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GENERAL ASPECTS

ITU-APT Foundation of India (IAFI)

FURTHER UPDATES TO THE WORKING DOCUMENT TOWARDS PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R M.[IMT.VISION 2030 AND BEYOND]

ANNEX 3.7 TO WORKING PARTY 5D CHAIRMAN'S REPORT

1 Introduction

At the 38th meeting of WP 5D, a Working document towards preliminary draft new RECOMMENDATION ITU-R M.[IMT.VISION 2030 and Beyond] on a future vision of IMT-2030 and beyond was initiated by the new subgroup, SWG Vison. The proposed new ITU-R Recommendation is expected to define the framework and overall objectives of the future development of International Mobile Telecommunications (IMT) for 2030 and beyond in the light of the roles that IMT could play to better serve the needs of the networked society, for both developed and developing countries, in the future.

2 Discussion

It is noted that WP 5D is also working on a draft new Report on future technology trends towards 2030 and beyond to assess where the technology heading.

The proposed new ITU-R Recommendation on vision needs to identify a global vision of what is expected from the next generation of the wireless technology to meet future needs of the mankind. It is also essential to identify the gaps in the current generations of IMT so that the industry and research community could work on the necessary technical enablers to fulfil these gaps in the 2030 timeframe.

3 Proposal

We have proposed the following changes to the working document.

i For ease of reference, a table of content has been added in the Annex to the main recommendation and editorial changes have been made to align the table of contents.

ii New text has been added to section 2.4 similar to section 2.5 of Recommendation ITU-R M.2083.(highlighted in Yellow)

Attachment: 1

ATTACHMENT

[Editor's note: Following title is aligned with a detailed workplan.]

IMT Vision – Framework and overall objectives of the future development of IMT for 2030 and beyond

[Editor's note: Following texts for preamble/main body will be reviewed at the 39th meeting.]

Summary

To be developed

[Editor's note: Following main body of a Recommendation will be developed later.]

Scope

This Recommendation defines the framework and overall objectives of the development of International Mobile Telecommunications (IMT) for 2030 and beyond. IMT will continue to better serve the needs of the networked society, for both developed and developing countries in the future and this Recommendation is being developed to outline how that will be accomplished. Meanwhile, this Recommendation also can be helpful to drive the industries and administrations to encourage further development of IMT for 2030 and beyond. In this Recommendation, the framework of the development of IMT for 2030 and beyond, including a broad variety of/key capabilities associated with envisaged usage/key/typical scenarios potential applications, is described in detail. Furthermore, this Recommendation addresses the objectives of the development of IMT for 2030 and beyond, which includes further enhancement and evolution of existing IMT and the development of IMT-[2030]. It should be noted that this Recommendation is defined considering the development of IMT to date based on Recommendation ITU-R M.2083.

[5D/614 KOR]

Keywords

IMT, IMT for 2030 and beyond, IMT-2020, IMT-2030, IMT-advanced

Abbreviations/Glossary

[5D/614 KOR]

IMT International Mobile Telecommunications

[Editor's note: Abbreviations/Glossary will be made when the working document will be stabilized.]

Related documents: ITU Recommendations, Reports, Documents and Handbook

[5D/613 KOR]

Recommendation ITU-R M.1645 – Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000

Recommendation ITU-R M.2083 – IMT Vision - "Framework and overall objectives of the future development of IMT for 2020 and beyond"

Recommendation ITU-R M.1457 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)

Recommendation ITU-R M.2012 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)

Recommendation ITU-R M.2150 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020)

Report ITU-R M.2243 – Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications

Report ITU-R M.2291 - The use of International Mobile Telecommunications for broadband public protection and disaster relief applications

Report ITU-R M.2320 – Future technology trends of terrestrial IMT systems

Report ITU-R M.2370 – IMT Traffic estimates for the years 2020 to 2030

Report ITU-R M.2376 – Technical feasibility of IMT in bands above 6 GHz

Report ITU-R M.2134 – Requirements related to technical performance for IMT-Advanced radio interface(s)

Report ITU-R M.2410 – Minimum requirements related to technical performance for IMT-2020 radio interface(s)

Report ITU-R M.2441 – Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)

Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS TOWARDS 2030 AND BEYOND] – Future technology trends of terrestrial IMT systems towards 2030 and beyond

Report ITU-R M.[IMT.INDUSTRY] - Applications of IMT for specific societal, industrial and enterprise usages

[5D/613 KOR] [Editor's note: Following considering, recognizing, noting and recommends are proposed based on Recommendation ITU-R M.2083 for discussion.]

The ITU Radiocommunication Assembly,

considering

[5D/613 KOR]

a) that ITU has contributed to standardization and harmonized use of IMT, which has provided telecommunication services on a global scale;

b) that technological advancement and the corresponding user needs will promote innovation and accelerate the delivery of advanced communication applications to consumers;

c) that Question ITU-R 229/5 addresses further development of the terrestrial component of IMT and the relevant studies under this Question are in progress within ITU-R;

d) that Question ITU-R 262/5 addresses usage of the terrestrial component of IMT systems for specific applications and the relevant studies under this Question are in progress within ITU-R;

e) that Recommendation ITU-R M.1645 defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000;

f) that Recommendation ITU-R M.2083 defines the framework and overall objectives of the future development of IMT for 2020 and beyond;

g) that for global operation and economies of scale, which are key requirements for the success of mobile telecommunication systems, it is desirable to establish a harmonized timeframe for future development of IMT considering technical, operational and spectrum related aspects;

h) that IMT interoperates and/or interworks with other radio systems,

[5D/613 KOR] [Editor's note: Some other texts such as trends and characteristics of IMT for 2030 and beyond can be described further, if necessary.]

recognizing

[5D/613 KOR]

that development of new radio interfaces that support the new capabilities of IMT for 2030 and beyond is expected along with the enhancement of IMT-2000, IMT-Advanced and IMT-2020 systems,

noting

[5D/613 KOR]

that pursuant to Article 44 of the ITU Constitution, Member States shall endeavour to apply the latest technical advances as soon as possible,

recommends

[5D/613 KOR]

that the Annex should be used as the framework and the overall objectives for the future development of IMT for 2030 and beyond.

ANNEX

TABLE OF CONTENTS

[Editor's note: Table of Contents to be developed when following sections are stabilized.]

[Editor's note: Section title from 1 to 2.4 were discussed at the 38th meeting.]

[Editor's note: Texts in section 1 to 6.2.2 will be reviewed at the 39th meeting.]

[Editor's note: Contributions highlighted in grey and turquoise are proposed at the 38th and 39th meeting respectively.]

[Editor's note: Square brackets in yellow " [ ] " mean that further discussion is needed in the future meetings.

Table of Contents

1 Introduction

[Editor's note: Following is an initial text for section 1. It would be updated based on the progress of other sections.]

[In the world of 2030 and beyond, human intelligence will be augmented by being tightly coupled and seamlessly intertwined with the ubiquitous intelligent network and digital technologies. Future IMT [technology/system] towards 2030 and beyond will support and further accelerate a change for a better and sustainable world with significantly increased efficiency in the use of resources, energy and cost and thus facilitating new and sustainable ways of living in the next decades.

Everyday experience in the future will be enriched by the seamless unification of the *physical*, *digital* (virtual) *worlds* achieved through a new ecosystem of networks, sub-networks and device technologies. An enhanced virtual world consisting of multi-sensory experiences to enable transformative forms of human collaboration as well as human-machine and machine-machine interactions will bring life-improving use cases and create new economic value creation. At the same time, there is the need to accomplish the highest possible standards regarding sustainable energy, cost and resource efficiency, capacity, low latency, strong security, resilience, safety from the societal challenges and efficiency under all circumstance in coverage and operation, for enabling sustainable growth with trustworthy systems as AI-native future system, distributed cloud and communication systems. Despite increasing ambitions with more use cases and more performance, IMT for 2030 and beyond should be an integral part of a fully sustainable and carbon neutral world.

The objective of this Recommendation is to establish the vision for IMT for 2030 and beyond, where driving forces are new and expanded megatrends such as technical and spectrum aspects, usage scenarios, establishing a framework and needed capabilities as a foundation for IMT for 2030 and beyond. **]**

2 Trends of IMT for 2030 and beyond

[Editor's note: There was some discussions how to deal with item related to use cases. Outcome from the discussion is captured in appendix to this working document for further consideration at the next meeting.]

[

[5D/653 Nokia et al]

The development of the future networks and system heralds applications that go far beyond the user and vertical centric applications of current and former network systems. To address the growing societal concerns of the sustainability of the environment and society, the future network system is expected to help reduce the digital divide. Extreme performance and global service coverage will be needed to empower the underserved and bridge the digital divide virtual-realistic remote experiences as well as provide means to monitor and counter-act current and impending environmental challenges. Connected intelligence and network of networks will enable operations to be optimized for sustainable performance.

It is also expected that future networks and systems will be a mixture of the physical, biological and digital representation in every spatial and time instant, unifying human experience across these aspects. New themes are likely to emerge that will shape the future system requirements and technologies, such as:

a) new human–machine interfaces created by a collection of multiple local devices acting in unison;

b) ubiquitous computing distributed among end devices, base stations, edges and the cloud;

c) multi-sensory data fusion to create multi-verse maps and new mixed-reality experiences;

d) precision sensing and actuation to understand and control the physical world.

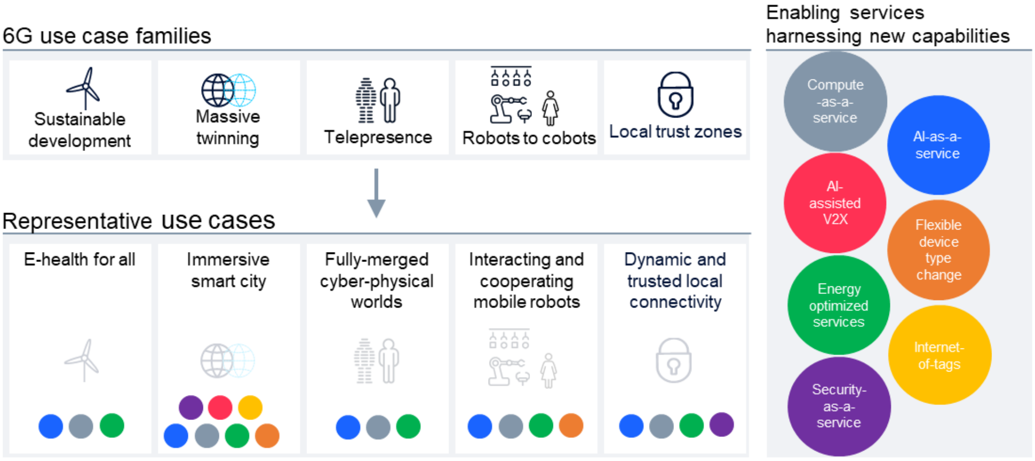
e) mega constellation of VLEOs and drones integrated with terrestrial networks to provide ubiquitous high quality mobile broadband services

With rapid advances in Artificial Intelligence, it has the potential to become the foundation for systems and network in the future, making data, computation and energy the new resources to be exploited for achieving superior performance.

Hexa-X project has created 5 use case families detailing different aspects of the future networking needs and requirements. In the following five representative use cases are from Hexa-X vision [Hexa_D1.2] are described.

FIGURE 1

Use case families, representative use cases and new capabilities



In the following selected use cases from the Hexa-X vision are described:

Use case 1: E-health for all

With accurate, highly secure and reliable MBB connections to medicine expertise basic e-health services can be delivered anywhere. Connectivity can be complemented by local analysis of samples etc. with dedicated devices, and availability of expertise can be extended with AI agents giving first-line support. Local mobile e-health hubs can provide last-mile connectivity in areas with infrastructure challenges.

Providing virtual doctor visits to all who need would be an enormous health benefit, requiring a full expansion of cellular network coverage capable of supporting these services. Reaching everyone in the world in a cost-effective way and in areas where deployment of fibre is not an option (remote islands, rural areas, politically unstable regions) is a meaningful challenge for future networks. Sensitive medical data would need to be routed, stored, and processed throughout a network that may consist of multiple hops and access types, and service availability needs to be assured with affordable solutions.

Use case2: Immersive smart city

City liveability is a concept that is determined by large parameter sets, which are weighted. The sets correspond to wide application areas, relevant to the city infrastructure (e.g., roads, buildings, networks etc.), the ambience/environment (e.g., climate, air quality, etc.), healthcare aspects, education and culture issues, the stability/safety, and many others. Technical challenges are associated with aspects related to the volume of traffic that needs to be transferred, the associated time scales and reliability, etc. Societal value lies in the potential of perceiving, predicting and managing hazards or other less critical situations. Business opportunities occur for operators and other ICT players, by assisting cities in the accomplishment of their goals. A city in the 2030s will be a dynamic system of systems with many constituting elements such as people, infrastructure and events. In conjunction with real-time feedback from the physical world and its associated assets, the digital twin city model will be a powerful tool for future evolution and planning as well as enhanced and efficient operations of future smart cities. An interactive 4D map can be used to plan utilities management such as public transport, garbage, piping, cabling, buildings, heating, etc., or to connect the many parts of a factory that can be inspected and steered in detail. By overlaying physical modelling, the 4D map can be used to forecast expected and predicted actions and behaviours of the environment and of other users, follow the history, and to check and control the function of parts. Human and AI operators can explore the rich data and simultaneously modify to manage and schedule activities, effectuating changes and tasks through actuators and controllers in the network. This use case requires the transfer of vast amounts of data within certain time limits (from ultra-low latency to vehicles or health, to “near” real-time). This is important for enabling actions that will influence the city operation and enhance its liveability. In parallel, the highest possible levels of sustainability are called for, while technologies for enhancing privacy and security are most important.

Use case 3a: Fully merged cyber-physical worlds

Mixed Reality (MR) and holographic telepresence will become the norm for both work and social interaction. Via holographic telepresence it will be possible to make it appear as though one is in a certain location while really being in a different location – for example, appearing to be in the office while actually being in the car. Other example of use cases includes facilitating collaboration and performing remote home-working beyond office type of work by white-collar workers, improving diagnosis during tele-consultations and enhancing teacher-student interactions in e-learning classes. This can also mean virtual traveling to far-away places and telepresence meetings with friends and family. You would experience the world where your hologram is, through very rich sensing of multiple sorts, synchronized to devices on your body for an enhanced sensory experience.

Users want to communicate with distant persons with a quality of interaction very close to reality. They want a better perception of body language (gesture, intonation, expressions, surrounding sounds, etc.), and also of other senses (e.g. touching objects).

MR telepresence allows interaction with both physical and digital objects, them being near or far in physical reality. This experience and use case will be enabled by wearable devices, such as earbuds and devices embedded in our clothing and other novel user interfaces. Humans will carry multiple wearables, working seamlessly with each other, providing natural, intuitive interfaces.

Touchscreen typing will likely become outdated. Gesturing and talking to whatever devices are used to get things done will become the norm. The devices we use will be fully context-aware, and the network will become increasingly sophisticated at predicting our needs. This context awareness combined with new human–machine interfaces will make our telepresence interaction intuitive and efficient.

Use case 3b: Sensor infrastructure web

A simple autonomous vehicle (with no or limited sensor capabilities) is moving around the environment, while relying on external third-party sensors as if they were on-board sensors. The vehicle obtains external sensor data or navigation commands through the network with utmost confidence in the reliability, timeliness and confidentiality of the data as well as share its own sensor data. This allows aggregation of sensor data across different systems, even to devices lacking their own sensor capabilities.

The network can advertise locally relevant and trusted sensor information that all connected device, e.g., vehicle can access.

Today telecommunication systems don not allow diffusion or sharing of sensor data in predefined local environments and to networks or network parts under external security management. Depending on the implementation, this use case might require the split of network ownership, network control, network transport, and network security. Finally, it is today not possible to allow a network to advertise and distribute third party provided sensor data in well-defined local areas.

Use case 4: Flexible Manufacturing

With increasing personalization and modularization of production (e.g., lot size of a production of a single, highly customized product) and flexibility of manufacturing systems (e.g., mobile robots) comes the need for powerful wireless communication and localization services as well as flexible, dynamic configuration of communication services in the network. The machinery and associated communication will be configured dynamically for each production task, either by a production system or even in a self-organizing way by direct collaboration among (mobile) production machines. This involves the orchestration of Automated Guided Vehicles, as higher flexibility in the production process requires higher flexibility in logistics. Dynamic configuration of real-time communication services is required, potentially initiated by end systems themselves and executed in a distributed fashion. Respective communication resources and capabilities (e.g., local compute, direct D2D communication, dynamic frequency range allocation) need to be assigned. High availability and functional safety requirements need to be met, and data from the production process needs to stay secure and private. This use case extends existing industrial 5G functionality in more dense industrial environments with higher flexibility, self-organization capabilities, local processing and direct communication among entities.

Use case 5: Dynamic and trusted local connectivity zones

Local, secure and private communication capabilities of sensitive information in a well-defined area or sub-network are needed in use cases such as body area networks supporting personalized health applications, vehicles with on-board networks, mobile automated machines platooning or collaborating on common target, such as in a harvesting campaign, cameras and mics being connected during program making and special events. All these example use cases have in common that highly reliable, trusted and private connectivity is required temporarily and often only in small local areas between or within devices. The portfolio of supported applications will comprise safety-relevant applications (e.g., emergency halt, alerts), sensitive proprietary data processing (automation control data), as well as privacy related services (e.g., on-board humans). Local trust zones protecting individual or machine specific information have to be established without compromising the communication and shared information even when using services from wide-area networks. For MNOs, it may not be economically feasible to provide connectivity for these local scenarios by their wide-area cellular networks. Thus, alternative dynamic and trusted local connectivity solutions with security concepts beyond classical security architectures are needed with the capability to seamlessly integrate with the wide-area networks.

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[5D/675 Ericsson]

We can expect the society of 2030 to have transformed around increasingly advanced technologies, where IMT plays a key role and the future networks act as the communication and information backbone, allowing anything to communicate anywhere and anytime.

[Editor's note: The following are examples of megatrends that will be important for future IMT]

– **Simplified life**: With artificial intelligence (AI), it is possible to optimize and simplify many processes and improve operations by reducing the need for human participation and supervision. We should expect a dramatic increase in the use of AI to further optimize society and simplify our lives, but it needs to be designed for the highest security and explainability.

– **Trust**: Society must be able to rely completely on networks delivering critical services while being able to ensure the integrity of the information. People as well as industries must be able to rely on verified data and identities even as they enjoy full privacy

– **Sustainable world**: Wireless communication already plays an important role here, and there is clear potential to further accelerate its contribution in enabling increased efficiency in the use of resources and support of new ways of living, making it a tool for sustainable change

In addition, there is already now a very strong increase in highly demanding applications (virtual, augmented, and mixed reality as well as remote control of sensitive operations). Going towards 2030, we can expect this evolution to continue with even higher demands placed on the performance that networks should deliver.

[5D/783 KOR]

Applications and services enabled by future wireless communication technology will connect not only humans, but also machines and various things altogether. With advances in new human-machine interfaces such as extended reality (XR) displays, haptic sensors and actuators, e-smell and e-taste, and brain interfaces, connected humans can enjoy truly immersive experiences that are virtually generated or happening remotely. On the other hand, connected machines are intelligent and have been automated so that they can move ultra-fast and ultra-precise as intended through advances in machine perception, robotics, and artificial intelligence (AI). In a real physical world, such humans and machines will continuously interact with each other, working with a digital world that extends the real world by using a great number of advanced sensors. Such a digital world not only replicates but also affects the real world by providing virtual experiences to humans and computed control to machines. These systems are required to be trustworthy and at the same time allow significant amounts of computing split distributed across networks and devices. To interconnect the digital and physical world, future IMT systems need to play an important infrastructural role: 1) collect real-time sensory data everywhere in the physical world, 2) compute real-time controls of automated machines and immersive senses for humans, and 3) deliver this data back to the physical world so that humans and machines can continuously interact with each other.

[5D/843 Ericsson et al]

IMT for 2030 and beyond envisions a future in which everyday experience is enriched by the seamless unification of the physical, digital and human worlds achieved through a new ecosystem of networks, sub-networks and device technologies. The vision for IMT for 2030 and beyond revolves around interactions between these three worlds: a human world of our senses, bodies, intelligence, and values; a digital world of information, communication and computing; and a physical world of objects and organisms. The future network system should make it possible for these worlds to tightly synchronize and integrate to make it possible to seamlessly move between them. Realizing these interactions will open up many new use cases, applications, and services that will benefit people on all levels: as consumers, parts of enterprises or societies.

There are three major elements for IMT for 2030 and beyond around which the three worlds revolve including trustworthiness as a backbone of society; inclusiveness to be available for everyone and everywhere; and sustainability to play the largest role possible towards global development with regard to environmental, social and economic aspects.

Interactions between the physical and the digital world will enable digital twins of the world, where rich sensor information can be used for deep data mining and analysis. Intelligent agents can act on the digital twin and trigger actions in the physical world through actuators. Such actions would improve the efficiency and resilience of operation in the physical world via better planning and control as well as preventive actions, for example for maintenance before problems would emerge. This could lead to a massive scale of usage of digital twins and hence massive needs for communication.

At same time there is the need to accomplish the highest possible standards regarding sustainable energy and resource efficiency, low latency, strong security, and efficiency in deployment (coverage) and operation, for enabling sustainable growth with trustworthy systems. Despite increasing ambitions with more use cases and more performance, IMT for 2030 and beyond should be an integral part of a fully sustainable and carbon neutral world.

The following trends are identified for IMT for 2030 and beyond:

– Trustworthiness: The characteristics of trustworthiness —security, privacy, availability, resilience, compliance with ethical frameworks— are foreseen to become new fundamental requirements for network design towards 2030.

– Digital inclusion: Evolving towards 2030, connectivity will likely be regarded as a basic human right for accessing equal education, business and health opportunities.

– Pervasive AI and distributed computing for human-centric and trustworthy automation and intelligence everywhere: future connected devices will become fully context-aware for more intuitive and efficient interactions among humans, machines and the environment, and the networks will become increasingly advanced at predicting needs, optimizing and simplifying processes and improving operation without or with minimal human participation and supervision.

– Foundation of global economy; Wireless technology serves and will continue to serve the global economy as critical digital infrastructure for all possible industrial sectors (e.g., automotive, industrial, transportation, agriculture, education, health and entertainment) and inherently enable sustainable growth in all those sectors.

– New applications: Future networks will be able to integrate localization, sensing, and imaging functions into its system design and provide ultra-high data rates and capacity, which opens a new door for use case and business innovation, for example, holographic communication, future decomposed handsets and wearable devices, and other novel human-machine interfaces with immersive multi-sensory experience.

– Network as a powerhouse for twin ecological and digital transitions: network industry must carry out this twin ecological and digital transition itself, incorporate it into the design of future networks and empower all the other industry sectors for such a transformation towards a sustainable and circular economy.

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2.1 User and application trends

[

[5D/631 T-Mobile]

- AI powered intelligence everywhere
- Mobile only societies
- Global Inclusion
- Security and Trustworthiness built from the foundations
- Customization of Experiences

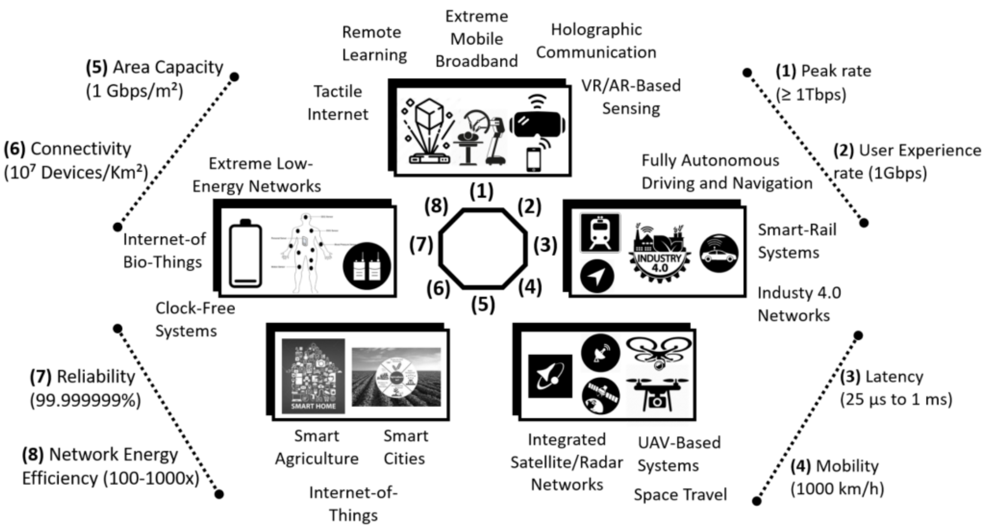
[5D/775 SparkNZ]

New services and application trends

The major applications and usage scenarios for IMT 2030 require capability shown in Figure 1 below and are based on extremely high-speed wireless connectivity [1][4]. By reviewing the published ITU-T Network 2030 report [2]and other literatures, potential IMT 2030 use cases are categorized and described as follows:

FIGURE 1

A vision for IMT 2030 systems and its underlying use cases [4]



Use Case 1: Holographic Communications

Holographic displays are the next evolution in multimedia experience delivering 3D images from one or multiple sources to one or multiple destinations, providing an immersive 3D experience for the end user. Interactive holographic capability in the network will require a combination of very high data rates and ultra-low latency. The former arises because a hologram consists of multiple 3D images, while the latter is rooted in the fact that parallax is added so that the user can interact with the image, which also changes with the viewer's position.

Use Case 2: Tactile and Haptic Internet Applications

There are many applications that fall in this category, such as Robotic and Industrial Automation, Autonomous Driving, and Health Care.

Robotic and Industrial Automation: Manufacturing has been stimulated by networks that facilitate communications between humans, as well as between humans and machines. It requires communications between large connected systems without the need for human intervention. Remote industrial management is based on real-time management and control of industrial systems. Robotics will need real time guaranteed control to avoid oscillatory movements. Advanced robotics scenarios in manufacturing need a maximum latency target in a communication link of 100 microseconds (µs), and round-trip reaction times of 1 millisecond (ms). Human operators can monitor the remote machines by VR or holographic-type communications, and are aided by tactile sensors, which could also involve actuation and control via kinesthetic feedback.

Autonomous Driving: Enabled by vehicle-to-vehicle (V2V) or vehicle-to-infrastructure communication (V2I) and coordination, autonomous driving can result in a large reduction of road accidents and traffic jams. However, a latency in the order of a few ms will likely be needed for collision avoidance and remote driving. Thus, advanced driver assistance, platooning of vehicles, and fully automated driving, are the key application areas that 6G aims to support, and mature, with first components to be implemented in Third Generation Partnership Project (3GPP) Release 16. Yet, since no fully functional autonomous vehicles exist, further requirements and applications are sure to emerge over the next decade within this area.

Health Care: Tele-diagnosis, remote surgery and telerehabilitation are just some of the many potential applications in healthcare. With the aid of advanced tele diagnostic tools, medical expertise/consultation could be available anywhere and anytime regardless of the location of the patient and the medical practitioner. Remote and robotic surgery is an application where a surgeon gets real-time audio-visual feeds of the patient that is being operated upon in a remote location. The surgeon operates then using real-time visual feeds and haptic information transmitted to/from the robot; this is already happening in some instances. The tactile internet is at the core of such a collaboration. The technical requirements for haptic internet capability cannot be fully provided by current systems.

Use Case 3: Network and Computing Convergence

Mobile edge compute (MEC) will be deployed as part of 5G networks, yet this architecture will continue towards IMT 2030 networks. When a client requests a low latency service, the network may direct this to the nearest edge computing site. For computation-intensive applications, and due to the need for load balancing, a multiplicity of edge computing sites may be involved, but the computing resources must be utilized in a coordinated manner. Augmented reality/virtual reality (AR/VR) rendering, autonomous driving and holographic type communications are all candidates for edge cloud coordination.

Use Case 4: Extremely High Rate Information Showers

Access points in metro stations, shopping malls, and other public places may provide information shower kiosks. The data rates for these information shower kiosks could be up to 1 Tbps. The kiosks will provide fibre-like speeds. They could also act as the backhaul needs of millimeter-wave (mmWave) small cells. Co-existence with contemporaneous cellular services as well as security seems to be the major issue requiring further attention in this direction.

Use Case 5: Connectivity for Everything

This use case can be extended to various scenarios that include real-time monitoring of buildings, cities, environment, cars and transportation, roads, critical infrastructure, water and power etc. Besides these use cases, internet of bio-things through smart wearable devices, intra-body communications achieved via implanted sensors will drive the need of connectivity much beyond mMTC.

Use Case 6: Chip-to-Chip Communications

While on-chip, inter-chip, and inter-board communications nowadays are done through wired connections, those links are becoming bottlenecks when the data rates are exceeding 100-1 000 Gbps. There have thus been proposals to employ either optical or THz wireless connections to replace wired links. The development of such "nanonetworks" constitutes another promising area for 6G. Important criteria for such networks - besides the data rate - is the energy efficiency (which needs to incorporate possible required receiver processing), reliability, as well as latency. Wireless Chip to chip communication is not use case that the customers/users can relate to but it will provide a potential signal processing approach for IMT technologies.

Use Case 7: Space-Terrestrial Integrated Networks

This use case presents a scenario that is based on internet access via the seamless integration of terrestrial and space networks. The idea of providing internet from space using large constellations of LEO satellites has re-gained popularity in the last years. The key benefits of these are: Ubiquitous internet access on a global scale including on moving platforms (aeroplanes, ships, etc.), enriched internet paths due to the border gateway protocols across domains relative the terrestrial internet, and ubiquitous edge caching as well as computing. The mobile devices for these integrated systems will be able to have satellite access without relying on ground base infrastructures.

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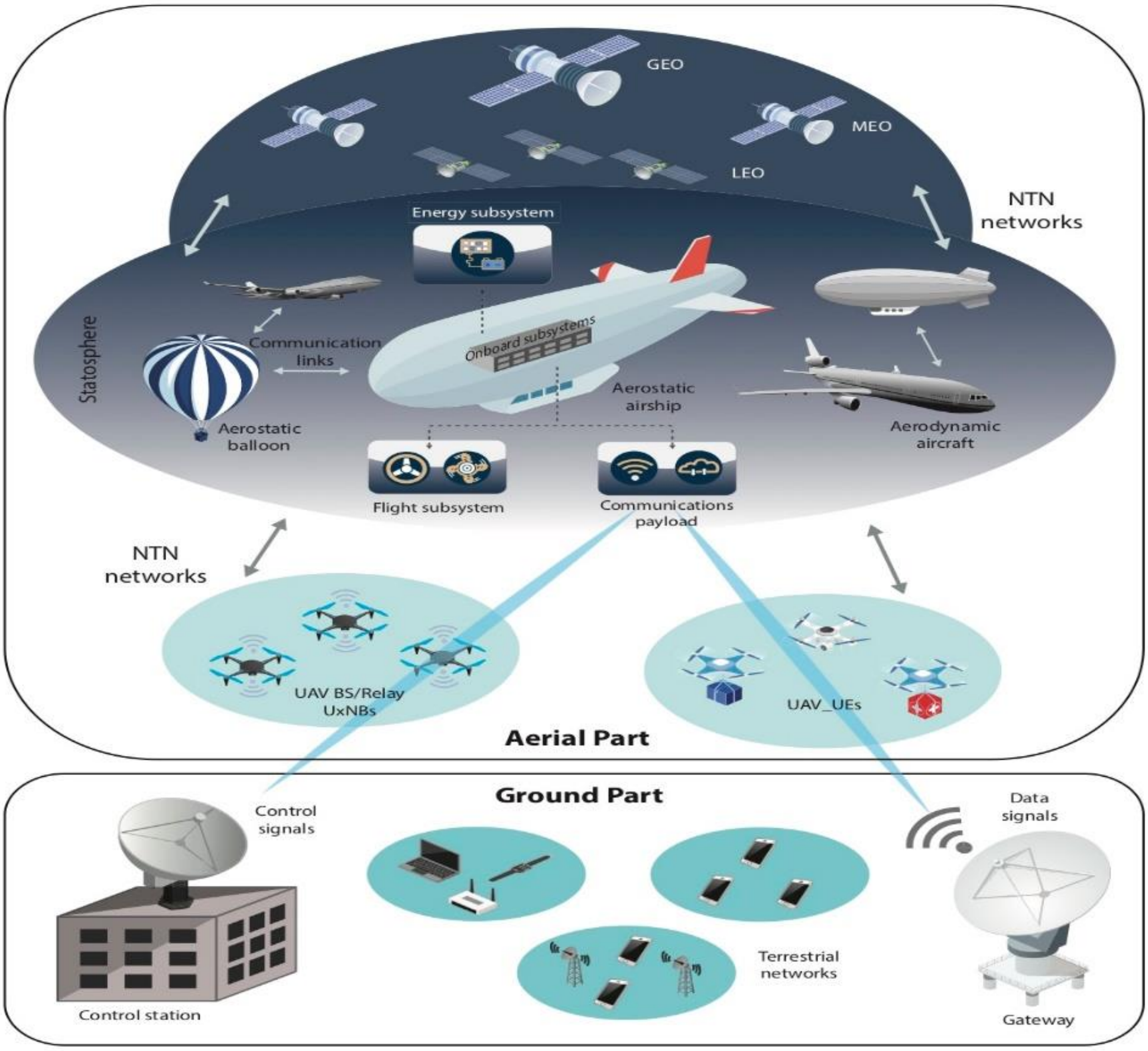
[5D/822 WWRF]

- Global Inclusion

For Global Inclusion to be achieved, cost efficiency is essential. Some of the functionality required in developed countries may be expensive and not required in the initial stages of deployment in developing countries, and therefore technology or technologies that maybe considered for 2030, must be flexible enough to be upgradable through software updates. As it is well known fact that some countries are just about to go from 3G to 4G, and this based on fact that return on investments on 3G is achieved before going onto 4G. Return on investment is an essential ingredient for businesses to succeed. Many of the developing countries are not thinking about 5G, so it is essential that technology or technologies selected can be upgraded by software to connect the unconnected and are affordable by developing countries as they migrate from 4G to beyond IMT-2020, either directly or via IMT-2020.

The diagram below shows that a number of different technologies will be needed to achieve global inclusion, hence the need for upgrading technologies as they are developed.



- Security and Trustworthiness built from the foundations

As we move IMT towards 2030, air interface specifications need to take on the role of further supporting security in devices. A combination of air interface and networked infrastructure with built-in security functionalities will achieve the strongest protection possible, and thereby increase user confidence and trust. Future IMT systems need to provide robust and secure solutions to address the threats to security and privacy brought by new radio technologies, new services and new deployment cases.

A system is only secure, as long as the least secure component is secure. Hence, a system should follow several security and privacy principles, including:

i) minimizing the attack surface, authentication with adequate strength - for UE, base stations, and network nodes;

ii) enforcing least privilege (e.g. a UE should not be able to send control messages beyond a restricted network zone);

iii) separation of duties (e.g. entities or components should be separated based on data sensitivity;

iv) protection of sensitive data in storage, transit and display;

v) enforce minimal trust (e.g. limit trust of third-party services);

vi) fail securely and gracefully (e.g. failure to authenticate should not allow a malicious user to gain sensitive information to further the attack);

vii) apply defence in depth (e.g. use multiple layers of validation, different security auditing, and logging mechanism);

viii) apply security and privacy by default and simplicity, KISS principle:
  - secure by design, development, and deployment;
  - avoid security by obscurity (e.g., there should be sufficient security without hiding protocol or encryption algorithms).

It is expected that in year 2030 and beyond, sensing and advanced AI will enable a much fuller context awareness, moving from “connecting things” to “connected intelligence”. In its turn, context awareness can drive the Quality of Security (QoSec) experienced by users and enable the adaptation of security controls. These are especially pertinent for constrained wireless systems, such as Internet of things (IoT), with ultra-low latencies and massive connectivity. The roadmap for the incorporation of context awareness into wireless security encompasses the following ideas:

- harvesting context through sensing;
- distilling security-relevant context through semantic compression;
- context-aware risk assessment, through the semantic fusion of the distilled context with network and application layer information;
- developing security controls that can adapt to context.

Examples of these domain areas might include how physical-layer security (PLS) can offer lightweight solutions for adaptive security schemes under statistical Quality of Service (QoS) delay constraints in the radio access. Additionally, techniques for lightweight distributed anomaly detection in constrained wireless sensor networks, based on results from signal processing and deep-learning-enabled indoor localization, can be applied to allow early authentication in multi-factor authentication protocols. Overall, it is clear that emerging techniques using context gathered from the radio network can significantly enhance the experienced Quality of Security.

[5D/867 CHN]

Future IMT systems will bring a wealth of new possibilities to various aspects. From the perspective of all possible future applications, these service and application trends explained in § 2.1.1 to § 2.1.10 are merely examples of what the future holds.

2.1.1 Supporting human-centric applications with ultra-low latency and ultra-high throughput

Facing 2030 and beyond, people expect the experience of immersive interactive with in-depth integration of virtual and reality wherein services required ultra-high data rate to achieve multi-dimensional realistic presentation and ultra-low latency to avoid motion sickness and obtain real-time feedback, such as immersive cloud XR (Extended reality) which including AR, MR and VR, synaesthesia interconnection with all sense information (vision, hearing, haptic, smell, taste), Holographic communication and etc. Besides the ultra-high data rate and ultra-low latency, before mentioned applications would also require high-reliability in certain scenarios at the meantime, e.g. Holographic telemedicine surgery. The future communication system that supports such immersive interactive behaviour thus becomes an enabler for the future development of those new applications, e.g. in entertainment, medical, education, industry, emergency rescue and many other fields.

2.1.2 Supporting vertical applications with ultra-low latency and ultra-high reliability

In the future, there are some vertical applications requiring intelligence such as autonomous driving smart factory for automated product delivery, personalized "digital human" of precision medicine, and etc. It is critical that data is delivered in time, need to be enabled through technologies that support ultra-low latency and ultra-high reliability basically. And also the capabilities such as massive data transmission, ultra-high accuracy positioning, and ultra-low jitter need to be supported at the same time for certain scenarios. Future automated vertical communication systems will be cantered on collaborative robots, cobots, or even cyborgs. Real-time intelligence interaction between robots and humans requires even lower latency and higher reliability.

2.1.3 Supporting ultra-massive connections

As the digitalization progresses, it is expected that we will live in a world where physical reality is accompanied by a digital twin in the cyber world, in which automation and intelligence can be created and then delivered to the physical world. As such, a massive number of highly-reliable and low-latency connections, are required to enable ubiquitous and real-time information collection, sharing, and intelligent control and feedback in various scenarios, such as massive connections of wearable devices, electronic devices or sensors in daily life, smart factories, smart transportation, smart city, smart building, and medical and health scenarios, etc. Accurate positioning would also be beneficial in many of these scenarios. Meanwhile, as more and more devices become capable for distributed deep learning, frequent exchange of local processed data or model will be required, which makes high throughput an important feature in these cases to support real-time intelligence.

2.1.4 Supporting global seamless coverage

As services converge and the amount of new applications increases, terrestrial and non-terrestrial networks are being integrated to provide continuous mobile broadband and wide range IoT service everywhere in ultra-breadth and depth, including but not limited to ground, aerial, space, maritime, indoor, high speed railway, etc. The global seamless coverage will also support communications in emergency or disaster conditions e.g. deluge, earthquake. Also, user will expect ubiquitous broadband mobile communications services with the same device even in remote areas, or areas that are not well covered by current IMT systems. Furthermore, high communication quality, such as ultra-high data rate of services, such as multimedia, is expected even in deep coverage with poor channel quality such as underground parking, indoor etc. Meanwhile, to enable fluent experience for mobile users in train, aircraft and other advanced high speed vehicles, the coverage with higher mobility up to 1 000 km/h will be necessary.

2.1.5 Supporting maintaining high quality communications at ultra-high mobility

Users and devices with ultra-high speed such as located within high-speed trains, subway, airplane, cars or other vehicles, expect the similar user experience as people are at home or those devices in the factory. To offer the high quality user experience such as maintaining service continuity, satisfying the QoS requirements and extremely low interruption latency for users with ultra-high mobility, robust and reliable connectivity solutions and full coverage capability are needed as well as the ability to efficiently maintain service high quality.

2.1.6 Supporting high accuracy and resolution sensing applications

The integration of sensing and communication in future wireless systems will provide beyond-communication capabilities such as imaging, mapping and localization, which in turn will enable applications with new and multiple dimensions of performance, such as high resolution and accuracy in object detection and estimation of range/angle/velocity, respectively. Various va1ue-added innovative applications will be introduced, such as ultra-high precision positioning/localization, high resolution and real-time radio map construction for fully autonomous driving and robot collaboration, gesture and activity recognition for touch free applications, fall detection at public space, pollution or natural disaster monitoring, flaw and materials detection etc. These applications further lead to new level of precise and personalized services in smart factories/smart transportation/smart medical care, and many others. Further combined with AI technologies, sensing will be a key enabler for the fusion of physical, biological and cyber worlds towards pervasive intelligence.

2.1.7 Supporting applications with pervasive intelligence

Full-scenario AI usage will be a fundamental use case in the future. With the steady progress and fast spread of AI and machine learning technologies, algorithms and applications are under transformation from human coded to data coded, where massive data is provided to deep learning algorithms to train the AI models for each application. The AI and learning capabilities will be native and ubiquitous inside the future IMT system to make every component intelligent from the application to physical layer, achieving different levels of automation and customized optimization. Meanwhile, a mobile communications system as a whole is expected to provide AI as a service for intelligent applications. Different from the communication-oriented services, AI-oriented services add new dimensions of performance, such as high accuracy and low latency inference, low loss and fast convergence training, energy and resource efficient learning, etc. Such real-time learning and decision making capability will extend the intelligence in immersive XR interactions and teleoperations, smart factories and homes with collaborative robots, smart cities and transportations with unmanned vehicles, to a next level. For instance, the collaborative robots in a future factory can share the observed data or locally trained models through distributed learning supported in wireless networks to continuously update and perfect their models, which, in turn, improves manufacturing efficiency.

2.1.8 Supporting intelligent interaction

Intelligent agents including human and autonomous-things with perception, recognition and thinking capability will produce active intelligent interactive behaviours. The user-tool relationship between people and intelligent agents will evolve to equal human-like interactions with emotions and mutual understanding. Such intelligent devices will be able to sense the psychological and emotional states of users through dialogue and facial expressions to help the users mitigate health risks. Supporting lossless transmission of brain information, mind-controllable machines will be available to help the disabled overcome their physiological difficulties in their daily lives and work while quickly accumulating knowledge and skills. Active intelligence interaction will integrate a variety of information such as voice, face, gestures, and physiological signals, and the ability of human thinking and situation understanding will also be improved. Therefore, the reliability needs to be further improved.

2.1.9 Supporting high quality interaction of virtual and reality

Apart providing connections for everything in the physical world, future IMT network is expected to provide extra connections between everything in the physical world to its digital reflection in the digital world, and to provide connections between every digital reflection. Digital twin network is a virtual representation of the physical network for its full life cycle, analysing, diagnosing, simulating and controlling the physical network based on data, model and interface, so as to achieve the real-time interactive mapping between physical network and virtual twin network. Digital twin network enables network self-boosting, self-evolving, self-optimizing by the integration of communication, sensing, AI technologies, computing etc. Interaction both physical and digital mainly supports applications in vertical industries. Take medical systems for instance, a person will be capable of performing efficient researches on viral mechanism, organ, etc., and can also assist doctors to conduct the accurate surgical prediction. In agriculture, the production process can be simulated and deduced to predict adverse factors and improve production as well as utilization of the land. In the industrial field, product design can be digitally optimized to reduce costs and improve efficiency. Digital twin demands real time and high accuracy sensing to ensure the accuracy, and low latency and high data transmission rate to guarantee the real time interaction between virtual and physical worlds.

2.1.10 Task oriented applications with adaptive capabilities

Many applications and services will be expected to work together for one task which includes multiple working steps and each step demands different capacities. For example, 'smart control' task in smart factory, one step requires ultra-high data rate for higher resolution video collection, the second step requires ultra-low latency, high reliability for control order delivery, the third step requires high-data rate with ultra-high precision positioning and sensing, in order to obtain accurate location. Thus, the future IMT system is expected to supporting combination of applications which not only requires different capacities, but also requires smoothly adaptive.

[5D/638 IAFI]

2.1.11 Support for a ubiquitous intelligent mobile society

[5D/882 One6G-A]

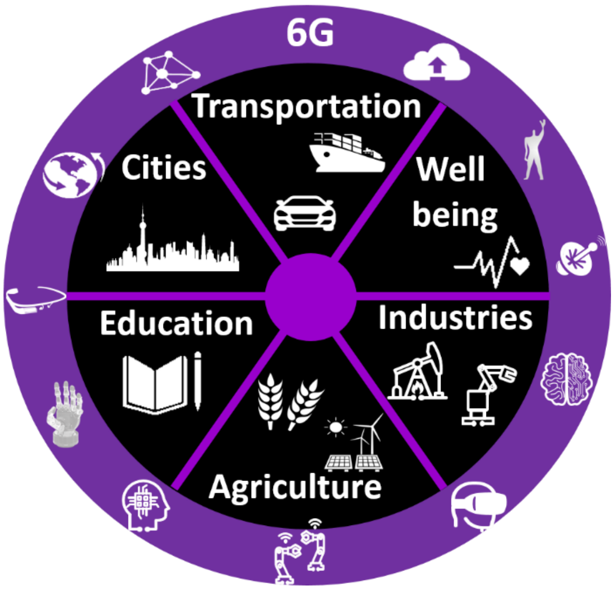
The ever-increasing rate of change in society coupled with the continual emergence of new and revolutionary technologies call for the need to rethink our current communications and networks systems. We expect a paradigm shift where the communication between intelligent agents, be natural or artificial, is not anymore an isolated process of transporting bits from one point to another, but rather just one part of the process of achieving common goals. This carries the necessity of cross-designing systems to sense, compute, communicate and actuate all together as part of the same system, leaving behind the classical vision of communications as a mere commodity.

These systems must be part of the solution towards a more sustainable world as expressed by the United Nations (UN) in its 2030 goals [1]. This means that 6G has to be *One* sustainable, affordable, accessible, and open system. In our commitment towards such endeavor, we set the first driver of 6G to be sustainability and social responsibility, embracing connectivity for everyone, everything, and everywhere. It is crucial that deploying, operating, monitoring, and managing 6G networks and services be cost- and energy-efficient, easy, and automated. Figure 1 shows One6G vision, including potential use case classes and technology enablers.

Proliferation of intelligence is widely expected to be another strong driver of 6G systems. Because pervasive intelligence -supported by distributed and decentralized machine learning (ML), brute-force computing, and big data analytics- is becoming the key enabler of business and economic growth, a new re-design of radio technology and network architecture will crave native support of Artificial Intelligence (AI), data protection, trustworthiness, and ecosystems diversity.

FIGURE 1

6G Use Case Classes and Technology Enablers



In addition, more applications will emerge as drivers for 6G. Extended reality (XR) cloud services together with haptic feedback and holographic display are expected to become mainstream of Human-centric applications. This type of applications will cause exponential increase in the traffic demand per device, together with strict latency and reliability requirements. Fully automated factories, as another type of applications of the future, will further impose demanding requirements in terms of deterministic latency and jitter, while also demanding guaranteed availability and reliability. Such applications drive the extreme and diverse performance that will define 6G.

In a nutshell, one6G aims to evolve, test, and promote next-generation cellular and wireless technology-based communications solutions. By supporting global 6G research and standardization efforts, the goal is to accelerate its adoption and overall market penetration, while addressing societal and industry-driven needs for enhanced connected mobility. This is with the ambition to speed up the development of new services and applications in domains such as advanced autonomous driving, advanced manufacturing, advanced wireless e-health, remote education, and many more.

Use cases

We expect 6G technologies will be the one of the main drivers in in 6 relevant domains, namely sustainable agriculture, well-being, education, inclusive, safe, resilient, and sustainable cities, and sustainable industries:

6G for sustainable agriculture

6G will improve the quality and quantity of agricultural production by making farms more intelligent and connected. Advanced wireless technologies and solutions can improve operational efficiency, maximize yield, and minimize wastage (such as, water) through real-time field data collection and data analysis. Ubiquitous wireless coverage over farming lands that are spread across vast areas and in remote regions can be efficiently monitored and managed for abnormalities such as, growing weeds and parasites, using connected devices such as robots and drones. Beyond mere monitoring, 6G will allow remote farmers to spontaneously capture photos, analyze and take suitable measures. One such measure includes appropriately regulating the use of pesticides in farms by remotely controlling the movement of connected devices. With capabilities such as artificial intelligence and sensing, plants can be aptly identified and customized plant-based farming methods can be developed.

6G will enable a data-based agriculture industry, one that is capable of central evaluation of decentrally collected data from farms from different regions to support creation of region-specific sustainable farming solutions.

6G for well-being

6G will enable the spread of cheap and proactive healthcare for everyone and everywhere by providing secure and private computation and connectivity. We expect the wide-spread use of applications such as doctor-as-you-go, where your terminal actively monitors your health, allowing the eradication of predictable diseases and reducing the cost of access to good medicine. Such applications must however protect anonymity and privacy of everyone, while exploiting the power of massive amounts of data. Federated and distributed systems that harness data from many different sources while preserving data privacy and anonymity will be a key technological factor supported in 6G. 6G will also support tele-surgery and tele-medicine thanks to its native support for haptic feedback, digital twinning, and immersive reality. Such applications require not only extreme low latency and high bandwidth and reliability, but also an integrated design of the communication, sensing, localization and actuation parts. This will allow everyone to access very high quality physicians even when they are not near top hospitals and therefore democratizing the access to healthcare.

Beyond healthcare, the UN also recognizes the need to address the increasing mental health and nutrition problems for an improved well-being in the society in an easy and cheap way, accessible to everyone. 6G will enable the required connectivity and distributed intelligence to help reduce the cost and barriers to such fundamental services.

6G for education

6G has the potential to tremendously influence education sector in the future. With the capability to support extremely immersive experience via eXtended reality (XR) – including augmented reality (AR), virtual reality (VR) and mixed reality (MR) – and telepresence, the digital classrooms of the future will significantly improve the interaction and collaboration capability among teachers and learners. With haptic and multi-sensory communication, acquiring skills such as those obtained via lab work and hands-on experience can be enabled virtually. With the integration of artificial intelligence based techniques, the teaching and/or learning material and methods can be personalized in real-time for individual learners. By providing global wireless network coverage and access, 6G will accelerate the spread of quality educational resources to learners from underserved and remote parts of the world, a step towards equal educational opportunities for all.

6G for intelligent and connected transportation

6G will help towards the goal of intelligent and shared transportation such as connected autonomous driving and achieve its promises of freeing space in crowded areas, reducing commutes, increasing productivity, and reducing the number of accidents and fatalities, among many other expected benefits. However, these benefits come with their own share of challenges. For example, to deal with unforeseen situations common in autonomous driving, 6G will provide ubiquitous access with very large constellations of VLEOs and UAVs, sensing and AI capabilities, as well as ultra-low latency, high reliability, and precise localization. Along with autonomous vehicles, see and air transportation will also benefit from the ubiquity of 6G networks thanks to the seamless integration of satellite communications.

6G for inclusive, safe, resilient, and sustainable cities

Cities in the future should be safer, more inclusive, resilient, and sustainable according to the UN goals. Smart building will help reduce the energy bill of cities and conduct them towards self-sustainability. The usage of 6G in smart buildings will enable a common infrastructure with high efficiency and intelligence. Due to the massive number of sensors installed in a smart building, they will need to support large-scale connectivity and low energy consumption. Far beyond that, buildings and city infrastructure in general will be endowed with ubiquitous intelligent surfaces to minimize the distance of every connected device to the closest access point, greatly reducing the necessary energy to communicate and making cities more sustainable. New technologies such as next generation MIMO, higher frequencies, and flexible programmable infrastructure expected in 6G will make this vision a reality.

Autonomous city maintenance will help increase liability in the cities of the future by making them safer and more resilient and adaptable. This requires the seamless integration of robots, surveillance systems, and very dense IoT networks that 6G will provide.

6G for sustainable industries

6G will accelerate the digital transformation of vertical industries. With the ability to meet extremely low latency and high reliability requirements on the wireless links, the factories of the future will see fewer cables and truly flexible operations, such as fully adaptable and automated assembly lines. With the integration of reliable artificial intelligence and digital twin techniques, industrial robots and machines will have the capability to share their knowledge and experience, and cooperate among each other to enable resource and energy efficient optimizations in manufacturing processes. New applications in manufacturing and inventory management will be enabled by complex connected network of robots, UAVs and new human-machine interfaces. Highly accurate integrated communication and sensing capability in 6G will facilitate multiple robots and/or drones to reliably control their actions and collaboratively carry out challenging tasks, such as carrying and precisely positioning large and even fragile objects in different parts of the factory. Furthermore, ubiquitous high-performance sensing will enable safe coexistence of human and robots in close proximity in future industries.

REFERENCES

[1] United Nations, Department of Economic and Social Affairs, “Transforming our world: the 2030 Agenda for Sustainable Development”， 21 October 2015.

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2.2 Technology trends

[

[5D/614 KOR] [Editor's note: Section 2.2 will be developed based on material(s) from SWG Radio Aspects.]

[5D/631 T-Mobile]

- Stand-alone support of voice services
- IMT-[2030] in existing spectrum e.g. 600 MHz to 72 GHz
- Studies on technical feasibility of IMT-[2030] above 72GHz

[5D/830 NGMN]

Consideration, characterization, research and the development of future ecosystems should prioritise the following key challenges:

– Address societal and environmental needs, including well-being, prosperity, sustainability, trust, safety, affordability, resilience and inclusion. Advance enablement of digital transformation and automated industries to address future market needs, with expanded and differentiated opportunities, operational efficiency, productivity, sustainable business and return on investment. Some examples of attributes and design considerations are indicated below more specifically;

– Introduce new human machine interfaces that extend the user experience across multiple physical and virtual platforms, sensing, and immersive mixed realities for a variety of use cases, including the use of large bandwidths in existing and new spectrum bands;

– Advance enablement of seamless multi-access service continuity, using terrestrial and non-terrestrial networks, and provide coverage across land, sea, and sky, efficiently addressing any traffic and connection density;

– Ensure cost and energy efficient delivery of heterogeneous services that have extremely diverse requirements, under the stringent constraints of energy consumption and carbon emission limits and towards achieving the goals of sustainability and carbon neutrality;

– Advance and build from design the forward-looking capabilities introduced with IMT-2020 such as disaggregation and software-based agile, cognitive and autonomous networks, to ensure the introduction of new technology plug-ins in both the network and the user terminal / interaction mechanisms, that are market driven, support innovation, and create new value opportunities;

– In support of Artificial Intelligence (AI) by design, develop an energy and cost-efficient structure that is highly scalable, flexible, and portable, allowing abstraction and distribution of complexities, development of digital twin representation, and embedded intelligence. Identify appropriate AI-based frameworks, with the objective of supporting value creation and delivery, resource allocation optimization, and sustainable deployment and operation, among others.

Furthermore, the following end-to-end considerations should be regarded in the outline, analysis, characterization, and subsequent evaluation of technology trends, which in turn will prominently motivate and guide the development of technologies to respond to the fundamental needs:

– Take a holistic end-to-end view of the entire ecosystem, and not only its parts;
– Reconsider the traditional notion of a "generational" change driven solely by advancement in radio and core technologies;
– Assess new technological development with respect to its differentiation from IMT-2020;
– Ensure interoperability, sustainability, and global harmony supporting value creation and delivery.

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2.3 Studies on technical feasibility of IMT in bands above 100 GHz

[Editor's note: Section 2.3 will be developed based on material from SWG Radio Aspects.]

2.4 Spectrum implications

[Editor's note: Refer to section 2.5 Spectrum implications in the Recommendation ITU-R M.2083.]

The development of IMT for 2030 and beyond is expected to enable new use cases and applications, and addresses rapid traffic growth, for which contiguous and broader channel bandwidths than currently available for IMT systems would be desirable. This suggests the need to consider spectrum resources in higher frequency ranges.

[Report ITU-R M.XXX provides the results of studies on estimated global spectrum requirements for terrestrial IMT in the year 2030. The estimated total requirements include spectrum already identified for IMT plus additional spectrum requirements.]

It is noted that no single frequency range satisfies all the criteria required to deploy IMT systems, particularly in countries with diverse geographic and population density; therefore, to meet the capacity and coverage requirements of IMT systems multiple frequency ranges would be needed. It should be noted that there are differences in the markets and deployments and timings of the mobile data growth in different countries.

For future IMT systems in the year 2030 and beyond, contiguous and broader channel bandwidths than available to current IMT systems would be desirable to support continued growth. Therefore, availability of spectrum resources that could support broader, contiguous channel bandwidths in this time frame should be explored. Research efforts must be continued to increase spectrum efficiency and to explore the availability of contiguous broad channels.

Furthermore, while considering identification of new spectrum bands for IMT, the potential implications to the existing uses of that spectrum will need to be addressed.

2.5.1 Spectrum harmonization

As the amount of spectrum required for mobile services increases, it becomes increasingly desirable for existing and newly allocated and identified spectrum to be harmonized. The benefits of spectrum harmonization include:

facilitating economies of scale, enabling global roaming, reducing equipment design complexity, preserving battery life, improving spectrum efficiency and potentially reducing cross border interference. Typically, a mobile device contains multiple antennas and associated radio frequency front-ends to enable operation in multiple bands to facilitate roaming. While mobile devices can benefit from common chipsets, variances in frequency arrangements necessitate different components to accommodate these differences, which leads to higher equipment design complexity.

Therefore, harmonization of spectrum for IMT will lead to commonality of equipment and is desirable for achieving economies of scale and affordability of equipment.

2.5.2 Importance of contiguous and wider spectrum bandwidth

The proliferation of smart devices (e.g. smartphones, tablets, televisions, etc.) and a wide range of applications requiring a large amount of data traffic have accelerated demand for wireless data traffic. Future IMT systems are expected to provide significant improvement to accommodate this rapidly increasing traffic demand. In addition, future IMT systems are expected to provide gigabit-per-second user data rate services. The currently available frequency bands and their bandwidth differ across countries and regions, and this leads to many problems associated with device complexity and possible interference issues. Contiguous, broader and harmonized frequency bands, aligned with future technology development, would address these problems and would facilitate achievement of the objectives of future IMT systems.

In particular, bandwidths to support the different usage scenarios in § 4 [(to be summarised from section 4 e.g.)] would vary. For those scenarios, that would require up to several GHz of bandwidth, there would be a need to consider wideband contiguous spectrum above 100 GHz.

From the Current Radio regulations, following portions of the spectrum above 60 GHz could be considered for further studies:

3 Evolution and role of IMT

3.1 How IMT has evolved

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[5D/783 KOR]

[Korea's note: Section 3.1 is updated based on the Recommendation ITU-R M.2083.]

Since the early 1980s when different mobile communication systems were being developed in various regions, the ITU has adopted research challenges to create the international mobile communication systems on the global scale.

Following the adoption by International Radio Consultative Committee (CCIR) of the Study Question on the Future Public Land Mobile Telecommunication Systems (FPLMTS) in 1985, it took a total of 15 years for the identification of the radio spectrum in 1992 and development of IMT-2000 specifications (Recommendation ITU-R M.1457) in 2000. After this development, deployment of IMT-2000 systems started.

The ITU then immediately started to develop the Vision Recommendation (Recommendation ITU-R M.1645, June 2003) on Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000. Based on this Recommendation, the ITU has released the Recommendation ITU-R M.2012 in the terrestrial radio interface of IMT-Advanced in 2012. It took nine years for the ITU to develop the second phase of IMT after the completion of the Vision Recommendation. After this development, deployment of the IMT-Advanced systems started.

At the same time, the ITU started developing the Vision Recommendation (Recommendation ITU-R M.2083, September 2015) on Framework and overall objectives of the future development of IMT for 2020 and beyond. Based on this Recommendation, the ITU has released the

Recommendation ITU-R M.2150 in the terrestrial radio interface of IMT-2020 in 2021, which took six years after the completion of the Vision Recommendation.

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3.2 Role of IMT for 2030 and beyond

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[5D/675 Ericsson]

[Editor's note: This section should point at the role of IMT for the fast evolving digital and sustainable world, where the UN Sustainable Development Goals is one basis. An overview and timeline for the IMT development and deployment could also be given here.

Two examples are given below]

– **Sustainable development:** This includes energy and resource efficiency of ICT itself, but also the role of ICT in society, for the environment and to empower individuals.

– **Always present connectivity:** To serve as an ever-present means for dialogue, collaboration, exchange and meetings, for digital inclusion in daily social life as well as for bridging gaps and remoteness.

[5D/757 ISO]

[Editor's note: Following text are from Document 5D/757 ISO.]

Effective 100% mobile coverage of all roads is absolutely necessary to enable the safe, robust and secure management of enforceable electronic traffic regulations, which ISO/TC 204 is in the process of standardising (ISO/PWI 24315-1), and the safe, robust and secure, as well as complete and correct, availability and application of these electronic traffic regulations.

[5D/783 KOR]

IMT systems is becoming not only a communication tool for people and for connecting things but also social infrastructure as an important component of various industry sectors. IMT should continue to contribute to the mega trends described in § 2.

[5D/830 NGMN]

The continuing evolution of the IMT systems, and the underlying technologies, must be guided by the imperative to satisfy fundamental needs, and contextualized in terms of how they can help the society, the end users, and the value creation and delivery:

Societal Goals

Future technologies should help contribute to the success of a number of UN SDG goals such as environmental sustainability, efficient delivery of health care, reduction in poverty and inequality, improvements in public safety and privacy, support for ageing populations, and managing expanding urbanization.

Factors such as security, resilience, end-to-end environmental impact of ICT industry and its role for other sectors, energy efficiency and digital inclusion will be central in considering future technologies.

Market Expectations

Need to identify a quantifiable and differentiated role for any new technology that is justified by market and commercial needs. To achieve this, new technologies should enable significant and novel capabilities, supporting radically new and differentiated services, opening up greater market opportunities than the currently existing technologies:

In addition, any new communication technology needs to have sufficient flexibility in its design to be able to adapt to needs that were not anticipated at the time it was designed, and sufficient potential to enable innovation.

Operational Necessities

The need to manage complexity, drive efficiency, and reduce costs is paramount, in evolution of IMT. There is a need to focus on aspects such as:

– End-to-end System Automation: Fully automated life-cycle management by operators, across services, networks, and business/policy domains, with end-to-end system visibility and fully integrated AI functionality.

– End-to-end System Visibility: With sufficient resolution and granularity across services, networks and business / policy domains.

– System Efficiency and Management: Across all aspects such as operations, spectrum management, energy consumption, emissions, security management functions and device management.

[5D/638 IAFI]

Societal Goals

Key to next generation of IMT lies in what the future heterogenous mobile broadband networks can offer to the society and the economy through the applications and services they support. It needs to target the changing global scenario on how we work and how we stay safe during the societal challenges such COVID-19 pandemic and global climate changes. We need to review if the IMT has really delivered on digital inclusion and connecting the rural and remote communities. broadband for all. We need to review if the IMT has really delivered on digital inclusion and connecting the rural and remote communities.

The focus of "IMT-2030 and Beyond" should be on tackling societal challenges identified in UN Sustainable Development Goals (SDGs). The traditional focus in the first four generations of IMT should be refocussed towards the 17 SDGs, in particular to meet the needs of Industry, Innovation and Infrastructure.

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3.2.1 Societal consideration for IMT for 2030 and beyond

[

[5D/812 J]

3.2.1.1 Points to be considered towards 2030

It is desirable for IMT to support measures to overcome or deal with those points taking account of the following social issues.

3.2.1.1.1 Social issues

– Population engaged in production would be decreased in several areas.

– Underground natural resources such as rare metal, rare earth, and critical metal, would be short.

– Issues related to care caused by the increase of the population to be cared (short of care nurse. productivity of care operators, scientific care, increase of social security cost)

3.2.1.1.2 Natural phenomena

– climate change, concentrated heavy rain, forest firing, infection pandemic

3.2.1.2 Social image expected in year 2030s

– Physical communication in the physical space is replicated in the form of digital data in cyber space. It is predicted that events of physical space will be replicated faster and in detail in cyber space rather than physical space. Decision to next act in physical space is possible in cyber space.

It is expected that the volume of information transmitting and receiving between both spaces would be vastly increased. The vast volume of data would be analysed by AI and it is possible that the picture of the condition in physical space would be got as needed. If it is not possible the whole data is stored in cyber space, it is required that movement of things should be visualized, and demand and supply is matched.

– It is possible that required quantity of goods and services would be provided to those who need timely.

– Proper use of both spaces could deal with resolution of a various kinds of social cost and issues and economic growth at the same time.

– It contributes strongly to realize "societies with leaving no one, diversity, and inclusive" and "maintaining earth environment" as indicated in SDGs

3.2.1.2.1 Expected Concrete Social Image and its required Technologies

(1) "Inclusive society" (Society anyone participate actively)

Anyone participate actively in the society in which various kinds of difference are excluded, such as between urban and remote area, geographical barrier like border and so on, age, whether challenged or not, and so on.

Technologies expected to be required for the above society are as follows:

- "Ultra-telepresence technology"

  It is possible for anyone to be able to access in real experience everywhere on the earth via avatar, robots and so on.

- "Ultra-cybernetics technology"

  Human thinking and action can be supported timely from cyber space via wearable terminal. Physical ability and cognitive ability will be expanded.

(2) "Sustainable society" (Sustainably growing society)

Actual world replicated in cyber space is optimised and the corresponding cyber world is fed back to actual world. This fed-back world is free from social loss and convenient sustainably growing society.

Technologies expected to be required for the society are as follows:

- "Ultra-mutually controlled network technology"

The technology makes things mutually controlled each other to realize traffic system with no waiting by traffic signal, no traffic jam and so on.

- "Ultra real-time optimization technologies"

  The technologies, consisting of demand forecast in the high precision and real-time matching between multi points, realize loss-zero societies such as in disposal of foods.

(3) "Dependable society" (Society in which people can act safely)

Safety and stability of the telecommunication network as social infrastructure are secured autonomously. Everyone can act in safety. The society is human centric with unchanged ties of trust.

Technologies expected to be required for the society are as follows:

- "Ultra-autonomous technology of security"

  Security and privacy would be maintained without the user being conscious by automated detection, automated protection, and automated restoration performed by AI technology.

- "Ultra-failsafe network technology"

  The technology is realized by no-interrupted secured communication even in disaster with flexible and autonomous changing network structure, consumption of electric power/means to supply electric power.

3.2.1.2.2 Picture of IMT for 2030 and beyond required to support expected social image

– It would be required to gather latest data as much as possible on various events occurred in every point on the land, in the sea, in the air, in the space by using various sensors. The data gathered is stored in cyber space and is analysed with the past data and the data obtained by other sensors. If the effective and efficient future result could be selected, the result is fed back to physical space and transmitted to actual human/things.

– Communication infrastructure higher than 5G is mandatory required to realize extremely high order synchronization of data across both spaces everywhere in safety and security. It is required for high-order optical fiber networks to be prepared to support the communication infrastructure as nerve network of data.

– This kind of communication infrastructure requires for extremely big volume of data stream and its energy consumption will be expanded. In order to reduce the load to the earth environment and facilitate the safety distribution of data, thought to distribute data within a necessary area is required.

– It is required that communication infrastructure should be configured with using software which can flexibly change its function and structure and is high available since various services are required depending on purposes to resolve various social issues.

– Node equipment of communication infrastructure request high speed processing realized by dedicated hardware.

– White box as general-purpose equipment should be controlled by software.

]

4 [Usage scenarios] for IMT for 2030 and beyond

[Editor's note: The term "Usage scenarios" to be discussed further.]

[

[5D/631 T-Mobile]

– Multi-sensory Telepresence (Holographic, tactile, haptic AR/VR/MR)
– Digital Twin/Smart City
– Manufacturing/Industry 4.0

[5D/675 Ericsson]

[Editor's note: The description of usage scenarios should relate to the existing scenarios derived for IMT-2020 and how IMT will expand into broader and new use.]

The usage scenarios have expanded through IMT technologies from cellular service with voice and data (3G), through broadband data services for high mobility as well as nomadic/local access (4G) to the three usage scenarios Enhanced Mobile Broadband, Ultra-reliable and low latency communications and Massive machine type communications (5G). The next step for IMT would encompass existing scenarios, but will also expand into broader use, including for example:

– **Immersive communications:** The "internet of senses" will give an immersive physical experience of the world away from you through interaction in the digital world.
– **A digitalized and programmable physical world**: A factor which will have high impact on the role of future IMT is the evolution to having digital representation of everything, where the physical and the digital worlds are synchronized with sensor/actuator data.
– **Artificial Intelligence**: Rapid advances in AI and machine learning will ultimately give fully autonomous connected machines that are interoperable and communicate with any other intelligent machine.

[5D/783 KOR]

[Korea's note: Use cases having similar requirements can be categorized into specific usage scenarios. The following paragraphs describe example usage scenarios that might be important in future IMT systems. Use cases for each usage scenario should be listed based on further inputs.]

IMT for 2030 and beyond is envisaged to support diverse and AI-native usage scenarios and applications. The usage scenarios of the future IMT would consist of improved and advanced usage scenarios and newly defined usage scenarios. Furthermore, a broad variety of capabilities would be tightly coupled with these intended different usage scenarios and applications for IMT for 2030 and beyond.

The improved and advanced usage scenarios for IMT for 2030 and beyond include:

– **Ultra Mobile Broadband communications (uMBB)**: This usage scenario supports extremely high data rates.
– **Hyper-Reliable and Low Latency Communications (hRLLC)**: This usage scenario requires extremely high reliability and low latency.
– **Hyper-connected Machine Type Communications (hMTC)**: This usage scenario requires an extremely massive number of simultaneous connections per area including the air within the terrestrial IMT component.

The newly defined usage scenarios for IMT for 2030 and beyond include:

– **Precision Positioning (PP)**: This usage scenario requires extremely precise positioning.

– **3D Coverage (3DC)**: This usage scenario requires ubiquitous coverages for both horizontally and vertically (within the terrestrial IMT component).

– **Ultra Low Energy (uLE)**: This usage scenario requires the optimization of the end to end energy consumption at the mobile networks.

The examples of mixed usage scenarios for IMT for 2030 and beyond include:

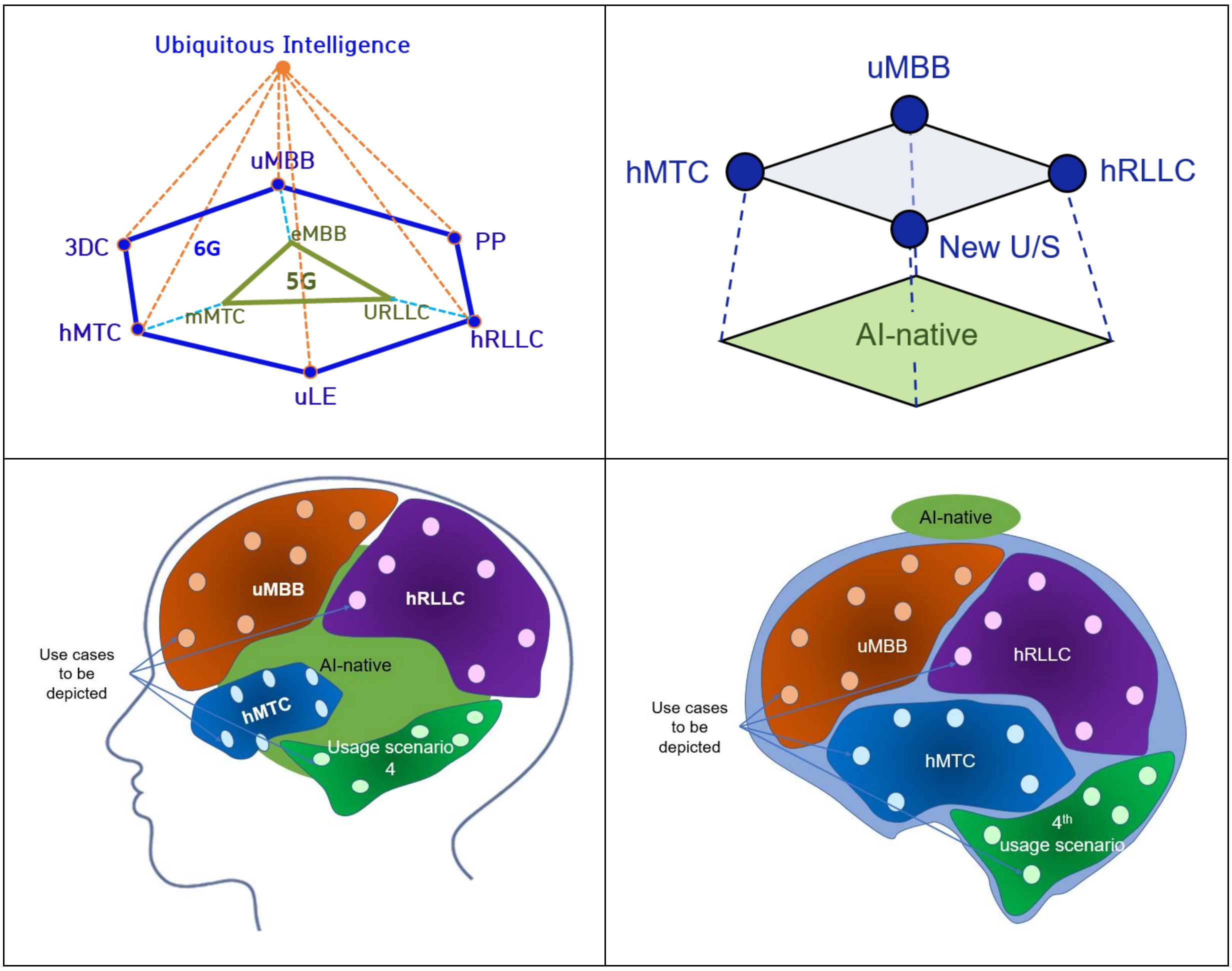
– Mixed scenario of uMBB and hRLLC – This mixed scenario requires both the requirements of uMBB and hRLLC such as immersive tactile internet applications.

– Mixed scenario of hMTC and hRLLC – This mixed scenario requires both the requirements of hMTC and hRLLC such as tactile IoT and industrial IoT (IIoT) applications.

Figure 1 illustrates some examples of envisioned usage scenarios for IMT for 2030 and beyond.

FIGURE 1

Examples of usage scenarios for IMT for 2030 and beyond



[Korea' note: Considering it is an initial phase of discussion, the Republic of Korea also provides other possible example cases as follows. Figure 2 illustrates the case where there are only improved and advanced usage scenarios (all connected with verticals). Meanwhile, Figure 3 illustrates the case where AI is considered as one of the newly defined usage scenarios.]

FIGURE 2

Improved and advanced usage scenario only

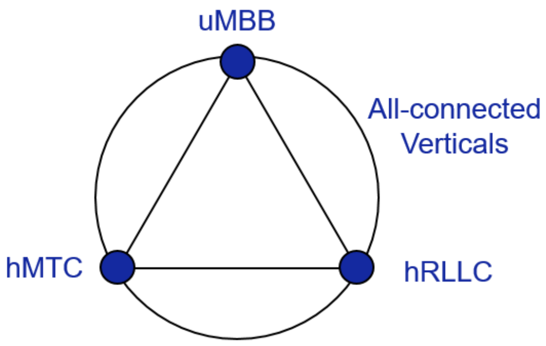
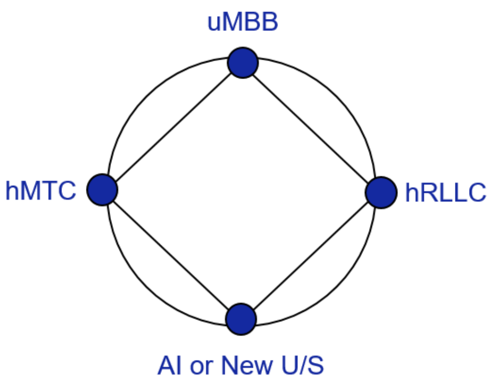


FIGURE 3

Improved and advanced usage scenario with newly defined usage scenarios such as AI



[5D/812 J]

IMT for 2030 and beyond will be required to support usage case and applications used in the following social conditions and scenes.

[Japan's note: The following description of application could be listed up in ANNEX. In the case, the above sentence is changed to "IMT for 2030 and beyond will be required to support usage case and applications used in some social conditions as indicated in ANNEX-X."].

– Production is proceeded continuously in the world during 24 hours with coordinating time differences by utilizing remote control in real-time. Although it is expected that the ratio of the number of autonomous robots used (thinking by themselves and no need to input from human) to the number of robots controlled remotely becomes bigger, some robots controlled by human (depending on human affiliation and perception power) will be continuously operated.

– Robots with bird's eye viewpoint in the virtual space is remotely controlled. Plural number of robots are operated as one robot. Real space is operated based on the information obtained from virtual space.

– Robots having only radio communication equipment without sensors are operated by moving on CG space like game in such a way that the robots obtain all information on the existence of traffic signal and pedestrians through communication, and predict danger from the experience of activities, distance to physical human, time, without approaching sensor. All the processing function exist in the side of platform. There is a certain need of high definition picture since some images are needed.

– Electronic currency will be usually used in daily life. It is important that transaction and communication network are secured in safety.

– Time watching TV will be decreased. Time to use handy terminals / smartphone is longer. Time to contact digital devices is largely increased within disposable time.

– It is expected that looking and listening 3D and AR/VR are felt closer in broadcasting.

– Personality will be expanded by unity of the maintaining/recovery of human capabilities and digital assistants.

– Society, in which people can keep alive by themselves in coexistence of customize and total optimization, will come.

– The most part of the entertainment is image and game. The ratio of time consumption occupied by game is higher. The ratio of time consumption in playing game is becoming higher in developing countries. There could be needs in increase of frame rate on animation. Attention should be paid on e-sports when considering from the aspect of traffic of network.

– On contents physical is still strong in market size. Digital has the tendency to increase in its market size. Especially the tendency on the market size of digital is significantly high in Asia area.

– Introduction of technologies such as AI, IoT, and robots could be supported to improve drastically productivity of agriculture, dissolution of shortage of manpower and leaders.

– It would be needed to develop technologies of automated driving, various kinds of transportation means such as drones, and their management/operation support, which could support maintaining the public traffic network in the local area and realize the innovation in the field of materials flow.

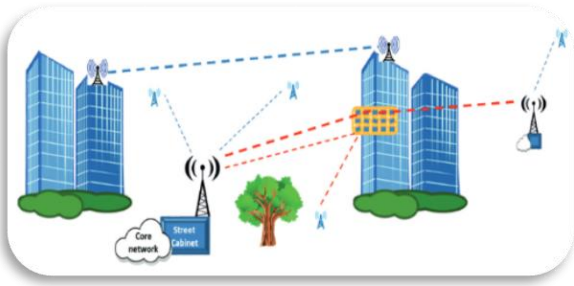
– It would be performed broadly to utilize in remote surgery, on-line medical care, electronic artificial skin type sensor, embedded type sensor, digital clinical trials, and counter measure to pandemic.

[5D/822 WWRF]

To expand, complement and refine the usage scenarios considered in 5G in order to incorporate the notions of immersion, digitization and intelligence, the following usage scenarios can be considered.

Usage Scenario 1: Backhaul/fronthaul global connectivity

Due to the forecasted exponential data rate increase and the requirement for global inclusion, mobile access networks in the forthcoming beyond 5G networks are going to emigrate towards heterogeneous cell structures, dominated by the backhaul/fronthaul connectivity scenario. The high potential of mmWave spectrum and/or the beyond 100 GHz spectrum is expected to be exploited in order to accommodate, through the higher offered bandwidth, the ever-increasing data-rate demands of mobile users.



In terms of deployment targeting global inclusion and heterogeneous connectivity, the following scenarios are envisioned:

- **Long-range LOS rooftop point-to-point backhauling**
- **Street-level point-to-point and point-to-multipoint backhaul/fronthaul**
- **Long range (‘fiber-extender’) rural coverage.**

Usage scenario 2: Immersive connectivity

The requirement for dynamic reconfiguration in obstructed/NLOS scenarios, in order to track slowly moving users, introduces several challenges wrt transceivers adaptation, channel estimation, localization and resources management. Examples of advanced NLOS connectivity include immersive communications, materialized by means of the internet of senses, where integrated communications and sensing usage scenarios are foreseen.

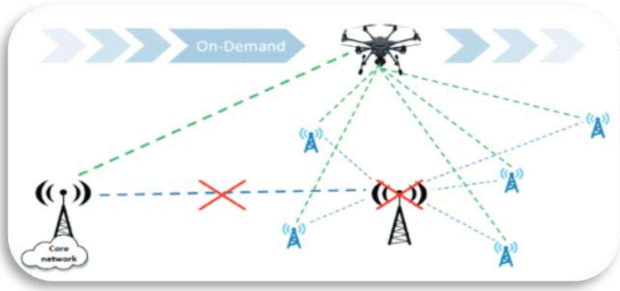
Immersive connectivity will enable Augmented/Virtual/Mixed Reality application empowered by holographic communication technologies and Digital Twinning capabilities.

In terms of deployment targeting immersive connectivity, the following scenarios are envisioned:

- **Advanced NLOS immersive connectivity empower by reconfigurable intelligent surfaces**
- **Data kiosk /data shower**
- **Extreme data rate and ultra low latency for Mixed Reality and Digital Twinning**

Usage scenario 3: Intelligent connectivity in dynamic network topology

Drones in future networks are seen as a way to extend the notion of coverage to that of intelligent connectivity. They can be essential in emergency cases when backhaul/fronthaul nodes stop operating due to malfunctioning or physical disaster. Due to the failure of a remote radio head, a drone can be deployed with attached remote radio head to serve the affected users.



Vehicles can be equipped with transceivers for reliable fast communication of road/traffic conditions to preceding cars (vehicle-to-vehicle - V2V). Moreover, traffic lights may dispatch critical information to vehicles approaching (vehicle-to-everything -V2X).

Intelligent connectivity in dynamic network topologies will largely depend on the integration of Artificial Intelligence and Machine Learning principles and the extend to which AI-native communications vision could be materialized.

In terms of deployment of intelligent connectivity in dynamic network topologies, the following scenarios are envisioned:

- **Dynamic front/backhaul connectivity for mobile 5G access nodes and repeaters**
- **V2V and V2X connectivity**

Usage scenario 4: Internet of Senses

The integration of sensors/actuators is expected to play a decisive role in realizing the vision of digitization and programmability of the physical world, the real time interaction between virtual and physical entities and the joint design of communication and sensing systems. The latter would require the seamless incorporation of multiple senses (haptic, smell, taste etc) and the efficient design of multidimensional sensing approaches. Ultra-high precision, resolution, synchronization and analysis of heterogeneous data signal is of paramount importance

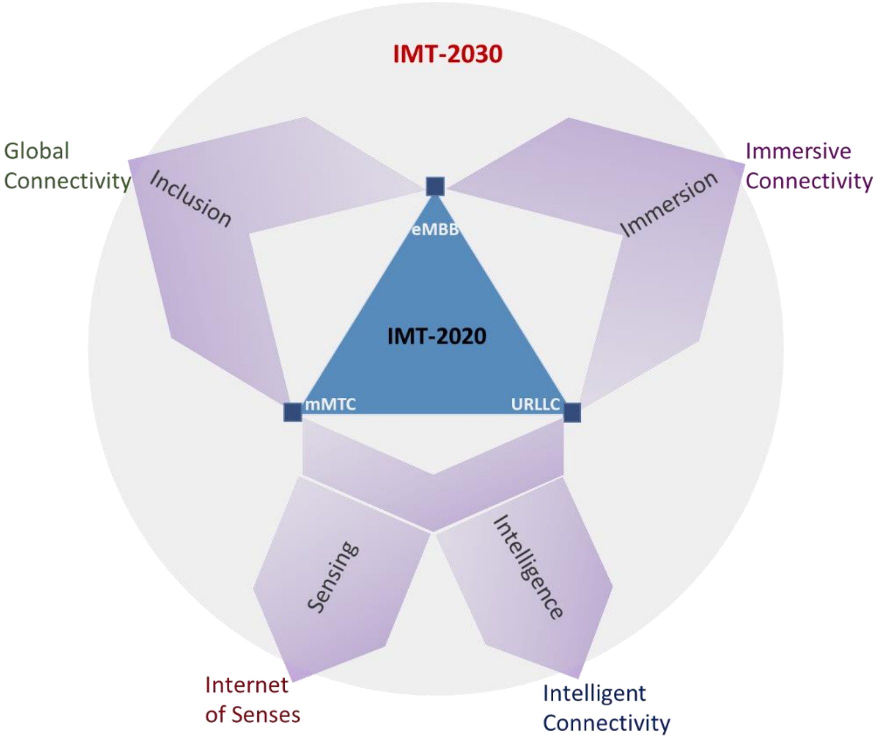
In terms of deployment of the internet of senses, the following scenarios are envisioned:

- **Multi-dimensional sensing**
- **'Sixth sense' communications**

[Figure proposed by WWRF]

FIGURE X-Y

Usage scenarios evolution from IMT 2020 to IMT 2030: 4 new usage scenarios envisioned, namely Global Connectivity, Immersive Connectivity, Intelligent Connectivity and Internet of Senses



[5D/843 Ericsson et al]

The following five use case families are envisaged for IMT for 2030 and beyond:

– ***Sustainable development***, illustrate how 6G can contribute to the transformation of society, targeting UN sustainable development goals and the EU Green Deal, providing global access to digital services and energy-optimized infrastructures and services.

– ***Massive twinning*** is another use case family involving the massive use of digital twins to represent, interact and control actions in the physical world.

– The ***Telepresence*** use case family covers immersive telepresence for enhanced interactions, involving mixed reality or merged reality, providing extreme and fully immersive experience.

– The use case family ***Robots to cobots*** includes various use cases involving interacting robots, at home to facilitate everyday life as well as in professional environments to improve the efficiency of processes. 6G will also integrate multiple sorts of networks and handle the complexity and heterogeneity of a network of networks.

– The use case family ***Local trust zones (for human and machine)*** encompasses different use cases, involving in-body networks to wide area deployment of sensors networks

[5D/867 CHN]

Given the technology trends and use cases discussed in section 2, IMT for 2030 and beyond will be a game-changer in terms of both economy and society with enhancements and innovation over previous generations. In light of this, as a principle for usage scenarios discussion of "IMT-2030", we propose that "IMT for 2030 and beyond would be designed to support diverse usage scenarios. Future IMT usage scenarios would be coupled with richer combination of broader variety of capabilities, i.e. not limited to those communication capability combinations required in IMT-2020, as well as possibly higher performance requirement, to support more diversified applications. Also new usage scenarios or applications not supported by the existing network, coupled with new key capabilities, are proposed to be highlighted, such as sensing and proliferation of AI, intelligent interaction."

]

5 Capabilities of IMT for 2030 and beyond

[

[5D/614 KOR] *[Editor's note: Introductory texts are needed.]*

[5D/675 Ericsson] *[Editor's note: Capabilities for "IMT-2030" will consist of many key capabilities that are carried forward from previous generations, including the Key Performance Indicators of radio network performance and efficiency. Some of these may remain and some may be stretched to higher performance. In addition, new capabilities will be needed which may encompass additional "dimensions" and goals for IMT to support the expanded usage scenarios. Additional capabilities are needed to address for example sensing, extreme devices, security and privacy, trust,, and also service availability and versatility.]*

[5D/614 KOR] *[Editor's note: Following items for capabilities are proposed for initial discussion. And other items could also be considered further. The proposed definition for each capabilities items are based on Recommendation ITU-R M.2083 and Report ITU-R M.2410.]*

Peak data rate

Maximum achievable data rate under ideal conditions per user/device (in Gbit/s).

User experienced data rate

Achievable data rate that is available ubiquitously[1] across the coverage area to a mobile user/device (in Mbit/s or Gbit/s).

[1] The term "ubiquitous" is related to the considered target coverage area and is not intended to relate to an entire region or country.

Spectrum efficiency

Average data throughput per unit of spectrum resource and per cell[2] (bit/s/Hz).

Latency

The contribution by the radio network to the time from when the source sends a packet to when the destination receives it (in ms).

Reliability

Reliability relates to the capability of transmitting a given amount of traffic within a predetermined time duration with high success probability

Mobility

Maximum speed at which a defined QoS and seamless transfer between radio nodes which may belong to different layers and/or radio access technologies (multi-layer/-RAT) can be achieved (in km/h).

Connection density

Total number of connected and/or accessible devices per unit area (per km^2).

[5D/631 T-Mobile]

Sustainability

Portability of applications across devices

[5D/638 IAFI]

Coverage

Minimum and maximum Inter cell distance (in KM)

End to End Latency

The time from when the mobile terminal sends a packet to when the destination mobile terminal receives it (in ms).

Support for a Ubiquitous Intelligent Mobile Society

Ubiquitous" or "pervasive" mobile society relates miniaturization of mobile wireless devices and the proliferation of always-on, everywhere communications. This phenomenon has been referred to as "'pervasive communications", "ambient computing", "ubiquitous computing" or "ubiquitous networking". Technological convergence is set to play a key role in realizing this wireless ubiquity.

Movement speed of mobile terminals

Both High and low speed should be covered.

[5D/771 IOWN GF]

[2] The radio coverage area over which a mobile terminal can maintain a connection with one or more units of radio equipment located within that area. For an individual base station, this is the radio coverage area of the base station or of a subsystem (e.g. sector antenna).

Energy efficiency

[5D/775 SparkNZ]

In order to satisfy the new services and future needs of mobile network towards 2030 and beyond, the key requirements for new technologies and network design are summarized (in the style of corresponding requirements for IMT-2020 systems [3]) as below. It is to be noted that the values of the KPIs in Table below are being shown as an example only to show the challenges that underlying technologies must address:

– **Peak data rate**: ≥1 Tbps catering to holographic communication, tactile internet applications and extremely high rate information showers. This at least 50× larger than that of IMT-2020 systems.

– **User experience data rate**: At least be 10 × that of the corresponding value of IMT-2020.

– **User plane latency**: This is application dependent, yet its minimum should be a factor 40× better than in 5G.

– **Mobility**: It is expected that IMT-2030 systems will support mobility of up to 1000 km/h to include mobility values encountered in dual-engine commercial aeroplanes.

– **Connection density per-km2**: Given the desire for IMT-2030 systems to support an internet-of-everything, the connection density could be 10× that of 5G.

Technical performance requirements of 6G systems [4]

Key Performance Index	IMT-2020	IMT-2030
Peak Data Rate	20 Gbps	≥1 Tbps (Holographic, VR/AR, and tactile applications)
User Experience Rate	100 Mbps	1 Gbps
Connection Density	10^6 devices/km^2	10^7 devices/km^2
User Plane Latency	4 ms (eMBB) and 1 ms (uRLLC)	20 µs to 1 ms (Holographic, VR/AR and tactile applications)
Mobility	500 km/h	1000 km/h Handling multiple moving platforms

Proposals for References

References

[1] R. Li, “Network 2030: Market drivers and prospects,” in Proceedings of the First International Telecommunications Union (ITU-T) Workshop on Network 2030, October 2018.

[2] ITU-T, “Network 2030: A blueprint of technology, applications, and market drivers toward the year 2030,” November 2019.

[3] M. Shafi, A. F. Molisch, P. J. Smith, T. Haustein, P. Zhu, P. De Silva, F. Tufvesson, A. Benjebbour, and G. Wunder, “5G: A tutorial overview of standards, trials, challenges, deployment, and practice,” IEEE J. Sel. Areas Commun., vol. 35, pp. 1201-1221, June 2017.

[4] H. Tataria, M. Shafi, A. F. Molisch, M. Dohler, H. Sjöland and F. Tufvesson, "6G Wireless Systems: Vision, Requirements, Challenges, Insights, and Opportunities," in Proceeding of the IEEE, doi: 10.1109/JPROC.2021.3061701.

[5D/783 KOR]

Positioning

Capability to locate a terminal both horizontally and vertically.

Coverage

Horizontal or vertical distance (within the terrestrial IMT component) where the cell can communicate with a terminal (in km).

Area traffic capacity

Total traffic throughput served per geographic area (in Gbit/s/m^2 including the air within the terrestrial IMT component)

[5D/822 WWRF]

Energy efficiency

Assessing performance metrics unit per energy unit required (in bits/Joule) is a key design efficiency indicator for both the network and the user equipment sides.

Other capabilities may be also required for IMT-2030, which are mainly associated with qualitative or 'soft' attributes tightly connected to the key visionary pillars of immersion, programmability and intelligence. These capabilities include:

Sensing resolution

Sensing accuracy, adaptability, agility and reliability are decisive parameters for the efficient integration of sensing into future communication systems and networks [in max acceptable sensing error margin].

Localization accuracy

Localization accuracy will significantly impact the implementation of immersion, digital twinning and native intelligence [in meters].

Trustworthiness

The ability to provide advanced system and service resilience, reliability, availability, confidentiality, privacy and safety.

[5D/867 CHN]

Facing 2030 and beyond, service and application requirements will be more diversified, and the 6G network key performance indicators will be more comprehensive.

– Reliability
– Availability
– Positioning
– Coverage
– AI-related capabilities

– Sensing-related capabilities

– …

[Editor's note: Following table shows, as only information, that which items are proposed as candidate items for capabilities by the 39th meeting.]

Proposed capabilities as of WP5D #39 Oct 2021

	Capabilities	M. 1645	M. 2083	Korea (614, 783)	T-Mobile (631)	IAFI (638)	SparkNZ (775)	WWRF (822)	China (867)	IOWN GF (771)
1	Peak data rate	O	O	O			O			
2	User experienced data rate		O	O			O			
3	Spectrum efficiency		O	O						
4	Latency		O	O						
5	Reliability			O					O	
6	Mobility	O	O	O			O			
7	Connection density		O	O			O			
8	Sustainability				O					
9	Portability of applications across devices				O					
10	Coverage			O		O			O	
11	End to end latency					O				
12	User plane latency						O			
13	Control plane latency						O			
14	Positioning			O					O	
15	Area traffic capacity		O	O						
16	Energy efficiency		O					O		O
17	Sensing resolution							O		
18	Localization accuracy							O		
19	Trustworthiness							O		
20	Availability								O	
21	AI-related capabilities								O	
22	Sensing-related capabilities								O	
23	Support for a ubiquitous intelligent mobile society					O			O	
24	Movement speed of mobile terminals					O			O	

Other capabilities	Spectrum and bandwidth flexibility		O
	Reliability		O
	Resilience		O
	Security and privacy		O
	Operational lifetime		O

]

6 [Framework] and objectives

[Editor's note: The term "Framework" to be discussed further.]

6.1 Relationships

[Editor's note: Section 6.1 describes relationships between IMT-[2030] and existing IMTs/other systems]

[Editor's note: To clarify "Relationships" and more additional explanatory description such as positioning and mapping at future meeting.]

6.2 Timelines

[

[Editor's note: Following texts based on Recommendation ITU-R M.2083 are proposed for discussion. It could be improved based on further inputs and discussion.]

In planning for the development of IMT-[2030] as well as future enhancement of the existing IMTs, it is important to consider the timelines associated with their realization, which depend on a number of factors:

– user trends, requirements and user demand;
– technical capabilities and technology development;
– standards development and their enhancement;
– spectrum matters;
– regulatory considerations;
– system deployment.

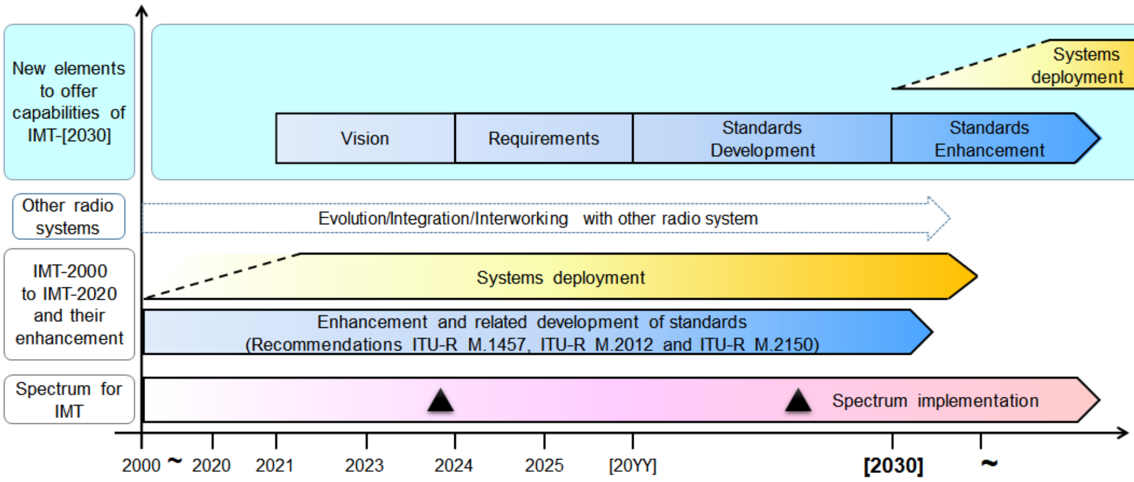
All of these factors are interrelated. The first five have been and will continue to be addressed within ITU. System development and deployment relates to the practical aspects of deploying new networks, taking into account the need to minimize additional infrastructure investment and to allow time for customer adoption of the services of a new system. ITU will complete its work for standardization of IMT-[2030] no later than the year 2030 to support IMT-[2030] deployment by ITU members expected from the year 2030 onwards.

The timelines associated with these different factors are depicted in Fig. A. When discussing the phases and timelines for IMT-[2030], it is important to specify the time at which the standards are completed, when spectrum would be available, and when deployment may start.

[Editor's note: Timelines related to standardizations "New elements to offer capabilities of IMT-[2030]" in figure would reflect outcome from AH-Workplan.]

FIGURE A-1

Phase and expected timelines for IMT-[2030]



The sloped dotted lines in systems deployment indicate that the exact starting point cannot yet be fixed.

▲ : Possible spectrum identification at WRC-23 and WRC-27

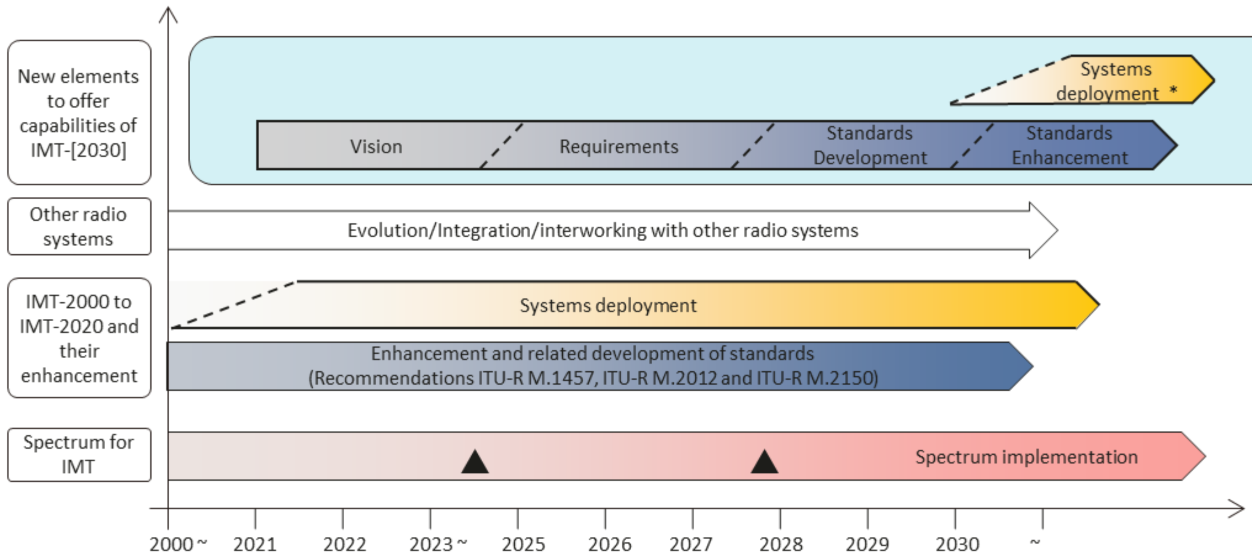
* : Systems to satisfy the technical performance requirements of IMT-[2030] could be developed before year 2030 in some countries.
: Possible deployment around the year 2030 in some countries (including trial systems)

[Editor's note: The use of the term "IMT-[2030]" above is a placeholder terminology and the specific nomenclature to be adopted for the future development of IMT is expected to be finalized at the RA-23.]

[Figure A-2 proposed from CHN]

FIGURE A-2

Phase and expected timelines for IMT-[2030]



The sloped dotted lines indicate that the exact starting point of the particular subject can not yet be fixed

▲ : Possible spectrum identification at WRC-23 and WRC-27

* : Systems to satisfy the technical performance requirements of IMT-[2030] could be developed before year 2030 in some countries
Possible deployment around the year 2030 in some countries (including trial systems)

]

[5D/614 KOR]

[6.2.1 Medium term]

[

In the medium-term (up to about the year 2030) it is envisaged that the future development of IMT-2000, IMT-Advanced and IMT-2020 will progress with the ongoing enhancement of the capabilities of the initial deployments, as demanded by the marketplace in addressing user needs and allowed by the status of technical developments. This phase will be led by the growth in traffic and the emerging new use cases within the existing IMT spectrum, and the development of IMT-2000, IMT-Advanced and IMT-2020 during this time will be distinguished by incremental or evolutionary changes to the existing IMT-2000, IMT-Advanced and IMT-2020 radio interface specifications (i.e. Recommendations ITU-R M.1457 for IMT-2000, ITU-R M.2012 for IMT-Advanced and ITU-R M.2150 for IMT-2020, respectively).

It is envisaged that the bands identified by WRCs will be made available for IMT within this timeframe subject to user demand and other consideration.

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[6.2.2 Long term]

[

The long term (beginning around the year 2030) is associated with the potential introduction of IMT-[2030] which could be deployed around the year 2030 in some countries. It is envisaged that IMT-[2030] will add enhanced capabilities described in § 5, and they may need additional frequency bands in which to operate.

]

[6.3 Focus areas for further study]

[Editor's note: The use of the term "IMT-[2030]" above is a placeholder terminology and the specific nomenclature to be adopted for the future development of IMT is expected to be finalized at the RA-23.]

APPENDIX

[Editor's note: This element is related to item in terms of use case in section 2. This item will be discussed at the next meeting based on input contributions.]

Summary of Offline discussions

- Different levels of descriptions and details are contributed to section 2 , in some parts generic views on trends are given , other describe detailed use cases
- A need to align and understanding of the terms use case/use case family", "User and application trends", "Usage scenario"
- Discussion also on the content of section 2.1 that should focus on the overall trends and not go into detailed use case descriptions. Detailed description can be captured in different parts of the working document.

Suggestion from Offline discussions

- Extract the use cases and user/application trends and separate them
- Streamline and find similarities in text proposed and out of it make Use case groups (currently 10 groups identified)
- Use case section should be described in a very high-level way and align and adopt to extent possible Recommendation ITU-R M.2083 style.

Outcome from Offline discussions

1 Use cases

[5D/653 Nokia et al]

- E-health for all
- Immersive smart art
- Fully merged cyber-physical worlds
- Sensor infrastructure
- Flexible manufacturing
- Dynamic and trusted local connectivity zones.

[5D/775 SparkNZ]

- Holographic Communications
- Tactile and Haptic Internet Applications
- Network and Computing Convergence
- Extremely High Rate Information Showers
- Connectivity for Everything
- Chip-to-Chip Communications
- Space-Terrestrial Integrated Networks.

[5D/882 One6G-A]

- 6G for sustainable agriculture
- 6G for well-being
- 6G for education

- 6G for intelligent and connected transportation
- 6G for inclusive, safe, resilient, and sustainable cities
- 6G for sustainable industries.

[5D/873 China]

- Immersive Cloud XR
- Holographic Communications
- Synaesthesia Interconnection
- Intelligent Interaction
- Multidimensional sensing
- Digital Twin
- Proliferation of intelligence
- Global Seamless and Deep Coverage.

2 Use case groups (should these perhaps be based on the user and application trends?)

- Uses cases related to: trustworthiness
- Use cases related to: Smart city, Global inclusion
- Use cases related to: Pervasive AI, AI powered intelligence everywhere
- Use cases related to E-health, well being
- Use case related to sensing and recognition
- Use cases related to immersive media, holographic communication etc
- Use cases related to Internet of senses
- Use cases related to mobile and computing convergence
- Use cases related to Robotics, industry 4.0 etc.

3 User and application trends

[5D/653 Nokia et al]

a) new human–machine interfaces created by a collection of multiple local devices acting in unison;

b) ubiquitous computing distributed among end devices, base stations, edges and the cloud;

c) multi-sensory data fusion to create multi-verse maps and new mixed-reality experiences;

d) precision sensing and actuation to understand and control the physical world;

e) mega constellation of VLEOs and drones integrated with terrestrial networks to provide ubiquitous high quality mobile broadband services.

[5D/675 Ericsson]

- Simplified life
- Trust
- Sustainable world.

[5D/783 KOR]

- New human-machine interfaces
- Connected machines
- AI
- Digital extended world
- Trustworthiness.

[5D/843 Ericsson et al]

- Trustworthiness
- Digital inclusion
- Pervasive AI
- Foundation of global economy
- New applications
- Network as a powerhouse for twin ecological and digital transitions.

[5D/631 T-Mobile]

- AI powered intelligence everywhere
- Mobile only societies
- Global Inclusion
- Security and Trustworthiness built from the foundations
- Customization of Experiences.

[5D/822 WWRF]

- Global inclusion
- Security and Trustworthiness built from the foundations
- Harvesting context through sensing
- Distilling security-relevant context through semantic compression
- Context-aware risk assessment, through the semantic fusion of the distilled context with network and application layer information
- Developing security controls that can adapt to context.

[5D/867 CHN]

- Supporting human-centric applications with ultra-low latency and ultra-high throughput
- Supporting vertical applications with ultra-low latency and ultra-high reliability
- Supporting ultra-massive connections
- Supporting global seamless coverage
- Supporting maintaining high quality communications at ultra-high mobility
- Supporting high accuracy and resolution sensing applications
- Supporting applications with pervasive intelligence
- Supporting intelligent interaction
- Supporting high quality interaction of virtual and reality
- Task oriented applications with adaptive capabilities.

[5D/638 IAFI]

- Support for a ubiquitous intelligent mobile society.

[A potential list of main IMT 2030 trends, which may help concisely articulate the VISION and serve as a basis to select/classify/group all relevant Use Cases. (The items on the following list have already been part of various proposed lists in this doc. An effort is made to include in this list ONLY then main visionary trends for the future and avoid mixing trends with {services, applications, specific use cases and usage scenarios. After explaining the IMT 2030 vision and its major trends in chapter 2, use cases and usage scenario can further elaborated in the document.)

- Sustainability
- Security and Trustworthiness
- Global Inclusion
- Intelligent Interaction
- Immersive Presence and Connectivity
- Integration of communication, sensing and control]

[5D/873](originally submitted to FUTURE TECHNOLOGY TRENDS report section 4.1)

The three usage scenarios described in IMT-2020 i.e. eMBB, mMTC and URLLC will still be important and new use cases and applications should be all taken into account for the continuing evolution, especially for those driving the technologies development and reflecting the future requirements. In this subsection, potential new services and applications are briefly described as the background need for introducing driving factors and new technologies, but not limited to:

– **Immersive Cloud XR:** X-Reality, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) is expected to provide higher resolution, larger FoV, higher FPS, and lower MTP, which all translate into higher demand on the transmission data rate and end-to-end latency.

– **Holographic Communications:** Holographic communication provides real-time three-dimensional representation of people, things, and their surroundings into a remote scenario. It requires at least an order of magnitude high transmission rate and powerful 3D display capability.

– **Synaesthesia Interconnection:** Synaesthesia Interconnection is the joint communication of the multiple senses (haptic, taste, smell, etc.). The absolute latency to support real-time feedback is very challenging and the relative synchronization among the multiple senses would also need to be maintained to make it real.

– **Intelligent Interaction:** Intelligent agents with perception and thinking capability will produce active intelligent interactive behaviours, and realize emotional judgment and feedback intelligence at the same time, which needs extremely high reliability.

– **Multidimensional sensing:** Sensing based on measuring and analysing wireless signals will open opportunities for high-precision positioning, ultra-high resolution imaging, mapping and environment reconstruction, gesture and motion recognition, which will demand high sensing resolution, accuracy, and detection rate.

– **Digital Twin:** Digital twin is a digital replica of entities in physical world, which demands real time and high accuracy sensing to ensure the accuracy, and low latency and high data transmission rate to guarantee the real time interaction between virtual and physical worlds.

- **Proliferation of intelligence:** Real-time distributed learning, joint inferring among proliferation of intelligent devices, and collaboration between intelligent robots demand a re-thinking of the communication system and networks design.
- **Global Seamless and Deep Coverage:** In order to connect the unconnected, improve the indoor deep coverage, and provide continuously high quality mobile broadband service for anyone or anything in various areas, it is expected that the terrestrial and non-terrestrial networks shall be integrated to provide such services. The terrestrial networks shall support various types of wireless and wired access to improve the indoor deep coverage.