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Vision on Non-Terrestrial Networks in 6G system (or IMT-2030)

USE CASES, REQUIREMENTS, AND POSSIBLE STANDARDIZATION APPROACH
A PERSPECTIVE FROM THE 6G-NTN PROJECT[1]

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1 INTRODUCTION

In this white paper, the 6G-NTN consortium partners provide a consolidated view on NTN in 6G.

The paper includes an identification of the targeted market segments, connectivity scenarios, general design principles for NTN in 6G followed by a proposed standardization approach.

2 USE CASES AND ASSOCIATED REQUIREMENTS FOR NON-TERRESTRIAL NETWORK CONNECTIVITY BY 2030 AND BEYOND

2.1 MARKET SEGMENT DESCRIPTION

In this section, different classes of connectivity scenarios are identified, each addressing different market segments and use cases.

The purpose of this section is to establish the interest of the integration of a non-terrestrial network component into 6G systems. It shall evidence the main corresponding market segments, and particularly those associated to mass market (consumer and enterprise), as these will be driving the demand and defining the requirements for this integration.

Note: The purpose of this section is not to introduce any system requirement that will be discussed by the corresponding standardization bodies.

2.1.1 Consumer market

This market segment is associated with general public users, equipped with smartphones or wearable devices. These users are looking for either a guaranteed reach of their corresponding MNOs' coverage, or for an extension of the reach of this coverage when the terrestrial radio network cannot be extended due economic or physical reasons (mountains, oceans, etc.) or in case of terrestrial network failure or disaster.

Users are equipped with a single User Equipment (UE). They expect voice and data services. Access to satellite or terrestrial network shall be seamless, with no modification to hardware or software. When considering automotive, possible use of dedicated user equipment and associated automotive constraints will have to be assessed when defining the corresponding system requirements.

Out of total number of mobile subscribers (5.2Bn), some market research [2] estimates that at least 7.5% would acquire NTN capable user equipment by 2030. This percentage is recognized to be very conservative and could be much higher in the subsequent years.

This market segment also includes connectivity to cars with at least emergency calls, distress messages. But also an increasing demand for data services. Worldwide car sales are around 75 million per year. One can expect that at least 5% of the new cars will be equipped with satellite connectivity by 2030. This percentage will most likely continuously increase together with a continuous demand.

2.1.2 Enterprise market

Enterprise users are also concerned by the need for connectivity in rural areas or less developed areas where terrestrial networks are not available. As for the consumer market, significant opportunities are also identified, under the same assumption that a unique user equipment will be used for both terrestrial and satellite components. Use cases will be similar to today's enterprise market, but as the technology becomes cheaper and compact and easier to access, the adoption is expected to rise.

2.1.3 Verticals

Verticals such as, aeronautical platforms, railways, land users, governmental users, are market segments which have very specific requirements associated with autonomy, security and possibly sovereignty. Fewer hundreds of thousands of subscribers [3] are anticipated to call for satellite connectivity.

It is therefore considered that such niche verticals and the associated specific requirements should be addressed in a second stage when the core mass market and associated key requirements have been addressed in a first instance.

2.2 CONNECTIVITY SCENARIOS

2.2.1 Direct connectivity to smartphones/wearable devices including in light indoor/in car scenarios

The end-user typically uses handheld User Equipment. The end-user is expecting to benefit from a service everywhere including in car environment as well as light indoor conditions. However, it can be assumed that the users are aware that coverage may not be ensured in deep indoor conditions or that services in such conditions may be degraded. As a natural trend, users expect to be able to establish real time video communication even in remote areas, for example, for assistance purposes. Given that non-terrestrial networks are expected to extend the service coverage of the terrestrial networks, the transition between both types of networks should be seamless for the users.

Note that the non-terrestrial networks providing such connectivity shall be able to support all application regulations including emergency communications, lawful intercept, and public warning services.

Smartphones may be operated in cars or even fast trains.

2.2.2 Broadband connectivity to land vehicles

To further differentiate among themselves, automotive vendors plan to provide connectivity services to the passengers as well as to the drivers. They are increasingly proposing terrestrial mobile connectivity, but also consider satellite connectivity to extend the service availability in remote areas and hence achieve ubiquitous connectivity.

Non-terrestrial network connectivity needs to be integrated with the existing terrestrial mobile connectivity possibly through the sharing of the same antenna system.

The applications that should be supported by the connectivity services range from messaging over voice services to video calls in the long term. As per the regulations, emergency calls shall be enabled. This requires the capability of reliable determination of the vehicle position.

2.2.3 Broadband connectivity to drones (or UxV)

Drones refer to un-crewed aerial vehicles (UAV) of different sizes and flying capabilities in terms of range or endurance as well as maximum payload. According to the category, a flying drone can operate at an altitude from several meters up to several thousands of meters. NTN connectivity is needed for those flying drones with mid (tens of km) to large (hundreds of km) range or endurance. Drones can serve multiple missions including High-Definition video observation for situation awareness as well relay of local area telecommunication traffic. Flying drones may also include urban air mobility vehicles.

Drones can also refer to un-crewed maritime ships or land vehicles. In this case, NTN connectivity can also serve remote piloting provided that it supports high reliability and relatively low latency. This is in particular the case for agricultural vehicles in closed areas and railway trains.

2.2.4 Connectivity to homes and small offices

The NTN component of 6G could be used to provide connectivity to homes and small offices. The perceived latency shall be as low as possible for high Quality of Experience.

2.2.5 High speed broadband connectivity to transportation platforms

The transportation sector, whether aeronautical, maritime, railway or road transport, will benefit from satellite connectivity in order to support assistance to pilots/drivers as well as added value services to passengers (e.g. entertainment). Higher data rate connectivity is needed to support the growing traffic demand of passengers on board these transportation platforms.

2.2.6 Fast set-up of Connectivity to an Area/theater of operation (for utilities and public safety)

Vertical stakeholders such as public safety, utilities (water or electricity distribution, telecom networks) for crisis response or in field operation purposes will also require complex network topology combining, NTN connectivity to smartphones and/or to wireless area networks embarked on a land vehicle, a ship or a drone.

2.3 SELECTED OF USE CASES ANALYZED IN THE HORIZON EUROPE 6G-NTN PROJECT

As part of the Horizon Europe 6G-NTN project, a selection of use cases has been analyzed in [4] to identify new service requirements that would be applicable to the 6G system:

- Maritime coverage for search and rescue coast guard intervention
- Autonomous power line inspection using drones
- Urban air mobility
- Adaptation to public protection disaster relief or temporary events

- Consumer handheld connectivity and positioning in remote areas
- Continuous bidirectional data stream in high mobility
- Direct communications over satellites

2.4 GENERAL REQUIREMENTS FOR INTEGRATION OF AN NTN COMPONENT IN 6G SYSTEMS

In general, the NTN component is expected to contribute to the “ubiquitous and resilient connectivity” use case of the 6G system.

The NTN component is also expected to enhance the sustainability of 6G by enabling reduction of the overall energy consumption of the system including the user equipment.

The NTN component shall be designed to support smooth integration with terrestrial MNOs networks at network and service management level.

The NTN component connectivity needs to be integrated with the existing/planned terrestrial mobile connectivity. The transition between both types of networks or components should be seamless.

The perceived latency shall be as low as possible for high Quality of Experience.

3 6G AND DRIVERS FOR NATIVE INTEGRATION OF SATELLITE COMPONENTS

3.1 SERVICE AND SYSTEMS

As initially exposed in [5], the IMT-2030 or 6G system aims at supporting a fully connected world, where the physical world is digitalized with high detail so as to be analyzed and acted upon. As such, it will support Augmented and Virtual Reality (AR/VR), digital twinning, and immersive communications and multi-sensory interactions (e.g., tactile/haptic Internet), integration of sensing and communication, collaborative robots, autonomous driving of vehicles and drones. It is expected to be designed as a cloud-based network infrastructure thanks to distributed computing and intelligence.

In [6], a framework has been described for future mobile telecommunication systems to be deployed in 2030 and beyond. In this ITU-R Recommendation, it is stated that “*External standards developing organizations involved in the development of IMT radio interface technologies have ongoing standardization activities that facilitate IMT interworking with non-terrestrial networks of IMT (including satellite communication systems, HIBS and UASs), as well as with other non-IMT terrestrial networks (including RLAN and broadcast). IMT-2030 should continue this path of interworking to offer users an improved connectivity experience, including the option of offering ubiquitous and continuity of services, in line with service and operational goals*”.

IMT-2030 will leverage and integrate a complementary set of access technologies (mobile, satellite, HAPS, wireless, wireline, etc.) as well as previous generation access technologies through smooth interworking enablers.

This IMT-2030 framework includes the identification of Usage scenarios of IMT-2030:

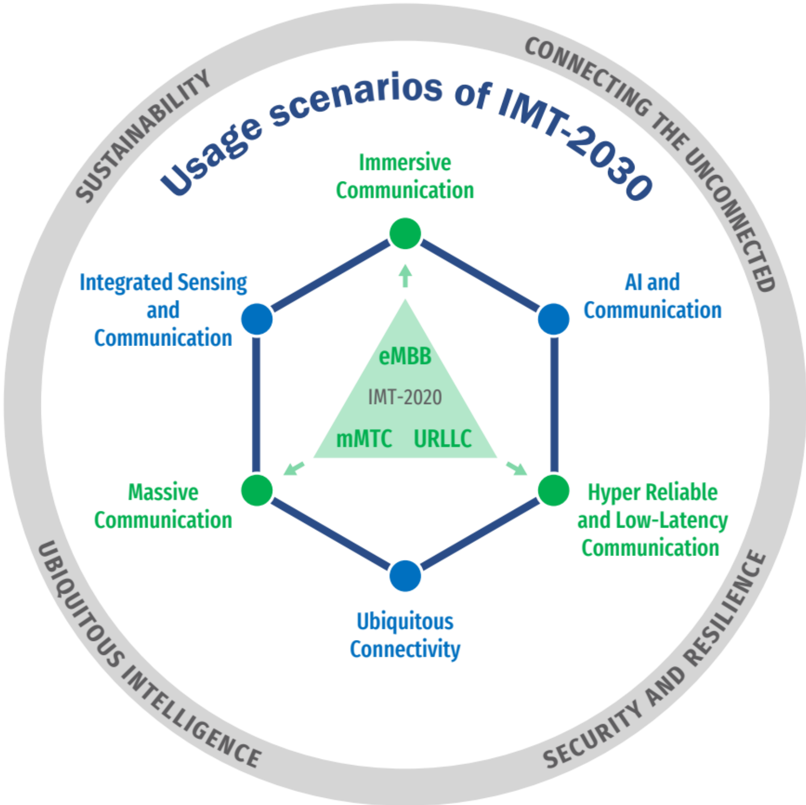

FIGURE 1: USAGE SCENARIOS AND OVERARCHING ASPECTS OF IMT-2030

In line with the above, non-terrestrial networks of IMT are expected to contribute to "connecting the unconnected", "security and resilience" and possibly to the "sustainability" overarching aspects.

This will require to ensure that the specific characteristics (delay, Doppler, spectrum, etc.), of the NTN component are considered since the inception of the development of the specifications of the 6G systems. It will also require ensuring an economic sustainability of such a system under the constraint to provide affordable services to the end users.

As the main opportunity will be for the mass market, which includes consumer and enterprise market segments, the effort for the inclusion of satellite components into 6G network will be prioritized on this market segment.

The following principles should be adopted:

- The specifications of the 6G systems, networks and UEs shall be driven by terrestrial networks. Specifics associated to satellite components such as delay & Doppler should be addressed when considering the tuning range of the corresponding radio protocols.
- User equipment shall have the capability to natively address any 6G terrestrial or satellite component.
- Access to spectrum shall be implemented so as to ensure the protection of networks, whether existing or under development, and to guarantee the development of future

networks. This principle shall be applicable for any network operating in the corresponding allocated service frequency band.

3.2 RADIO ACCESS NETWORK

6G radio network design principles will be driven by the needs of the terrestrial market segments. The design and specifications of the architecture, functionalities, and interfaces of the 6G radio access networks will be driven accordingly.

As the added value of satellite components is also recognized, such as radio coverage extension and reliability improvement, such components should natively be taken into account when designing and specifying the radio protocols of 6G networks, to the extent that these radio protocols remain globally effective for their main terrestrial target.

Such a single set of specifications for the radio protocols would ensure that baseband and UE chipsets would be available for 6G networks, natively including satellite components.

3.3 CORE NETWORK

At this stage, the native inclusion of satellite components in 6G radio networks is not anticipated to lead to significant impact on the architecture and interfaces of core networks. As for the RAN, any potential impacts should be addressed from the start.

3.4 USER EQUIPMENT

The strength of an NTN component of 6G lies in its capability to provide connectivity to a wide range of mobile devices (pedestrian, land/air vehicle-mounted, flying/surface drone-mounted, aeronautical or maritime moving platforms, satellite-mounted), fixed devices (facility-mounted) and device-to-device communications. Great care shall be taken when addressing usage conditions associated to these different devices as well as the installation and operation constraints for example in terms of casing, energy consumption, etc.

For pedestrian-carried devices, the NTN connectivity service shall not significantly impact the design of handheld user equipment. This also applies to handheld in light indoor or vehicle conditions, although it could possibly result in reduced service performance due to building penetration loss.

Vehicle-mounted devices will most likely be embedded in the roof of the vehicles which constrains their design. Moreover, the energy consumption of such devices shall be similar to that of handheld devices [7]. This requires cost effective antennas able to track the motion of satellites.

Similar installation and operational constraints typically apply to medium range drones, railway trains as well as to fixed mounted devices especially deployed by utilities and telecom operators.

Even though most aeronautic and maritime vessels may accommodate larger terminals, sticking to these design constraints would ensure a compatibility to all types of vessels and airplanes.

With the objective of maximizing the benefits and the efficiency of the inclusion of satellite components with 6G networks, UEs should be designed for 6G networks with the capabilities to address terrestrial frequency bands as well as specific satellite frequency bands and implementing radio protocols designed as identified in the above.

4 STANDARDIZATION APPROACH

4.1 PRINCIPLES

3GPP has proven to be an efficient forum to endeavor a truly efficient collaboration between market and vertical representatives, chipset vendors, UE manufacturers, network vendors, as well as network operators. As a global organization including the key regional standardization bodies, 3GPP has had significant impacts for the development of the cellular markets since the initial developments of the 3G, 4G, and 5G standards.

It is anticipated that the development of the 6G services, system, UE and associate network specifications in such a global cooperation environment will also contribute to a significant market.

With this understanding, the members of the 6G-NTN project recognize the benefits of the integration of satellite components as part of this 6G effort. A converged specification effort would foster a larger ecosystem, sharing of scientific knowledge, industrial capabilities, as well as market access channels.

Satellite industry representatives, whether satellite operators, service providers, infrastructure vendors or suppliers, and members of 3GPP are therefore strongly encouraged to contribute actively to 3GPP working groups and associated plenary meetings to facilitate the inclusion of satellite components in 6G networks.

It is therefore proposed that the native inclusion of satellite components be fostered, in line with the above principles, by including NTN in the baseline 6G study item in Rel-20, and the first normative work item in Rel-21. Therefore, the priority for Rel-20/21 shall be to address the conditions for native inclusion of satellite components in 6G networks.

As a consequence, in Rel-21 a first set of specifications endorsing the inclusion of satellite radio components as part of 6G networks shall be approved, targeting the most prominent mass market and corresponding access networks. Subsequent releases could elaborate on additional improvements to address further needs.

4.2 POTENTIAL TIMELINE FOR 6G STANDARDS AND ROLL-OUT

In December 2023, 3GPP committed to develop 6G specifications. Based on its success over several technology generations — from 3G to 5G — 3GPP is uniquely positioned to develop the standard for the sixth generation of mobile systems. The merits of proactive, consensus-based process and collaborative work implemented by this organization are recognized for contributing to the development of technologies, solutions and services by a global ecosystem now including mobile and space industry stakeholders but also representatives from user groups and market representative partners (e.g. TCCA, 5GAA, EUTC, etc.).

As part of Rel-20, some initial studies on use cases and service requirements are expected to start followed by technology studies on system architecture and radio protocol/access. The first requirements studies are expected to be approved in September 2024, followed by technology studies in June 2025. In these studies, it will be essential to search for a common technology framework (architecture and protocols) supporting natively both terrestrial and non-terrestrial networks hence avoiding any specific add-ons for the support of NTN.

The development of technical specifications at system level and radio access network level are expected to start as part of the Rel-21.

In the schedule reported in Figure 2 the initial activities leading to the definition of 6G system in both ITU-R (see FIGURE 3 with "Anticipated perspective of the timelines for IMT-2030" of [6]) and 3GPP (see Slide 2 of [8]) are depicted.

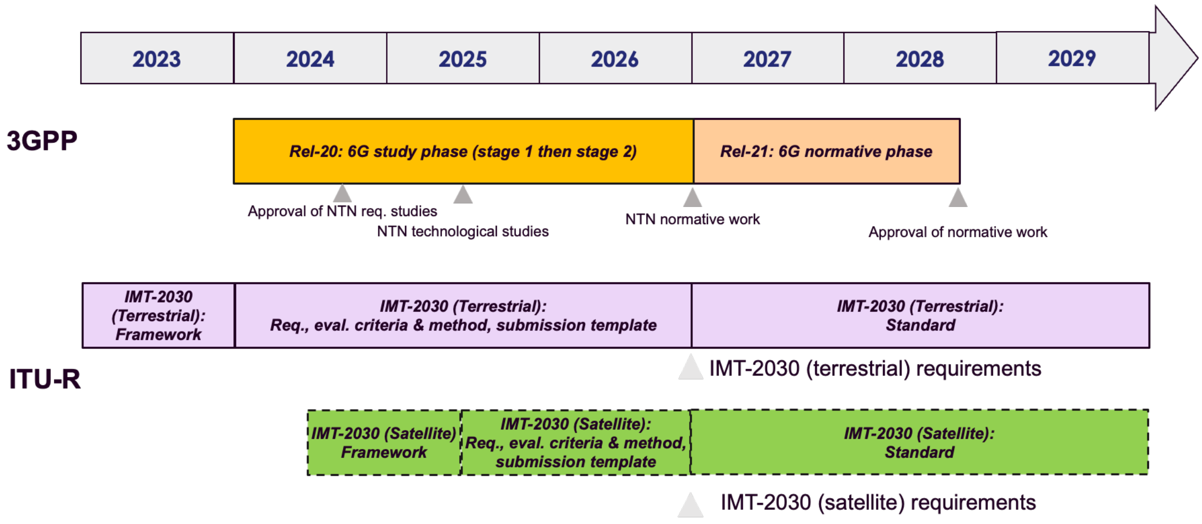

FIGURE 2: 3GPP STANDARDISATION SCHEDULE WITH RESPECT IMT-2030 DEFINITION IN ITU-R

4.3 ITU

Consistent with the approach promoted for 3GPP, the same effort is proposed to be engaged also in ITU to promote the corresponding specifications as a candidate radio technology for IMT-2030 in the corresponding ITU Working Groups, and to support its approval by ITU. It is expected that a submission in response to IMT-2030 requirements will be based on Rel-21.

As WRC-27 (e.g. AI 1.13 & 1.14) shall identify possible new frequency allocations for mobile satellite services, proper technical and regulatory conditions are essential for a fair access to spectrum fostering the development of a number of radio networks accessing the same frequency bands.

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