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Evolution Of Wireless Technologies towards Fifth Generation (5G) Network Deployment

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Abstract
The future of the next-generation of mobile communications system lies with the fifth generation (5G) network which the world is preparing towardsits deployment in 2020. The diversed services of 5G technology comprises of improved Mobile BroadBand (MBB)that produces high data rates, larger system capacity,covers wider range, supports high reliability of Machine-to-Machine (M2M) communications and Internet of Things (IoT) that accesses all varieties of things on the network wirelessly. This paper presents a general overview of 5G activities happening globally including standardisation and deployment scenarios. The paper gave definition of the 5G technology, atticulates the types of services and requirements of the system, explains the concept, technicalities and standardisation activities of the technology as well as the strategy towards its launch in 2020. Furthermore, the efforts of continuous researching and development of the 5G technology in some organisations has also been highlighted.

INTRODUCTION
The fifth generation (5G) wireless cellular system has been under discussion ever since the devlopment of the 4G technology by ITU. Upon the development of 4G standardisation, the 3GPP, a leading standardisation for mobile communications systems started working on the 5G systems in 2015 standardization, marking the beginning of serious discussions on 5G standardisation. One of the major performance goals of the 4G cellular system includes peak data rates of 1 Gbps and 500Mbps in the downlink and uplink respectively. Driven by the explosion of users' demands for mobile data along with new services and applications as well as the need for a ubiquitous and wirelessly accessible cloud platform, the evolution of future mobile traffic is expected to boom (Akyildiz *et al.*, 2014). Nevertheless, the demand for more applications and services is increasing and predicted that by 2020 mobile data traffic will increase thousand folds. The long-term result of this trend is what has transformed into 5G: as a set of seamlessly integrated radio technologies that promise to bring Mobile broadband networks to support the ever-growing consumer data rate demands and tackle the exponential increase in the predicted traffic volumes.It is the convergence of these wireless networks that make selection of the best Radio Access Technology (RAT) possible as depicted in Figure 1.

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It is no secret today that services and applications such as video and voice streaming as well as music over the internet are being enjoyed anywhere and anytime. All these have become possible with the proliferation of smartphones, tablets and other smart devices. In addition, there has been spontaneous increase in traffic due to mobile service demand since 2010.One of the solutions to these high volumes of traffic demands, is for telecommunication operators to provide enhanced Mobile Broad Band (MBB) system for these services by ensuring high level of quality of service (QoS) to user. Furthermore, the global trend now is that all kinds of things are expected to wirelessly connect to the network termed Internet of Things (IoT). However, this developmenthas been receiving great attention from researchers in recent years. Therfore, the challenge rest with both the mobile operators and major telecommunication carriers to explore the opportunities in this and provide the required infrastructure necessary to support these new servicesin a new business horizon of IoT.

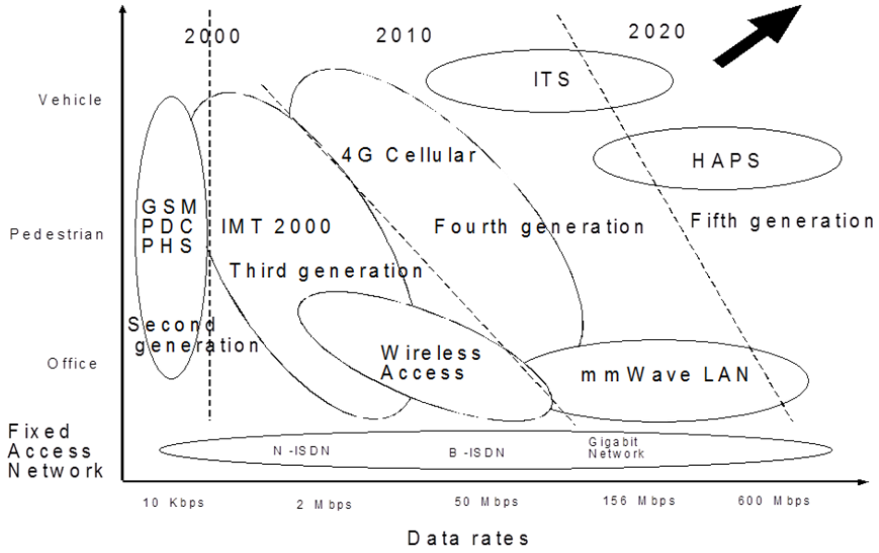

Figure 1. Radio Access Technologies towards 2020 (Miyim *et al.*, 2017)

In the midst of these expectations, discussions have been going on in recent years that the integration of two technologies of fourth-generation (4G) LTE and fifth-generation (5G) mobile communications systemswill manifest as the next generation of LTE-Advanced networks (Abeta *et al.*, 2015). Various organisations saddled with the promotion of the 5G projects have launched researches throughout the world into different areas of the 5G concept and associated requirements (Kishiyama *et al.*, 2016). The study of 5G which started in 2010 and has recorded some success in a variety of 5G activities starting from technical concepts, to conducting transmission experiments and standardisations. This article presents an overview of the evolutionary developments of cellular wireless networks, their activities and in particular, services and requirements envisioned for the 5G era.

The Trends of Mobile Communications System

There has been a paradigm shift every decade in the mobile communication systems that have seen so far four generations. The first generation (1G) systems in the 1980s were the original analogue mobile voice networks. The second generation (2G) systems that emerged in the 1990s are based on digital technologies for mobile voice and data traffic. The third generation (3G) systems, firstly introduced in 2001 in Japan, are characterized by high-speed digital mobile voice, data and multimedia services. The fourth generation (4G) systems were commercialized and hit the market in 2010. Recently, full implementation of 4G has just become a reality at the end of the year 2012(Miyim *et al.*, 2017). The summary of key

milestones towards the development of the 4G technology from 1G through 4G is summarized in Table 1. Milestone of 1G, 2G, 3G and 4G Cellular Systems.

Table 1: Stages of Wireless Technology Development

Generation	Requirements	Comment
1G	Analogue Technologies without requirements	Developed in the 1980s
2G	Digital Technologies without requirements	Developed in the 1990s. -New services of SMS introduced. - Technology: IS-95 CDMA & GSM.
3G	ITU-R IMT-2000 requirements: -Mobile – 144Kbps -Pedestrian – 384Kbps -Indoors – 2Mbps	Developed in 2001. -Technology: CDMA20001xEV-DO & UMTS/HSPA. -WiMAX: declared 3G Technology.
4G	ITU-R IMT-Advanced Requirements: Capable of operatingwithin 40MHz Radio Frequency Channels with High Spectral Efficiency.	Developed in 2010. IEEE802.16m and LTE-Advanced technologies to meet requirements.
5G	ITU-R IMT-2020 requirements: Ability to provide higher bit rate, wier coverage, improved latency & reliability, higher system capacity, massive device connectivity and reduced energy and cost	Developed and ready to be deployed in 2020. The technology promise to provide diverse array of services of enhanced mobile broadband (MBB) and Internet of Things (IoT)

The analogue mobile systems constituted the first generation of cellular networks designed for voice communications. The second generation (2G) systems that emerged in the 1990s are based on digital technologies for mobile voice and data traffic. It was a motivation to acquire data services and improve the spectral efficiency using digital modulations and time division or code division multiple access (CDMA). The development of 3G systems were characterized by high-speed digital mobile voice, data and multimedia services by using technologies such as Wideband Code Division Multiple Access (WCDMA) and High Speed Packet Access (HSPA). The technology of HSPA combines High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), that brought lot of improvements in the current 3G networks performance by utilizing WCDMA protocols. Minor changes were introduced to the LTEtechnology by 3GPP that gave birth to the fourth generation (4G) wireless technology, through Release 9. Such additions include; femtocells and dual-layer beamforming, which have been added to the standard. The requirements for 4G as established by the ITU-R, has common global equipment functionality, but maintaining the flexibility to support a wide range of services and applications in a cost-efficient manner; Compatibility of services within IMT and with fixed networks; Compatibility of internetworking with other radio accesssystems; User-friendlyapplications; global roamingcapability; Enhanced peak rates to support advanced services and applications (100 Mbit/s for high mobility and 1Gbit/sforlow.

The diagram depicting the trend of LTE advancement is demonstrated in figure 2.

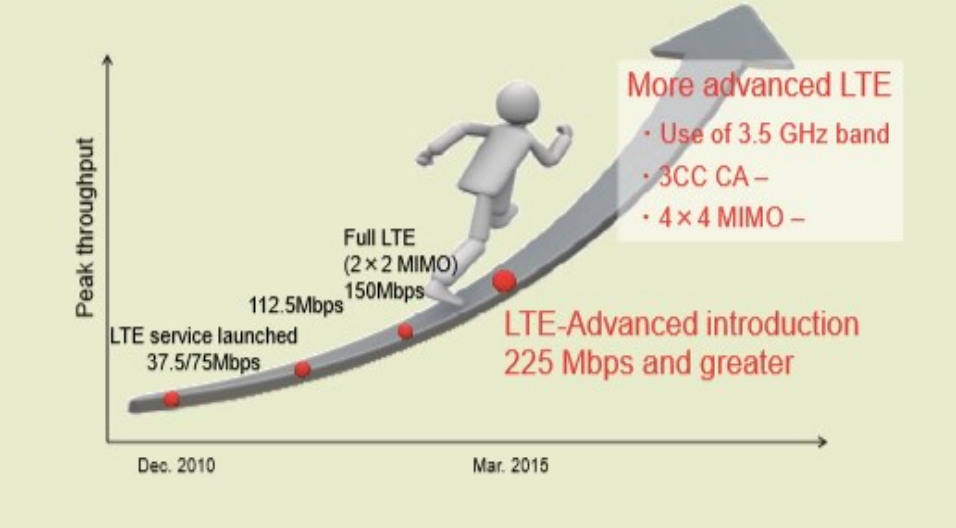

Figure 2. Towards More Advanced LTE [10]

SERVICES AND REQUIREMENTS OF 5G

The Services.

Though 2G and 3G systems are capable of providing improved services with the assistance of smartphones, it is clear that there is little or no straight relationship between mobile communications and services provided by them. However, 4G technology is said to provide most of the services required by 5G. This simply means that it is possible to deploy enhanced LTE-Advanced in a spectrum already occupied by LTE with no impact on the existing LTE terminals. Some of the requirements of IMT-Advanced as established by the ITU-R (Uchino *et al.*, 2015 and METIS, 2013) includes the followings: (i) Uniformity of equipment functionalities globally and maintaining flexibility of a wide range of services and applications in a cost-efficient manner; (ii)service Compatibility within IMT and with traditional telephone networks; (iii) internet working with other radio access technologies; (iv) High-quality mobile devices; (v) suitability of user terminal for worldwide usage; (vi) User-friendly applications, services and equipment; (vii) Capability to roam globally; (viii) conducting research for peak data rates enhancement to support advanced services and applications. All the above do not quantify the performance requirement except for the last one. When it concerns detailed description of the IMT-Advanced requirements, specific targets in addition to the usual peak data rates have been set for average and cell-edge performance. This was a necessary issue to be addressed since they define the experience for the typical user. More so, advances in communications technologies provides efficient services in a greater way. The creation of novel services leads to enhancement of 5G communications quality that will later be recognised as the future next generation networks technology.

It is expected that the 5G system could have variety of services that can be broadly segmented into two; the IoT and enhanced MBB as presented in Figure 3.

(1) The services of Internet of Things (IoT), intends to wirelessly connect all kind of things onto the network and provides to end users (organisations and industries) numerous services. To achieve these, equipment like homes appliances, accessories, wristwatches, vehicles, eyeglasses, robots, sensors, etc., by connecting to the network

via Machine-to-Machine (M2M) technology. It is also capable of controlling and managing the huge amount of data that will automatically and intelligently be gathered.

(2) The enhanced MBB services will wirelessly enable a better and more complex applications and services over the network with high-speed, high-capacity and low-latency. These will strengthen the possibilities of high-definition video (HDV) streaming, media-rich social network services, augmented reality (AR) services and closely coordinated with big data on the cloud and media communications. Moreover, autonomous driving, a new and branded services that require certainty and safety will be facilitated by wireless communications.

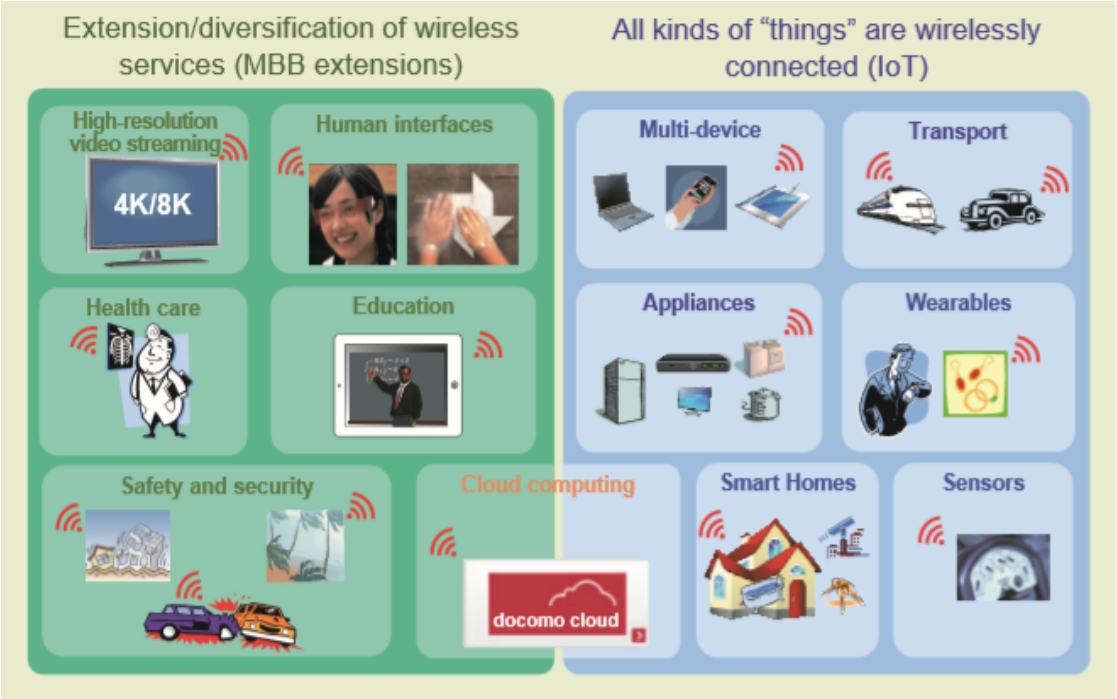

Figure 3: Diversity of Services to be Offered by 5G (Abeta *et al.*, 2015)

The Requirements

To support these diversities of services and possible expectations in addition to the universalities of existing mobile communications systems, it is considered that the evolving trends of IoT will deal with these new requirements. Such envisioned wide range of 5G requirements are summarised and demonstrated in figure 4.

(1) Higher System Capacity

In recent time, the cellular mobile communication system is experiencing spontaneous increase in volume of mobile data traffic at an alarming rate. It is equally predicted by Cisco (2018) that the number of mobile data traffic will multiply sevenfold between 2016 and 2021 reaching 49.0 Exabyte per month. Furthermore, mobile-connected devices will hit 11.6 billion by 2021. Dealing with this explosive increase will therefore witness a dramatic increase in system capacity and is considered to be the most basic requirement for the 5G network.

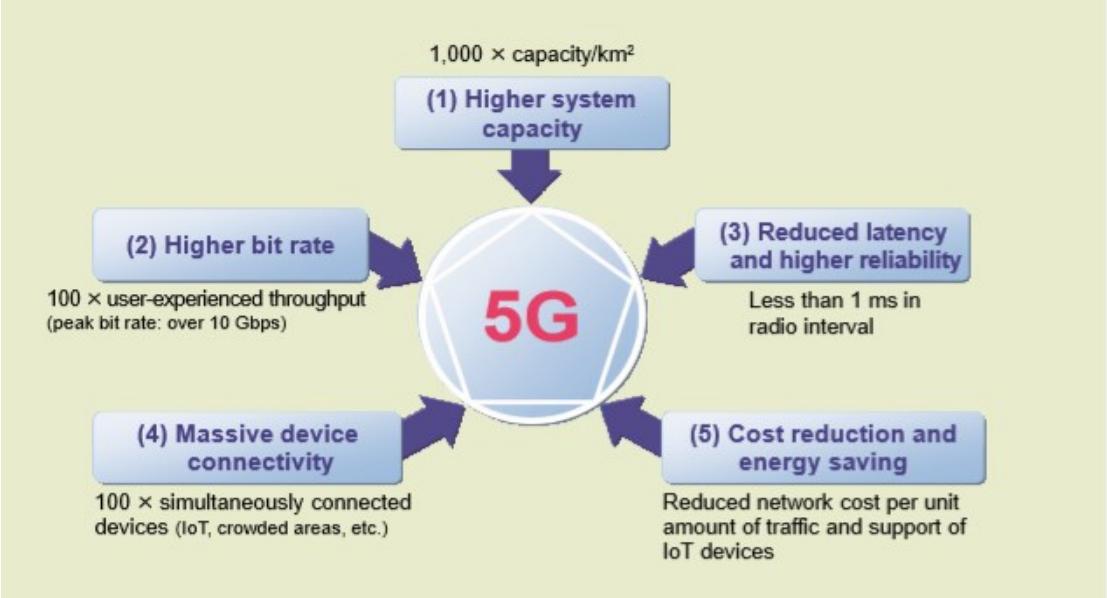

Figure 4: 5G Requirements

(2) Higher Data Rate

Looking at the proliferation of cloud applications and rich content services, it is evident that 5G is very capable of providing quantum leap in bit rate. Therefore, the quality of service (QoS) is important and must satisfy, at all times, the required provisions regardless of location and time of the day. Ideally, mobile users are supposed to access 100 times more of peak data rate than what is obtainable in LTE (>10 Gbps) with a good wireless environment.

(3) Improved Latency and Reliability

The 5G technology is expected to introduce some new emerging services like AR that require low latency than what used to appear in the LTE. The expected latency in 5G radio interval is less than 1ms as compared to that of LTE. In addition to the low latency, high reliability will be necessary for services such as autonomous driving that require certainty and safety.

(4) Massive Device Connectivity

Though it is predicted that there will be a dramatic increase in the number of devices that will connect to the wireless network for the IoT services, it has become necessary then, to support simultaneous connection of devices under different schemes. These may not only be limited to environments of mass user gathering such as stadia alone, but also event centres and natural disasters situations in which multiple attempts to access the network is highly expected to occur simultaneously.

(5) Energy and Cost Reduction

Though setting such high performance targets for 5G networks, it is equally important to provide cheaper and even better services to end users. That is to say that network cost per user traffic will be greatly reduced and possibly improved energy consumption that guarantees high network performance. It is however, important considering life-span extension of sensor batteries of devices used for IoT services. The inexpensiveness of such devices motivates the wireless network to support such IoT characteristics. These requirements are currently being studied at various forum like world leading telecom

carriers, European project, mobile and wireless communications enablers for twenty-twenty (2020) Information Society, etc., (Akyildiz *et al*., 2014 and Kishiyama *et al*., 2016).

Definition and Technical Concept of 5G

1) *Approach*

There are two suggested ways to deploy Radio Access Technology (RAT). The first step is to consider using evolved forms of LTE and LTE-Advanced. It involves continuous development of the technologies while maintaining backward compatibility with the existing LTE system. The second method involve introduction of a new RAT. It places improvement on performance as a high priority rather than continue to be maintaining the backward compatibility of the LTE system.

2) *Technical Concept* (e-LTE + New RAT)

The continuous development in LTE/LTE-Advanced rather known as enhanced LTE (e-LTE) together with the introduced RAT could be regarded as the definition of the fifth generation of networks and is depicted in figure 5.The introduction of the new RAT as a concept will achieves better performance with improved data rate and capacity. This in turn find applicability in broader frequency bands while providing good coverage and services by the evolved-LTE (e-LTE). Additionally, the incorporation of Non-Orthogonal Multiple Access (NOMA) technology, leads to low latency, improved capacity (Benjebbour *et al*., 2016) of the present frequency bands and radio access technologies, regardless of the frequency band. It is therefore desirable to adopt an e-LTE approach with the LTE in order to maintain backward compatibility when applying such technologies.

It is difficult to secure enough coverage and at the same time improve the performance when operating in high frequency bands that have not used in mobile communications before. Therefore, it is necessary for Radio frequencies operating in the centimetre waves (3–30 GHz) and millimetre waves (30 GHz and higher) to be considered when introducing the new RAT. Furthermore, the purpose of introducing massive number of antenna elements by employing Massive Multiple Inputs Multiple Outputs (MIMO) technology (Suyama *et al*., 2016)is to improve radio parameters. The new technical development of RAT requires pragmatic design to coexist with the LTE technology for improved system throughput regardless of frequency band.

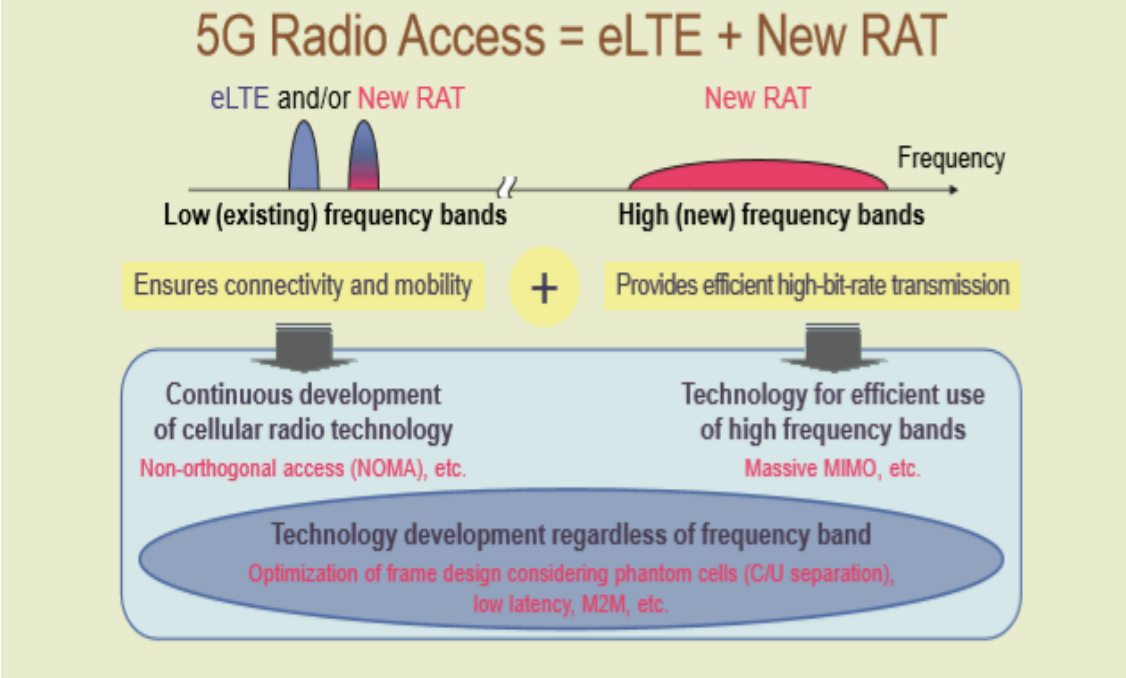

Figure 5: The Definition of 5G

3) *Deployment Scenario*

The picture shown in figure 6, illustrates the deployment scenario of 5G with the two novel technologies of enhanced LTE (e-LTE) and the new RAT.As urban cities require higher capacities, it is appropriate to deploy LTE and new RAT at the initial stage in order to achieve the 2020 deployment target. However, Carrier Aggregation (CA) technologies (Uchino *et al*., 2015) is the preferred technology for the future 5G system capable of interworking in order to achieve higher capacities while maintaining coverage. Consequently, 5G deployment enables little expansion of the suburban coverage from the urban areas, in such a way that the introduction of very high frequency bands like the millimetre waves are necessary when the need arises in the future. However, further evolution of the 5G technology into 2021 and beyond will be referred to as 5G+ or Beyond 5G (B5G).

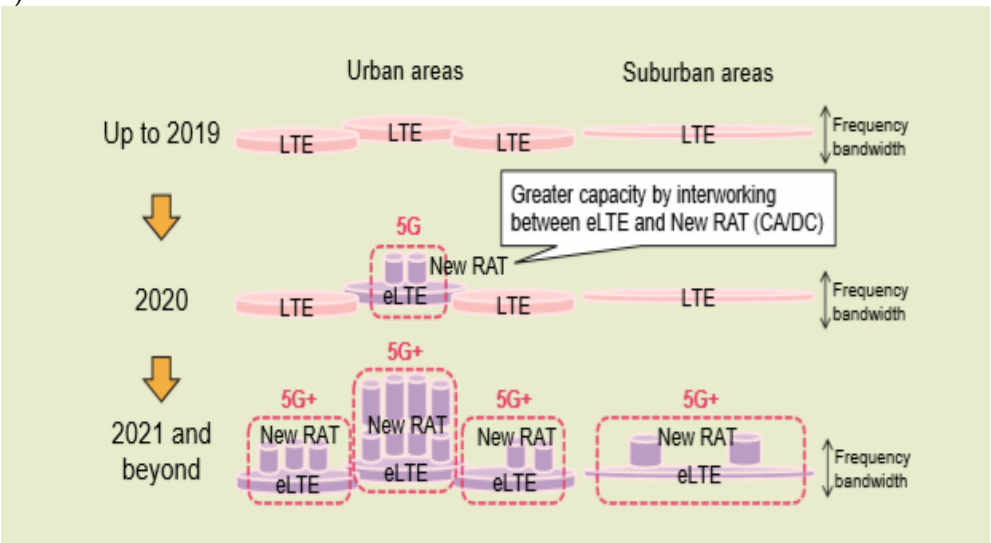

Figure 6: 5G Deployment Scenario (Benjebbour *et al*,.2016)

STANDARDISATION AND SYSTEM STRATEGY

Stepwise Standardisation Approach

By the year 2020, both the existing frequency bands and the new frequency spectrum that will become available as well as those licensed bands that exists today will all be candidates for the 5G frequency bands. As illustrated in figure 7, some research and development of telecom companies like NTT DOCOMO is planning to introduce 5G in 2020 and aims at its continuous development as 5G+ in years to come. However, discussions have been going on at different international fora such as the Radio working group of the International Telecommunications Union-Radio (ITU-R) and at its World Radio Communication conference (WRC) on additional new frequency bands.It is envisioned that the technologies applicable to radio access and the network may as well be extended.

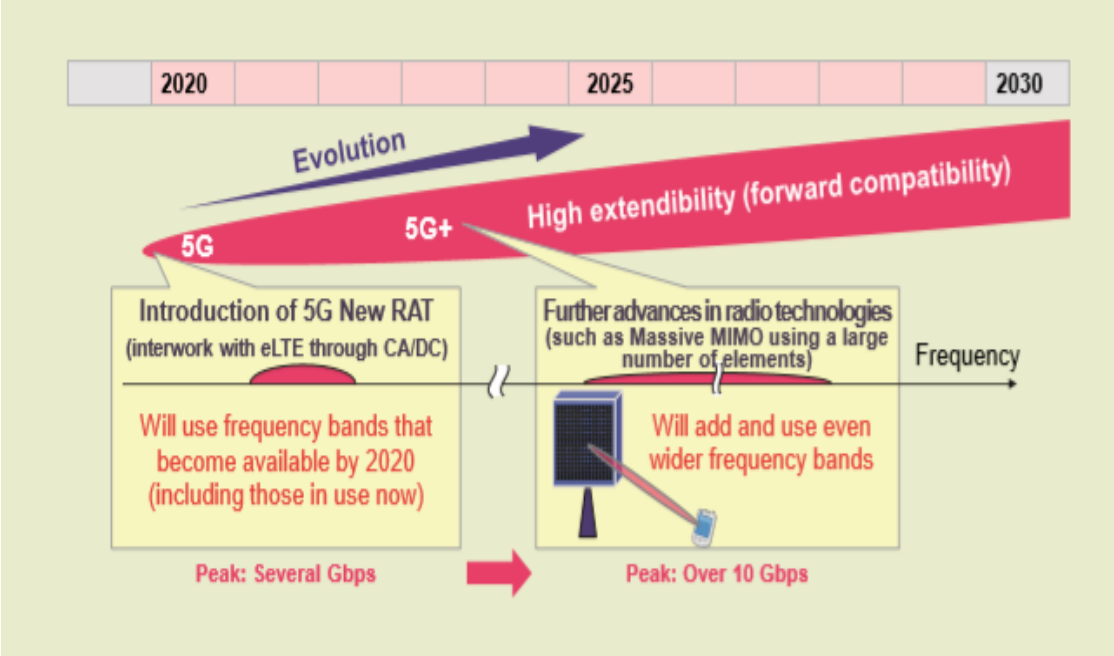

Figure 7: The Evolution of 5G (Abeta *et al.*,2015)

1) *Stepwise Standardisation*

The introduction of new RAT in 2020appears that 3GPP standardisation has been completed. However, according to the programme schedule of the ITU_R, standardisation of radio interface has to also satisfy the requirements of ITU-R specifications of 5G better known as (IMT-2020) and must be completed by the end of 2019. For this reason, two types of standardisation are being considered,5G and 5G+.The purpose is for the deployment of initial specifications of the new RAT be realised in a shortest possible time by 2020. Indeed, this require priority to be placed on good design, performance and emphasis on future extendibility rather than incorporating additional functions from the beginning.

The fifth generation technology (5G) as was defined earlier, is configured as a combination of e-LTE and new RAT as depicted in figure 8. The continuous evolution of 5G will lead to 5G+ while maintaining compatibility with the 5G technology. However, this is similar to the compatibility relationship that exists between LTE and LTE-Advanced technologies of 4G (Roh et al., 2014).

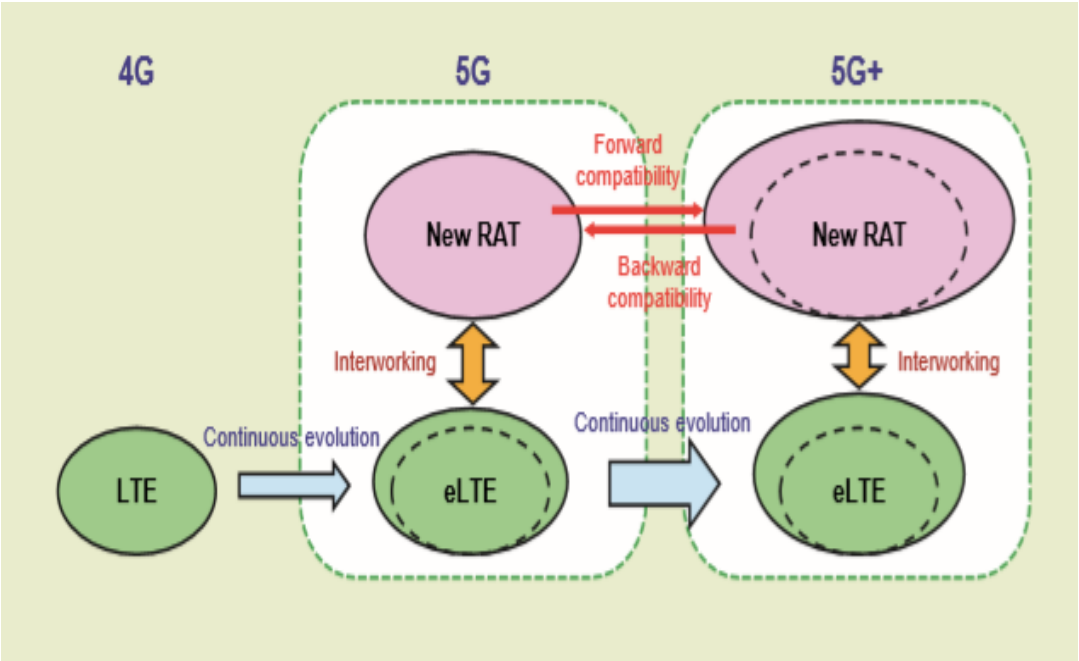

Figure 8: Inter Relationship of 4G, 5G and 5G+

2) *Roles of e-LTE and New RAT in 5G, 5G+*

The enhanced MBB and IoT service forms the 5G service demands that demands high speed capacity. In addition, it prioritises support for the enhanced MBB that requires high bit rates and capacity in urban areas. This service support provided by 5G is shown in figure 9.

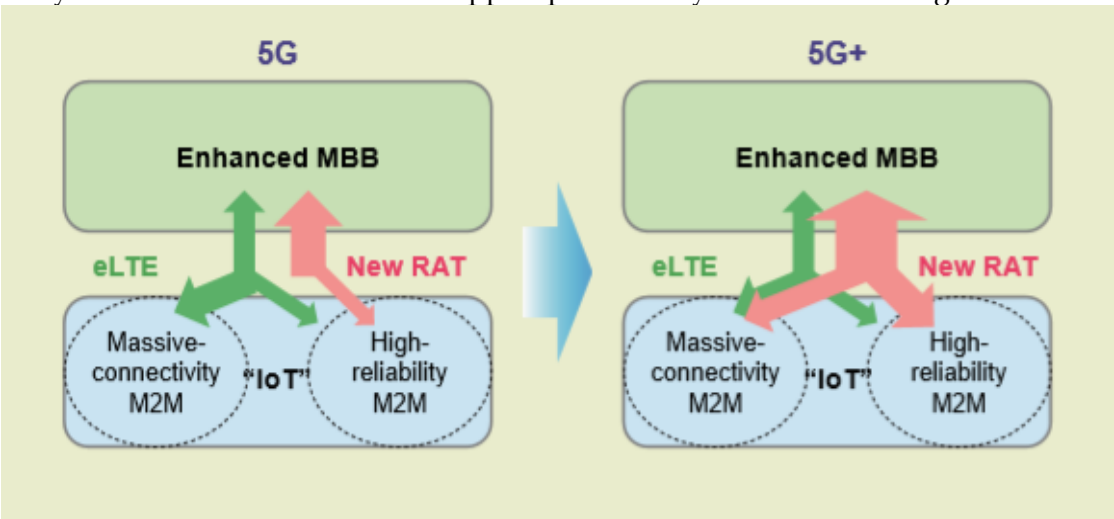

Figure 9: 5G Service Support by e-LTE and New RAT

The enabler of wide coverage (e-LTE), will complement by supporting high reliability of various IoT-related functions such as support for low-cost M2M communications. In the future, thenew RAT (5G+) will is incorporate supporting scenarios,series of functions and multiple services including those services of 5G yet to be known. It is the believe of NTT DOCOMO (Abeta *et al.*, 2015) that 5G services could be achieved in 2020 by combining e-LTE and New RAT Technologies. The candidates radio access technologies for 5G deployment in 2020 are illustrated in figure 10.

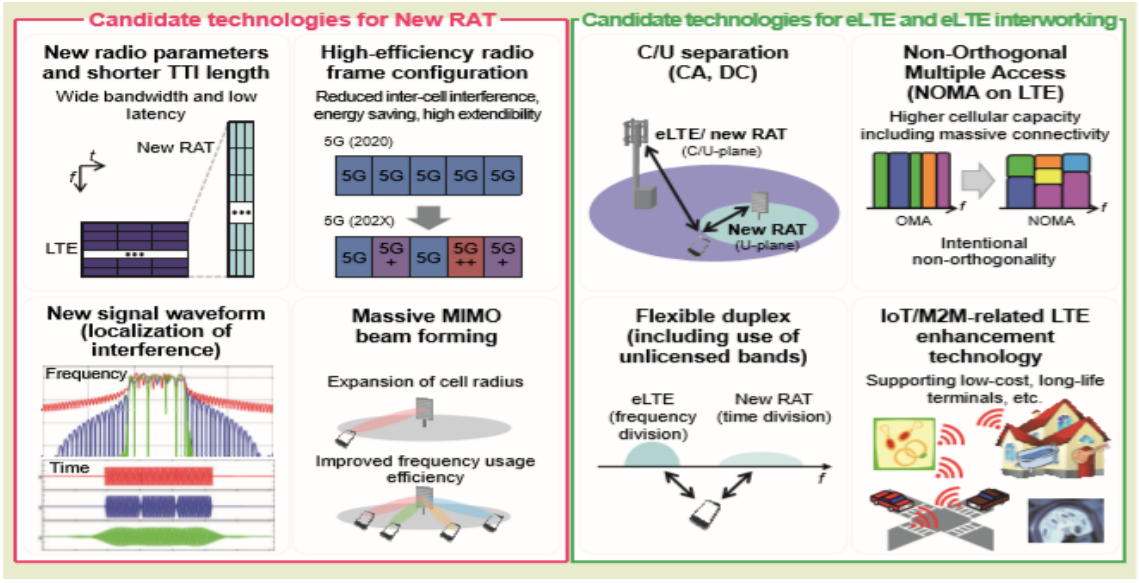

Figure 10: Candidate Technologies for 5G Deployment (Abeta *et al.*, 2015)

4.2 *Overview of 3GPP on 5G*

A Workshop on 5G was organised and held by 3GPP in September 2015, thereby setting in motion the beginning of 5G standardisation. The final schedule for 5G and 5G+ is therefore demonstrated in figure 11. With the mind-set of introducing 5G that comprises of two (2).While phase 1 gives specification of the New RAT, the second Phase looks at specifications that will satisfy ITU-R requirements and expected to roll out as 5G+ few years later.

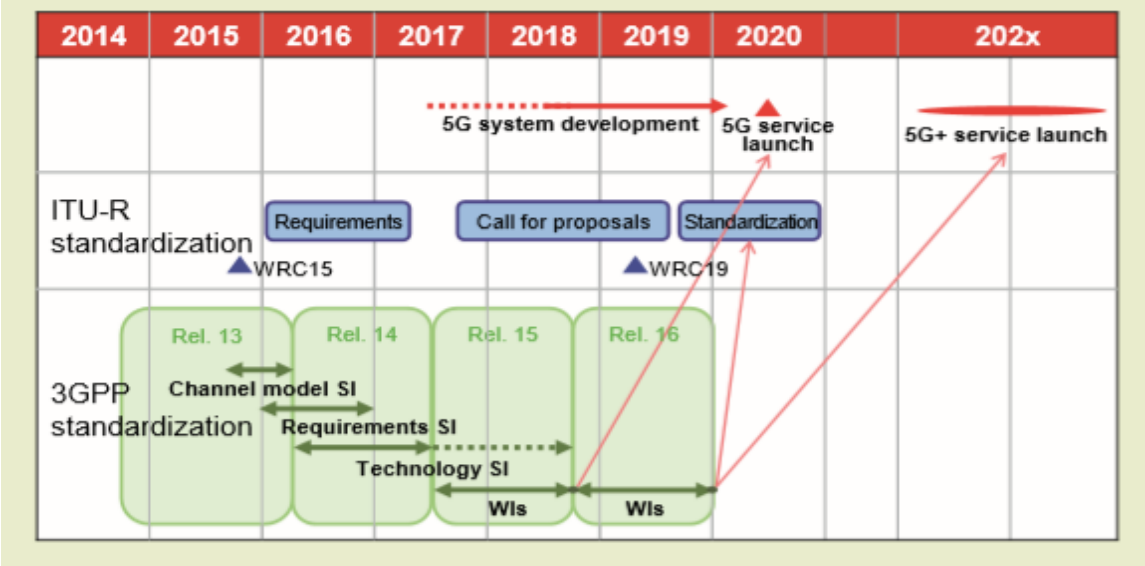

Figure 11 Standardisation Schedule (Tentative) (3GPP Release, 2020)

CONCLUSION

The paper focuses on next-generation networks (5G) of mobile communications system that promise to bring a lot of innovation by providing new services such as enhanced MBB for higher speeds, bigger channel capacity, improved bit rate as well as introduction of IoT services capable of connecting all kinds of things to the network wirelessly. It highlighted some research and development activities towards the deployment of the 5G technology. Some organisations like NTT DOCOMO, are leading the way to promoting 5G standardisation activities with the hope of deploying the 5G services in 2020. Suggestions

were made on continuous support to enhance the system and upgrade it to 5G+ (B5G) in the years ahead. Though the technology is in the process of deployment, the not so developed countries should carefully study the technology before its acceptance and deployment.

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