Beginning of the Journey toward 6G: Vision and Framework

Ruiqi Liu, Hui Lin, Hyunjoong Lee, Fabiano Chaves, Hanna Lim, and Johan Sköld

Introduction

The sixth generation (6G) mobile telecommunication will become a reality around 2030. Several research initiatives have started preliminary and conceptual work worldwide. Similarly to previous mobile communication generations, the Radiocommunication sector of the International Telecommunication Union (ITU-R) has a fundamental leadership role of defining framework and overall objectives of the new mobile communication generation, named IMT-2030, as well as developing global specifications of its radio interface.

ITU-R Working Party 5D (WP 5D), the expert group on International Mobile Telecommunications (IMT) systems, started in March 2021 the work on IMT systems for 2030 and beyond. This work includes a critical milestone for the development of 6G: an ITU-R Recommendation describing framework and overall objectives for the development of the terrestrial component of IMT-2030. As a result of numerous technical inputs from ITU-R Member States (national administrations) and Sector Members (industry and academia) and extensive discussions, WP 5D completed this work in its 44th meeting in June 2023, as planned, resulting the IMT-2030 Framework Recommendation [1]. The Recommendation was adopted by ITU-R Study Group 5 in September 2023 with some revisions and is subject to subsequent publication.

Supported by broad consensus, the IMT-2030 Framework Recommendation will serve as a roadmap and provide guidelines for 6G research and development. In this paper, we introduce key takeaways of the IMT-2030 Framework Recommendation including next steps of the development of 6G.

Trends of IMT-2030

The motivation for the development of IMT-2030 is to continue to build an inclusive information society while supporting sustainable development. In this context, a range of user and application trends are foreseen to become an integral part of IMT-2030, including ubiquitous intelligence and computing, immersive multimedia and multi-sensory interactions, digital twins, digital health, smart industries, ubiquitous connectivity, integration of sensing and communication, as well as sustainability. These trends illustrate the growing demand for a more advanced network, from the perspective of both private users and vertical industries.

To fully support these trends, novel technologies and designs need to be considered, including artificial intelligence-native air interfaces, advanced carrier aggregation, non-orthogonal multiple access (NOMA), grant-free multiple access, in-band full duplex, reconfigurable intelligent surface (RIS), ultra-dense network, radio access network (RAN) slicing and RAN infrastructure sharing. The emerging novel technologies and designs are expected to work coherently within the whole system, complementing and possibly enhancing each other. In a separate ITU-R report [2], the aforementioned future technology trends are elaborated in rich detail.

Current IMT systems rely on multiple frequency ranges with different characteristics to support a variety of use cases and deployments. The same is expected for IMT-2030, with the potential utilization of a wide range of frequency bands ranging from sub-1 GHz up to sub-THz bands to meet the expected capacity and coverage requirements. It is envisaged that wider channel bandwidths will be needed to support future applications and services for IMT-2030 in a wide variety of deployments, including wide-area deployments.

Usage Scenarios of IMT-2030

A usage scenario is a set of use cases enabled by a common set of capabilities. In order to support the aforementioned user and application trends, IMT-2030 is envisaged to expand the usage scenarios of IMT-2020 (5G), i.e., eMBB, mMTC, and URLLC, with enhanced and new capabilities, as well as enable novel usage scenarios arising from capabilities, such as those related with artificial intelligence (AI) and sensing. Furthermore, IMT-2030 is expected to be built on a set of overarching aspects, which act as design principles commonly applicable to all usage scenarios. In total, six usage scenarios and four overarching aspects are introduced as illustrated in Fig. 1.

The expanded usage scenarios include Immersive com-munication, Hyper reliable and low-latency communication, and Massive communication. Immersive communication extends the eMBB scenario of IMT-2020 and covers use cases which provide rich and interactive mobile services to users, including interactions with machine interfaces, such as immersive extended reality (XR) and holographic communications. Hyper reliable and low-latency communication extends the URLLC scenario of IMT 2020 and covers specialized use cases that are expected to have more stringent requirements on reliability and latency. Massive communication extends the mMTC scenario of IMT-2020, and involves connection of massive number of devices or sensors for a wide range of use cases and applications.

The new usage scenarios include ubiquitous connectivity, AI and communication, as well as integrated sensing and communication. The ubiquitous connectivity scenario is intended to enhance connectivity with the aim to bridge the digital divide. The AI and communication scenario would support distributed compute and AI-powered applications and enable unprecedented and specialized use cases by leveraging AI-related functionalities. The integrated sensing and communication scenario

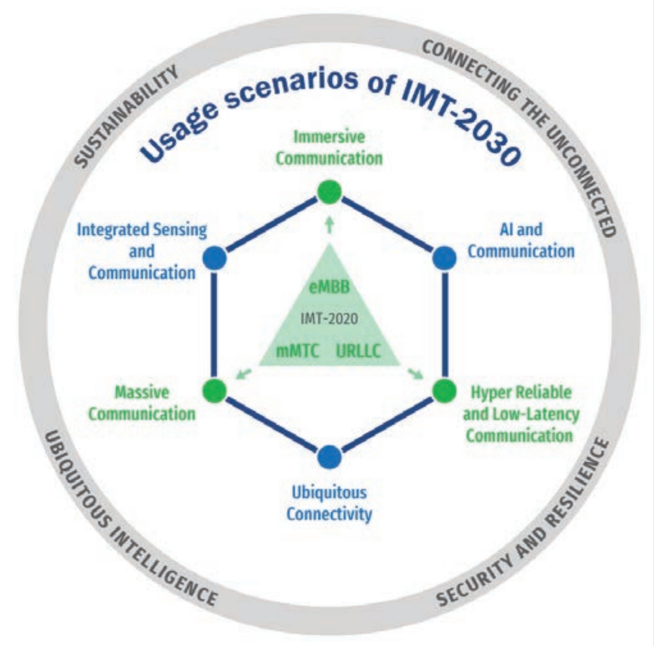

FIGURE 1. Illustration of usage scenarios and overarching aspects of IMT-2030, also referred to as the "Wheel diagram". (Source: ITU-R internal document, 09/2023).

would facilitate new applications and services, offering wide area multi-dimensional sensing that provides spatial information about unconnected objects as well as connected devices and their movements and surroundings.

Capabilities

IMT-2030 is expected to provide enhanced capabilities compared to those described for IMT-2020 [3], as well as new capabilities to support the expanded usage of IMT-2030. In total, 15 capabilities are recommended, including nine enhanced capabilities and six new capabilities, as presented in Fig. 2.

The enhanced capabilities are inherited from IMT-2020. They focus on communication aspects including peak data rate, user experienced data rate, spectrum efficiency, area traffic capacity, connection density, mobility, latency, reliability, as well as security and resilience. Under similar definitions, recommended target values for research are generally enhanced by around 5 to 10 times compared to those of IMT-2020. For example, ITU-R recommended 20 Gbit/s as research target for peak data rate of IMT-2020 in 2015 [3], while for IMT-2030, the recommended example values include 50, 100 and 200 Gbit/s, with the possibility of greater values also being explored. The improvement of spectrum efficiency is expected in the range of 1.5 to 3 times that of IMT-2020, also with possibility of greater values, considering the further advances in technologies such as multiple-input and multiple-output (MIMO) and interference management.

In addition, six new capabilities are introduced related to new usage scenarios, such as AI and sensing, as well as considerations of sustainability, coverage, positioning and interoperability. It is expected that IMT-2030 system will support beyond communication functionalities to facilitate AI and sensing related applications, for example range/velocity/angle estimation to enable network assisted navigation and distributed AI model inference for collaborative robots' operation.

Summary and Way Forward

The IMT-2030 Framework Recommendation lays out the path for developing 6G mobile communications, which will support enriched and immersive experiences, enhanced ubiquitous coverage, and enable new forms of collaborations. Expanded and new usage scenarios compared to those of 5G will be supported, including integration with AI and sensing. This is enabled by both enhanced capabilities as well as new capabilities for the new scenarios.

In the next step, ITU-R will develop technical performance requirements and evaluation criteria for IMT-2030, based on the capabilities and usage scenarios outlined in the IMT-2030 Framework Recommendation. In parallel, activities to study requirements for 6G will start in external standardization bodies such as 3GPP. The IMT industry is expected to work closely with all stakeholders to build a consensus that can reflect the technical innovations, meet the market expectations as well as economical and societal goals.

Guided by the ITU-R work, the IMT industry targets deployment of IMT-2030 capable systems around the year 2030, forming another step in the evolution of IMT, and building on the success of previous generations.

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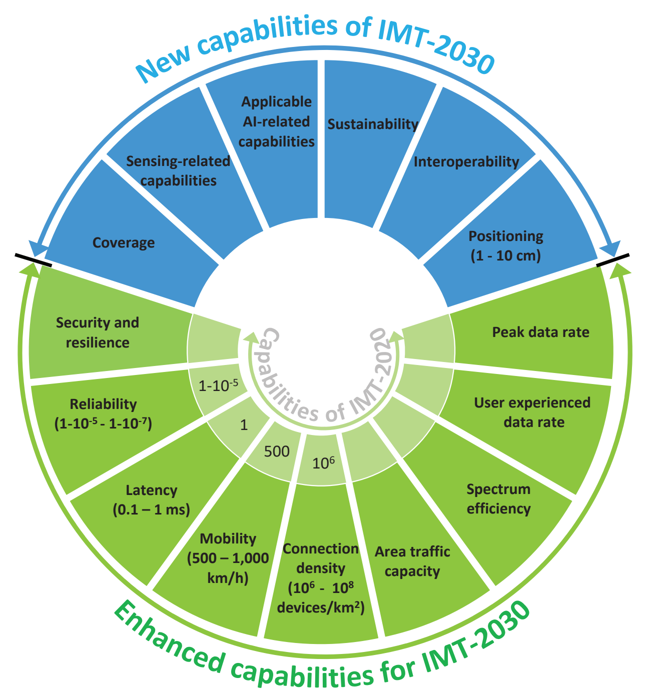

FIGURE 2. Illustration of capabilities of IMT-2030, also referred to as the "Palette diagram". The range of values given for capabilities are estimated targets for research and investigation of IMT-2030. (Source: ITU-R internal document, 09/2023).

References

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Biographies

Ruiqi (Richie) Liu is a master researcher with the Wireless Research Institute of ZTE Corporation. He is also with the State Key Laboratory of Mobile Network and Mobile Multimedia Technology. He takes on multiple leadership roles in the ETSI, 3GPP and ITU and is a frequent speaker at international conferences.

Hui Lin is an expert engineer in Huawei Corporation. He has been working on the research and standardization of 4G, 5G and 6G mobile communication systems in relevant organizations including 3GPP and ITU for nearly 20 years. He is co-author of the book "6G: the next horizon, from connected people and things to connected intelligence".

Hyunjoong Lee is a staff researcher at Samsung Research, Samsung Electronics. He has been working on research and standardization of 6G mobile communication systems in ITU.

Fabiano Chaves is Head of Spectrum Standardization North America at Nokia. He has over 20 years of experience in telecommunications, with activities spanning from research on wireless systems and networks to spectrum research, strategy, regulation and standardization. He has been continuously contributing to ITU-R and other research/regulation/standardization bodies on overall radio system aspects of IMT.

Hanna Lim is a senior staff engineer at Qualcomm Korea YH. She has been working on research and standardization of 4G, 5G, and 6G mobile communication systems since 2003, in relevant organizations including 3GPP and ITU.

Johan Sköld is a principal researcher at Ericsson Research and has been working on the evolution and standardization of 2G, 3G, 4G, 5G and 6G mobile systems since 1989, mainly in the areas of RF requirements and system performance. He is co-author of the popular book series on mobile communication including "5G NR: The next generation wireless technology".