A Review Article on Various 5G High Efficiency and Performance Oriented Models

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***Abstract*—**The invention of long distance radio transmission by Guglielmo Marconi and its subsequent demonstration which provided continuous contact with ships marked the beginning of wireless mobile communication and since then, the ability to communicate with other people while moving has evolved remarkably with the evolution of wireless mobile in a very short span of time. In the last few decades, the evolution of wireless mobile began from Zero Generation (0G), followed by First Generation (1G), Second Generation (2G) and Third Generation (3G). Currently, the Fourth Generation (4G) systems are being deployed with the main purpose, Quality of Service (QoS), efficiency and performance.With this, the wireless mobile technology are going forward to Fifth Generation (5G). 1G, 2G, 3G and 4G technologies fosuced on alanog wireless mobile communication, digital wireless communication, voice and data communication, and Quality of Service (QoS) and increased data rate respectively. Currently, the 5G term is not officially used. But in 5G, researches are being focused on the development of WWWW, Dynamic Adhoc Wireless Networks (DAWN), etc.

I. INTRODUCTION

The evolution of wireless mobile industry began from early 1970s and from mid 1990s, the cellular communication industry witnessed explosive growth. Wireless communication networks have become much more prevalent than anyone could have ever imagined right when the cellular concept was first deployed in 1960s. Mobile cellular subscribers increased up to 40% per year and by the end of 2010, the number of mobile cellular subscribers became 4 times more than that of fixed telephone lines subscribers. This rapid worldwide growth in mobile cellular subscribers has demonstrated conclusively that wireless communication is a robust and viable voice and data transport mechanism. The widespread success of cellular has led to the development of newer wireless system. Various standards for many other types of telecommunication traffic besides mobile voice telephone calls were also developed.

Wireless technology can be differentiated on the basis of their range. While some of them offer connectivity via Bluetooth within few feet and others cover medium sized office space, the mobile phone covers whole continents. Wireless technology offers e-commerce more flexible and inexpensive ways to send and receive data. The four benefits of wireless technology are as under:

- Increased efficiency: High technology communication systems lead to faster transfer of information within business and between customers.
- Rarely out of touch: There is no need to carry cables or adapters in order to access office Networks.
- Greater flexibility: Wireless workers in the office can be networked without sitting at their dedicated PCs.
- Reduced cost: Wireless networks are mostly cheaper to install and maintain than wired networks.

II. HISTORY

In order to know the future and direction the current wireless industry is leading, there is a need to understand its roots.

The evolution of wireless mobile classify the various technologies into different generations based on their main focus and objectives. The first generation (1G) of wireless mobile is quite rudimentary as compared to networks that exist today. It was an analog service, which was focused purely on basic voice service.

The second generation (2G) of wireless mobile was still designed for voice, but the whole system is switched to digital standards. 2G saw the development of both GSM and CDMA standards - both of which are still widely in use today for voice communication. These protocols made significant improvements in terms of coverage and capacity over the analog networks of the first generation. But, these improvements were not adequate for large-scale data use.

The third generation (3G) introduced data services, thus expanding the functionality beyond voice, multimedia, texting and some other limited internet access and it was not until the fourth generation (4G) that the wireless mobile industry got a full Internet Protocol (IP)-based specification.

The 4G protocol LTE is designed to support mobile broadband which basically focuses on the speed of the internet, and is currently leading the mobile industry standard. The waves of new generations of technology have come in roughly decade-long cycles starting from 1G in the 1980s to 2G in the 1990s followed by 3G in the 2000s and 4G in the 2010s.

Currently, the fifth generation (5G) is not yet clearly defined. Since 5G is currently not in practical stage, it is not clear that a single standard will drive the shift to the next generation of wireless technology. In fact, 5G is used to refer to a number of different technologies, and not necessarily a particular standard or specification.

The evolution of the wireless mobile industry are contributed by various organizations from different parts of the world. The era of 1G began in 1979 when Nippon Telegraph and Telephone (NTT) commercially launched 1G cellular network in Japan followed by NMT in Denmark, Finland, Norway and Sweden in 1981.

The 2G came to light in 1991 when Radiolinja commercially launched 2G network on the GSM standard in Finland and since then, the technology has been evolved to 2.5G (GPRS) and 2.75G (EDGE) respectively which served as the standard for the next generations to come. Then in the year 2001, 3G first came into the scene in the wireless mobile industry. In May, 2001, the first pre-commercial trial network with 3G technology was launched by NTT DoCoMo in Tokyo, Japan. Then the first commercial 3G network was launched on October 1, 2001 by NTT DoCoMo using WCDMA technology. Later in 2002, to rival CDMA2000, the first 3G networks on 1xEV-DO technology were launched by SK Telecom and KTF in South Korea, and Monet in the USA. Monet has since gone bankrupt. By the end of 2002, the second WCDMA network was launched by Vodafone KK (now Softbank) in Japan. In March, Italy and the UK marked the first European launches of 3G on WCDMA by the Three/Hutchison group. The year 2003 saw a further growth with 8 commercial launches of 3G, 6 more on WCDMA and another 2 more on the EV-DO standard.

By the end of 2007, there were already 295 Million subscribers of 3G networks worldwide, which reflected a growth of 9% of the total worldwide subscriber base. The WCDMA standard held about two-thirds of the subscribers and the remaining one-third were the subscribers of the EV-DO standard. During 2007, over 120 billion dollars of revenues were generated by the 3G telecom services and the majority of new phones activated were 3G phones in the mobile markets. Second generation (2G) phones were no longer supplied in Japan and South Korea.

Earlier in the decade, there were doubts about whether 3G might happen or not, and also whether 3G might become a commercial success or a failure. But by the end of 2007, it had become clear that 3G technology was a reality and was clearly leading on the path to a profitable venture in the mobile market.

4G technology started from the year 2009 with the introduction of Long Term Evolution (LTE) standard which was commercially launched in Norway and Sweden by TeliaSonera on December 14, 2009. Sprint then released the first WiMAX smartphone, HTC Evo 4G in the US on 4 June, 2010 while MetroPCS released the first LTE smartphone, Samsung Craft on November 4, 2010. Since then, the service has been upgraded for various applications like high-definition mobile TV, video conferencing, gaming platforms, cloud computing and 3D TV.

III. TECHNOLOGICAL ADVANCEMENTS OF WIRELESS MOBILE TECHNOLOGY

A. Zero Generation (0G): 0G started wireless telephone, which became available only after World War II. In those days, mobile operators set up the calls and there were only a handful of channels available. These mobiles do not support handover feature i.e., change of channel frequency. 0G refers to the pre cellular or pre-cell mobile telephony technology in 1970s. One such example is Radio telephones that were installed in cars before the introduction of cell phones. Mobile radio telephonic system produced modern cellular mobile telephone technology. Since they were the predecessors of first generation (1G) of cellular telephones, these systems are called Zero Generation (0G).

B. First Generation (1G): 1G is the first generation wireless telephone technology, cell phones. First introduced in 1980, they were analog cell phones. In 1979, the first cellular system in the world became operational in Tokyo, Japan by Nippon Telephone and Telegraph (NTT). In 1980s across the Europe, the two most popular analog systems i.e., Nordic Mobile Telephone (NMT) and Total Access Communication System (TACS) were also introduced. Handover and roaming capabilities were available in all the systems, but unfortunately the cellular networks were unable to interoperate between the countries. This was the main drawback of the first generation mobile networks. 1G has low capacity unreliable handoff and poor voice links. Since voice calls were played back in radio towers, there was no security in the networks making these calls susceptible to unwanted. In USA, AMPS was first 1G standard which was launched in 1982. The Federal Communication Commission (FCC) allocated the AMPS system a 40 MHz bandwidth within the frequency range of 800-900 MHz. Additional 10 MHz bandwidth, called Expanded Spectrum (ES) was allocated to AMPS in 1988.

C. Second Generation (2G): 2G, also called the Second Generation wireless mobile technology was based on digital technologies and was introduced in the early 1990s. In 1991, 2G was launched in Finland. This technology provided services such as text message (SMS), and picture and video messages (MMS). 2G has a greater security as compared to 1G for both sender and receiver. All the text messages are digitally encrypted, which allows a better security for the transfer of data in such a way that only the intended receiver can receive and read the messages. 2G system uses two digital mobile access technology, TDMA and CDMA. TDMA divides a signal into different time slots while CDMA allocates each user a special code to communicate over a multiplex physical channel. GSM, iS-136, iDEN and PDC are some examples of TDMA technologies but GSM was the first 2G System. IS-95 is an example of CDMA technology.

GSM (Group Special Mobile), originated from Europe is the most admired standard of all the mobile technologies. It is used in more than 212 countries across the globe. GSM standard made international roaming possible, even between different mobile phone operators, enabling subscribers to use their phones in different parts of the world. GSM uses TDMA to multiplex up to 8 calls per channel in the 900 and 1800 MHz frequency bands. GSM can not only deliver voice data but also circuit switched data at the speed up to 14.4 kbps. FCC also auctioned a new block of spectrum in the 1900 MHz band in the US. In the span of 20 years, GSM technology has been continuously improved and upgraded to offer better services in the wireless mobile market. Based on the original GSM standard, new technologies have been developed leading to some advanced systems. Some examples include 2.5 Generation (2.5G) and 2.75 Generation (2.75G) systems which are commonly known as GPRS and EDGE respectively.

D. Third Generation (3G): Developed and launched by NTT DoCoMo in Japan, 3G is the third generation wireless mobile technology which replaced the previous generation 2G in the wireless mobile market. Based on the International Telecommunication Union (ITU), it formulated a plan called International Mobile Telephone 2000 (IMT-2000) to implement a global frequency band in the 2000 MHz range, which will support both single and global wireless communication standard for all countries throughout the world. 3G evolution for CDMA standard is based on IS-95 and IS-95B technologies which lead to CDMA 2000 and its several variants. 3G evolution for GSM standard is based on IS-136 and PDC systems which lead to wideband CDMA (W-CDMA), also called Universal Mobile Telecommunication Service (UMTS).

E. Fourth Generation (4G): 4G is the fourth generation wireless mobile technology that succeeded 3G. The International Telecommunications Union-Radio (ITU-R) communications set the 4G standard, also called the International Mobile Telecommunications Advanced (IMT-Advanced). It focuses on interoperability between different sorts of networks, with high speed data transfer that peaks at 100 Mbps for high mobility communication and 1 Gbps for low mobility communication. The high mobility criteria is considered for moving vehicles like cars and trains while low mobility is considered for pedestrians and stationary users. In 2009, the first Long Term Evolution (LTE) was deployed in Norway and Sweden. The 4G network uses a wide range of frequencies which are 700 MHz, 850 MHz, 1800 MHz, 1900 MHz, 2100 MHz, 2300 MHz and 2600 MHz depending on the requirements of different countries.

F. Fifth Generation (5G): 5G or fifth generation is a marketing term used for the next generation wireless mobile technology. It follows the ITU IMT-2020 standard and a 20 Gbps speed of theoretical download capacity peak is required as per this standard. The 5G is divided into three major services which includes enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communications (URLLC) and Massive Machine Type Communications (MMTC). eMBB deals with the enhancements of handset’s capabilities while URLLC deals with industrial applications and autonomous vehicles and MMTC for sensors but initial deployment is set to focus on eMBB and fixed wireless. 5G will use the existing LTE frequency range which is from 600 MHz to 6 GHz along with millimeter wave bands from 24 to 86 GHz. As of now, it is confirmed that Intel and Qualcomm are developing 5G technology while Samsung, Nokia, Huawei, Lenovo, Ericsson, etc. are developing its architecture. The commercial launch of 5G is expected to roll out in 2020 with major carriers like AT&T, Verizon, Sprint and T-Mobile deploying in the US, EE in UK, Vodafone in Spain and KT, LG U+ and SK Telecom in South Korea.

IV. CHALLENGES OF 5G

While 4G was largely focused on mobile broadband, 5G allows engineers and developers to look at new ideas and new uses which can be implemented thus broadening their horizons. While considering different use cases, different demands are introduced on the network, and these demands impact different sectors of the economy. 5G must consider various demands like the various networking requirements of industrial automation, precision agriculture, and augmented reality. Where demands are overflowing, engineers push up against the boundaries of what the 4G technology is currently capable of doing, researchers start to consider big leaps to whole new technologies instead of adding more features one by one to the current LTE specification.

Due to the fundamental challenges that 4G networks are currently facing, the development of 5G is driven. The fundamental challenges can be roughly divided into whether they are primarily for human users or for machine users. Thus, the different uses cases that drive to the development of 5G can be grouped into three types:

- Enhanced Mobile Broadband,
- Internet of Things (IoT),
- Critical Infrastructure or Public Safety.

V. METHODOLOGY

There are several reasons why a deterministic model is considered to be more suitable for 5G wireless communications such as accuracy, spatial & temporal consistency, site specific simulations, frequency dependency & large bandwidth, support of 5G use cases such as mesh networks, D2D, massive/distributed MIMO & CoMP, spherical wave & large antenna arrays beyond consistency interval.

A. MAP-BASED MODEL

The map-based models are most often based on:

- Ray-tracing,
- Digital description of propagation environment,
- Deterministic modeling of propagation in terms of rays.

Penetration, diffraction, diffuse scattering blocking and specular reflection are also accounted for. Thus in the formulation, the frequency dependency is included. There are a number of pathways which contribute to the received power for each specific link between Tx and Rx.

B. HYBRID MODEL

The map-based model which is based on ray-tracing is able to simulate the mechanisms of free-space propagation, reflection and diffraction well when the digitized map of deployed scenario is given. Its accuracy is directly relative to the resolution of digitized map, which is also relative to the modeling complexity. But for other important factor of radio propagation like diffuse scattering, this propagation theory is not that mature and it requires a huge computational effort for the modeling of diffuse scattering.

To ease the modeling complexity of diffuse scattering, the idea to combine both the stochastic and deterministic approaches has been proposed as channel modeling methods to ease the modeling complexity of diffuse scattering. These methods are able to maintain the modeling accuracy of scenario-specific propagation paths such as METIS hybrid model, quasi-deterministic model, semi deterministic or hybrid model based on ray-tracing and propagation graph and point-cloud model. These models are proposed mainly based on the new frameworks. Using the measurement data in different scenarios, many of the parameters involved in these models can be calibrated.

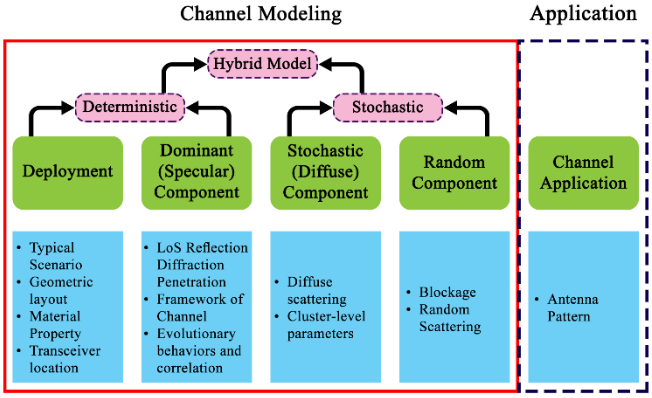

Fig. 1: Framework of map-based hybrid model

The map-based hybrid model has been endorsed as an alternative modeling methodology in 3GPP New Radio (NR). This method takes advantage of both ray-tracing (i.e., calculating the dominant propagation paths through a few numbers of reflection and diffraction bounces) and stochastic approach (i.e., expanding the paths to clusters by calculating the diffuse scattering from rough surfaces, and complement the channel response by calculating the random scattering from the small objects which are hard to be included in digitized maps). This is well illustrated in fig. 1. The additional features that the 5G high-frequency channel modeling requires is supported by the calculated dominant paths and the stochastic part of this hybrid model is highly compatible with the standardized stochastic models like 3GPP 3D model or NR high- frequency model. The innovation of this map-based hybrid model is that the statistical parameters in the standardized stochastic models can be fully reused. Therefore, as long as the digital maps are available there is no barrier for large-scale applications in various scenarios. This map-based hybrid model has also been recommended in 5G's ITU IMT-2020 standard evaluation report.

VI. CONCLUSION

This review article gives a general idea of map-based model which is is a deterministic modeling methodology by using ray-tracing approach. The benefits and the reasons for its use are also explained. But more importantly, the hybrid modeling is discussed as it offers additional advantages like speed or modeling the stochastically missing environmental information. This concludes that the map-based model provides consistency in frequency, time, and space domains as well as supports many novel 5G use cases.

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