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Thème

The band wide manegement for 6G Network

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Dédicace

My humble effort is dedicated: To my sweet and loving father and mother: madani and frieha. The source of inspiration and strength, whom continually provide their moral, spiritual, emotional, and financial support. To the angel of mercy for being with me during this work .To my dear brothers: Yahia, choaib and Zakaria and my four sisters and their children: aissa, Baraa Manisa, Asia Orjwan, Assinet farouk and Iskandar for their prayers. To my friends for their inspiring advice. Especially Kheira and Rachida to the soul of Ahmed chaib Silaa, peace to his soul

Abstract

With the launch of the fifth generation of mobile networks with 10 gigabits per second as minimum of data rate using high frequencies than 4G, doors are opened to several services such as the Internet of things, virtual reality and others. However, a demand of more transmitted data and low latency is needed. In order to answer all that, a new release of mobile network is under study, called beyond 5G (b5G) or 6G. The main tool that is expected to be used for increasing the throughput is the terahertz frequencies band wide for new physical layer. That will guide us to create a new technic for the huge band wide manegement, which was not needed in the precedent generations.

In the simulation done, we tried to modify the cell number and user's number to observe the sum-rate evolution. For deducing the parameters that could manage the new physical layer under study.

Keywords: b5G, 6G, physical layer, terahertz frequencies.

Résumé

Avec le lancement de la cinquième génération de réseaux mobiles avec 10 gigabits par seconde comme minimum de débit utilisant des hautes fréquences supérieures à la 4G, une porte s'ouvre sur plusieurs services comme l'internet des objets, la réalité virtuelle et autres. Cependant, une demande d'augmentation de données et de faible latence est nécessaire. Afin de répondre à tout cela, une nouvelle version du réseau mobile est à l'étude, appelée au-delà de la 5G (b5G) ou 6G. Le principal outil qui devrait être utilisé pour augmenter le débit est la bande de fréquences Téra hertz large pour la nouvelle couche physique. Mais cela nous guidera pour créer une nouvelle technique de gestion des bandes de haies larges, qui n'était pas nécessaire dans les générations précédentes.

Dans la simulation effectuée, nous avons essayé de modifier le numéro de cellule et le numéro d'utilisateur pour observer l'évolution du taux de somme. Pour en déduire les paramètres pourraient gérer la nouvelle couche physique à l'étude.

Mots clés : b5G, 6G, couche physique, fréquences Téra hertz.

ملخص

مع إطلاق الجيل الخامس من شبكات المحمول بسرعة 10 جيجابيت في الثانية كحد أدنى لمعدل البيانات باستخدام ترددات عالية تفوق الجيل الرابع ، تم فتح أبواب للعديد من الخدمات مثل إنترنت الأشياء والواقع الافتراضي وغيرها. ومع ذلك ، هناك حاجة إلى طلب المزيد من البيانات وزيادة زمن الوصول المنخفض. للإجابة على كل ذلك ، هناك إصدار جديد لشبكة الهاتف المحمول قيد الدراسة ، يسمى ما بعد الجيل 5G (b5G) أو 6G. الأداة الرئيسية التي يُتوقع استخدامها لزيادة الإنتاجية هي نطاق ترددات تيراهيرتز العريض للطبقة المادية الجديدة. ولكن هذا سوف يرشدنا إلى إنشاء تقنية جديدة للإدارة الواسعة لنطاق التحوط ، ولم تكن هناك حاجة اليها في الأجيال السابقة.

في المحاكاة التي تم إجراؤها ، حاولنا تعديل رقم الخلية ورقم المستخدم لمراقبة تطور معدل المجموع. لاستنتاج المعلومات يمكن إدارة الطبقة المادية الجديدة التي هي قيد الدراسة.

الكلمات المفتاحية:

الطبقة المادية، تيراهيرتز6G، b5G ترددات .

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General introduction.

General introduction

Despite the fact that the fifth generation (5G) cellular system with millimeter Waves of frequencies ranging from 30ghz to 300ghz being a key enabler to many services such as the internet of things (iot), Virtual Reality (VR) and many other extensive varieties of services as well as spanning the basic enhanced mobile broadband (embb), ultra-reliable and low-latency communications (urllc) and machine type communication (mmtc). However, as wireless markets are constantly developing leading the wireless data traffic and the magnitude of connected things to be unsupportable by 5G. Moreover, mm Wave spectrum cannot support the new ultra-high data-hungry applications such as holographic communications that require larger bandwidth. Therefore, moving beyond 5G (b5g) with data rate of 1Tbps is highly requested for the next few years.

With all that been said, it is time to wonder about what relies beyond 5G networks? Is there a need to move to higher frequencies? What are the visions and requirements of b5g networks? And what services and applications that will be achieved from such networks? What are the technologies and techniques that will be used in b5g networks to achieve such requirements?

In this work, we tried to answer these questions through a study of b5g network. The main of our work, is to simulate the b5g band wide physical layer at the first level, than in order to see how to control the physical layer to obtain the most quality of service possible, we will modify both of the band wide and the network capacity through the number of users and number of cells to observe the sum-rate for evaluating the network quality.

As a tool of the work, we used MATLAB software to simulate the high frequencies physical and see the network evolution to develop a way for band wide management.

The present thesis is organized through tree chapters. The first one will prepare how to move from the 5G to the 6G. The second chapter will treat the 6G technologies and requirements. Than finely, we will prepare the band wide management by simulation a high frequencies physical layer, manipulating the network capacity and the band wide to see the quality of the network evolution.

CHAPTER I :

The road to beyond 5G.

Introduction:

Mobile Wireless communication systems has witnessed a huge evolution during the past few decades, the change in the technology used as well as frequency, speed and the nature of the system has created the cellular wireless Generations through time, each generation is defined by its standard, capacities, techniques and the new services that it provides, the road of mobile wireless communication has started from the 2 nd generation and is still on-going as the wireless device users increases every year. nowadays, we have reached the fifth generation (5G) networks with its first release been launched in the end of 2019, although the 5G specification and development work is still on the progress with a great deal of imperfection remains yet the research for beyond 5G networks is a trending subject in the wireless network community. in this chapter, we will start by addressing the different phases of 5G networks while moving beyond 5G as we introduce the future wireless Terabit-per-second (Tbps) communication network system that is known as beyond 5G networks (b5G), the visions of b5G will be then presented. Moreover, the requirements in order to reach the ultra-high data rate for b5G network will be listed. in addition, we will provide a full study of the future promising Terahertz communications as we address the spectrum opportunities and constraints, then we will give the promised services expected from b5G networks. Finally, a detailed description of b5G potential applications and use cases will be discussed.

The performance of higher layers, We have used MATLAB software to simulate The fifth generation with the addition of some modifications at the level of the physical layer With all that been said, it is time to wonder about what relies beyond 5G networks? Is there a need to move to higher frequencies? What are the visions and requirements of b5G networks? And what services and applications that will be achieved from such networks? What are the technologies and techniques that will be used in b5G networks to achieve such requirements?

In our end of the year project, we tried to answer these questions through a detailed study of b5G network. The main aim of our work is to simulate the future b5G network, in order to investigate.

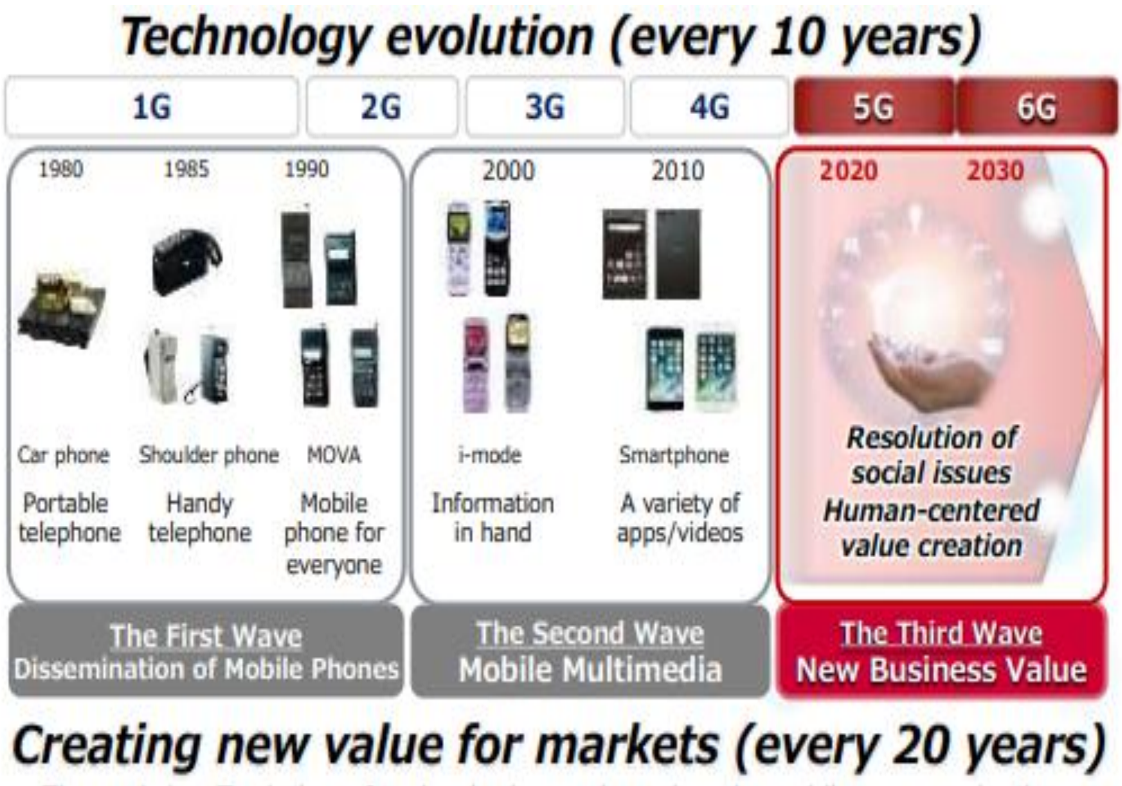

Fig. 1-1. Evolution of technologies and services in mobile communications

1. Evolution from 1G to 5G:

Wireless communication has seen unprecedented success and, in such a small period, has managed to capture the interest of billions of users. The first analog communication system was deployed in the 1980s, and from then a new generation of mobile communication system has been developed and introduced within the next ten years approximately [1]. The advancement of each generation is a complex process and often adapting different standards, technologies, and varying capacities [2].

1.1. First generation (1G):

During the first generation period, monopoly operators owned by the state offered telecommunication. These operators usually did not have to buy spectrum and received it free of charge. Compared to today, phone calls, mobile equipment, and subscriptions were much more expensive. As a result, only around 10% of the worldwide population used these services. Voice calling was provided as the basic service and the quality of the voice calls and network coverage were excellent. Some data transmission was possible with the help of acoustic routers and fax service was also provided.

1.2. Second generation (2G):

The 2G era saw more competing systems than 1G, for example, the IS95 in the United States and the Personal Digital Cellular (PDC) in Japan. GSM, with higher than 90% of the market share, was the dominating system standard. This huge success of GSM can be contributed to the process of competition and regulations that was introduced during the 2G era. The marketplace was later authorized for additional operators so that there were three or four operators in each country. Starting with only voice calls, SMS and MMS services were also added after some time. Unlike 1G, 2G operated using digital modulation schemes such as CDMA and TDMA. Digital data services of around 9.6 kb/s were also provided which increased to around 35 kb/s with the introduction of GPRS (General Packet Radio System). Ultimately, a speed of 200 kb/s could be reached once EDGE (Enhanced Data Rates for GSM Evolution) had been introduced.

1.3. Third generation (3G):

In 2000, a third generation of mobile communication system was proposed, the goal of which was to provide high speed transmission of data. A data transmission rate of 2 Mb/s can be reached in 3G networks along with fast access to the Internet. As a result, advanced services such as TV streaming, web browsing, navigational maps etc. are supported by 3G which were not possible in case of 1G and 2G. The organization 3GPP (Third Generation Partnership Project) was formed in order to establish technical specifications and define mobile systems and standards so that global roaming was possible. In Europe, this was known as UMTS (Universal Mobile Telecommunication System) a TSI driven 3G telecommunication system that used WCDMA as its air-interface technology. The American 3G variant was called CDMA2000, while ITUT named it IMT2000, which has acknowledged a novel 3G standard from China, the TD-SCDMA.

1.4. Fourth generation (4G):

The fourth generation communication system is an IP based network system and was introduced at the end of the previous decade, during the late 2000s.The main objective of the 4G technology was to provide the users with high speed, high capacity and quality, security, while also making sure to provide voice and data services, internet, and multimedia services over IP at a low cost. An uplink speed of 500 Mb/s and a downlink speed of 1 Gb/s is possible in 4G networks. 4G has increased spectral efficiency while also decreasing latency. One of the key factors of 4G is terminal mobility, which indicates automatic roaming across various wireless networks. This is necessary for 4G to provide its wireless services anywhere and at any time. Through the integration of various future and existing wireless technologies, such as OFDM, LAS-CDMA etc . 4G technologies ensure that uninterrupted roaming between different technologies is possible while also delivering freedom of movement. WiMAx (Wireless Interoperability for Microwave Access) and LTE (Long Term Evolution) are considered to be 4G technologies.

1.5. Fifth generation (5G):

5G mobile communication networks are expected to be done with standardization processes, construction of their hardware facilities and initial tests soon, after which they will be deployed for commercial use. Ensuring ground breaking advances in data transmission rates, reliability, massive connectivity, latency and energy efficiency is one of the main goals of a result of using the new microwave band of the spectrum (3.3-4.2 GHz) along with the first-time innovative utilization of the millimeter-wave band, data rates can be increased greatly with speeds reaching up to 10 Gb/s. Advanced access technologies such as BDMA (Beam Division Multiple Access) and FBMC (Filter Bank Multicarrier) are employed in 5G . Usage scenarios of 5G can be categorized into three groups, which are eMBB (enhanced mobile broadband), mMTC (massive machine-type communications), and URLLC (ultra reliable low-latency communications). Some technologies of 5G are the millimeter-wave (mm Wave) communications, NOMA (non-orthogonal multiple access), massive MIMO (multiple-input multiple output), scalable OFDM (orthogonal frequency division multiplexing), ultra-dense heterogeneous networks etc. 3GPP (third generation partnership project) Release 15 is the first among 5G standards and will be employed in 2020. The eMBB scenario of 5G networks is highlighted by this standard where the key measure is the data rate. For mMTC, the standard simply reuses LTE based NB-IoT and mMTC in 3GPP Release 14. As a result, for URLLC, the latency and reliability can only be as good as that ensured in case of eMBB [3].

2. Release 15

Release 15 is the first full release of 5G wireless network standards by 3 rd Generation Partnership Project (3GPP) that provides outstanding results in its Key performance Indicators (KPI) essential for extreme mobile broadband service, data rate, spectral and latency, surpassing what 4G is capable of [4]. we can distinguish two important events: December 2018 the release of Non-stand Alone (NSA) specifications, and June 2019 the release of Stand-Alone specifications, Devices used today are all based on these specifications.

Fig. 1-2 5G standards Evolution .

As for the architecture of 5G, according to 3GPP Releases 14, it is going to reuse the 4G LTE core network (CN) being deployed in non-stand-alone (NSA) and stand-alone (SA) modes with some modifications, the figure below describes 5G architecture in a simple NSA mode [5]:

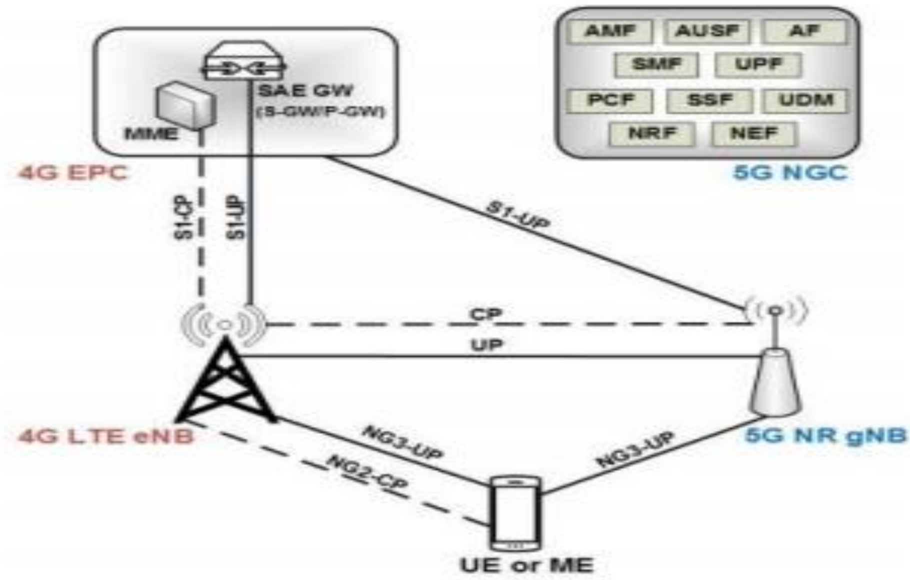

Fig. 1-3 5G NSA Architecture .

As for the Physical layer the table below summarizes the protocols applied for each layer, 5G will also be using virtual multi-wireless network [6]:

Table 1-1 OSI layers for 5G Mobile Terminal Design

Application Layer	**Application (Service)**
Presentation Layer	Application (Service)
Session Layer	Open Transport Protocol (OTP)
Transport Layer	Open Transport Protocol (OTP)
Network Layer	Upper Network Layer
Data Link Layer	Lower Network Layer
Physical Layer	Open Wireless Architecture (OWA)

5G was able to achieve the following requirements [7]:

- High speed and high capacity.
- Large broadcast of data in Gbps.
- Large phone memory, dialling speed, clarity audio/video.

2.1. Release 16:

Release 16 has been finalized by 3GPP of the 5G New Radio (NR) radio access specifications, which can be the first step of 5G evolution, the main goal of Release 16 is to enhance the NR performance by supporting unlicensed spectrum focusing on 5GHz and 6GHz unlicensed frequency bands [5], working in unlicensed bands will allow traffic and capacity to extend and therefore achieve high data rate in many scenarios. NR supports both licensed-assisted access (LAA) and Stand-alone operation unlicensed spectrum using certain features that are introduced in NR Release 16 such as Dynamic channel access that relies on listen before talk where the transmitter listens to potential transmission activity on the channel.

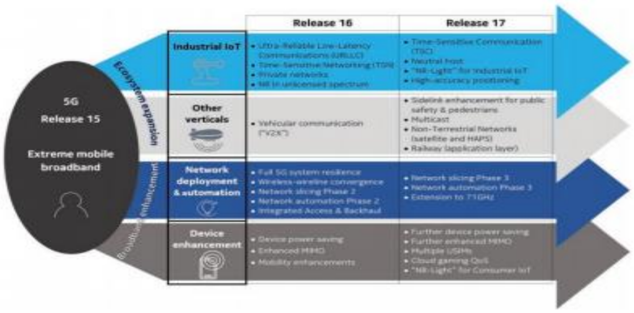

Fig. 1-4 Key elements of 5G releases 16 & 17

2.2. Release 17: Next Step of the 5G Evolution [6]

The content of release 17 was meant to be on December 2019. But, due to covid-19 and its effect on 3GPP, the etude on release 17 was delayed on fall of 2020 and is expected to be launched on spring 2021, the features of this release are mentioned below briefly:

- Spectrum beyond 52,6GHz.
- More general side-link: since release 16 introduced the possibility of device-todevice communication, release 17 will focus on v2X use cases
- Reducing energy consumption in the devices.

3. The Disruptions of 5G on data-driven technologies and applications:

3.1. “5G Evolution and 6G”:

3.1.1. Considerations for 5G evolution:

Commercial introduction of 5G has already started worldwide .Meanwhile, we have found the issues and further expectations to be fulfilled regarding 5G, and this necessitates technological development of a more enhanced version of 5G called "5G evolution" in several years within the 2020s. Fig. 1-5 shows current technical challenges of 5G. In fact, 5G is the first generation of mobile communication systems advanced enough to support high-frequency bands above 10 GHz, such as millimeter waves, with technology that enables super-fast wireless data communication of several Gbps-class speeds using a several hundred MHz frequency bandwidths, by far wider than before. On the other hand, it is becoming clear from 5G technical trials that millimeter wave (mm Wave) technology in mobile communications has many aspects that need to be improved, such as coverage in a non-line-of-sight (NLOS) environment and uplink performance. Furthermore, 5G is attracting a lot of attention as a technology that supports future industry and society, especially for industrial use cases demanding special requirements and high performance. In Japan, "Local 5G" has started, which is dedicated to such industry applications and has become of a focus of interest by industry [8]. It is necessary therefore to further develop 5G technology in order to flexibly deal with such a wide range of industrial requirements in the years to come. In the initial stage of 5G standardization (New Radio (NR) Release 15), 3GPP focused on high data rate / high-capacity communication (eMBB: Enhanced Mobile Broadband) and part of Ultra-Reliable and Low Latency Communications (URLLC). It is because of this background that 5G has been developed with a focus on achieving best-effort services emphasizing faster downlink speeds, as was the case with LTE. In contrast, 5G evolution is expected to propel high-reliability communication technology, which guarantees communication quality mainly for industrial applications, while improving uplink performance. Some industrial use cases include services with the prospect of uploading a huge quantity of video data or services requiring a guaranteed quality and constant speed. For this reason, it is more important for industry applications to improve the coverage and throughput on the uplink and provide communication technology ensuring guaranteed quality than for services geared toward general users.

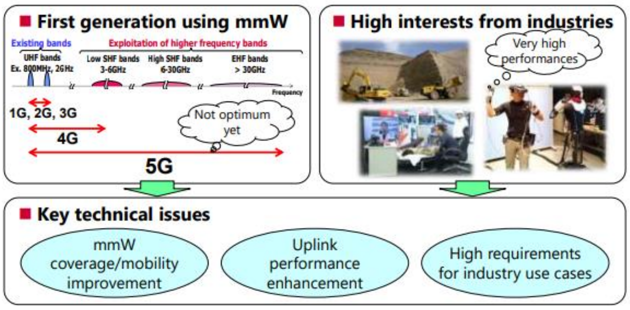

Fig. 1-5. Current technical challenges of 5G

Today, as big data and AI are widely applied, cyber-physical fusion is drawing an increasing attention [9], cyber physical fusion is a system concept where AI creates a replica of the real world on the cyberspace (Digital Twin) and emulates it beyond the const+-raints of the real world to “predict the future” and discover "new knowledge." By making practical use of this concept for services in the real world, we can offer various values and solutions for social problems. If we view this real world as one of many worlds reproduced on the cyberspace, we can assume that there are a large number of humans, things and events present in all worlds, not only the real ones but also their avatars and variants are present, and this recognition can potentially contribute to resolving social issues, such as labor shortage and low-birth rate and aging population [10]. Wireless communication is anticipated to play certain roles in this cyber physical fusion system, such as sending a huge quantity of real-world data including video and sensing information to the cyberspace, which will require high capacity, low-latency transmission, and actuating the real world, which will demand low-latency control signal transmission. This assumption is generating high expectations for high-performance communication utilizing 5G features. If we compare a cyber physical fusion system to a human body, communication in the cyber physical fusion would be the nervous system, which transmits information signals between the brain (AI) and different organs such as eyes and arms and legs (devices). We can easily imagine that an overwhelming quantity of information (Uplink) enters the brain. Therefore, the directions of performance improvement apply in this case as well.

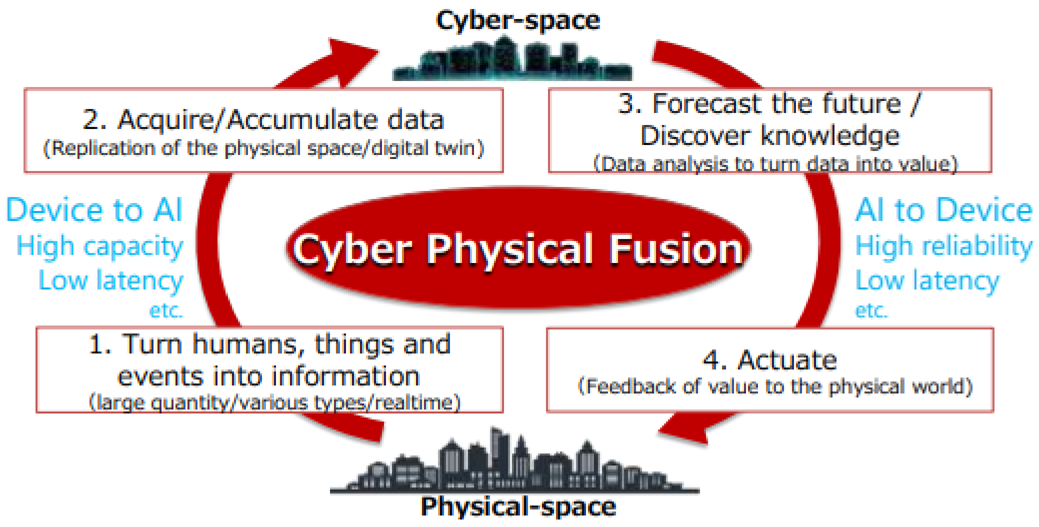

Fig. 1-6. Cyber-physical fusion and wireless communications

3.1.2. Considerations for 6G:

For discussing the requirements, use cases and technological developments regarding 6G, we should consider our vision of a future world in the 2030's, when 6G is anticipated to be introduced. The use cases and solutions for social issues expected to be achieved by 5G will have considerably realized and become widespread by the end of the 2020's. Even in the 2030's, we will need their wider and deeper dissemination in their evolved forms. In addition, we will witness further advanced services, the fusion of multiple use cases and the creation of needs for new use cases arising along with faster signal processing and a wider range of advanced devices. Following are some specific examples of our vision.

Fig. 1-7. Image of a future world in the 6G era

4. Technological development and research areas:

Fig 1-8 illustrates technological evolution from the past generations of mobile communications to 6G. In early generations including 3G, each had one representative technology symbolizing its wireless access technology (RAT: Radio Access Technology). In contrast, in 4G and onwards, each generation's RAT has consisted of a combination of OFDM-based multiple technologies. In 6G, its technology field will be more diversified. This is because the existing OFDM-based technologies have already achieved the communication quality close to the Shannon Limit, and the requirements and use cases have been expanding to a wider range as described in the previous chapter. In 6G, therefore, more combinations of the radio access technologies will be required after going through 5G evolution. Use cases and requirements given in the previous chapter will be realized through integration with other technologies as described later. 5G has been specified as a combination of upgraded LTE and NR (New Radio). As 5G's NR is designed to be highly "future proof" in consideration of new technologies to be introduced in the future, it will be also necessary to consider the definition of 6G RAT. In the core network, we have promoted the modularization of 5G functions and the utilization of general-purpose technology for inter-functional interfaces. In addition to this trend, there may be acceleration in the introduction of software-based network functions and open architecture. Hence, in designing network architecture, it will be necessary to consider functional configuration optimization and general-purpose equipment introduction. The following sections give an outline of each candidate technical areas for 5G evolution and 6G and their problems.

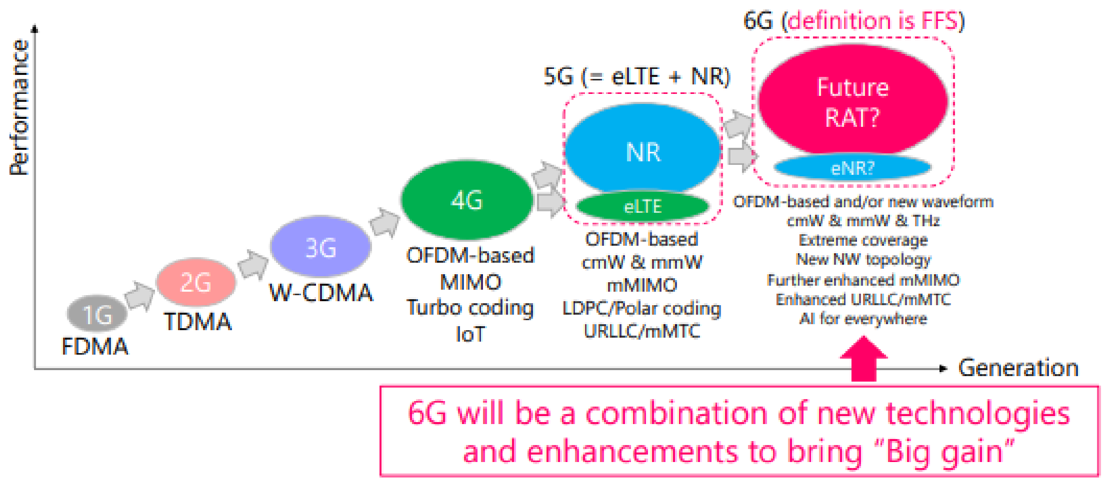

Fig.1-8. Technological evolution up to 6G in mobile communications

4.1. New radio network topology:

For pursuing extreme high data rate, extreme high capacity (especially uplink) wireless communication with improved reliability, it is ideal to communicate in a shorter distance with a LOS (Line of Sight) environment (in a path with a smaller loss) and increase the number of communication paths to provide more options (more redundancy) as much as possible. Satisfying these conditions will require a network topology distributed in the space domain. As shown in Fig. 4-2, early generations considered it ideal to configure a cellular network with hexagonal cells to avoid inter-cell interference. In the future, however, there will be an evolution to a New Radio Network Topology. This new form of wireless network will be a further extension of a heterogeneous network which has been studied since 4G, with overlapping multiple cell areas for creating more LOS environments and path options, and with more connection routes to/from 16 mobile terminals nearby as well as other networks including NTNs (Non-Terrestrial Networks) described later. Such a spatially distributed network is considered to be compatible with the high frequency bands to be explored discussed later, Distributed MIMO technology, wireless sensing and wireless power supply.

On the other hand, from a common-sense viewpoint, this New Radio Network Topology may not be an ideal network configuration as it generates inter-cell interference and has many redundant antennas. This topology is not immune to interference because it does not adopt advanced beam control or path selection, or a cell configuration where each antenna forms a zone to avoid interference. Hence, a technical solution is required to help prevent interference, such as a Cell-free configuration [1-8], which configures a cell by multiple antennas. How to economically realize this New Radio Network Topology is also a fundamental problem, and we can think of various approaches to tackle this question. The standard solution would be not to use conventional base station antennas. As shown in Fig. 1-9, there are a lot of research areas that can be addressed: the use of existing objects such as street lamps, street/traffic lights, signboards, vending machines and window glass for communication antennas, integration of sensors and communication antennas and radio relay schemes such as IAB (Integrated Access and Backhaul) and repeaters for high-frequency bands. In addition, it is also necessary to establish new optical interconnection and transmission systems which enable a distributed network topology and have a scalability to follow future evolution of wireless communications, as well as fronthaul and backhaul technologies. Furthermore, it would be necessary to consider this type of new solution in combination with existing cellular configurations. The following sections outline comparatively new technical areas related to New Radio Network Topology.

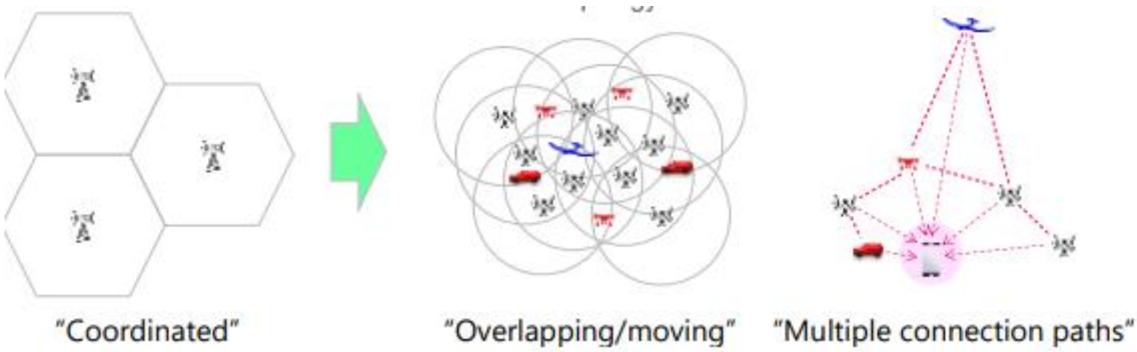

Fig. 1-9. Evolution to New Radio Network Topology

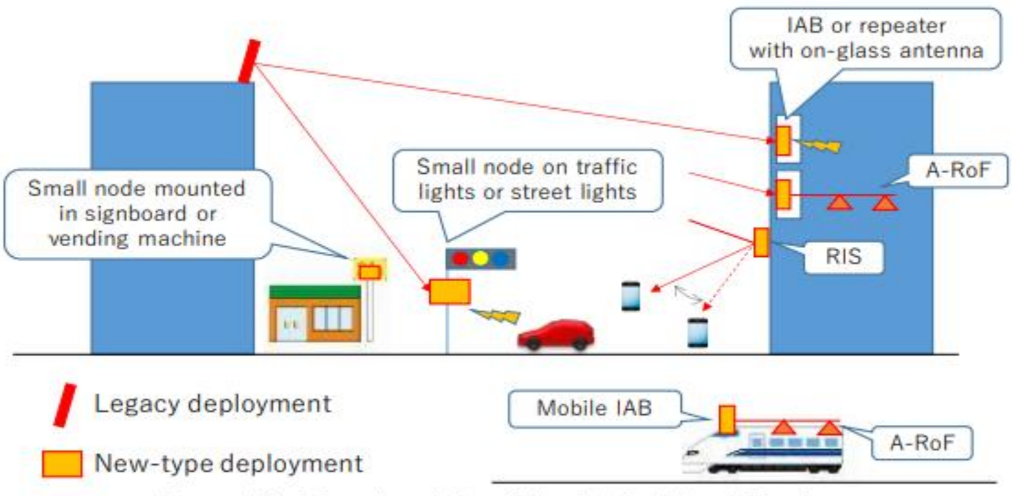

Fig. 1-10. Example solution of New Radio Network Topology

4.1.1. Distributed antenna deployment with a "line":

In New Radio Network Topology, how to deploy numerous antenna systems efficiently will be a challenge. In order to deal with this, an approach that offers promise is to connect a large number of miniaturized and economical antenna systems with a "line" [1-10]. One of such implementation methods is A-RoF (Analogue-Radio over Fibber), which transmits analogy radio signals to antenna systems over an optical fibre .A-RoF has more difficulty in maintaining its signal quality during optical transmission compared with D-RoF (Digital-Radio over Fiber), which transmits radio signals after converting them into digital information. On the other hand, by adopting A-RoF, neither A/D (Analogy/Digital) nor D/A converters are needed on antenna systems and that prevents from the transmission bandwidth expansion, i.e., the optical transmission bandwidth can be reduced. Thus A-RoF can be an effective means of miniaturizing and economizing a large number of antenna systems. With A-RoF, by connecting antenna systems in a cascading configuration, it is possible to realize a distributed antenna deployment like a "line." In addition, a technique to control the beam of an antenna system at a remote location by assigning a wavelength to each beam in A-RoF as shown in Fig. 1-11 has also been studied [11]. Traditionally, D-RoF has been used in wide areas, while A-RoF has been applied mainly in limited areas such as indoor facilities. Such technologies will make it possible to use A-RoF in wider areas by means of optical fiber transmission of 10 kilometers or more. Another technology being studied is to cause radio waves radiated from any part of a "line"-shaped antenna.

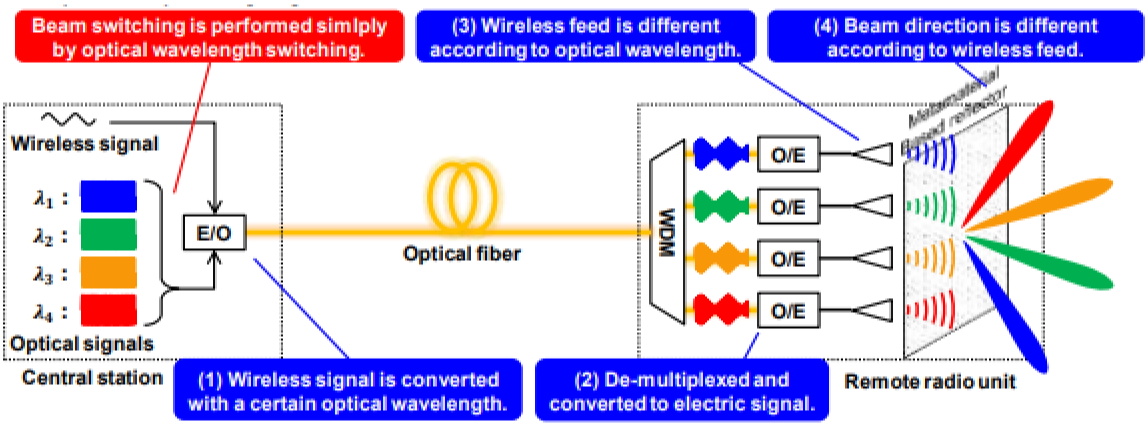

Fig. 1-11. Technology using A-RoF to control beams of remote antenna systems

4.1.2. Reflector (RIS) technology:

How to use multipath propagation of reflected waves has been one of the research areas pursued for a long time in mobile communications. Recently, advanced reflector (RIS: Reconfigurable Intelligent Surface) technology and its control technology are attracting attention for improving various radio performances in high frequency bands over millimeter waves. It is possible to use a RIS to provide a coverage area by attaching it on the wall or window glass and by controlling the radio waves reflecting on and pass through the RIS [12, 13]. DOCOMO is conducting R&D on a technology to use a transparent glass as an antenna [14, 15]in combination with the RIS technology. In an experiment using the metamaterial reflector shown in Fig. 1-12 (a), we verified a technology to reflect millimeter radio waves in arbitrary directions and expand the communication area [16].In an experiment using the transparent dynamic metasurface shown in Fig. 1-12 (b), we successfully demonstrated a technology to allow millimeter radio waves to reflect on and 18 pass through the transparent glass substrate [17]. Furthermore, in an experiment using the metasurface lens shown in Fig. 1-12 (c), we verified a technology to direct millimeter radio signals arriving from outdoors to specific points indoors by using a window glass quipped with this technology [18].For practical application of RIS, we need technological examination to clarify its use cases, size design and application effects. In addition, if the RIS and repeater can remotely control beam directions, etc., it will be effective for communication area extension especially in high frequency bands, and therefore, we also need to consider a method to implement that capability.

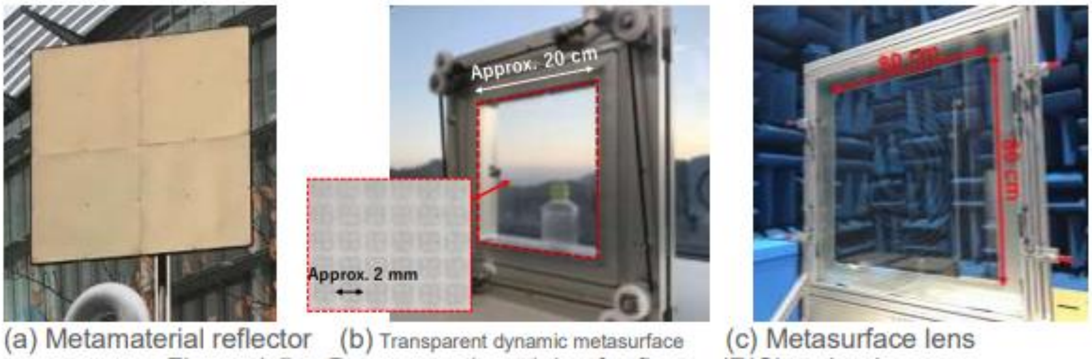

Fig. 1-12. Demonstration trials of reflector (RIS) technology

4.1.3. Inter-terminal coordinated transmission and reception technology:

As a technique to realize a New Radio Network Topology, it may be possible to use a technology to enable coordinated transmission and reception between terminals [19] In 5G, the requirement for massive connectivity (mMTC) is 1 million connections per 1 square kilometre. But for 6G, “extreme massive connectivity” with approximately 10 times the density of 5G is anticipated, driven by increasingly advanced wearable terminals and cyber physical fusion. This is equivalent to the density of 10 terminals per 1 square meter, and in such an environment where many terminals exist densely, it may be possible to create many communication paths through coordinated communication among terminals without increasing antenna systems on the network side. Use cases of "extreme massive connectivity" should support a variety of terminals that are expected to appear, ranging from high-function sophisticated terminals to energy-saving communication terminals. It is necessary therefore to consider a technical scheme that factors in a wide range of terminal capabilities (UE Capability).

4.1.4. Win-Win distributed antenna deployment with sensing and energy-saving communications:

As described later, sensing technology using communication signals for location estimation and object detection has been studied toward 5G evolution and 6G [20]. In recent years, energy saving communication technology has also attracted interest, such as backscatter communication for realizing battery-less terminals [21]. Networks that realize these technologies are considered to have common features in their configurations. In wireless sensing and backscatter communication, a source signal needs to be emitted from a base station, mobile station or device emitting some radio waves (the signal transmitter in the figure) in the communication area as shown in Fig. 4-6. In addition, some receiving points must be provided in the communication area for 19 observation purposes. This figure illustrates an example of multiple receiving points deployed using distributed antennas connected with a “line” as mentioned above. In radio sensing, radio waves reflected from objects are received by distributed antennas and analysed in the network for location estimation and object detection. In backscatter communication, battery-less devices can transmit information to the network with low power by externally modulating the source signal while receiving power using the source signal. It is also necessary to incorporate the network configurations used for such sensing and energy saving communication into radio communication systems in a natural way as part of the New Radio Network Topology concept.

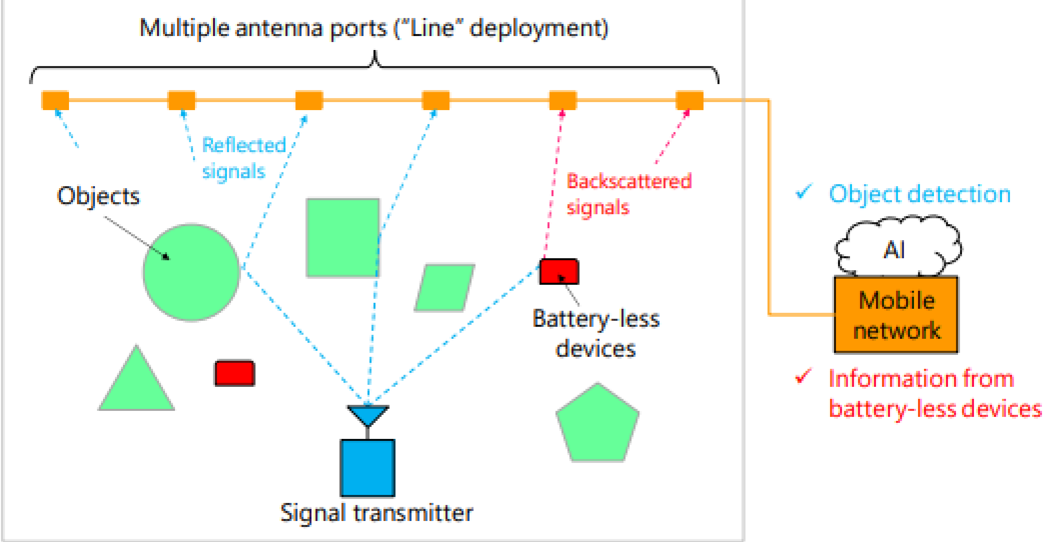

Fig. 1-13. Example of network configuration assuming sensing and Backscatter communication

4.2. Coverage extension technology including Non-Terrestrial Networks:

Extreme-coverage extension" assumes use cases that will cover all locations including the sky, sea and space. This will require extension of area coverage to provide mobile communication services to areas with drones, flying cars, ships, space stations, and so on that conventional networks have not sufficiently been able to cover. Therefore, it is necessary to examine the above-mentioned New Radio Network Topology in three dimensions including the vertical direction. In addition, 5G evolution and 6G will require a technology that enables long-distance radio transmission at least over a distance of dozen kilometres in a highly efficient manner. If we can use a geostationary satellite (GEO), low-earth orbit satellites (LEO) and high-altitude platform station (HAPS) systems as shown in Fig. 4-7, it will be possible to cover mountainous and remote areas, over the sea and space and provide communication services to these areas .The GEO satellite is placed on a geostationary orbit at an altitude of 36,000 kilometres. For the GEO satellite, one-way signal propagation between the satellite and the ground station antenna takes a relatively long time of about 120 ms. On the other hand, 3 or 4 GEO satellites can cover the whole earth surface while communicating constantly with ground stations, and thus they have complemented the networks on the ground as a mobile backhaul. As further capacity increase will be required in the 6G era, the use of a VHTS (Very High Throughput Satellite) is considered to be a method to increase system capacity by optimizing the power and frequency of multiple beams .The LEO satellite is an orbiting satellite that operates at an altitude of several hundred to about 2,000 kilometers. By comparison with GEO satellites, LEO satellites are in orbit at a lower altitude, therefore they are used for satellite mobile phones and satellite sensing, taking advantage 20 of its low latency communication with a one-way signal propagation time of approximately 3 ms. LEO satellites can be also used as a large-capacity, low-latency backhaul if we can reduce satellites' manufacturing costs, extend the expansion of communication capacity by MIMO technology, etc. and achieve satellite constellation in which multiple satellites cooperate to form a network in the future. Recently HAPS has attracted a renewed attention because of its capability to stay at a fixed location at an altitude of about 20 kilometers, forming a coverage area with a cell radius of more than 50 kilometers on the ground. As HAPS systems stay at a lower altitude than LEO satellites, they can achieve even a lower latency with a one-way propagation time of about 0.1ms, depending on the cell radius. It would be effective therefore to use HAPS not only for disaster countermeasures but also for many industrial use cases anticipated in 5G evolution and 6G. As shown in Fig. 1-15, HAPS can be used for backhaul applications (fixed system) for high-data rate, large-capacity terrestrial networks (fixed systems), which are even faster than satellites, for directly supporting mobile terminals using radio access standards such as LTE and NR, or for use cases that support terminals via relays (IAB) and repeaters (mobile systems). HAPS is thus expected to be used for a wide range of applications including those mentioned above. On the other hand, from the radio technology perspective, there are some areas that require further study, such as extending the radio interface to so as to be suited to long distance communication, finding a method for achieving higher spectrum efficiency with ground networks, realizing network design for highly efficient cooperation between HAPS systems and ground networks. 3GPP has started its study on the extension of NR to non-land network (NTN) using these satellites and HAPS

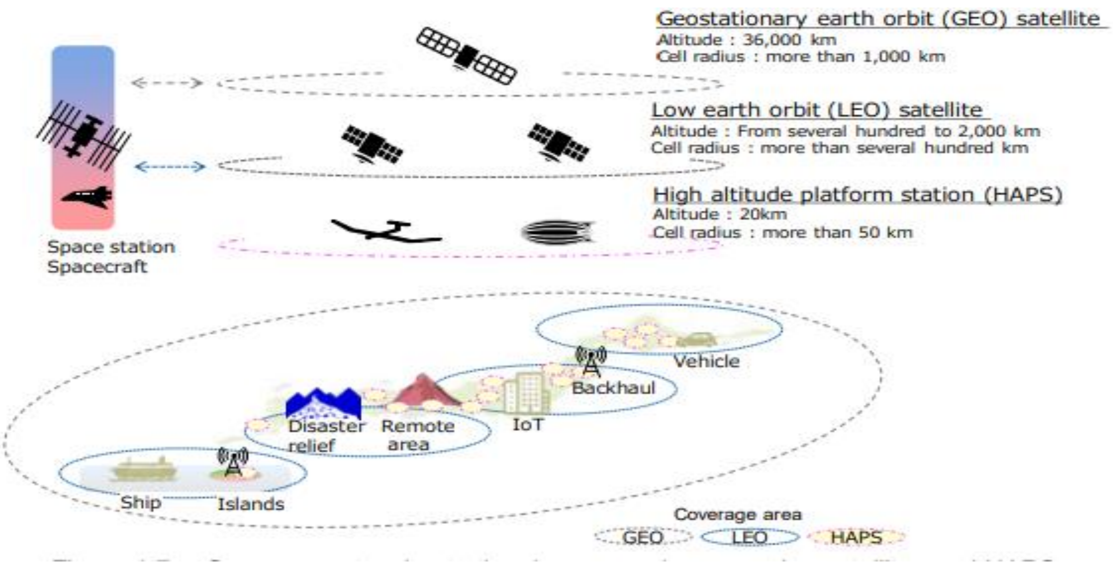

Fig. 1-14. Coverage extension to the sky, sea and space using satellites and HAPS

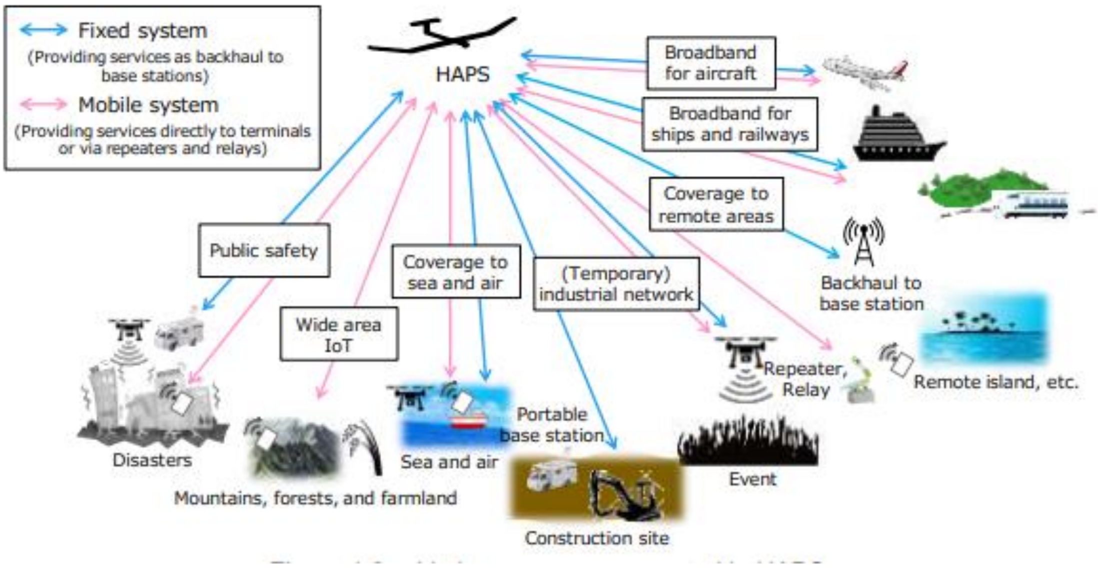

Fig. 1-15. Various use case expected in HAPS

4.3. Technology for further broader frequency domain and advancement of frequency utilization:

As shown in Fig. 1-16, 5G NR supports the frequency bands up to 52.6 GHz, and the possibility of extending its support to about 90 GHz is being studied for future releases. In addition, the Federal Communications Commission (FCC) recommends that higher frequency bands than those used in 5G, such as 95 GHz to 3 THz, be studied for 6G .In the higher frequency spectrum from the "millimeter waves" to "terahertz waves," it is possible to use a drastically wider bandwidth compared to 5G. For this reason, studies have started on the possibility of achieving "extreme high data rate and high capacity" communication exceeding 100 Gbps .At present, as shown in Fig. 1-16, "radio waves" up to about 300 GHz are considered to be within the scope of 6G. However, "terahertz waves" have a stronger tendency to travel through a straight path than "millimeter waves" and cannot propagate for a long distance. In order to address this problem, it is necessary to carry out technical examination on terahertz waves to clarify their radio propagation characteristics and establish their propagation model and high-precision propagation simulation technique, as well as to study how to utilize terahertz waves based on the New Network Topology mentioned above. For example, as for device technology, it is necessary to realize a digital signal processing circuit able to support further wider bandwidths, DAC (Digital to Analog Converter) and ADC (Analog to Digital Converter) at low cost and low power consumption. In addition, antennas, filters, amplifiers, mixers and local oscillators that operate in high frequency bands must be developed so as to be compatible with Massive MIMO's multiple antenna elements described later. RF (Radio Frequency) circuits must be enhanced for higher performance and higher integration in high frequency bands exceeding 100 GHz. As semiconductor devices, they must be manufactured with a level of precision and cost applicable to actual commercial services. As the wiring loss will be larger in those high frequency bands, the composition of chips and circuits, and implementation method for connecting antennas are also major challenges. A research theme would be how to achieve optimization of both the pursuit of performance of the device itself and the improvement of performance of the device by digital signal processing, factoring in the evolution of future semiconductor manufacturing technology. Deciding whether to adopt chemical compound-based or silicon-based semiconductor will still be an issue in 5G evolution and 6G. When it comes to utilizing those semiconductor devices for terminals, how to achieve initialization, low power consumption and high heat dissipation also needs to be addressed. Figure 1-17 illustrates a concept of radio access technology in consideration of such high frequency bands and the above-mentioned "extreme-coverage extension" to the sky, sea, and space. These are different directions of development, but have common technical problems in the sense that this is the area where the coverage and power efficiency will become more important than the spectrum efficiency. In this area, single-carrier signal waveform becomes more dominant over OFDM as a radio technology. As we apply radio technologies including IAB to a wider range of areas, the importance of power-efficient radio technology such as single carrier may increase. In addition, as we add new frequency bands such as millimeter and terahertz waves in addition to the existing frequency bands, we will have to utilize more very wide frequency bands than in the past. This may necessitate consideration in a lot of related technological fields to achieve optimized selection of bands for different applications, re-examine inter-cell frequency reuse methods, upgrade uplink/downlink duplexing methods and review spectrum utilization methods in low frequency bands. In 5G, not only millimeter wave bands but also Sub 6GHz (3.7/4.5 GHz) bands are important, and this will be also the case toward 6G. It will be important to explore new frequency bands and improve performance in millimeter-wave and lower frequency bands as shown in Figure 1-16, because such efforts will lead to improved user experience everywhere and also to stronger motivation for introducing 6G for mobile carriers. It is also necessary to examine the possibility of newly introducing technologies that have not been achieved prior to or for 5G, because they may also contribute to improving the spectrum efficiency in the existing frequency bands and expanding the scope of new use cases. Such technologies include the above-mentioned New Radio Network Topology, AI technology described later in Section 4.6, optimization technology using cyber-physical fusion and high-precision sensing technology linked to high frequency bands, as described in, Section 4.6, it is possible to improve the frequency utilization efficiency of existing frequency bands and expand the scope of application to new use cases. In addition, the advanced radio transmission technology described in Section 4.4 can be widely applied to lower frequency bands below millimeter wave frequencies. Furthermore, for the existing frequency bands, designing new radio technology which can coexist with existing technologies such as 5G NR will also be become also an important requirement.

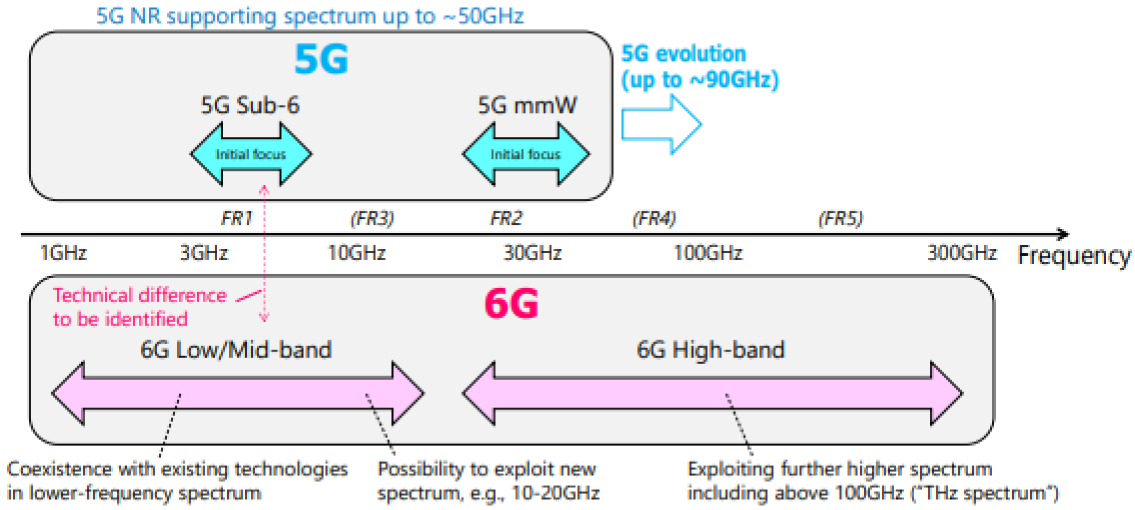

Fig. 1-16. Exploration of frequency bands for 6G

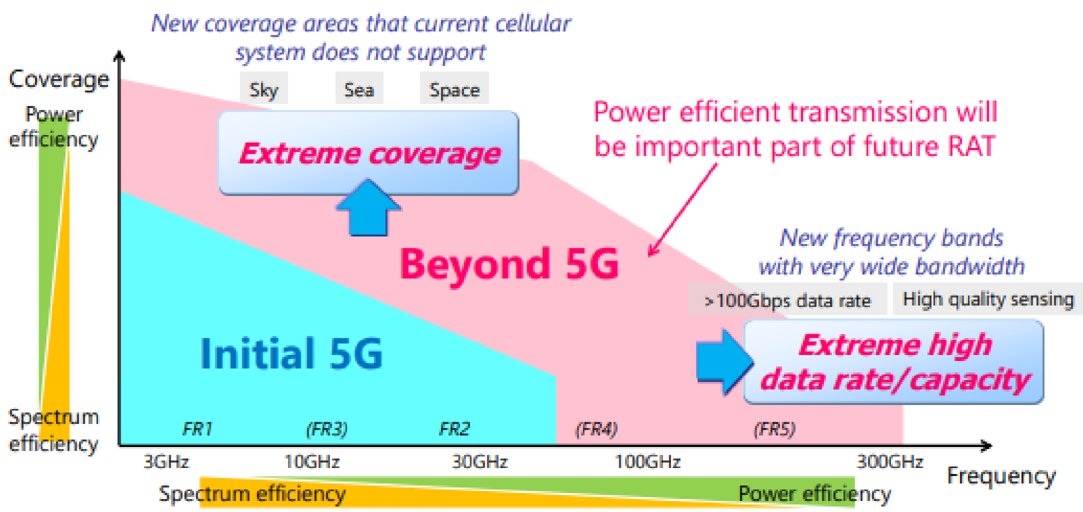

Fig. 1-17. Expansion of radio access technology for higher frequency band exploration and coverage expansion

4.4. Further advancement of Massive MIMO and wireless transmission technologies:

In 5G, Massive MIMO (mMIMO) technology using a massive number of antenna elements has been a key, especially as a technology to make effective use of millimeter waves. In 5G evolution and 6G, further advanced forms of mMIMO are expected, such as multi-element/multi-layer mMIMO and Distributed mMIMO for a distributed antenna configuration combined with New Radio Network Topology. Distributed MIMO combined with New Radio Network Topology is particularly promising in high-frequency bands such as millimeter-and terahertz waves. As shown in Fig. 1-18, it will be necessary to examine how to achieve the following technologies:

(i) the technology to deploy distributed antennas to ensure LOS (line-of-sight) propagation paths for mobile terminals with a high-probability,

(ii) the technology to control distributed propagation paths to switch the communication paths and track very narrow beams following the movement of user terminals and

(iii) the technology to achieve distributed cooperative MIMO that realizes multi-user transmission for a large number of user terminals by using several cooperation methods such as inter-terminal communications .Regarding radio access technologies, ones based on the OFDM signalling approach the Shannon limit. Faster-than-NY Quist (FTN) signalling has been recently studied, which packs data non-orthogonally at a sampling rate faster than bandwidth .Even if the system employ the FTN signalling, it would be difficult to exceed the Shannon limit. However, the FTN signalling may yield another gain, e.g. peak-to-average power ratio (PAPR) .Furthermore, as shown in Fig. 1-19, Virtual Massive MIMO (VM-MIMO) technology has been proposed as a technique for realizing spatial multiplexing antenna gain comparable to mMIMO with a single antenna .VM-MIMO technology can create a super-massive number of virtual antennas and increase the number of space division multiplexing channels by using a reception sampling rate greater than the frequency bandwidth as is the case for FTN, and by changing the antenna characteristics at ultra-high data rates and periodically. In contrast to FTN, VM-MIMO can bring about the effect of extend the bandwidth relative to the Shannon Limit by causing the propagation path to fluctuate at high data rate, and has the potential of obtaining large gain theoretically, despite certain remaining challenges such as its application conditions and feasibility under real environments.

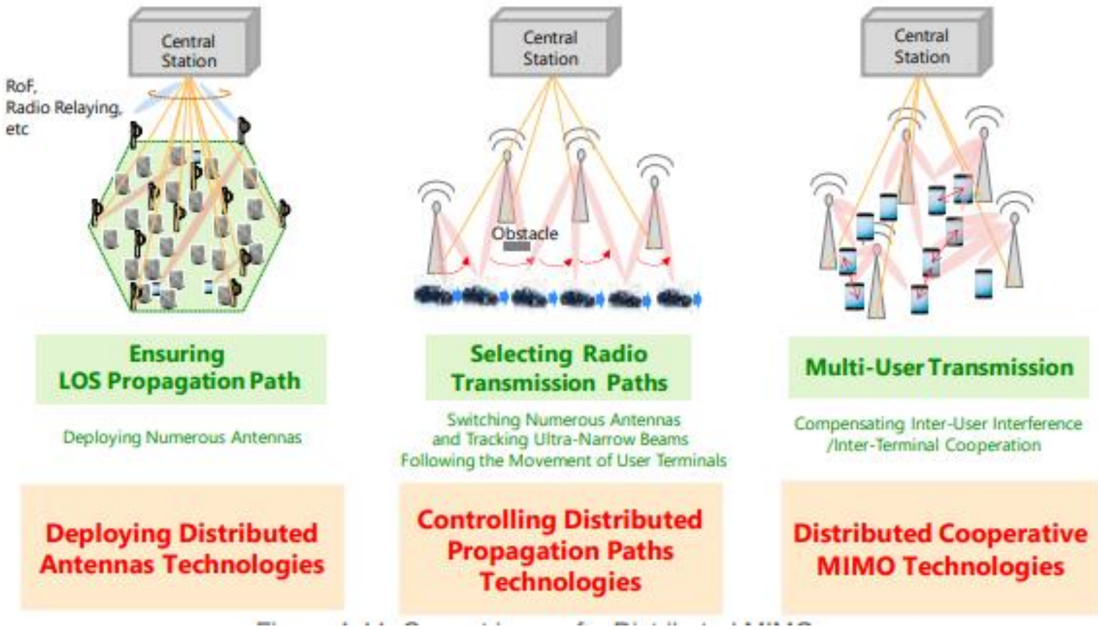

Fig. 1-18. Current issues for Distributed MIMO

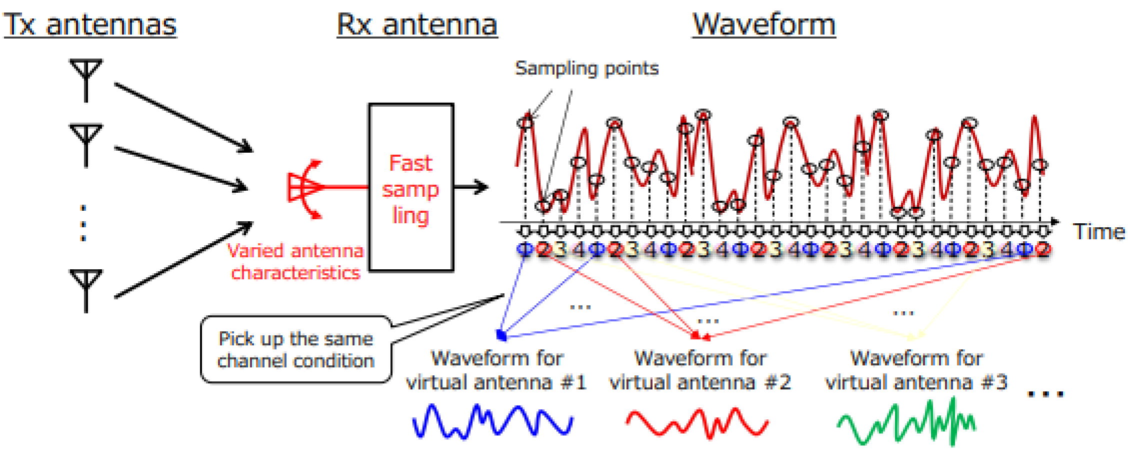

Fig. 1-19. Example of non-orthogonal transmission technology using a sampling rate greater than the frequency bandwidth (VM-MIMO)

4.5. Extension of Ultra-Reliable and Low Latency Communications (URLLC) and industrial networks:

Many industrial use cases such as remote control and factory automation require guarantee of necessary performance. A recent focus of attention is Non-Public Networks (NPNs), which are specialized for industry applications and differentiated from Public Networks characterize by best-effort services, leading to various discussions on how to implement it efficiently. In addition to "Local 5G" in Japan, current global research projects such 5G-ACIA are joined by many companies .Industrial use cases are characterized by their wide range of requirements, which vary among industries and applications. Low latency is not always required; however, it is necessary to anticipate use cases that would require very demanding conditions and not be simply satisfied with an average low latency but demand stable low latency that will never fluctuate. Automation systems in factories are expected to use different applications to make their automated operation more effective. As shown in Fig. 1-20, it is anticipated that factory automation 25 will need to support "Mixed Traffic," in which different systems with different communication requirements coexist. In this example, a data transmission system that requires high-capacity communication and a control system that requires low-latency and high-reliable communication are simultaneously operated. It is necessary therefore to realize a system that can respond to a wide range of requirements, such as achieving high-capacity communication while maintaining low latency and high reliability .6G is also expected to provide higher levels of reliability and security than 5G. As shown in Fig. 1-21, there are a lot of options being studied in terms of performance, cost and speed of deployment regarding the mobility between Public Networks used by general users and NPNs for industry applications and network configurations, which are now discussed at 5G-ACIA and other groups.

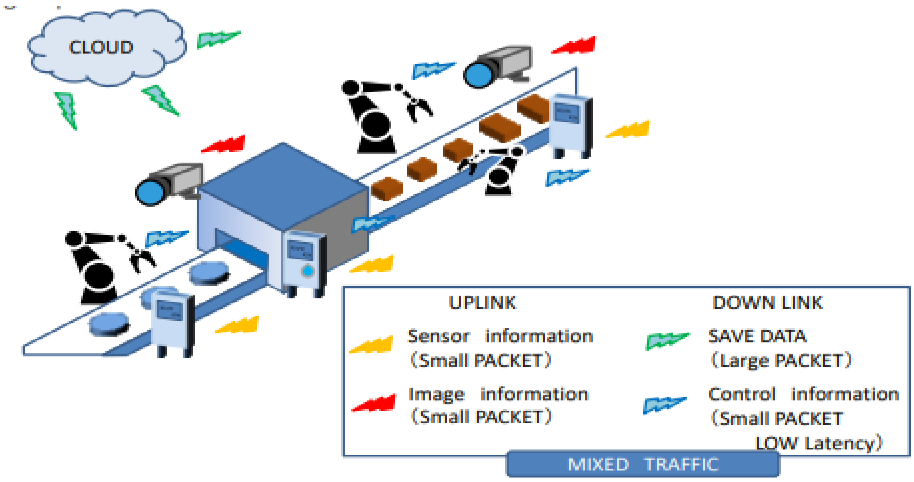

Figure 1-20. Support of various types of traffic in industrial networks.

Fig. 1-21. Overlay of Public Network and industrial network (NPN).

4.6. Multifunctional wireless communication systems and utilization of AI technology in all areas:

In cyber-physical fusion, images and a variety of sensing information are transmitted to the network through IoT devices. There should be certain technological areas for analysing transmitted information as well as information measured by radio communication signals by AI technology and utilizing them to upgrade radio communication control functions such as propagation path prediction and beam control. In addition, there is a potential for an evolution in which radio communication waves will be used not only for information transmission but also for various applications, including sensing such as positioning and object detection and wireless power supply technology (energy harvesting etc.). High frequency band such as millimeter and terahertz waves will worth attention from the aspect of realizing high-precise positioning and sensing as well as for the purposes of high-data rate, high-capacity 26 communication. Also utilizing AI technology is a key. AI analysis of various kinds of information in addition to information from radio communication signals can greatly improve the accuracy of positioning and object. In addition, technological areas have been expanded to include object and behaviour recognition beyond object detection such as human detection as a result of recent computational capability improvement and AI technology advancement. Specifically, the following technologies are widely examined: Intrusion detection (one or multiple persons), congestion rate calculation in a certain area, human action recognition (walking, sitting, cooking, watching TV, etc.), gesture recognition by fingers and arms, vital sign monitoring and user identification. From the technical point of view, the conventional object detection technology has mainly taken an approach of detecting objects based on the changes in the received power. On the other hand, the recent wide use of OFDM and MIMO has made it possible to obtain more detailed propagation channel information (CSI: channel state information) in frequency and space domains. This has brought about an explosively increase in the quantity of information available for analysis. Since most of information that can be obtained from wireless networks still remain untapped, this area is expected to grow continuously. As shown in Fig. 1-22, the use of AI technology has been considered in all areas of wireless communication systems, including different types of control and algorithms, network and device management and automatic optimization functions for use cases and environments. AI application is considered in different technologies such as those to improve latency and reliability in non-orthogonal multiple access (NOMA) ,to predict a propagation environment and communication quality with environmental changes ,to perform intelligent route switching with other integrated and coopering radio technologies based on a predicted propagation environment and communication quality and to autonomously and continuously install mobile base stations in optimum locations .For efficient and effective use of the above-mentioned New Radio Network Topology, topology management and control technology utilizing AI will also be an important factor. The sensing information acquired by utilizing AI is considered to be effective for network control and parameter optimization in 5G evolution and 6G as well as for provision of additional value for users. Thus, AI is also expected to contribute to stable network operation. It is necessary to discuss what kind of wireless network standards will suit the needs of such AI technology utilization. But in the future, we may be able to let AI technology do all the work of wireless network interface design.

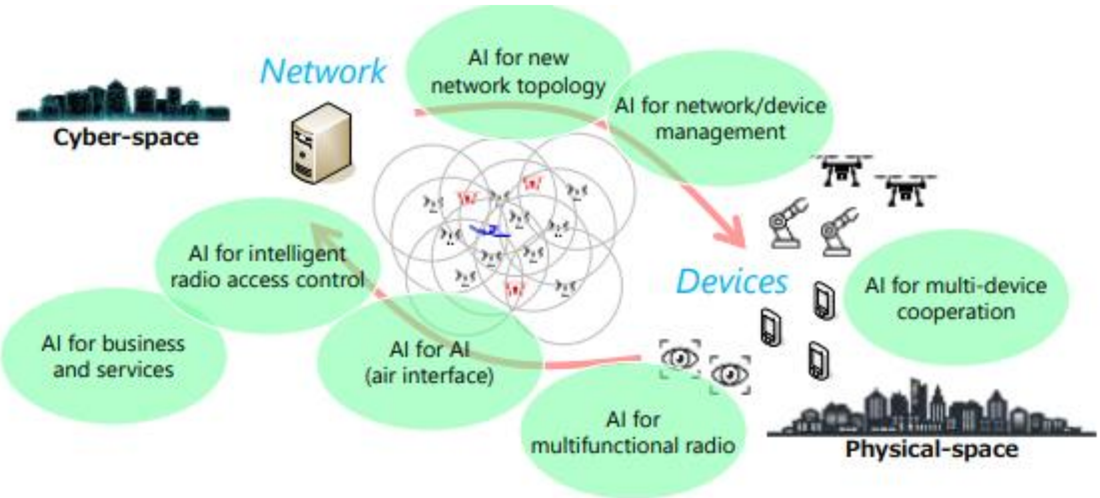

Fig. 1-22. Utilization of AI technology in all areas of mobile communications systems

4.7. Integration of various wireless technologies:

As we continue to expand the 5G evolution and 6G technology areas in order to support all use cases, it will become necessary to consider how to coordinate or integrate mobile communication technologies with other current and future wireless technologies dedicated to specific applications as shown in Figure 4-16. As with 5G, it will be important to complementary use or cooperate with unlicensed-band wireless communications, such as wireless LAN and Bluetooth, and short-range wireless communications. In addition, we should consider how to achieve new forms of cooperation with wireless communications using waves other than radio waves, such as optical wireless communications and underwater acoustic communications .Further integration of fixed and mobile communications is also a possibility. As mentioned above, cooperation with satellite communication systems is also important in order to realize the coverage extension to the sky, sea and space. On the other hand, we can also refer to other examples such as the expansion of mobile communication technology to unlicensed bands (LAA: License Assisted Access) , integration of access and backhaul links by mobile communication technology (IAB) and examination of NTN in 5G. In view of these wireless technologies, we can potentially take an approach to supporting their use cases comprehensively by extending mobile communication technologies, instead of applying other communication standards or frequency bands as we have done so far. In order to realize all requirements and use cases of 5G evolution and 6G, it will be mandatory to integrate such multiple types of wireless network technologies through their cooperation and integration and will be necessary to find out implementation methods to achieve these. This may also be related to how to “define” 6G. The ideal is to establish an ecosystem that can support a wider range of use cases in a user transparent manner, in other words, without making users aware of which wireless network technology they are using.

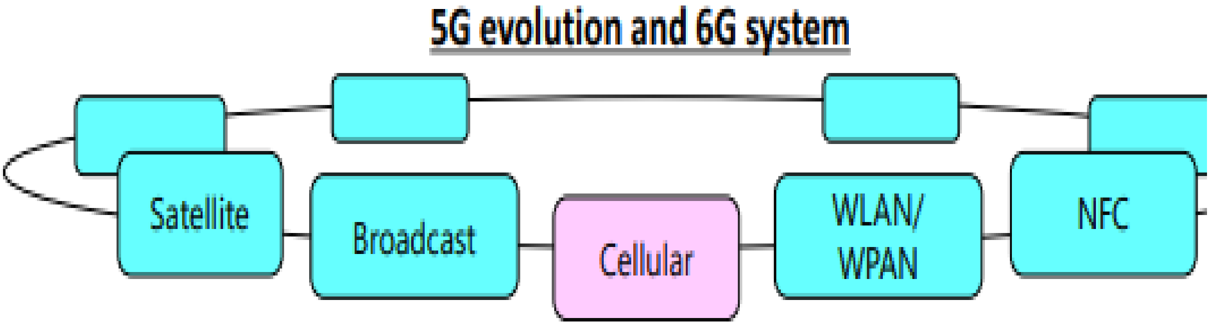

Fig. 1-23.Integration of wireless communications technologies.

4.8. Network architecture:

5G’s network architecture needs to satisfy the requirements for high-data rate, high capacity, low-latency and high-reliability communication and massive connectivity and support a wide range of services and applications in the market. To achieve this, new technologies and concepts have been introduced to 5G, such as virtualization technology, network slicing and Service Based Architecture (SBA) in the core network as well as in the wireless access network. It is still necessary however to examine the network architecture including its drastic review in order to follow the market trend in the latter half of 2020s and 2030s, further demanding requirements, and the speed of market changes. The following requirements should be taken into consideration in examining the network architecture.

1. Practical application of even more diverse use cases from a wide range of industries.
2. Responding to a dramatic increase in traffic, mainly data from vehicles, cameras and sensors reflecting the age of advanced cyber-physical integration.

3. Use of communication networks as a lifeline, increasing demand for important communications in various industries, and ensuring the robustness of communication systems against frequent disasters 28.
4. Diversification and increase of devices used by humans such as wearable devices, and responding to the sharing economy also expanding to the telecommunications industry.
5. Responding to the efforts for sustainable global environment such as global warming gas emission control, decarbonisation and reusability.
6. Rapid implementation of new services in response to rapid market changes.
7. Strong defence against advanced cyber attacks, increasing security threats such as personal information leakage and provision of secure communication services.
8. COVID-19's rapid transformation into a remote society due to the spread of infection The following sections discuss issues regarding the network architecture to be examined.

4.8.1. Flat network topology:

In mobile communications, the use of tree and star network topologies is anticipated to continue even in the future in public networks. In consideration of various new use cases created in the future and the robustness required for systems, however, it should be necessary to consider diverse options to provide the capability to select a most appropriate topology for each location or application including new topology options. Use cases geared toward private networks represented by local 5G are expected to spread further in the future, as well as small network configurations with built-in network functions. For the coverage extension, we should also consider the possibility of introducing and disseminating technologies for distributed antenna deployment, relay node utilization and inter-terminal hopping. In addition, we need to consider network topologies factoring in the possibility of integrating technologies of mobile communications with those of Non-Terrestrial Network (NTN) communications utilizing HAPS and satellites, and with those of other wireless communications for the purposes of disaster response, rapid service area expansion and low-cost and efficient network operation.

4.8.2. Flexible deployment of network functions:

In order to support various use cases expected in the future, it is necessary to allow flexible network function deployment as well as the diverse network topologies mentioned above. Regarding the deployment of RAN (Radio Access Network) and CN (Core Network) functions, there are usually concentrated in large-scale facilities in public networks. In the future, however, it is anticipated that more functions will be distributed locally in use cases of private networks or their equivalents for improved safety and low latency transmission. In addition, we need to consider the fact that if mobile device functions are deployed on the network side, it will reduce the cost, size, and power consumption of the mobile devices. The direction shown above has been promoted by the recent trends of virtualizing and implementing network functions as software components including their containerization. In fact, considerably flexible functional development is possible even in the current stage. The core network functions are now being virtualized, as well as MEC/cloud services being offered by communication service providers, and RAN's functional virtualization has also started. More flexible distribution and unified stable operation of those diverse network functions and cloud services require further improved robustness, operability, and maintainability. In addition, it is required to ensure the scaling of network services in response to performance requirements from small to large scale communications, to reduce power consumption by software technology, and to achieve power consumption reduction, space saving and cost reduction for hardware itself. 29

4.8.3. Simple network:

The 5G system as a whole is becoming more complex as more functions and options are implemented in order to support a variety of use cases flexibly. For multiple parameters that supports one function, a wide range of values and many combinations of values are specified. This leads to an increasing number of test cases for functional tests, and interoperability tests between systems and vendors, requiring a large amount of human resources and cost. To cope with this, it will be necessary to take measures to suppress complexity, while maintaining system flexibility. The following measures can be considered.

1. Careful selection of functions and options required in the market
2. Redundancy elimination between RAN and CN
3. Reduction of layers in the protocol stack
4. Grouping of use cases and selection of parameter values and combinations for each group.
5. Unification of lifecycle management methods such as RAN and CN installation and configuration changes in virtualized environments.

4.8.4. Advanced OAM (Operation and Maintenance):

For reducing workloads and costs and quickly introducing new features to systems, zero touch operation is attracting worldwide attention, prompting its standardization and active system development. Zero touch operation means automating systems to enable them to autonomously and directly operate networks and services by utilizing AI technology without human intervention. In the current stage, the range of autonomous operation is limited, and in many cases, it requires the intervention of maintenance personnel. It is therefore necessary to gradually expand the range of autonomous operation and reduce the areas that require such human intervention.

4.8.5. Technology for integrated operation of multiple access technologies:

The 3GPP has already standardized the functions to accommodate multiple access technologies, including wireless LAN and fixed communications, as functions in CN. In the future, it will be necessary to develop an advanced integrated operation technology that can select various access technologies such as fixed and satellite/HAPS communications and broadcasting, deploy them in the right places and select an optimum access technology in a user transparent manner. The following methods should be considered toward future networks.

1. How to distribute sites (Global/Local, Central/Edge, etc.) for common services
2. How to enable one terminal to use different access technologies, addresses and slices depending on the situation
3. How to operate one user's multiple devices supporting different access technologies

4.8.6. Core network transmission/switching control technologies supporting extreme low latency:

One of 5G's achievements is the realization of low latency. 5G allows terminals to connect to multiple U plane nodes and to switch nodes at opportunities triggered by the terminals' mobility or applications in such nodes. The 5G can also monitor E2E latency. Specifications are being prepared for the nearest application server selection and cooperative switching of U plane nodes and application servers. However, in 5G, the realization of E2E low latency has only relied on the U plane's route selections within the range visible from the communication control function. In other words, 5G has never attempted to reduce the latency in consideration of any (i) transmission paths actually installed, (ii) actual switching equipment or (iii) interfaces between the wireless and wired sections. In order to realize E2E extreme low latency in the future, we should also give 30 consideration to the areas that 5G has not included in its study scope 5G for latency reduction. In other words, for example, it is conceivable to adopt a system in which (i) its communication control function is extensive enough to cover the control of actual physical media in the transmission path, so that the function can also control scheduling as well as path selection/configuration, (ii) no media conversion (e.g., Light - > Electricity - > Light) should performed in the switching facilities, and this is kept to the minimum even in the transmission section and (iii) slot allocation for data transmission/reception is aligned between the wireless and wired sections to eliminate the latency. As a secondary effect, this system can also improve efficiency and reduce power consumption of deterministic communication.

4.8.7. Wide-area time synchronization and wide-area deterministic communication supporting CPS:

Another achievement of 5G is the realization of time synchronization and deterministic communication required for industrial closed networks (deterministic communication, in which communication arrives at a specified time, has limited latency variations. Mainly used for periodic communications). IEEE's TSN specification which supports factory production technology has been supported since 5G. IP-based time synchronization necessary for audio visual production is also being specified. Studies on time synchronization, time maintenance and deterministic communication necessary for the security of power distribution grids have also begun. However, 5G currently does not support (i) time synchronization among widely scattered devices with no distance limitation comparable to that of an industrial closed network, (ii) wide-range deterministic communication with no distance limitation, (iii) IP-based deterministic communication or (iv) scheduling on wired transmission paths. In the future, time synchronization and deterministic communication over a wide area will be considered to support actuation of CPS. This will also contribute to the creation of new services full of reality that use tactile senses and multiple senses (i.e., multimodal) as new communication quality. In considering how to proceed regarding (i) (ii) and (iii), it is assumed to be inefficient to control a mixture of normal traffic and traffic with distinctive characteristics. Therefore, as shown in Fig. 4-17, we should start by enhancing a mechanism for selectively using multiple advanced transmission paths specialized for data transmission with specific traffic characteristics for each call. This transmission path should be able to control the communication quality finely on an off-path basis. Regarding, it is conceivable that information on the user data generation time/interval generated by the control node of deterministic communication can be leveraged for the scheduling on the above-mentioned transmission path on the wired section.

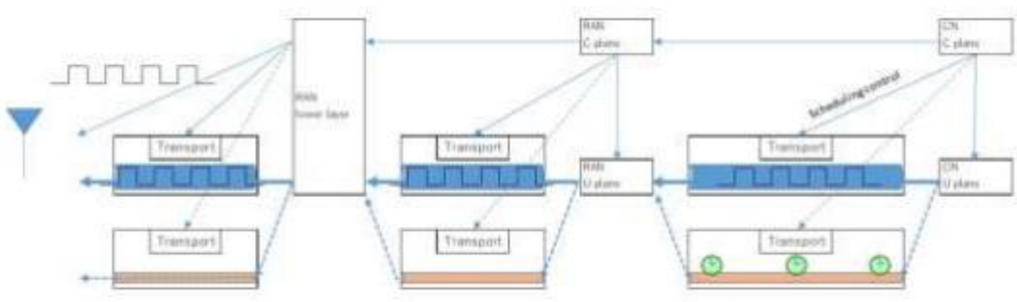

Fig. 1-24. Example of architecture for wide-area deterministic communication

4.8.8. Location-based mobility control supporting extreme-coverage:

In 5G, mobility control has remained largely unchanged since EPC. In other words, 5G's current mobility control (and services such as emergency calls subject to the regulations of the country where the terminal is served) does not work properly when (i) cells or base stations move relative to the ground, (ii) a combination of cells and base stations change or (iii) cells are large enough to cover part of another country across the border. In the future, the above-mentioned situations will occur normally, service coverage areas will be on the ground, in the sky and in space, and 31 terminals and base stations will move around in a three-dimensional space. Thus, there should be a review of mobility control. For example, location-based mobility control may be employed for the idle mode. This mobility control consists of the following three parts. As shown in Fig. 1-25, (a) each area is defined as a cube which is separated with other cubes in three dimensions by the coordinates of latitude, longitude and altitude, b) each cell determines whether a terminal with a location acquisition function is inside or outside itself and (c) information of the area covered by each cell is continually updated through enhanced link connection establishment between the cell, base station and core network. As a side effect, this scheme will make it possible to directly store the terminal's location registration information as part of a digital twin of the network in the cyberspace of the CPS that manages data in terms of location (and time). This digital twin can be easily overlaid on other digital twins (e.g., urban information, traffic information and disaster information). With additional use of AI, it will be possible to utilize such information updated every second for network operation and maintenance.

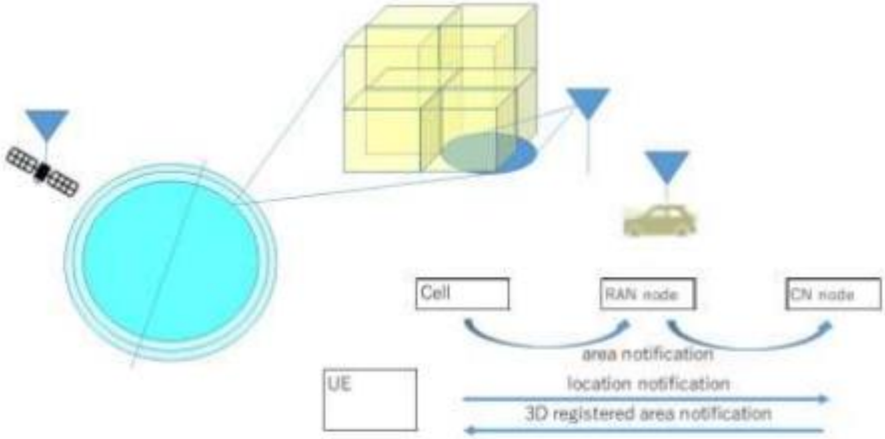

Fig. 1 -25. Location-based mobility control

4.8.9. Advanced security:

Cyber-attacks are becoming increasingly sophisticated, everyday examples include ransom ware and phishing, but at the same time even more complex targeted attacks are also taking place. These attacks are possible due to increased software and digitalization paired with connectivity and mobility that in turn increases the threat surface. We envision enhancements in 6G will lead to extreme-massive connectivity and sensing, digital twin becoming common, increased cooperation with third parties including cloud service providers and increased interworking with wireless communication technologies other than mobile communications. At the same time we will also see increased usage of very low power consuming devices with limited resources, which will also be in use by critical infrastructure. Together with these enhancements towards 6G, we should also expect technology enhancements in the dark web. Threat actors in the form of Artificial Intelligence (AI) should be expected to increasingly appear. All these aspects of 6G era will lead to increase in threat surface leading to potentially far more security attacks than seen today. Exposed low power limited resource devices without adequate security could lead to attacks on the network as well as sensitive data, while exposure of network and services to third party could lead to numerous attacks as well. Thus holistic security considerations from the very beginning becomes ever essential for 6G in order to provide safe and secure services so as to realize trusted cooperation across industries. Enhanced security for 6G should protect systems and data from these ever increasing threats while ensuring their confidentiality, integrity and availability. So as to protect services and networks from cyber-attacks, it is necessary to build solutions that eliminate vulnerabilities from the very beginning and continuously, solutions that are flexible and adaptable based on service or usage and that can, preferably, quickly and autonomously detect 32 cyber-attack as well as take remedial measures while localizing the attack. Work is already underway towards secure technologies using AI and network (NW) digital twin, advancement of vulnerability and attack detection technologies, automation of cyber-attack detection and remediation, and prediction based cyber-attack prevention techniques. The introduction of these state-of-the-art secure technologies will provide a robust security protection that will ensure confidentiality, integrity and availability. Together these will help towards the vision of zero touch and zero trust security. Higher data-rate requirements, associated to devices with sufficient resources (memory, CPU etc.), as well as very low resource limited resources devices with requirement of ensuring adequate security will also lead to simplification of protocols, lightweight cryptography and security functions. Such enhancements will enable even low-power consumption devices to execute advanced security functions with side-effect of reduced security risks due to lower protocol complexity. In addition enhancements in encrypted traffic analysis and secure computation technology will help prevent potential cyber-attacks and distributed ledger technology (DLT) or enhancements thereof can be beneficial for securing transactions for the expected open nature of 6G. Moving towards 6G, we should expect quantum computing to be available. The universal quantum computer, which can execute the algorithm of Shor could crack mainstream cryptographic algorithms (RSA, Elliptic curve cryptography, etc.). Thus in 6G era, the quantum-computer-resistant cryptographic algorithm is essential. All these aspects of security also requires associated considerations of network architecture. The image of advanced security in 6G network is shown Fig. 1-26. Finally, even with all the security enhancements, basic security concepts must not be forgotten such as: hardening, password management, identity and access management, monitoring, patching etc. Also, while enhancing security for 6G it is essential to understand that security is often a trade-off with business and architecture thus appropriate balance must be found that still reduces the overall security risk.

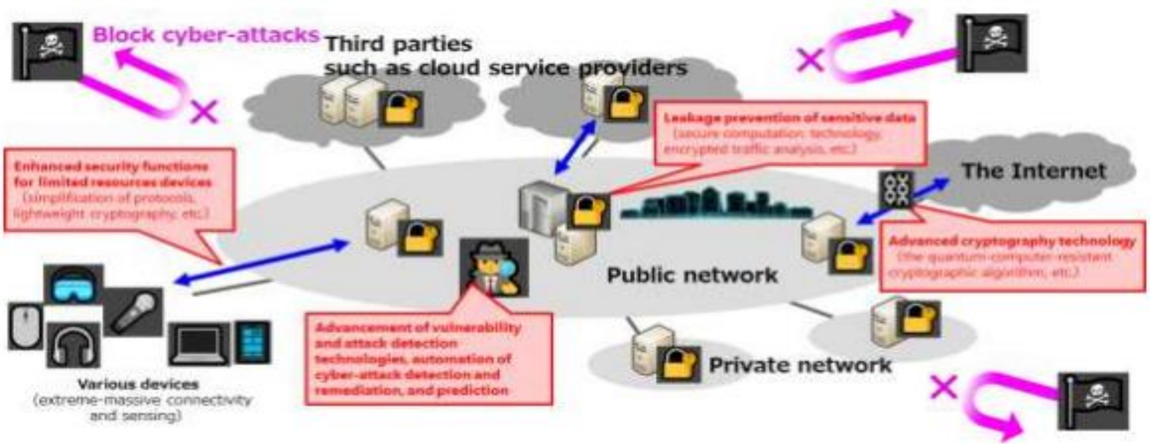

Fig. 1-26.Advanced security in 6G network

4.8.10. Distributed computing resources:

To realize cyber physical fusion and digital twins, it is necessary to collect information from the physical environment for the cyber environment. Constant transmission of high-definition images, which are part of physical information, requires a huge amount of communication resources throughout the path from a large number of camera devices to digital twins. In order to reduce such communication resource consumption, some pre-processing may be necessary, such as 33 removing redundant parts by image compression or aggregation or creating high-definition images by redundancy, using computing resources distributed in devices or in edge environments close to devices. Use cases like an AR tourist guide will require a level of latency so low that any lag with the real world cannot be felt for improving user satisfaction. It would be preferable to perform AR and other similar processing within the device, but that will be a trade-off with the need to reduce device's weight and power consumption. Therefore, such services are anticipated to use distributed edge computing resources. Another use case would be services that does what you currently do with your smartphone, using input/output devices around you, such as displays in your home or publicly installed cameras outdoors. Some of these services are anticipated to use edge distributed computing resources for control purposes, ensuring computing resources as well as input/output devices will always be available close to humans as they move around in order to maintain QoE. We will distribute computing resources to more locations in addition to the 4 locations nationwide deployed at service launch. In addition, companies and local governments are installing their private systems such as local 5G, and many of them may eventually deploy computing resources as well. In the 6G era, where digital twins and AR will become available anytime, anywhere, how much computing resources should be distributed? Suppose resources are only deployed in one location in each prefectural government or government-designated city, it would not be sufficient to meet the latency requirements. Resources should be distributed to degree that each of the special facilities such as stadiums and local tourist spots will have some. In view of the trend in which more RAN functions are deployed as software-based, virtualized components rather than in the form of physical equipment, computing resources could be deployed in all buildings accommodating RAN equipment in the way such resources are shared between end users and the RAN equipment. Furthermore, as technology makes anything smaller, computing resources could be made available in all antenna installations. As shown in Fig. 1-27, medium and small quantities of computing resources will be distributed everywhere, not just in the form of large data centers. By leveraging all of these resources, we'll be able to meet the processing demands of the 6G era. To ensure users can easily and safely use such resources in various places, it will be more important to develop technologies for automating orchestration to handle distributed resources uniformly and for protecting and enciphering data and logic to enable various players to provide services by combining data and logic on those resources.

Fig. 1-27. Distributed computing resources.

Table 1 -2. Challenges in 5G evolution and 6G Technologies:

Technological area	Challenges
New Radio Network Topology	・Low-cost distributed antenna deployment method and fronthaul/backhaul technology ・Interference control technology in high-density distributed antenna deployment ・Win-Win distributed antenna deployment with sensing and energy-saving communications
Coverage extension technology including Non-Terrestrial Networks (NTNs)	・Radio interface extension for NTNs ・Method for highly efficient frequency utilization with ground networks ・Method for realizing coordinated operation between HAPS systems and ground networks ・Coverage extension to space
Technology for further broader frequency domain and advancement of frequency utilization	・Clarification of THz-band radio wave propagation characteristics and establishment of propagation models ・Challenges in THz-band device technology (Miniaturization, low power consumption, high heat dissipation, etc.)

	• Establishment of signal waveforms and wireless technologies suitable for the THz band • Optimization of selective use of multiple bands including existing frequency bands
Further advancement of mMIMO and wireless transmission technologies	• Study of multi-element / multi-layer mMIMO technology • Transmission path control technology in distributed MIMO • Development of new wireless technologies for existing frequency bands
Extension of Ultra-Reliable and Low Latency Communications (URLLC) and industrial networks	• Support of a wide range of requirements including very demanding requirements and "Mixed Traffic" • Realization of further high-reliability and secure communications • Coordinated operation between public and private networks and network configuration
Multifunctional wireless communication systems and utilization of AI technology in all areas	• Simultaneous realization of wireless communications, sensing technology and wireless power supply technology • Study of radio standards suitable for deployment of AI technology
Integration of wireless communications technologies	• Method of cooperation or integration with other technologies • Control of wireless technology selection transparent to users
Network architecture	• Flat network topology • Flexible deployment of networkfeatures • Simple network • Advanced OAM • Support for multiple access technologies • Core network transmission / switching control supporting extreme low latency • Wide-area time synchronization and wide-area deterministic communication supporting CPS • Location-based mobility control supporting extreme coverage • Advanced security • Distributed computing resources

Conclusion:

In this chapter, we have discussed the direction of evolution of mobile communication technology for 5G evolution, which is an enhancement of 5G, and toward 6G, which represents a vision of the world in the 2030's. We have provided the concepts for the requirements, use cases and technological development and research areas. Table 5-1 summarizes the challenges that need to be addressed in each of the technological areas discussed in this chapter.

CHAPTER II:

6G technologies and requirement

INTRODUCTION:

While 5G is being rolled out in different parts of the globe, few research groups around the world − such as the Finnish 6G Flagship program − have already started posing the question: What will 6G be? The 6G vision is a data-driven society, enabled by near instant unlimited wireless connectivity. Driven by impetus to provide vertical-specific wireless network solutions, machine type communication encompassing both its mission critical and massive connectivity aspects is foreseen to be an important cornerstone of 6G development. This article presents an over-arching vision for machine type communication in 6G. In this regard, some relevant performance indicators are first anticipated, followed by a presentation of six key enabling technologies.

1. Power saving techniques for 5g and beyond:

Energy efficiency is one of the key performance indicators in 5G New Radio (NR) networks targeted to support diversified use cases including enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable and low latency communications (URLLC). Trade-offs have to be carefully considered between energy efficiency and other performance aspects 2

2. Machine learning techniques for 5g and beyond:

Wireless communication systems play a very crucial role in modern society for entertainment, business, commercial, health and safety applications. These systems keep evolving from one generation to next generation and currently we are seeing deployment of fifth generation (5G) wireless systems around the world. Academics and industries are already discussing beyond 5G wireless systems which will be sixth generation (6G) of the evolution. One of the main and key components of 6G systems will be the use of Artificial Intelligence (AI) and Machine Learning (ML) for such wireless networks. Every component and building block of a wireless system that we currently are familiar with from our knowledge of wireless technologies up to 5G, such as physical, network and application layers, will involve one or another AI/ML techniques. This overview paper, presents an up-to-date review of future wireless system concepts such as 6G and role of ML techniques in these future wireless systems. In particular, we present a conceptual model for 6G and show the use and role of ML techniques in each layer of the model. We review some classical and contemporary ML techniques such as supervised and un-supervised learning, Reinforcement Learning (RL), Deep Learning (DL) and Federated Learning (FL) in the context of wireless communication systems. We conclude the paper with some future applications and research challenges in the area of ML and AI for 6G networks. ND high band.

3. Potential Application:

3.1. Extended reality (XR) :

6G will have the capacity to enable many XR applications that are not possible in 5G networks due to the inability of 5G systems to provide low enough latencies that will support these data rate intensive applications. These XR applications require URLLC and eMBB while also incorporating perceptual factors originating from the users cognition, senses, and physiology for a truly immersive experience which 6G will need to be able to support. Only then can all sensory inputs be captured to provide a fully immersive XR application.

3.2. Connected robotics and autonomous systems (C R A S):

The upcoming deployment of CRAS, eg autonomous cars, drone-delivery systems, autonomous robotics etc. is one of the main drivers for 6G wireless networks. Such systems require very low latency, for example, for public and vehicle safety in case of autonomous vehicles [22], and even eMBB transmissions for obtaining high definition maps. These strict requirements of data rate, latency and reliability is not yet provided by 5G, and thus might influence the development of 6G networks. Moreover, applying machine learning techniques can assist in vehicular networks to undertake more informed and data-driven decisions in order to acquire autonomy. Since AI, and especially ML, is proposed to be a key technology of 6G, such autonomous vehicular networks will have a significant influence on the design and development of 6G.

3.3 Haptic communications:

Haptic communication implements the sense of touch and offers an extra dimension to traditional audio visual communications in order to provide complete control and immersive steering in remote environments, and is an important factor in the actualization of the vast potential of VAR. The features of 6G wireless networks will ensure that the requirements of haptic applications and systems are met, and networks by 2030 are expected to carry out haptic communications [23].

3.4 Wireless brain-computerinter actions (B C I):

While BCI applications have been restricted to use in healthcare scenarios for the operation of prosthetic limbs or control of computing devices through the application of brain implants, the advances in implants and wireless brain-computer interfaces will mean that new applications of such technologies will arise which will require 6G in order to operate. These services require performance metrics fundamentally different to those provided by 5G, and thus 6G wireless networks with their high rates and reliability, extremely low latency will be needed to fulfil these requirements .

3.5. Block chain and distributed ledger technologies (DLT):

Block chain and DLT will be transformative for IoE technologies .These blockchain and DLT applications are seen as distributed sensing services as well as security measures to a certain degree for the next generation. These services will require low latency, scalability and a reliable connection to carry out and thus facilitate the establishment of 6G wireless networks.

4. 6G requirements:

To address the possible future applications and challenges, 6G wireless networks will need to fulfil some of the requirements which are listed below :

• Extremely high data rates with a peak data rate of around 1 Tb/s at the very least.

• 6G is predicted to offer user experienced data rate of 1 Gb/s which is much larger than that afforded by 5G. In cases like indoor hotspots, the data rate is expected to be as high as 10 Gb/s.

• High mobility of more than 1,000 km/h and very low latency over the air (around 10 to 100 μs). These properties will ensure QoE for airline systems etc

. • Connectivity density is expected to be much higher compared to 5G with predicted connectivity density in case of hotspots to rise up to 107 devices per square kilometer and 1 Gb/s per square meter space traffic capacity.

• Energy efficiency will be very high and the network will have to have the capability to maintain battery free IoT devices.

• The network is expected to work with much broader frequency bands (eg , in the range 73 GHz-140 Ghz, also 1THz-3THz).

• A full coverage will be required through the implementation of ubiquitous always-on ultra broadband network available globally using terrestrial, satellite, as well as sea domains..

• Convergence of functionalities like control, computing, sensing and communication will be necessary for the realization of a multipurpose system that will support more wide-ranging applications and services.

• Distributed and ubiquitous intelligence and computing starting from the application layer all the way to the physical layer will also be a requirement. A potential 6G architecture has been depicted in Fig.1-28.

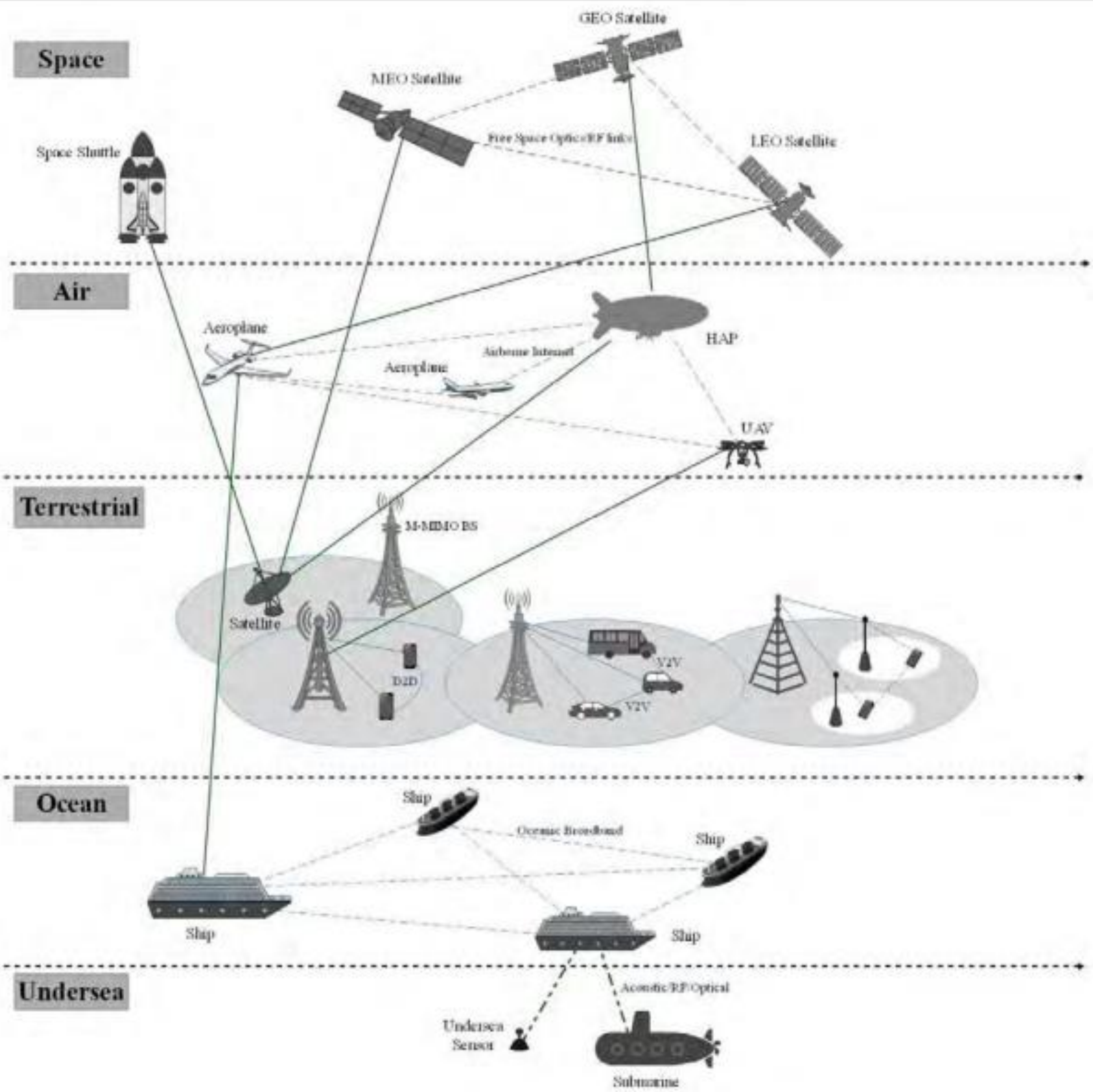

Fig. 1-28. Potential architecture of 6g

5.Design of transceiver front-end:

At THz frequencies, RF amplifiers might not be physically small enough for them to be located behind antenna elements. As a result, hybrid beamforming approaches could be needed in case of practical implementations. Performance metrics of transceivers like noise figure, peak out power and linearity of LNAs continue to deteriorate with the increase of operating frequency. Moreover, phase noise increases with increase in frequency. This makes providing good performance at these high frequencies challenging, which also makes carrying out higher-order modulations difficult. In the authors suggest the use of a new technique of using spatially-oversampled antenna while also presenting novel architectures of phased array devices and approaches to compact computation, all of which enable the steering of the beam using much lower chip real estate and power.

6.Multi-Wideband Terahertz Communications :

Recent years have heralded the arrival of the fifth-generation (5G) of mobile and wireless communication systems with a plethora of technologies promising to address current data rate, latency, or density challenges. Yet, while 5G networks are still being deployed, the sixth generation (6G) is already under intense development aiming at continuing to satisfy the ever-growing communication demands of society and industry. In this context, it has been stated that 6G networks may increase the data rate by 10-50×, the network efficiency by 10-100×, the area traffic capacity by 100×, while cutting down the latency by 10-100× with respect to that of 5G networks [24]. While 5G has tapped into the mmWave band (10–100 GHz) to combat the spectrum crunch, it is expected the 6G networks will need to enter the Terahertz band (0.1–1 THz) to continue increasing capacity and reducing latency through the exploitation of its ultra-broad bandwidth and the small form factor of its antennas. In this direction, THz-band communications will enable current networks to reach unprecedented locations, bridging them with Nano networks within the human body or air-space networks composed of high-altitude platforms or satellite swarms [24]. This way, 6G is expected to play a key role in transportation (fully automated driving), immersive experiences (virtual and augmented reality, tactile internet, UHD streaming), or medicine (robotic surgery, health) to cite a few examples. In contrast to its multiple advantages, THz-band communications face important challenges. Among them, we highlight the very large attenuation suffered by propagating THz waves due to spreading losses, penetration losses, and molecular absorption. This imposes the use of directive antennas and strong Line-of-Sight (LoS) requirements that are hard to meet in dense scenarios. In this context, the concept of Reconfigurable Intelligent Surfaces (RISs) has been widely regarded as a promising solution to provide reliable, fast, and versatile communications at THz frequencies [25]. To that end, a RIS is composed of an array of tenable unit cells whose collective response allows to control the strength, direction, and shape of the reflected waves. Such an array is referred to as a metasurface (MS) or a reflect array depending on whether the separation between unit cells is much lower than the wavelength or not Among the multiple uses of RIS in the context of THz band networks, this paper focuses on the case of short-range and high-rate indoor communication as shown in Fig. 1. We envision a network in which a number of devices are connected through one or multiple non-contiguous wideband channels, most likely exploiting the transparency windows

that exist in the THz band in a RIS-augmented environment. The use of bands may respond to aspects such as regulatory issues, gradual adoption of the THz band, the use of distance-aware modulations, or simply the need to maximize the network capacity using multiple carrier frequencies. In any case, the signals transmitted by the source, even with a highly directive pattern, will be subject to huge losses and therefore require the aid of the RIS to reach the receivers with enough power. The key observation here is that the unique benefit provided by the RIS will be lost unless its internal MS/reflectarray is able to control the waves at the different frequency channels.

The vision presented in this paper is that of an MS-based multi-wideband RIS, this is, a single device capable of controlling the amplitude, direction, and shape of the reflected beams at multiple non-contiguous THz bands concurrently. To realize such a RIS, the constituting unit cells need to be widely tenable to provide the required amplitude/phase response at the different THz bands, for which tuning mechanisms used in lower frequencies are slow, bulky, or ineffective. Instead, Graphene is an excellent candidate for this purpose thanks to its outstanding optoelectronic properties, which open the door to the development of ultrafast and highly integrated devices that naturally operate in the THz band and whose resonance can be tuned within a wide range by just adjusting a bias voltage .In fact graphene possesses distinct advantages with respect to common materials used for THz metasurface. Such metasurface may be composed of metallic, usually planar, elements with tenable response mediated by voltage controlled varying electronic interconnecting elements like diodes or properly selected layers infiltrated with voltage controlled liquid crystals. Compared to these configurations, graphene holds the advantage of being truly ultrathin while offering higher tuning speed and range. Another approach would involve the use of a phase changing materials like vanadium dioxide which, with thermal stimuli, undergoes a change from insulator to metal. Despite the high tenability range this choice does not allow the required continuously changing local states and the very fast tenability of graphene. Tenable THz metasurface may also use photoconductive semiconductors that offer high tuning speed, compared to that of graphene, but relatively low tuning range and would require a more complex system to control the local tuning.

In spite of their potential, work on graphene-based MS design has been mainly limited to a single functionality with a single-band operational frequency. Here, in the pathway to demonstrating the proposed vision, we instead present and evaluate a RIS capable of operating at three distinct bands based on a widely tenable graphene-based MS. In a typical multi-carrier frequency system, there is only one resonance in the frequency response spectrum of the hardware. There are some techniques for generating beams at very close frequencies but with limited bandwidth. In contrast, we are able to tune the resonance frequency by a large amount while keeping the beamforming criteria for operation in the technologically uncharted THz band. The chosen bands are 0.56–0.74 THz, 0.75–0.98 THz, and 0.99– 1.08 THz, identified in as feasible transparency windows ,which opens the door to high-speed transmissions to distances of several meters in all three bands, or even a few tens of meters in the lower band .In particular, we present a unit cell design able to provide the reflection amplitude and phase required to perform beam steering (to combat non-LoS propagation), beam splitting (for multicast transmissions), collimation (to implement RIS-based tunable antennas), or random scattering (to implement physical-layer security), which are later demonstrated. Hence, by supporting multiple bands and functionalities, a single RIS would be reusable and facilitate its adoption across different environments, protocols, and systems. However, the full realization of this vision poses

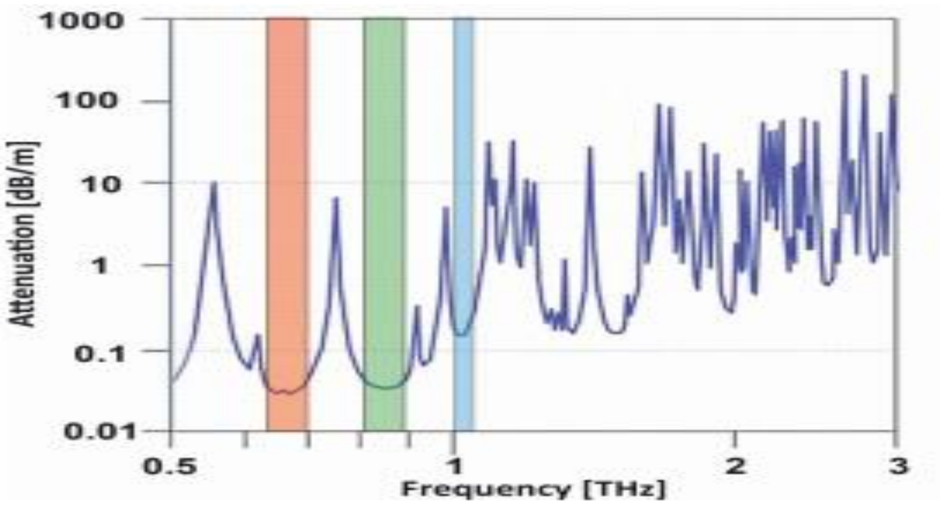

Fig. 1-29. Molecular absorption in a standard atmosphere at THz regime.

Selected communication channels corresponding to the chosen transparency windows at 0.56–0.74 THz, 0.75–0.98 THz, and 0.99–1.08 THz, are highlighted in red, green, and blue. Source: HITRAN.

7. GRAPHENE-BASED MULTI-WIDEND METASURFACE:

The behaviour of an MS is the result of the collective response of its building blocks, namely, the unit cells. Since the proposed MS acts as a reflector, the unit cells need to yield a high reflection amplitude at all times. Further, for beam manipulation, we need to provide a unit cell with the ability to control the phase response over a wide range of values. Additionally, in our case, both conditions need to be met for multiple widely spaced frequencies, although not necessarily concurrently. To enable dynamic re-configurability once the MS is deployed, it is necessary that both objectives can be met without physically changing the geometry. We thus propose that reconfigurability, both in frequency and phase, is achieved in the THz band by changing the biasing voltage of graphene sheets. Graphene exhibits a broadband voltage-tunable metal-like surface conductivity thanks to its unique support of plasmonic modes in the THz band, which opens the door to the design of tunable MSs in a wide range of frequencies and phases by just changing a bias voltage .It is worth noting that graphene's tunability margin begins to degrade in low THz frequencies. At the same time, due to the increasing free-space path loss at higher frequencies and the frequency-selective channel arising from the resonances of multiple elements present in a standard atmosphere, we cannot increase the operating frequency arbitrarily. Fig.1-29 shows the molecular absorption in a standard atmosphere in the THz spectrum, relative to the transmission distance. In light of this, the three highlighted windows at 0.56–0.74 THz, 0.75–0.98 THz, and 0.99–1.08 THz, are selected. In summary, to realize multiband communication with an MS-based RIS, we need a unit cell that resonates at these frequencies and provides a wide reflection phase margin.

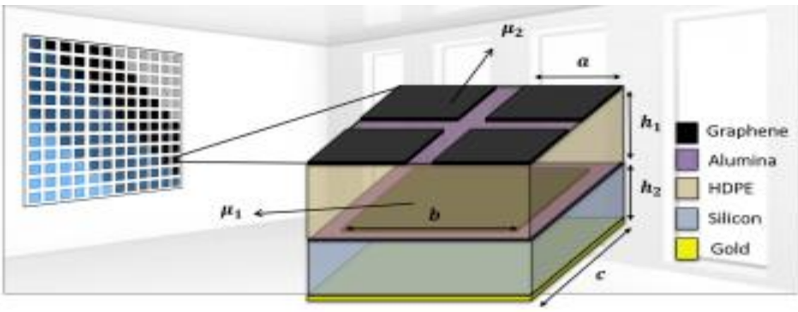

Fig.1- 30. Schematic representation of the unit cell layout. .

This unit cell is composed of two main dielectric layers (i.e., HDPE and silicon), four parasitic graphene patches on top and one graphene sheet sandwiched between the dielectrics. The unit cell is back plated with a thin layer of gold to be fully reflective

8.Unit Cell Design:

Fig. 3 shows the proposed unit cell whose lateral size is c = 35 μm (around λ/10), small enough to allow for fine resolution of the reflection phase profile, characteristic of MSs over standard reflect arrays. From top to bottom, the unit cell consists of a multi-layer structure with four parasitic graphene patches (a = 15 μm, chemical potential μ2) on top of an alumina layer with 0.1 μm thickness. Synthesis of graphene/alumina composite materials enhances strength, toughness, and wear-resistance with a low-cost process. This composite is stacked on high-density polyethylene (HDPE) substrate, due to its particularly low losses in the terahertz band [10]. HDPE permittivity is r = 2.37 and its thickness is selected h1 = 15 µm. The combination of graphene and HDPE leads to high electrical conductivity with good thermal and mechanical properties .Another layer of graphene/alumina composite (b = 20 µm, the chemical potential µ1) is sandwiched between HDPE and silicon (h2 = 10 µm) to allow for supporting multiple resonances and, thereby, being able to operate in three disjoint bands. Due to the native oxidation of silicon, a thin layer of silicon dioxide is grown in the outer layer in a short time. To analyze a realistic design we have considered a layer of silicon dioxide with 0.3 µm thickness on top of the silicon layer and the layout is back plated with gold. Regarding the fabrication feasibility of the proposed low-profile structure, there are advanced silicon substrate thinning techniques that can be used to achieve an ultra-thinning down to 4 µm without damage occurred due to thinning processes. As mentioned above, the frequency and reflection phase of a graphene-based unit cell can be controlled via changes in its biasing voltage. This is modelled through the frequency dependent surface conductivity of graphene σ(f), which in the THz band is given by σ (f) = (e^2µ/ π ¯h^ 2)(i/ 2πf + iτ^ −1), (1)

where e and ¯h are constants, while µ and τ are variables that correspond to the chemical potential and the relaxation time of the graphene layer, respectively [6]. When a graphene sheet forms one plate of a capacitor, any applied static voltage will alter the carrier density at its surface thus modulating its EM material properties, i.e., its complex-valued electric conductivity; the chemical potential, expressed in eV units, is typically used as the controllable variable, linked to the externally applied tuning voltage as µ ∝ √ Vbias. On the one hand, the amplitude response depends on the losses within graphene, Re{σ}, which in turn depend on the quality of the graphene sheets as modeled by the relaxation time value τ . For the purpose of this work, the relaxation time of graphene is assumed to be τ = 1 ps, which has been considered in multiple works and is realizable with state-of-the-art fabrication and encapsulation techniques [11]. On the other hand, to modify the resonance frequency and the phase of the response, the key tuning variable is the chemical potential value µ or, in our case, two distinct values µ1 and µ2 on top and bottom patches as shown next. All full-wave EM simulations at the unit-cell level were conducted in CST Microwave Studio (frequency domain solver).

9.Unit Cell States:

We explore the chemical potential design space by sweeping the values of µ1 and µ2 in the three desired operational frequencies. The inset figures in Fig. 1-31 show a trade-off between reflection amplitude and reflection phase versus chemical potential values at 0.65 THz as an example. Hence, by controlling the bias voltage we can tune the reflection characteristics. The results show the response of the MS for a continuous range of chemical potentials. However, to design a digital reconfigurable MS, we need to discretize the design space and select a set of chemical potentials to obtain a finite set of addressable states. Firstly, the number of unit cell states (per frequency band) has to be selected. Here, the number of states will determine the phase difference between consecutive unit cell states. As shown in our previous work four states (with π/2 phase difference between them) can offer high-quality beam-steering performance, given that the unit cell is fairly sub wavelength as in our case here. In the insets of Fig. 4, black circles indicate the four selected states at 0.65 THz. These states are selected manually with two goals i) π/2 phase shift to each other and maximum reflection amplitude. The blue symbols in Fig. 4 represent the selected states at 0.65 THz, whereas the red and yellow symbols represent the other two frequencies. We note that the selected states may need to change when the incidence angle changes. Assuming that a completely different set of states is needed to cover the neighborhoods of 0, 30, and 60 degrees, the minimum total number of required states is 4 states per frequency band × 3 frequency bands × 3 incidence angle neighborhoods = 36 states. Moreover, if the metasurface is brought in the near-field of transmitting/receiving antennas, the reflection phase/amplitude may vary and depend on the distance. This behaviour should be taken into account with additional states being foreseen to cover operation in such short distances.

10. Metasurface coding for beam steering :

Having selected the four sets of chemical potentials (μ1, μ2) that define the cell states, we retrieve the corresponding complex reflection coefficients (phase and amplitude) for each band, from charts similar to those in the insets of Fig. 1-31, as calculated from full-wave EM simulations. In this work, we assume that the operation between the three bands is decoupled, i.e., the four (μ1, μ2) sets that define the four states are different for each band. In this case, achieving independent control over the three bands is only possible via space multiplexing (large RIS panels divided into subpanels devoted to a particular frequency) or time multiplexing (slots reserved to each particular frequency) leveraging the fact that the response of graphene to the electrical tuning of its chemical potential is practically instantaneous. As discussed above, the phase-stepping is very close to π/2 along with the states of all three bands (horizontal axis of Fig. 1-31), with a worst-case reflection coefficient of −4 dB; these metrics ensure qualitative agreement with theory and can be further improved with cell redesign.

The Huygens-Fresnel principle (HFP) allows us to evaluate the scattering pattern of the MS for a given configuration as the aggregated response of its unit cells to a given incidence (frequency, polarization, wave front shape, and direction.

Where ϕ and θ are the azimuth and elevation angles, Amn corresponds to the complex amplitude of the wave incident for the mn-th unit cell, pmn denotes the scattering pattern of the mn-th unit cell, and Rmn is the complex reflection coefficient for the mn-th unit cell. Finally, $\zeta mn(\theta, \phi)$ is the relative phase shift of the unit cells with respect to the radiation pattern coordinates and their geometric arrangement on the MS. Tuning of the two voltages applied at each mn cell alters graphene's local $\mu 1,2$ and consequently the cell's response, Rmn; the collective effect of the tuning of all Rmn is a tuning of the scattering pattern, $E(\theta, \phi)$. The underlying approximation of the HFP is that unit cells are uncoupled, so that their Rmn can be tuned independently, which is valid for the cell sizes considered here. Finally, we note that HFP is an analytical method implemented on MATLAB using parameters calculated from 3D geometry and/or extracted from full-wave unit-cell level EM simulations.

The ideal MS coding or configuration, that is, the unit cell amplitudes and phases required to provide a given functionality, can also be analytically calculated in the same framework. This procedure can be summarized as forward propagating the source 'rays' while back-propagating the desired radiation pattern (prescribing a functionality) onto the MS, and then taking the complex-valued ratio of the propagated wave fronts on each cell; these ratios denote the required reflection coefficient Rmn profile to realize the functionality. Then, the unit cell states closest to the ideal ones are selected. As an example, normally incident plane waves can be steered away from the specular (normal) reflection direction by configuring the MS cells in stripes of progress sively increasing reflection phase, according to diffraction grating theory. More elaborate beamforming patterns can be engineered by more complicated configuration patterns; for instance, beam-splitting in two different directions can be accomplished by superimposing the stripes that correspond to single-beam steering thus generating a pattern of rectangular supercells.

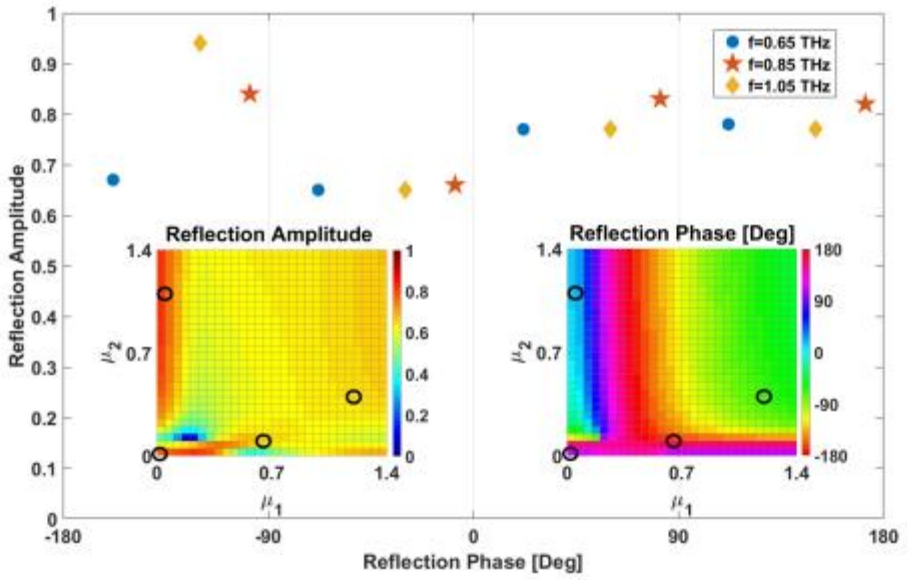

Fig. 1-31. Reflection characteristics of the selected states at respective operation frequency.

The insets represent the design space of different combinations of chemical potentials at 0.65 THz. The horizontal axis represents the chemical potential of sandwiched graphene patch (see Fig. 3) and the vertical axis represents the chemical potential of the graphene patches on top. Four states corresponding to the highest possible amplitude and spaced with π/2 phase are selected (black circles in the inset and blue circles in the outset figure). Reflection amplitude and phase at 0.85 and 1.05 THz versus chemical potentials have similar design spaces. Selected states are plotted with red stars (0.85 THz) and yellow diamonds (1.05 THz) in the outset figure.

In Fig. 1-32, we present a set of scattering patterns that demonstrate the potential of the proposed multi-wideband multi-functional RIS, assuming 40×40 35 μm-wide cells. This figure contains a selection of configurations and functionalities interesting in 6G contexts, demonstrated in three different frequencies namely:

11. Three-beam splitting :

At 0.85 THz, Fig. 1-32(a), shows a case where a normally incident plane wave is split in three beams, each one steered to a different direction that can be controlled independently of others: (θ, ϕ) = (15◦ , 315◦), (30◦ , 90◦), and (45◦ , 135◦). Fig. 1-32(a) depicts the scattering pattern both in spherical (3D) and in cylindrical (2.5D) coordinates, in the main view and topleft inset, respectively, together with the unit cell states with color-coded squares in the left-hand insets. This functionality could be useful for multicasting in multiband 6G networks.

12. Random scattering:

A normally incident radiation at 0.65 THz, Fig. 1-32(b). This is accomplished by totally random (uniform distribution) phase states across the MS; note that to eliminate back-scattering (or monostatic radar cross-section) the phase-states must be clustered in supercells of $\lambda/2$ size, as smaller randomly-coded cells emulate a metallic reflector and produce a specular reflection. This functionality is useful for physical-layer security methods, blocking certain users.

13. Collimation of a spherical wave front towards two far-field directions:

$(\theta, \phi) = (30^\circ, 0)$ and $(45^\circ, 90^\circ)$ at 1.05 THz, Fig. 1-32(c). In this case, the illuminating point-source is outside the near-field border, at 3 mm above the MS axis, so that emitted ‘rays’ impinge almost perpendicularly on the MS. This functionality is useful for the building of antennas where an integrated RIS acts as an intelligent reflector

14. IMPLEMENTATION CONSIDERATIONS :

The realization of the promising paradigm of widely tunable MS integrating graphene-based unit cells needs careful consideration of multiple aspects related to, among others, graphene technology and metasurface design. We discuss them next.

15. Technological implementation :

Although there are a rising number of methods for making various forms of graphene, the volume production for some of those methods remains limited. The focus will have to be on material quality and manufacturing cost. The main challenge lies in maintaining the quality of graphene, i.e. large τ , in large areas. Defects on the graphene layer will significantly affect the electrical conductivity. Therefore, choosing the most accurate method for producing graphene and good control over the graphene layer deposition is very important. Various fabrication approaches have been utilized to develop graphene. The more efficient among them, Chemical Vapor Deposition (CVD), has been shown to provide high quality, single layer, uniform graphene in large scale samples.

The contact of graphene with other materials, for example, dielectric substrates or metallic electrodes, modifies the doping level and chemical potential of graphene. In this case, encapsulating graphene in insulating materials such as hexagonal Boron Nitride (hBN) helps minimizing the influence of contacting materials and, hence, maintaining a high τ [6].

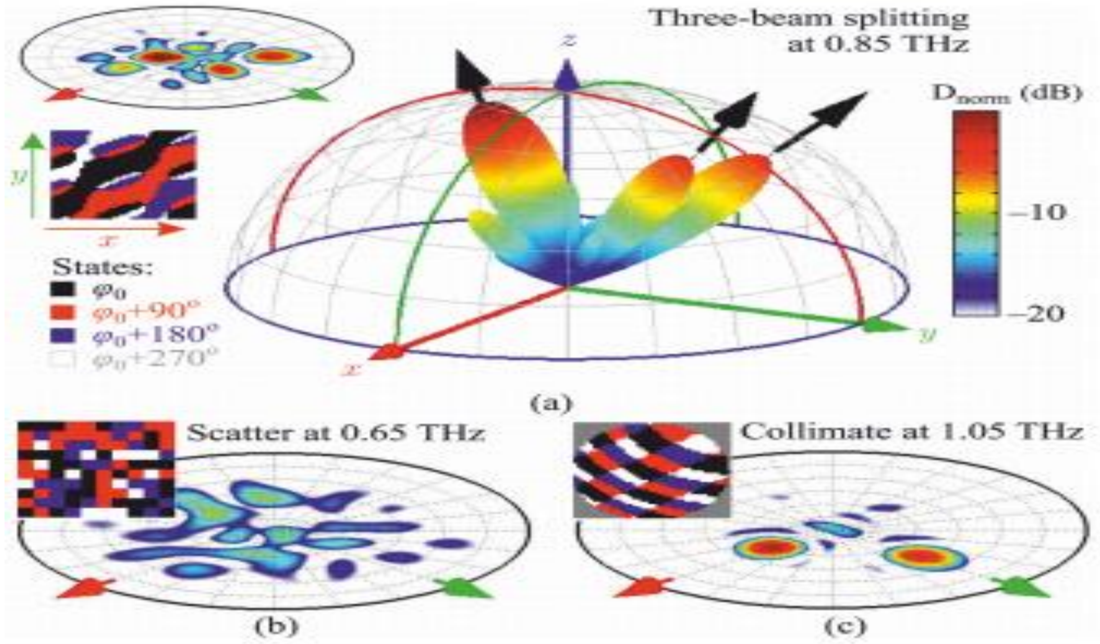

Fig. 1-32. Scattering patterns for normal illumination of the multi-band multifunctional RIS.

For the implementation of graphene-based MSs, it is usual to deploy a patterned scheme applied in a uniform sheet, as the patches discussed here. For the patterning, post-process techniques in pre-synthesized graphene are available, i.e., electron-beam, helium ion beam, lithography, nanostructure assisted, or Nano imprint technology .

16. Graphene tuning mechanisms:

As mentioned before, the properties of graphene depend strongly on aspects such as relaxation time and chemical potential, the latter of which can be tuned by imposing an external stimulus. Thus one can modify graphene's conductivity by altering the chemical doping, by thermal tuning, external electrostatic or magnetic field, and optical pumping or selfaction. Many of the works investigating the physical aspects of graphene's modulation capabilities focus on the global modification usually involving uniform graphene sheets. The most prevalent technique for locally manipulating the optical properties of graphene is controlling the biasing voltage, often enhanced with the use of an electrolytic medium. In this case, care must be taken in controlling the biasing voltage at each unit cell individually as required by the MS coding. This non-uniform modification can be achieved by properly placed transparent electrodes or by alternative techniques, for example, uneven ground planes or homogeneous dielectric spacers, which in any case are non-trivial at the granularity of the proposed unit cells. In all cases, we note that the tuning speed of graphene (in the order of picoseconds) is enough to support not only slow-paced indoor applications, but also the most demanding outdoor applications, even vehicular ones, whose reconfiguration speeds may be in the the order of hundreds of microseconds

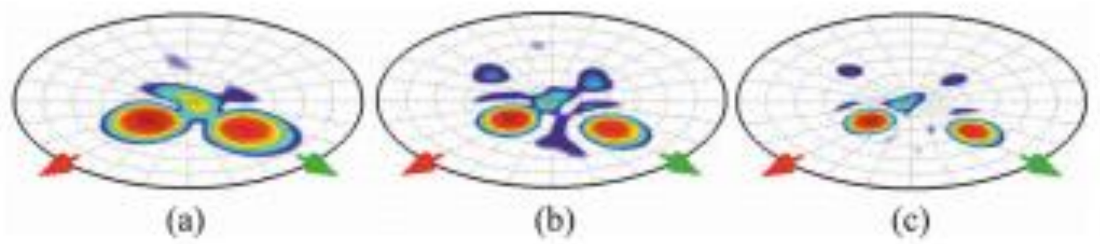

Fig. 1-33. Scattering patterns for two-beam splitting of a normally incident plane wave by a circular-aperture MS ({a, b, c} = {0.65, 0.85, 1.05} THz).

17. Multi-band metasurface design:

Assuming that the MS operation in all three bands is concurrent, e.g., without any time-multiplexing scheme to decouple them, means that setting the graphene chemical potentials (μ1, μ2) to optimize the four states for one frequency band will unavoidably simultaneously affect the graphene response in the other bands. In line with the vision outlined in this paper, an ideal unit cell would provide a large number of states with high amplitude and all possible combinations of equally spaced phases in the three target frequencies, i.e. $\phi = \phi 0 + \{0, \pi/2 , \pi, 3\pi/ 2 \}$ at f1, f2, f3. This would allow controlling the response at the three bands simultaneously and independently. However, such a unit cell would probably require heavy optimization to strike a delicate balance among multiple resonances.

In less ideal unit cells, the complex reflection coefficients in the other bands will in principle form a sub-optimal set of states deteriorating the performance. It can be intuitively understood that optimization of the unit-cell geometry can potentially lead to adequately broadband behaviour; alternatively, the four states can be assigned to four (μ1, μ2) sets that lead to a tolerable performance, on average across the operation bands. In Fig. 1-32, we present two-beam splitting of a normally incident plane wave by a circular-aperture MS (diameter 1.4 mm) of 35 μm-wide cells. Each panel in this figure corresponds to an operating frequency band ({a, b, c} = {0.65, 0.85, 1.05} THz) for which the (μ1, μ2) for the four states have been optimally selected. Evidently, the scattering patterns present two well-defined lobes at the desired directions, $(\theta, \phi) = (30^\circ , 0)$ and $(45^\circ , 90^\circ)$. In each case, the response at the bands for which the MS has not been tuned, which is not shown for space constraints, is degraded. Specifically, the scattering directivity in the desired lobes was decreased by 1-2 dB (worst-case) whereas parasitic side lobes were raised by 6-7 dB.

18. Near-field and link-budget considerations:

The Huygens-Fresnel principle introduced previously can be used to accurately estimate the far-field as a superposition of elementary scattering patterns from each cell. Even though this Huygens-Fresnel framework is strictly valid in the far-field, i.e., in a context similar to geometric-optics/ray-tracing, its applicability for performance evaluation extends well into the 'transition' (or Fresnel) region, bounded by the near-field and the Fraunhofer (rFF) regions. This means that a RIS can be envisioned as a part of the antenna system of a transceiver base station, providing digital beamforming that enhances path loss to virtual-line-of-sight mobile stations. Moreover, in real-world applications relevant to 6G THz communications, such as pico/femto-cells or short-range indoor channels, all incoming sources will practically be in the far-field of the MS, even for cm-sized apertures for which the Fraunhofer region is a few meters.

Finally, note that this multi-band RIS is capable of operating at frequency bands of almost an octave distance. In this sense, the path loss will exhibit a 6 dB deterioration switching from the lowest to the highest frequency, which could be considered for a short-range link budget. Nevertheless, this difference can be partially compensated by an increased directivity of the scattering pattern assuming that: (i) the RIS aperture is fixed, (ii) the channel is appreciably unobstructed so that a low exponent λ n, n $\rightarrow$ 2, can be assumed, and (iii) the MS reflection coefficients are approximately similar across the frequency bands; the latter can be attained by engineering the unit-cell and careful selection of its states, and/or using materials with sufficiently broadband response, such as graphene.

19. Six Key Enablers for Machine Type Communication in 6G:

19.1. Key Performance Indicators for MTC in 6G:

Reliability, latency, device density and energy efficiency are among the main key performance indicators (KPI) pertinent to MTC. The 6G reliability and latency requirement is expected to be diverse and use case specific, with the most extreme values being 10−9 and 0.1 millisecond (ms), respectively, corresponding to the current requirements for wired industrial control networks in Industry 4.0 applications. Extrapolating the ITU specified 5G device density of a million IoT devices per km2 and considering that 3D connectivity will be an important capacity measure in 6G ,we anticipate networks required to support about 10 devices per m2 − 100 devices per m3. In terms of energy efficiency, 6G will introduce ultra-long battery life aided by a combination of energy efficient communication, advanced battery technology and energy harvesting (EH) techniques. The ultimate vision is to completely remove the need for separately charging mobile devices. In addition, 6G is expected to be the first generation to consider from scratch a number of new requirements covering technical (e.g., positioning accuracy), societal (e.g., measuring connectivity as a human right), environmental (e.g., CO2 footprint) and economical aspects.

19.2. Major Contributions:

This paper presents an over-arching vision for MTC in 6G. In particular, we discuss six key technologies that will enable the ambitious design requirements outlined above. These six enablers and corresponding solution components are illustrated in Figure 1, and detailed in the rest of this article. We foresee that some existing elements like massive connectivity and energy efficiency will continue to evolve and be further optimized. Additionally, new security considerations and the applications of emerging technology components like multi-access edge computing (MEC) and machine learning (ML) are highly relevant. Within these aspects, topics like network slicing, edge intelligence and ML enabled algorithms will play prominent roles. With the growing need to provide vertical-specific wireless connectivity solutions, different vertical sectors will be intricately involved in 6G design and development. Consequently, ensuring seamless interoperability across different systems within the same vertical will be an important design challenge. The six enablers presented are by no means exhaustive. Other potential important enablers for 6G not covered in this article include ultra-high speed links exploiting terahertz and visible light communication, utilizing unmanned aerial vehicles and very low-earth orbit satellites as network infrastructure, and the integration of meta materials and intelligent structures like software-defined materials and fluid antennae with massive MIMO technology.

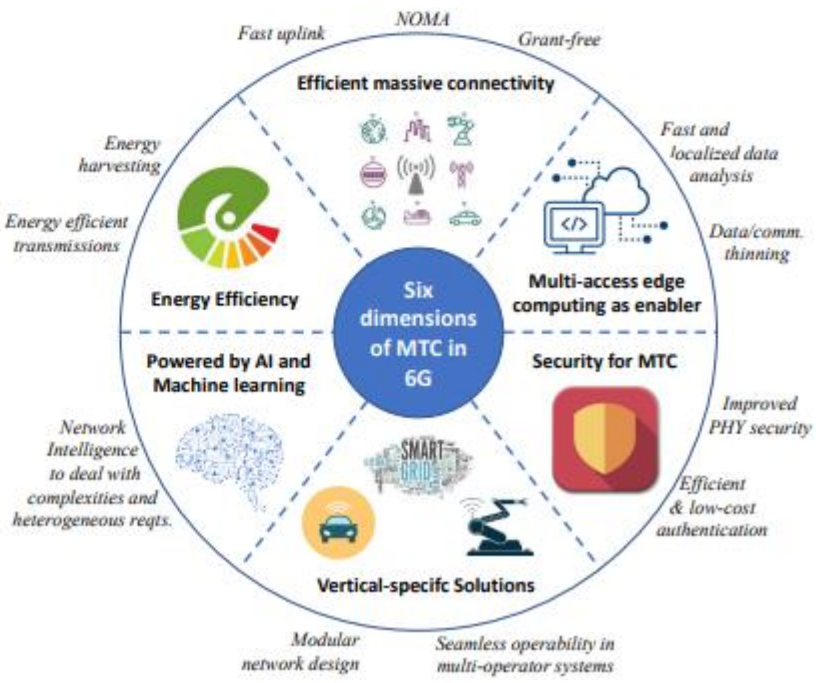

Fig. 1-34. Six key enablers for MTC in 6G and their respective solution components.

19.3. EFFICIENT AND FAST MASSIVE CONNECTIVITY:

Ensuring fast, efficient and reliable channel access for a large number of diverse MTC devices with dynamic and generally low payload traffic and varying latency/reliability requirements is a key design challenge for MTC. The conventional access mechanism of granting exclusive rights to users through a four-way handshake procedure is not suitable for URLLC/mMTC services due to their diverse and challenging requirements. Therefore, efficient radio access technology (RAT) solutions are imperative. In the physical layer (PHY), using agile numerology can improve the latency and reliability of wireless links. For instance, 5G NR has introduced mini-slots of duration as low as 0.07 ms as opposed to the fixed slot duration of one ms in LTE thereby, considerably reducing the minimum transmission time .Reducing the time it takes to establish channel access is also important for latency reduction. In this respect, grant-free.

The (GF) random access allows users to transmit immediately upon data packet arrival at PHY, thereby reducing the access latency and signaling overhead. As URLLC and mMTC services are becoming more interlinked moving towards 6G, novel unified solutions and further optimization of existing technologies are required to meet the challenges of efficient and fast massive connectivity. Three potential research directions are hereby presented.

19.4. Enhancement of GF Random Access :

Controlling and resolving collisions is one of the main challenges in GF random access. The use of advanced reception techniques like non-orthogonal multiple access (NOMA) and successive interference cancellation in cooperation with GF transmissions enhances its reliability. Moreover, GF can be combined with conventional schemes. For instance, the initial transmission can be performed over dedicated grant-based resources, while proactive hybrid automatic repeat request retransmissions can be performed over shared resources by using GF schemes. In this context, differentiated random access and scheduling policies considering the latency budget will gain increasing attention.

19.5. Improved NOMA Schemes :

NOMA allows transmissions to be multiplexed in time by relying on advanced receivers to detect overlapping transmissions. Most NOMA techniques can be grouped into signature-domain or power-domain multiplexing. Differentiation between users sharing the same resource is done based on the use of different signatures in the former, and by utilizing difference in their received signal power in the latter. NOMA studies in 6G are likely to focus on improving transmitter side processing for the signature domain NOMA and receiver side processing for the power domain NOMA.

19.6. Improved Physical Layer Security Techniques:

Physical layer security (PLS) techniques enable secure transmission while preventing eavesdropping by exploiting the wireless channel characteristics. PLS techniques have shown to be a promising alternative for providing security in MTC networks, as they do not rely on complex processes of encryption or decryption. However, it is crucial to develop more robust, efficient and appealing PLS techniques that simultaneously satisfy the requirements on reliability, energy overhead, latency, short payloads, and throughput, and tailored to MTC applications. Moreover, evaluating the performance of secure systems for MTC will demand new secrecy metrics for realistic and practical scenarios compared to the legacy secrecy capacity or secrecy outage probability.

19.7. MULTI-ACCESS EDGE COMPUTING:

Multi-access Edge Computing is the deployment and operation of distributed computing, caching, network communication, and data analytics resources at the edge of the cellular network. (i.e., locations which are geographically close to the devices that generate and/or use the data). MEC evolved from the fog computing concept, which was mainly introduced so that IoT-like applications could take advantage of cloud computing at the network edge. MEC extends this concept further to encompass additional capabilities like data processing, storage, and using the data to make network decisions .MEC will play a leading role in 6G by operating as an intermediate layer that provides fast and localized data processing for critical and resource constrained applications. Security, vehicle to anything (V2X) communication, energy efficiency and offloading for URLLC can be cited as particularly relevant use cases. Concrete examples of different MEC functionalities as enablers of multi-service communication for massive and critical MTC in 6G are illustrated in Figure 5 and detailed below.

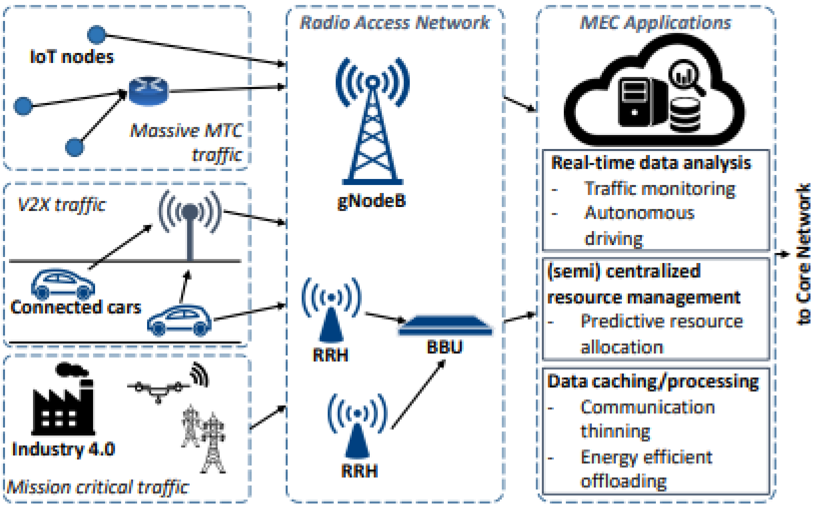

Fig. 1-35. Examples of different MEC functionalities as enablers for multi-service communication for massive and critical MTC in 6G.

CONCLUSION:

In this chapter, we outlined The concept of a multi-wideband MS in the THz regime has been explored in an attempt to extend the RIS paradigm to 6G networks operating at multiple frequencies concurrently. Embedding multiple layers of graphene into the design of the unit cells allows reconfiguring the local reflection phase at multiple frequencies by tuning the biasing voltage of each layer independently. With the aggregated response of the unit cells within the MS, we show that beam steering, beam splitting, random scattering, and collimation functionalities can be achieved at the desired frequencies (i.e., 0.65, 0.85, and 1.05 THz), which are characterized by low atmospheric attenuation. The realization of the proposed multi-band vision, however, still requires unit cells allowing for the concurrent yet independent control of the phases at each target frequency. Even though this complicates the design and implementation of the unit cells, the potential impact in the deployment and subsequent adoption of 6G networks is deemed considerable since a single RIS could be reused across environments, protocols, and systems.

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Chapter III:

The b5G physical layer simulation.

1. Introduction:

For the previous chapters, we gave a full study on the future beyond 5G networks, from different angles starting from the promised THz communications as we talked about the necessary to develop new THz channel models and Transceivers, moving on the technologies and the network solutions that will help to achieve the Thera bits ps high data rate. From the study done we have noticed a new challenges and potential for the physical layer, so we need to discuss some of the changes that will occur at the level of the sum Rate when the value of the bandwidth is changed.

2. Simulation objectif:

The main objectif of the simulation is to found the parameters that can allow us to manage the physical layer resources. In this case we are going to take the number of users and cells number as control parameters. The system simulated return the sum rate value as a quality of serves parameter for the network state evaluation.

Settings used: Bandwidth in MHz, frequency in GHz, SNR_original and tau_original, FreqFactor is a factor represents that we have 20 times higher frequency and 20 times more bandwidth.

3. The Scenario:

We suggest a scenario using MATLAB software.

The bandwidth chosen in case 1 will (50, 100, 500, 1000)MHz with frequencies ranging from 28GHz to 300GHz, as for the case 2 the bandwidth (is 2000, 9000)MHz with frequencies is 60 GHz and freqFactor = 20, the numbers of users and antennas it changes from 22.5 as a minimum to 100 as a maximum.

3.1. Scenario 1:

At this stage, we used a bandwidth with values that change from 50 to 1000 Mhz with a frequency of 28 GHz.

3.1.1 Step 1: Case 1: 28 GHz, 50 MHz bandwidth.

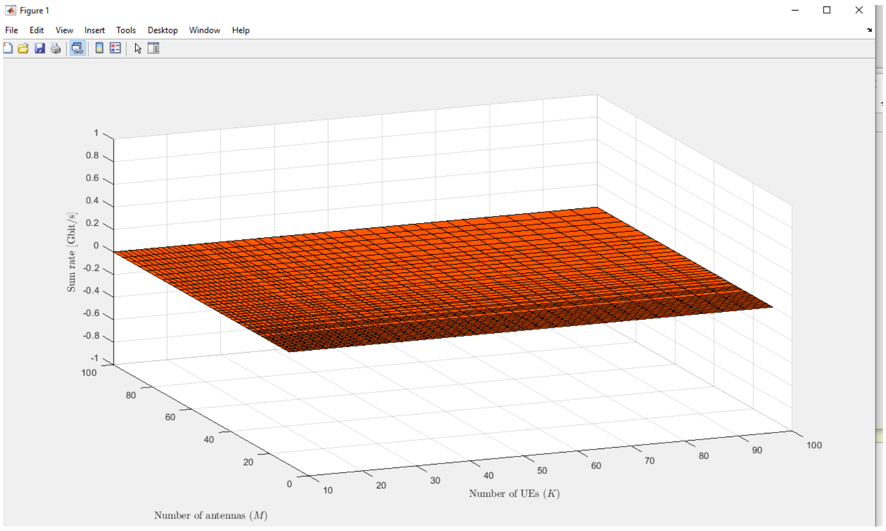

Fig.1-36. Sum rate evolution in terms of bandwidth=50 MHz

In this case, we can see that the value of the sum rate stay at 0 because the bandwidth is less than 100 MHz

3.1.2 Step 2: Case 1: 28 GHz, 500 MHz bandwidth.

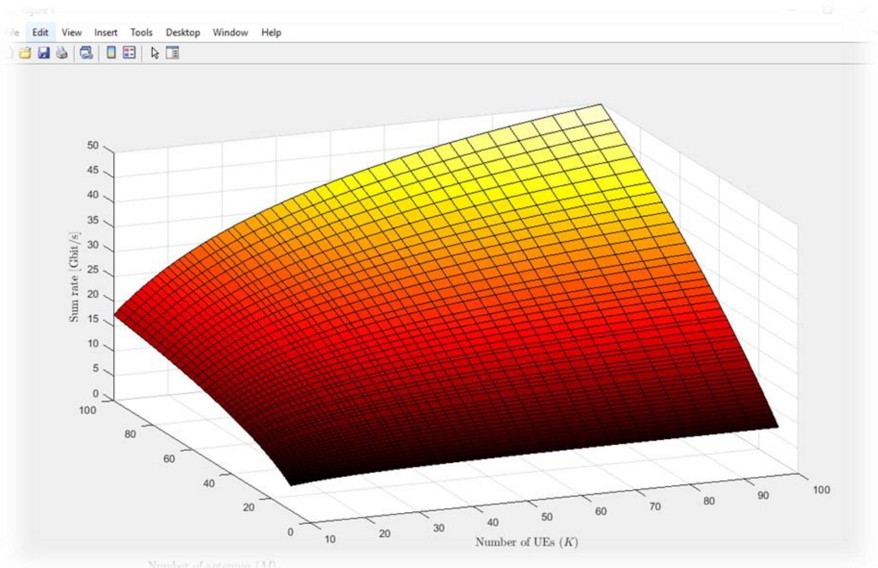

Fig.1-37. Sum rate evolution in terms of bandwidth =500Mhz

In this case, the sum rate starts to increase when both of users number and cells value increase.

First of all, we can see that the value of 500MHz can be acceptable to carry the information.

Second observation, very important, the sum rate increase when network cells increase even when the users number increase too.

3.1.3 Step 3: Case 1: 28 GHz, 1000 MHz bandwidth.

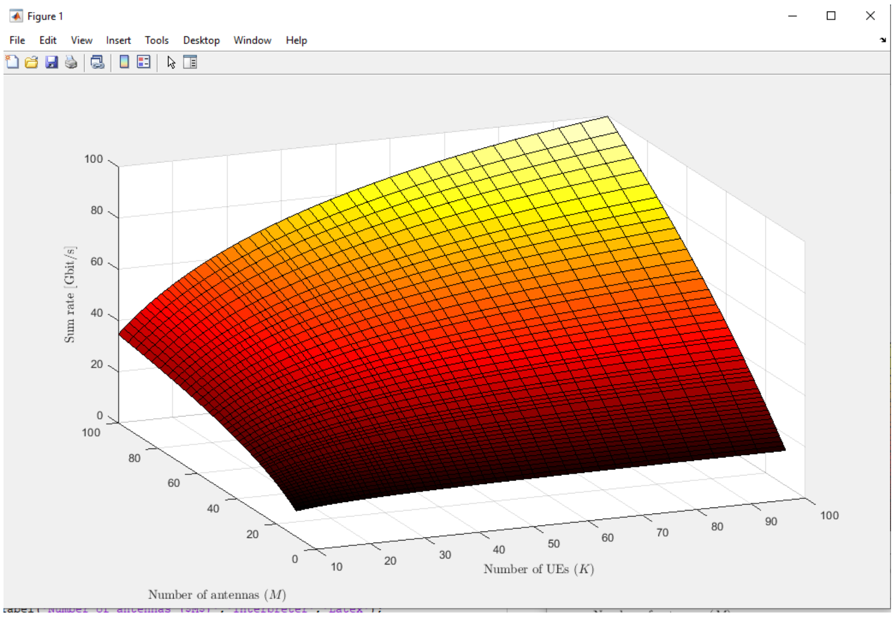

Fig.1-38. Sum rate evolution in terms of bandwidth =1000MHz.

In this case, the sum rate starts to increase when the bandwidth value increases

And from, it we can conclude that the sum rate changes with the change in the bandwidth, as well as the number of users and users

3.2 Scenario 2:

At this stage, we used a bandwidth with values that change from 100 to 1000 MHz with a frequency of 60 GHz.

3.2.1.Step1: Case 1: 60 GHz, 100 MHz bandwidth.

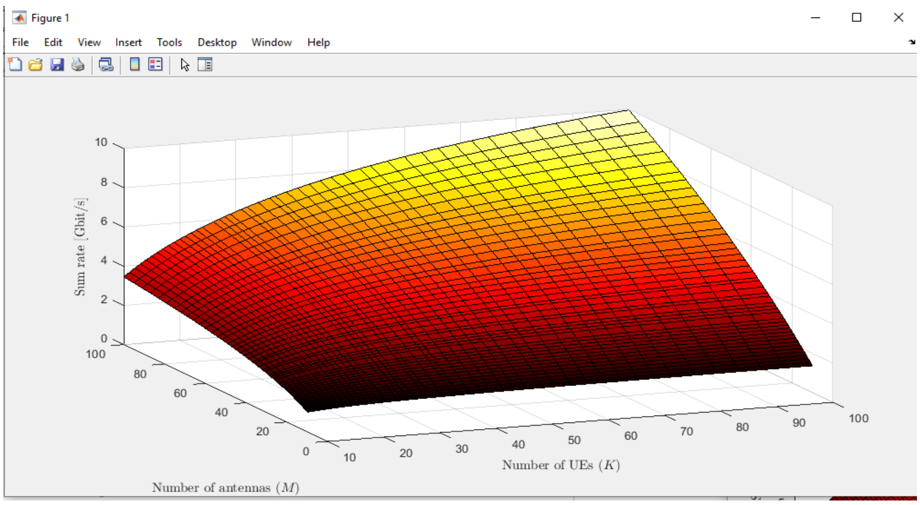

Fig.1-39. Sum rate evolution in terms of bandwidth =100MHz

Her, we can see when we use bandwidth=100 MHz, The value of sum rate will change from 3.5 to 10 GHz/s.

3.2.2.Step 2: Case 1: 60 GHz, 500 MHz bandwidth.

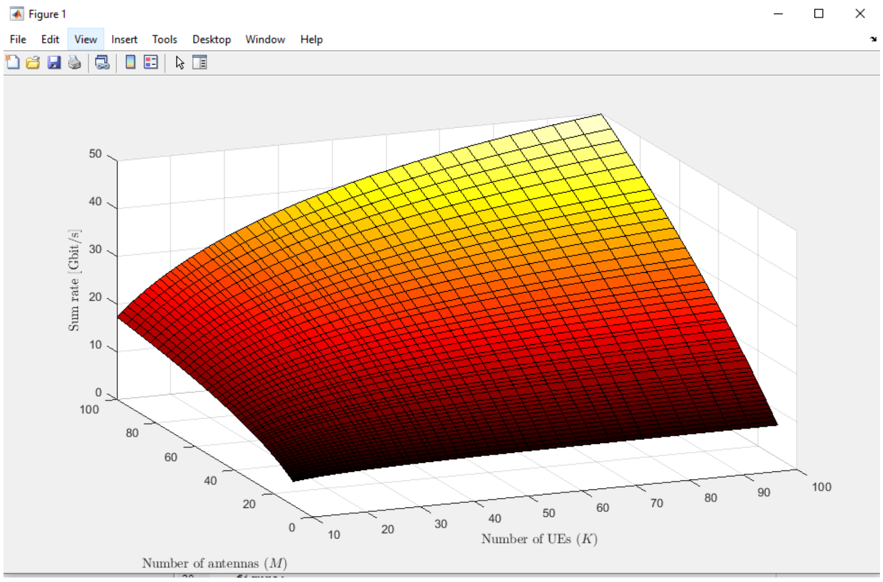

Fig.1-40. Sum rate evolution in terms of bandwidth =500Mhz

Also In this case we found when we increase the value of bandwidth to 500 MHz, The value of sum rate will increase from 17.5 to 50 GHz/s.

3.2.3.Step 3: Case 1: 60 GHz, 1000 MHz bandwidth.

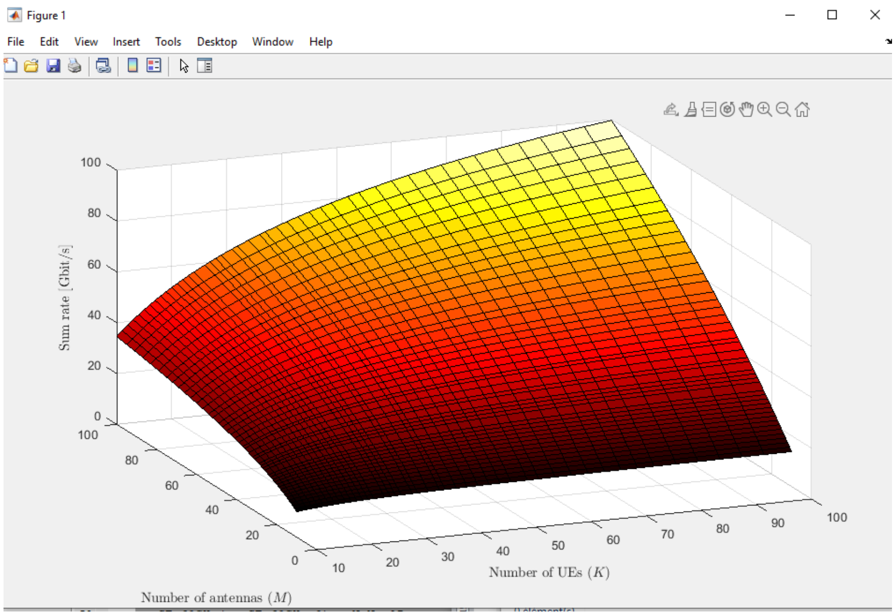

Fig.1-41. Sum rate evolution in terms of bandwidth =1000Mhz

. When we use bandwidth=1000 MHz, The value of sum ratewill changes from 35 to of 100 GHz/s.

At this stage, we notice that the sum rate value maintains the same values obtained when using the frequency=28GHz.

3.3 Scenario 3

3.3.1.Step 1: Case 1: 300 GHz, 100 MHz bandwidth.

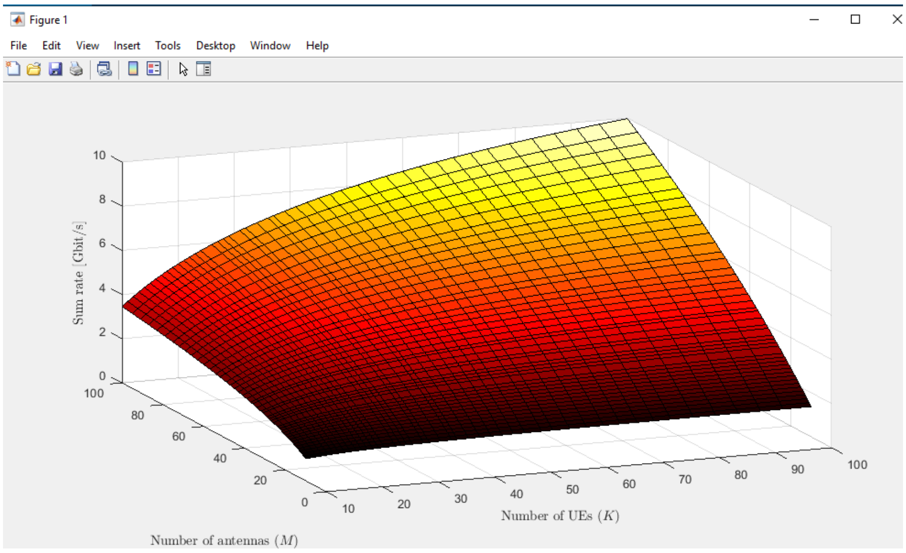

Fig.1-42. Sum rate evolution in terms of bandwidth =100 MHz

So here and after this part of the simulation, we have concluded about the change in sum rate is confirmed under précised network deployment parameters: small cells cover and capacity with frequencies, and we can build on it a rule.

After changing the values of the frequency and the bandwidth value, we notice that the value of the sum rate does not change except when changing of the bandwidth, which means that no matter how much we raise the value of the frequency, the sum rate is not affected.

3.4.Scenario 4:

We will changes in case 2 in the addition of new setting freqFactor to analyze the changes that will occur. FreqFactor = 20, B = 100*freqFactor.

3.4.1.Step 1: Case 2: 60 GHz, 1000 MHz bandwidth.

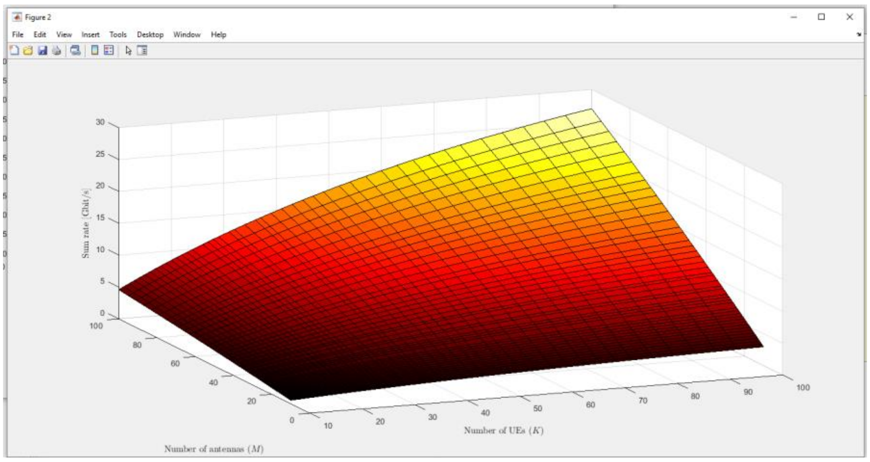

Fig.1-43. Sum rate evolution in terms of bandwidth B = 100*freqFactor

In this case, that is, when adding a new factor (freqFactor), which is related to doubling the bandwidth, in order to monitor the changes that will occur in the sum rate level, we note that the result may change or double in this case.

3.4.2.Step 2: Case 2: 60 GHz, 2000 MHz bandwidth.

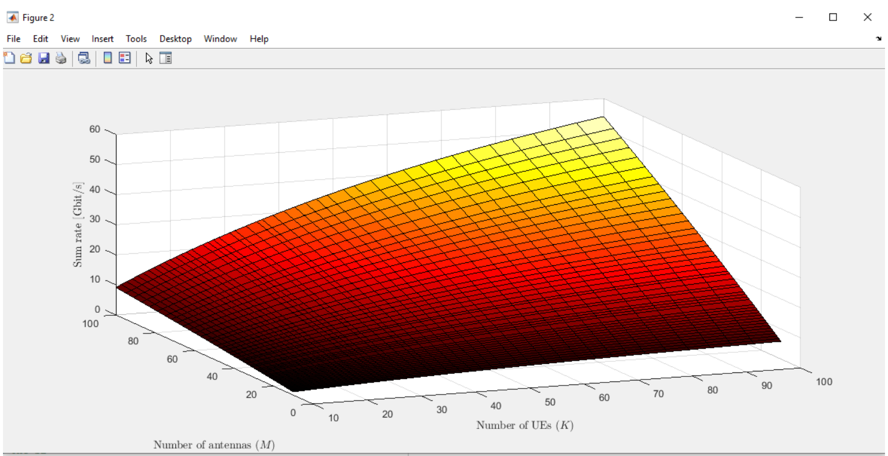

Fig.1-44. Sum rate evolution in terms of bandwidth B = 100*freqFactor

When we use bandwidth=100MHz, The value of sum rate will level, And from, it we can conclude That the new factor can double the value and change the result.

3.4.3. Step 3: Case 2: 60 GHz, 9000 MHz bandwidth.

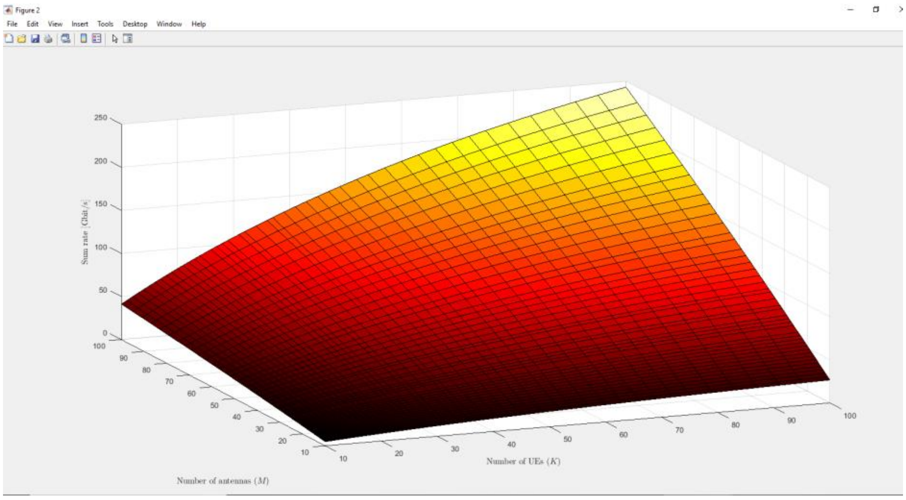

Fig.1-45. Sum rate evolution in terms of bandwidth B = 100*freqFactor

And at the end of the work, we can say that through the changes we made, we can determine the best bandwidth to cover the needs of the network

Conclusion:

After the simulation, we notice that when we use large values of frequencies with low bandwidth the value of the sum rate goes to zeros.

Since the frequencies expected to be used in the sixth generation of communication are THz band it in very necessary that the bandwidth be high to obtain a high sum rate.

Finely, when using a small number of antennas with a low value for the number of users, the colored part of the figure is dark, which indicates that the value of the sum rate is at its lowest, and when the number of both increases, the value of the sum rate begins to rise.

we notice also that the value of the sum rate does not change except by changing the value of the bandwidth.

General conclusion

General conclusion

In this work, we went through the future wireless communication systems that are beyond 5G networks (b5G). Particularly, the technologies that are expected to be applied in it such as the multiple antenna techniques and the multiplexing technologies. We have talked about the THz spectrum allocation as well as it standardization as we stated the challenges facing the deployment of THz bands in b5G networks hinting for the need to develop new Transceivers and Channels that can adopt to the THz frequencies. then, in order to have a full analyze of such bands and its behaviors in the network, we concluded that the THz issues needs to be overviewed from higher layers than the physical layer (link and transport layers) for the real integration of THz technologies in complex mobile networks.

We have tried through this work to conduct some studies on how to manage the bandwidth through a change in the latter and a change in the number of antennas with the number of users in term to obtain a suitable sum rate for the network to be implemented, and thus we have identified the appropriate bandwidth for this network when Obtaining the highest sum rate.

Finally, we want to propose a platform for smart system such as the Neuron network for intelligent 6G band wide management, in which we use the number of users with the number of users and the number of antennas and sum rate in order to get the best bandwidth for this network.

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