

A Survey of Extended Reality in 3GPP Release 18 and Beyond

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Abstract. Extended reality (XR) has recently attracted high interest of both academia and industry, which has led to a 3GPP study on architecture enhancement for XR and media services (XRM). This paper provides a survey of 3GPP standardization process of XR services. We first investigate the application sectors that could take advantage of XR services, and then discuss the key points for architecture enhancement in Release 18. Furthermore, we describe the extension of XRM study item in Release 19. Finally, the technical directions of XR services in future 6G network are presented.

Keywords: Extended Reality, 3GPP, standardization.

1. Introduction

Extended Reality (XR) is a term that embody several kinds of applications like augmented reality (AR), virtual reality (VR) or mixed reality (MR). AR technology augments a physical world by incorporating additional sensory input including video, sound, or global positioning data [1]. VR technology refers to an interactive computer-simulated environment which transforms the user into completely virtual worlds [2]. MR technology is the combination of AR and VR, which allows users to seamlessly navigate simultaneously across real and virtual environments. With the development of wearable devices, XR technology is rapidly improving the way we interact with the environment around us.

For real-time data transmission, XR traffics have the characteristics of high throughput, low latency, and high reliability requirements [3]. The high requirements of XR services are expected to be addressed by the Fifth Generation (5G) network and beyond, creating the circumstances to promote interactive communication services in a wide scale. A simplified XR system is illustrated in Fig. 1. Since haptic interaction can work in parallel with the acoustic and visual perception, such a system allows users to enter in an immersive virtual world which provides the mental feeling of being in the real world.

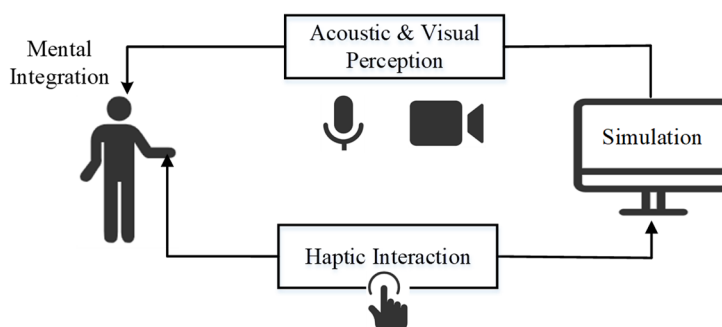


Fig. 1 A simplified XR system

The development of communication services is closely related to the support of standardization activities. Standardization work is also important for industries to eliminate fragmentation and reduce costs. The 3rd Generation Partnership Project (3GPP) is a global mobile telecommunications standards organization which specifies technical reports and technical specifications to promote the development of international communication standard. 3GPP SA WG1 specifies the scenarios, requirements and KPIs, which can be considered as the basis for the whole 3GPP standardization work. 3GPP SA WG2 focus on the network architecture enhancement to support new communication services. Both academia and industry are active in making contributions in these two working groups.

In the standardization of 5G network, 3GPP Release 15 defines the basic network architecture, in which Guaranteed Bit Rate (GBR) QoS Flow and QoS Notification Control (QNC) mechanisms are introduced to guarantee the QoS requirements. Release 16 introduces Alternative QoS Profile (AQP) mechanism to further improve network reliability and reduce latency. Release 17 defines new 5G QoS identifier (5QI), new QoS parameters and new requirements for cloud games, AR/VR and other interactive services. However, current 5G network cannot provide massive throughput, ultra-low latency and extremely high reliability, which are crucial requirements for XR services. In April 2021, 3GPP defined 5G-Advanced as the concept of 5G network evolution. Starting from Release 18, all aspects of the telecommunications industry will gradually improve the framework and enrich the content for 5G-Advanced network. In order to provide immersive and interactive communication capabilities, 3GPP SA WG1 first started the Release 18 study of tactile and multi-modality communication service (TACMM) to introduce new use cases and requirements [4]. Fig. 2 illustrates a multi-modality service with multiple UEs directly connected to 5G network. For a typical TACMM service, there can be multiple modalities such as audio, video, haptic sense and environment perception to ensure best user experience. Based on TACMM study, 3GPP SA WG2 has approved the study on architecture enhancement for XR and media services (XRM) to better support high-throughput, low-latency, and high-reliability media services [5].

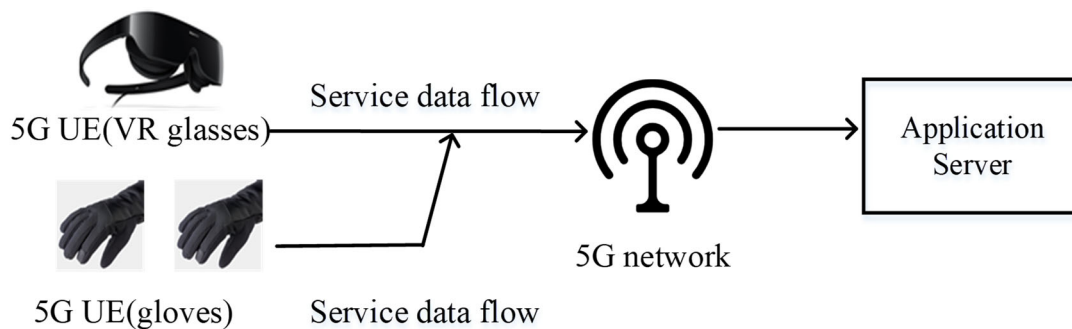


Fig. 2 Multi-modality service with multiple UEs

In this paper, we aim to provide a survey of 3GPP standardization process of XR services. The remainder of the paper is organized as follows. Section II investigates the application sectors that could take advantage of XR services. Then in Section III, we discuss the key points for architecture enhancement in Release 18. Section IV describes the extension of XRM study item in Release 19. In section V, we analyse future technical directions of XR services in 6G network. Finally, conclusions are drawn in Section V.

2. Application sectors

Based on the use cases introduced in TACMM study, the application sectors that could take advantage of XR services arise from many interesting fields such as entertainment, education, healthcare, industry and autonomous driving.

1) Entertainment: Cloud gaming is one of the most common sectors for providing XR services. As of today, many technology companies have developed powerful VR headsets to provide a wide field of view and immersive experience. Compared with traditional games, haptic sense is a very essential part of cloud gaming. The combination of sound, vision and haptic sense enables players to get the feeling that they are part of the game scene. Since future XR envisions ultra-low latency along with ultra-high availability, the transmission efficiency of multi-modal flows can be ensured. The ultra-low latency also allows users to enjoy a multiplayer game that can be played with friends.

2) Education: With the maturing of XR technology, the traditional teacher-centered teaching method will be replaced by the application-centered method. Conventional classroom will evolve into

interactive ones that students can visit places around the world without leaving the classroom. With the help of powerful wearable devices, those who have to study at home can also perform lab practices in a virtual space. This technology can be extended to other educational areas such as museum visits. Visitors can interact with the exhibits and the scenes in a virtual environment, which will improve their understanding and memorizing of the culture behind.

3) Healthcare: An XR system has enormous potential in the healthcare sector. To reduce the risk of high-precision and complex surgery, surgeons can use this technology to simulate the operative method and treatment outcome in advance. Such a system can capture real-time movements of doctors and patients, which allows to perform a remote physical examination and a remote surgery for patients living far away from the hospital. Other than tele-healthcare, an XR system can also be used in psychotherapy and rehabilitation training. Patients can receive tele-virtual reality treatment without physically visiting the hospital. This helps in protecting patient privacy.

4) Industry: With the digital transformation of industry, XR technology has shown its value in the manufacturing field. For example, engineers can accelerate the development process and rapidly exchange views with each other in an immersive environment. With synchronized sound, visual and tactile feedback, operators can obtain real-time guidance and give feedback on performing further operations. In addition, human can use remote control robot to operate some actions that they are unable to be on the spot. Anyway, industries can improve manufacturing efficiency and minimize the risks with XR technology.

5) Autonomous driving: In autonomous driving, traffic information is of great importance for autonomous vehicles. XR interface can benefit the recording and transmitting of real-time traffic information, thus the autonomous vehicles can avoid the traffic jam sections. In addition, the safety of autonomous vehicles has become one of the most concerned problems. With the help of XR services, communication delay among vehicles can be ultra-low to avoid collisions. An XR system can also create a training environment for autonomous vehicles, in which the manufacturers can improve the algorithms using the collected driving behaviour data.

3. Key points for architecture enhancement in 3gpp release 18

XR services have the characteristics of high throughput, low latency, and high reliability, which put forward new requirements for 5G network. According to XRM study item, the objectives of XRM study item in Release 18 include the following aspects [5]:

- Enhancements for supporting multi-modality service: study how to deliver multi-modal flows belong to the same XR services/applications to the user at a similar time.

- Enhancements for supporting network exposure: study how interaction between the application server and 5G system (5GS) is needed for application synchronization, QoS policy coordination, and quick codec/rate adaptation.

- Enhancements considering the characteristics of XR services: application data unit handling, differentiated QoS handling, round-trip latency and jitter need to be considered for traffic transmission.

- Enhancements of power management: considering the traffic pattern of XR services, how to realize power saving.

In this section, the potential enhancements to support XR services are discussed in detail.

3.1 Group QoS coordination

To guarantee user experience, multi-modal flows belong to the same application/service need to be transmitted at a similar time. The typical synchronization thresholds of different media components are illustrated in Table 1 [6].

Table 1. Typical Synchronization Thresholds [6]

Media components	synchronization threshold (note 1)	
audio-tactile	audio delay: 50 ms	tactile delay: 25 ms
visual-tactile	visual delay: 15 ms	tactile delay: 50 ms

Note 1: for each media component, “delay” refers to the case where that media component is delayed compared to the other.

Therefore, coordination among QoS flows within the same group is necessary to satisfy the synchronization thresholds, which can be called group QoS coordination. A group of QoS requirements and the indications indicating which flows belong to the same group and should be provided from the application server to the network. In addition, one or multiple flows within the group may be critical to the user experience. If any critical flows fail to be established or the QoS requirements of any critical flows cannot be fulfilled, the whole application becomes unusable. This knowledge should also be transmitted to the network to ensure optimal QoS fulfilment and resource reservation.

3.2 Network exposure

The characteristic of high throughput may cause rapid data rate fluctuation and may impact the coding efficiency. Additionally, if the application continues high-rate data transmission when the radio link capacity is degraded, there can be congestion in the RAN.

Since the application server has limited capability to detect the data rate and the congestion status, 5G system (5GS) can expose these information to the application server. QoS monitoring mechanism can be used to collect and report these information of different QoS flows. When the data rate measurement or the degree of RAN congestion reaches the report threshold, the network could send a notification to the application server to help adjust its codec and data throughput. Meanwhile, the network can quickly recover to normal state from congestion state.

3.3 Application Data Unit Handling

In current 5GS, the processing of QoS flows is at the IP packet level. However, XR services impose requirements in terms of Application Data Units (ADUs), rather than in terms of packets/Protocol Data Units (PDUs) [7]. As is shown in Fig. 3, an ADU can be a frame consists of multiple IP packets which should be jointly processed by application and require the same QoS treatment.

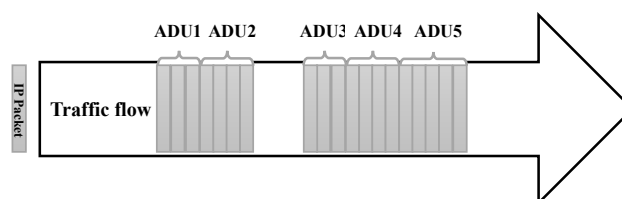


Fig. 3 An example of ADUs

Consequently, new QoS parameters at the ADU level should be introduced to estimate the latency and the reliability. First, 5GS should meet ADU delay budget (ADUDB) which defines an upper bound for the time that an ADU may be delayed between the UE and the N6 termination point at the UPF instead of packet delay budget (PDB) which is less meaningful to the application server. Second, ADU error rates (ADUER) which defines an upper bound for the ratio between the number of ADUs not successfully received and the total number of ADUs sent towards the receiver can be used to set rate adaptation target. With the ADU-level QoS awareness, 5GS can better meet the performance requirements of XR applications.

3.4 Differentiated QoS handling

The QoS model defined in TS 23.501 is shown in Fig. 4. In down-link (DL), the UPF classifies packets based on the DL packet detection rules (PDRs) and then transmits the classified packets belonging to a QoS Flow through an N3 (and N9) user plane marking using a QoS Flow identifier (QFI). The RAN can map QoS flows to RAN resources based on the QFI and the associated QoS profile.

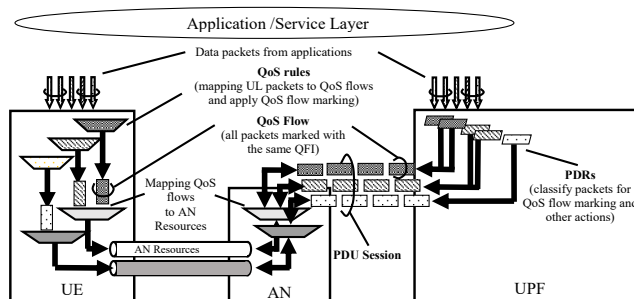


Fig. 4 QoS model defined in TS 23.501 [8]

For XR services, traffic flows usually consists of frames of different importance. For example, for video coding, the first I-frame is selected as the most important frame, P-frames are encoded based on the I-frame, and B-frames are considered as the ones that can be discarded. Therefore, the different importance information can be used in packets classification, QoS flow marking and QoS flow mapping to extend current QoS model. When the most important packets can be successfully detected and transmitted with limited radio resources, 5GS can provide better user experience.

3.5 Round-Trip Latency

The round-trip latency comprises both uplink (UL) latency and downlink (DL) latency. For XR applications, the minimization of round-trip latency is a key issue for real-time interaction. However, UL and DL can transmit different types of multi-modal flows, for example, haptic sense for UL and visual perception for DL. Therefore, UL and DL traffic flows experience different transmission latencies.

To realize UL-DL transmission coordination, 5GS should be adapt to a variable or unequal UL/DL latency. First, the round-trip latency requirements should be provided from the application server to 5GS. Second, the round-trip latency requirements should be split into the UL part and the DL part. Through QoS monitoring, the network can obtain the UL/DL dynamic transmission latency. Based on the monitored UL/DL latency and the round-trip latency requirements, the network can timely adjust the 5QI mapping, the QoS flow binding and the resource scheduling of DL/UL traffic to guarantee the loop latency does not exceed the round-trip latency requirements.

3.6 Jitter

For typical XR scenarios such as cloud gaming and autonomous driving, jitter is an important characteristic which brings challenges to latency compensation and render processing. The less the jitter, the easier for the application layer to perform performance optimization.

To minimize the jitter, 5GS should first know how to calculate the jitter value. With the help of QoS monitoring, the jitter value per QoS flow can be calculated based on the parameters such as packet delay value, measurement period and sample frequency. Meanwhile, the application server can provide the expected jitter value to the network. When the calculated jitter value cannot reach the expected jitter value, the network adjusts the QoS profile to reduce the jitter value until the expectation is reached.

3.7 Power saving

The characteristics of pseudo periodic traffic arrivals, high throughput and low latency bring a lot of challenges in UE power saving. Consequently, UE stays awake for a long period of time and its power consumption can be high.

3GPP has proposed the connected mode discontinuous reception (CDRX) mechanism for UE power saving. This technique allows UE to shut down its device periodically when it is not monitoring for the control channel or receiving/transmitting any information from/to the RAN. For XR traffic, 5G core network (5GC) can send the UL/DL traffic periodicity and the data burst to assist the RAN for CDRX parameter setting.

In addition, some UEs can dynamically switch between a high-power mode and a low-power mode. The high-power mode is configured when the UE requires high throughput and lower latency at the expense of power consumption. While the low-power mode is configured to maximize power savings at the expense of throughput and latency. Therefore, the RAN can provide UE with multiple CDRX configurations or an adaptable CDRX configuration so that the UE can choose to move from one CDRX configuration to another, or may choose to dynamically modify CDRX parameters based on current traffic periodicity and data burst.

4. The extension of xr services in release 19

Metaverse, in which everyone can safely engage in social activities that transcend the limits of the real world, can be regarded as the expansion of XR technology. In Release 19, 3GPP SA WG1 just started the study on localized mobile Metaverse services, which can also be considered as the extension of XR services. This study item is meant to introduce the use cases, scenarios and KPIs for Metaverse services that are associated or applicable only in a particular location, and the focus will be on the local representation of a remote user, and interaction with others. For localized mobile Metaverse services, the following areas are studied [9]:

- Support of interactive XR media shared among multiple users in a single location.
- Identification of users and other digital representations of entities interacting within the Metaverse service.
- Acquisition, use and exposure of local (physical and digital) information to enable Metaverse services.
- Other aspects, such as privacy, charging, public safety and security requirements.

Although Release 18 architecture enhancements for XR services can be considered as the basis for localized mobile Metaverse services, the development of Metaverse standards is still at the initial stage. In the follow-up study, network infrastructure, cyber-reality interface, data management, and application and authentication mechanism are the key aspects that need to be considered.

5. 6g networks for xr services

5G-Advanced evolution is still based on a centralized network architecture. It is predicted that a revolutionary sixth generation (6G) network will be practically implemented by 2030. With the improvement of equipment capabilities, 6G is envisioned as a decentralized and intelligent network, which is shown in Fig. 5. Decentralized technology and artificial intelligence (AI) technology will become a trend for future XR services.

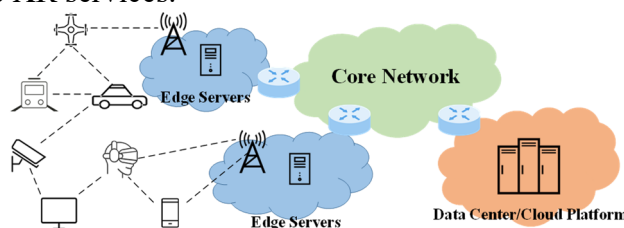


Fig. 5 A simplified decentralized network architecture

5.1 Decentralized architecture

1) Decentralized Computation: In the future, XR applications will become the main body of network traffic and there may be a variety of real-time computing requirements. With the gradual deployment of mobile edge computing (MEC) infrastructures in 5G network, some tasks can now be processed by edge servers. In a decentralized 6G network, the computing tasks can be completed by local terminals, ambient devices or edge/cloud servers instead of dedicated cloud servers. Hence, the computation costs on the server side can be effectively reduced. Since all computing powers can be gathered together to maximize the computing resources scheduling, the computing efficiency of XR services can be improved a lot.

2) Decentralized Storage: In a centralized network, the user-generated data are usually stored in specific cloud servers. This storage mode may result in some potential issues such as data privacy, data security and data access rights. For example, if the central server is hacked, the whole user database may be at risk. In a decentralized network, end-to-end communication will gradually evolve to peer-to-peer communication. User data of XR services will be stored in a decentralized peer-to-peer network, and services will migrate on demand. The users will be confident that the privacy cannot be leaked by the third-party application providers, thus XR services can be more trustful.

5.2 Artificial intelligence technology

AI technology is regarded as one of the most promising technology in 6G network. With the maturity of AI technology, increasing numbers of devices will have native AI functions to assist XR services. For example, when the user puts on an AI-enabled VR headset, this device may capture the user's motions for training, thus the follow-up movements can be predicted.

To support AI-based XR services, current QoS model and policy framework should be further extended to assist XR applications to be informed on the changing data rate, latency and reliability. 5GC should expose more assistant information to the UE to facilitate the model training and inference feedback at the UE side.

Under a decentralized architecture, the training data no longer need to be transmitted to dedicated servers and the model training process can be completed in the decentralized edge servers or devices. Finally, the global AI model can be established by exchanging parameters between the local models.

6. Conclusion

With the development of XR technology, haptic sense can work in parallel with the acoustic and visual perception. Many application sectors could take advantage of XR services to provide immersive and interactive user experience. In 3GPP Release 18, the characteristics of high throughput, high reliability and low latency could be taken into account to support architecture enhancements for XR services. In Release 19, the localized mobile Metaverse services will be provided based on XR services. In future 6G network, the decentralized architecture and AI technology will become a trend to provide better XR services. It is necessary to explore more scenarios and research core standards to promote the development of XR industry.

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