfer Bus (1998). The 3G technology is used in major telecommunication areas such as voice telephony, video calls, broadband wireless data and additional services like mobile television, Global Positioning System (GPS), other real time audio, video broadcast services. The three important technologies that paved the way to the development of 3G systems are: Universal Mobile Telecommunication System (UMTS), Frequency Division Duplex (FDD), and Time Division Synchronous CDMA (TD-SCDMA) Ramjee (1998).

4. The fourth generation mobile system (4G) offered very high speeds telecommunication service of up to 100 Mbps, which was extremely fast. As a matter of fact, most of the smartphones today are equipped with this technology. Such high rate of data transfer speed provides us high quality video and audio streaming over end to end Internet Protocol. There are two important standards in 4G technologies: Worldwide Interoperability for microwave Access (WiMax) and Long Term Evolution (LTE). 4G is the current technology used all over the important places of the world for most of the mobile hot devices and smartphone devices. However, there are still many countries where 4G services are not yet accessible due to the spectrum related issues Hara and Prasad (2003); Prasad and Munoz (2003),

2 Fifth-Generation (5G) Era

This section introduces the concepts of the fifth generation (5G) technology. The concepts of realizing this generation of communication systems resides in the advancement of Wireless System for Dynamic Operating Mega Communications (WISDOM). Some of the most recent advancements of significance of 5G initiates started from WISDOM in February of 2008, given at a keynote speech called “First International IEEE Conference on Cognitive Radio and Advanced Spectrum Management in Denmark. Afterwards, in November of 2008, 5G through WISDOM was initiated at the Center for TeleInFrastruktur, Aalborg University. At the same time, 5G systems based on Beam Division Multiple Access was initiated in South Korea IT R&D department Pirinen (2014). In the May of 2012, the First 5G System was initiated by Samsung Electronics. In the October of the same year, another team in U.K. initiated 5G technology in the 5G Research Center in University of Surrey. In November of 2013, Huawei Technologies started its 5G research. This information can be summarized in Table 1.1 of Prasad (2014).

Today 5G is expected to unleash a whole new digital era starting in the year of 2020. This wireless communications can incorporate a large number of advanced technologies in order to increase the bandwidth further. Additional interesting services that can further improve the quality of life is wearable or flexible mobile devices, Ultra High Display video streaming, smart

navigation, mobile cloud, real time interactive games, and so on. The spectrum remains a key challenge for the 5G technology as the high frequency bands are to be explored to achieve those higher data rates than any other currently emerging technology Prasad (2014).

2.1 Introduction to WISDOM

The work by Prasad (2015) poses a novel concept for a Wireless Innovative System for Dynamically Operating Mega-communications (WISDOM) that combines the aspects of personal- and cognitive radio-networks to let seamlessly bridge the virtual and physical worlds offering a constant level of all-senses, context-based, rich communication experience over fixed and wireless networks for the end users while realizing a new generation of ubiquitous communications with a speed of more than 1Tbps Prasad (2015). The drivers for the performance requirements of future networks are highly dependent on the user requirements imposed on both devices and technology. The user requirements can be concluded that capacity, connectivity, and pervasiveness are key enables of satisfying the user requirements. In turn, these drive the emergence of new environments that evolve from the gradual development and combination of present day cellular communications, Internet of Things (IoT) and Internet of Services, towards a more advanced vision of fully reprogrammable mobile devices, allows us to communicate with each other autonomously based on given even context.

2.2 Applications of WISDOM

Many prominent applications can be developed based on the WISDOM network systems. These marvelous applications include but not limited to home and office network, medical and health care, IT services, entertainment-movies high-speed data transfer, educational systems, rescue vehicular communications, meteorology, security, aviation, global communication, smart town, virtual reality, intelligent transportation systesm and so on. These diverse applications of WISDOM-based products form the major operating functionality and basis of the Global Information Multimedia Communication Village (GIMCV). The concept of GIMCV is summarized in Figure 1.

The GIMCV consists of national and international zones which are divided into macro cells (Suburban, Regional and National networks) Prasad (2014).Macro cells consists of many micro cells which refer to city-centres/highway networks) and can also contain small pico-cells which are in-house networks. The structure serves the demand of WISDOM application and it can vary from a person to a team of employees and to eventually a country of citizens. It is the way of groupings of many devices in close vicinity of user Ramjee (1998).

2.3 5G Cellular Network Architecture

To contemplate 5G network in the market, it is evident that the multiple access techniques in the network are almost at a still and requires sudden improvement. To meet the demands of the user and to overcome the challenges that has been put forward in the 5G system, a drastic change in the strategy of designing the 5G wireless cellular architecture is needed Gupta and Jha (2015). From Chandrasekhar et al. (2008), it is generally observed that most of the wireless users stay inside for approximately 80 percent of the time and outside for approximately 20 percent of the time. At present day cellular usage, for a mobile user to communicate whether insdie or outside, an outside base station present in the middle of a cell helps in communication. Hence, for the user indoor to make communication with the outside station, the signals will have to travel through the walls of the indoors, which result in very high penetration loss. 5The 5G cellular structure is such a novel idea in order to distinct outside and inside setups Wang et al. (2014). The following subsection expands a small discussion on the MIMO technology which is crucial for the 5G network.

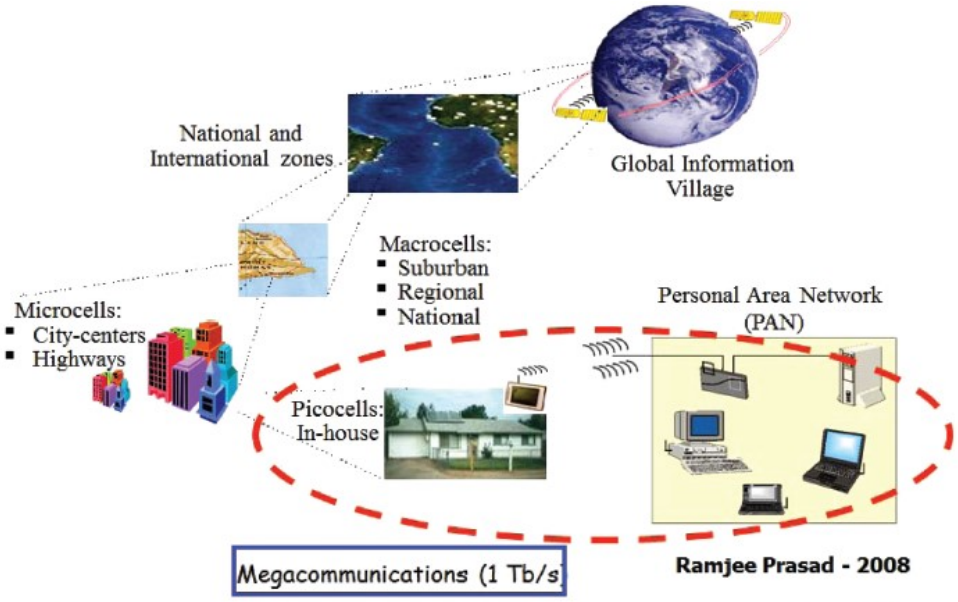

Figure 1.3 Global Information Multimedia Communication Village [1].

Figure 1: **Executive Diagram of GIMCV**.

2.3.1 MIMO

MIMO has becoming mature, and incorporated into emerging wireless broadband standards like the LTE Dahlman et al. (2010). For example, the LTE standard allows for up to 8 antenna ports at the base station. In plain language, the more antennas the transmitter is equipped with, and the more degrees of freedom that the propagation channel can provide, the better the performance in terms of data rate or link reliability. In detailed language, the work by Rusek et al. (2012) has put it in better terms. On a quasi-static channel where a codeword spans across only one time and frequency coherence interval, the reliability of a point-to-point MIMO link scales according to the probability of the link outage, which is modeled by a signal-to-noise ratio. On a channel that varies rapidly as a function of time and frequency, and where the circumstances permit coding across many channel coherence intervals, the achievable rate scales as $\min(n_t, n_r)\log(1 + SNR)$. For very large MIMO, Rusek et al. (2012) believes that the systems that use antenna arrays with an order of magnitude more elements than in systems being built otday, say a hundred antennas or more. Very large MIMO entails an unprecedented number of antennas simultaneously serving a much smaller number of terminals. The disparity in number emerges as a desirable operating condition and a practical one as well. A benefit from this fact is, expected by Rusek et al. (2012), in very large MIMO systems, each antenna unit uses extremely lower power in the order of mW.

2.4 Requirements of 5G

From previous subsection, the structure of network is categorized into pico, micro, and macro cells, which form the fundamental building block of the 5G technology. A necessity is for the mobile terminal to be recognized with a single ID. This way it allows seamless network connectivity irrespective of the access network. The envisioned high data rate applications would necessitate that possible authentication and access validation to the mobile device are granted in minuscule time period, i.e. latency as low as 1 ms Prasad et al. (2009). This nature can help minimize the possible shadowing effect and path. Shadowing effects caused by the obstructing presence of a human body can result in increased path loss in indoor wireless systems

Januszkiewicz (2018). It would be challenging to avoid the utilization of distributed antenna systems (DAS) and multi-input and multi-output (MIMO) antennas. Distributed antenna systems (DAS) have been widely implemented in state-of-the art cellular communication systems to cover dead spots. Recent academic studies have shown that in addition to coverage improvements, DAS can also have potential advantages such as reduced power and increased system capacity in a single cell environment Choi and Andrews (2007). Communication systems MIMO (Multiple Input Multiple Output) based on the use of an antenna array at the transmitter and receiver are able to offer high-speed transmission with a minimum quality of service guarantee Ghayoula et al. (2014). The current MIMO systems would be insufficient and the requirement would be for massive MIMOs Prasad (2013). In addition to the DAS and MIMO components, other standards required for the 5G technology can be the capacity of mobile devices to initiate and establish cellular connections among themselves, which is known as device-to-device communication (D2D). At present day, the communication of cellular operation spectrum is extreme crowded. This creates high data rate and makes the existing spectrum situation challenging due to significant utilization of frequency bands. Frequency bands, higher than referred as mm bands mm-waves are capable of supporting the high data rate along with the use of visible light communication (VLC), are two frequency bands that can suffice the operational requirements.

The standardization of WISDOM is shown in Figure 2. Th3 required areas (cited from Prasad (2014)) are

- *Multimedia Communications* where it needs to focus on the areas of Machine -to-machine (M2M) and Peer-to-Peer (P2P) with global identifications for home networking and smart cities and Techno-social Systems.
- *Cognitive Communications* where WISDOM based personalized cognitive communication includes all the educational, office, community, emergency, commercial and intelligent transportation systems.
- *Personalized Medicine* includes bioinformatics, multi-sensor networks, body sensors, and data protection and ethical guidelines.
- *Network without borders* basically comprises the wide range communications for the future Internet or the next generation networks. The main focus is on the Physical layer security, management and resource optimization, identity management, cooperative communications and Internet of things.
- *Embedded Optimal Resource and Computing* It has Energy harvesting techniques and models, time and power conscious hardware (HW) / software (SW) code sign methodologies, terminal energy tradeoffs and energy aware reconfigurable and heterogeneous Architectures.
- *Positioning and Localization* includes the navigation systesm, ubiquitous and cooperative localization, geo tagging, navigation ID systems and Robotics.

2.5 Vision of 5G

An overall vision of 5G which can be summarized into Figure 3 which is taken from Figure 1.5 of Prasad (2014).

M2M and IoT are the two essential criteria for making prominent achievements at the core of the 5G technology, which is the key for enabling ubiquitous networking and connectivity in a 5G context. M2M and IoT are the key enabling technologies for a pervasive and always-connected 5G mobile services. In addition, research challenges arise that are related with big data handling through M2M and IoT communications (e.g. heterogeneous gateways, energy efficiency, decentralization of routing, naming and addressing).

One important vision is to enable ubiquitous connectivity. This feature has two sides. First, technical challenges can arise and are related to sufficient coverage range even in scenarios

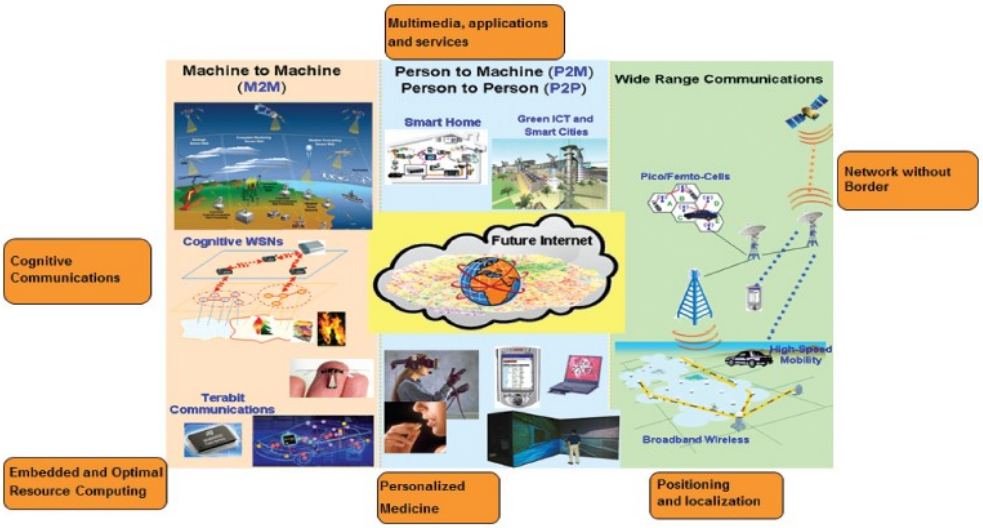

Figure 1.4 Standardization of WISDOM [1].

Figure 2: **Standardization of WISDOM**.

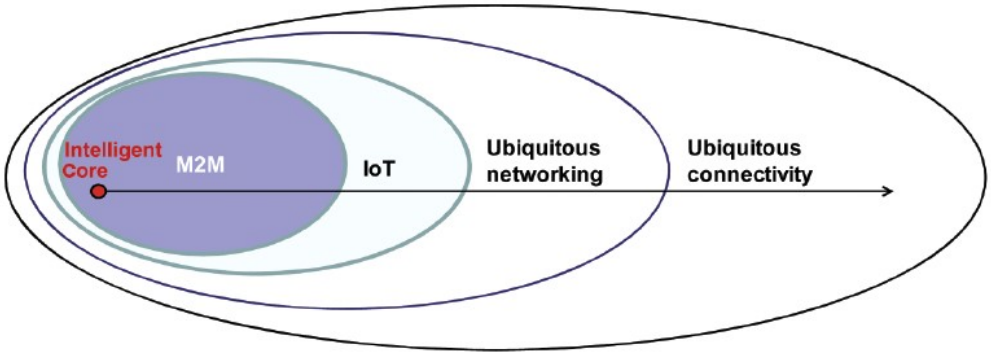

Figure 1.5 Plethora of technologies to deliver 5G services and applications [6], [13].

Figure 3: **Summary of 5G Services**.

of very high mobility and data rates. On the other hand, challenges can arise when moving application from device-to-device without any content interruption. Use of millimetre wave links novel multiple antenna concepts, virtualization, small cell depoyments, and novel spectrum usage methods are some of the key research enabling areas for ubiquitous connectivity LeBeane et al. (2016).

A bigger vision is to enable ubiquitous networking which means that regardless of the exploding number of access networks the quality of the delivered service must be met end-to-end Prasad (2014). In modern day data science and large-scale data science, the importance of the cloud computing concept for supporting the big data originating from the intelligent 5G core.

2.6 Why is it a big deal?

Thus far, the previous subsections have covered the fundamental building blocks of 5G technologies, applications of 5G technologies, and requirements and visions of the 5G technologies.

It is then within rationale to stress the importance of 5G and to convey the idea that it is a big deal.

Internet of Things (IoT) and the big deal of 5G are expected to be the dominant transition of modern day internet and mobile technological marvel. They will also be the milestone of this century just like in the old days the impact of the Industrial Revolution. So in order to convey the idea that 5G is indeed an important concept, it is thus important to emphasize the IoT expansion, which is the rapid increase in volume and speed of a collection of "things" that depend on the access of the internet to collect, share, and transmit data. As the technology advances forward, more and more "things" will have to join the IoT universe. Ordinary objects such as cars, trains, watches, thermostats, smart devices (e.g. Alexa, Siri, smartphones) and on have turned "smart" because they rely on the internet to gather and transmit data. Smartwatches, for instance, can use the internet to phone calls and track heart beats. The innovation of making watches and wearable devices more intuitive and intuned with our needs have since increased the number of "things" in the realm of IoT which is exponentially grow as more advancements are seen in modern day technology. According to a report from Business Insider: The Internet of Things Report, the number of IoT devices is projected to grow to 41 billion by 2027, and much of that increase is expected to be enabled by the expanded connectivity that 5G networks will eventually provide.

2.7 5G Helps IoT

To make better informed, faster economical decisions, the speed and strength of the network must be provided. the 5G network can provide speeds up to at least 20 times faster than the current-generation wireless technologies. With this deterministic advantage, the potential of the IoT is not only to streamline and standardize, but also to supercharge the industrial sector to a whole new frontier.

Imagine predictive and large-scale data analytic investigation with parallel computing and remote control technology of mega size industrial equipment accelerated with both hardware and software technologies that can power and drive each and every corner of our planet. This macro and globalized visions will not be possible to think of years ago, but now 5G has made it possible. It all adds up to a seismic shift and puts our society on the cusp of a Fourth Industrial Revolution.

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