eXtended Reality in 5G

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Khronos & MPEG Workshop, 29-30 September 2021, Electronic Meeting.
Content

- Introduction on 3GPP and 5G
- Definitions around XR
- 5G Media Streaming Architecture and Edge Compute extensions
- Study on Extended Reality on 5G
- XR Traffic characteristics
- Glass-based AR and MR over 5G
3GPP and 5G
5G – brings new growth

Perfect storm of technology trends:

- Availability of a reliable low latency radio and a fully flexible network
- Artificial Intelligence and Automation
- Device revolution for Augmented Reality and Virtual reality
- The Vertical industries going cellular
3GPP 5G Timeline

Release timing

Phases for the normative 5G work:
- Phase 1 (Rel-15) addresses the more urgent subset for commercial deployments
- Phase 2 (Rel-16) Completes the 3GPP IMT 2020 submission (ITU-R) and addresses all identified use cases & requirements...
- Release 17 brings enhancements to 5G
- Release 18 is also known as “5G-Advanced”
Three stage approach / SA4

Stage 1
Requirements: Overall service description from the user’s standpoint.

SA1 Requirements

Stage 2
Architecture: Overall description of the organization of the network functions to map service requirements into network capabilities.

SA2 Architecture

Stage 3
Protocols: The definition of switching and signalling capabilities needed to support services defined in Stage 1.

SA4 Multimedia Codecs, Systems and Services

SA6 Mission critical apps

RAN WGs
QoS/X-layer optimizations/advanced media-types

CT – Protocols & Coding

3GPP SA WG4 (SA4) is responsible for the specification of codecs for speech, audio, video, graphics and other media types related to traditional and emerging media services such as extended reality (XR) and online gaming, as well as the system and delivery aspects of such content.

SA4 specifies the content formats and delivery protocols as well as associated quality assessments, metrics and requirements for a broad range of scenarios, and the use of artificial intelligence and machine learning models for multimedia.
3GPP XR related activities


2019: Rel-17 – 3GPP SA1 - Stage 1 – Service requirements evaluated by 3GPP SA1 in 3GPP TR 22.842 on Network Controlled Interactive Service (NCIS) including e.g. VR and Cloud gaming and new service requirements defined in in 3GPP TS 22.261 (5G Service requirements).

2020: Rel-16 - 3GPP SA4 Study on eXtended Reality (XR) in 5G (FS_5GXR) documented in TR 26.928.

2020: Rel-17 – 3GPP SA2 - Stage 2 - 5G System Enhancement for Advanced Interactive Services (5G_AIS) resulted in New standardized 5QI values for Advanced Interactive Services in 3GPPP TS 23.502.

2021: Rel-17 – 3GPP SA4 Study on Typical Traffic Characteristics for XR Services and other Media (FS_XRTraffic) documented as addition to existing TR 26.925. To be used in support of 3GPP RAN1 activities and to be completed in Dec. 2021.

2021: Rel-17– 3GPP RAN1 Study on XR (Extended Reality) evaluations for NR (‘New Radio’). To be completed Dec. 2021: considerations on device power consumption, capacity, coverage and mobility.

### New 5QIs

Table 5.7.4-1: Standardized 5QI to QoS characteristics mapping

<table>
<thead>
<tr>
<th>5QI Value</th>
<th>Resource Type</th>
<th>Default Priority Level</th>
<th>Packet Delay Budget (NOTE 3)</th>
<th>Packet Error Rate</th>
<th>Default Maximum Data Burst Volume (NOTE 2)</th>
<th>Default Averaging Window</th>
<th>Example Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>87</td>
<td>25</td>
<td>5 ms (NOTE 4)</td>
<td>$10^{-3}$</td>
<td>500 bytes</td>
<td>2000 ms</td>
<td></td>
<td>Interactive Service - Motion tracking data, (see TS 22.261 [2])</td>
</tr>
<tr>
<td>88</td>
<td>25</td>
<td>10 ms (NOTE 4)</td>
<td>$10^{-3}$</td>
<td>1125 bytes</td>
<td>2000 ms</td>
<td></td>
<td>Interactive Service - Motion tracking data, (see TS 22.261 [2])</td>
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<tr>
<td>89</td>
<td>25</td>
<td>15 ms (NOTE 4)</td>
<td>10-4</td>
<td>17000 bytes</td>
<td>2000 ms</td>
<td></td>
<td>Visual content for cloud/edge/split rendering (see TS 22.261 [2])</td>
</tr>
<tr>
<td>90</td>
<td>25</td>
<td>20 ms (NOTE 4)</td>
<td>10-4</td>
<td>63000 bytes</td>
<td>2000 ms</td>
<td></td>
<td>Visual content for cloud/edge/split rendering (see TS 22.261 [2])</td>
</tr>
</tbody>
</table>
Definitions

« Extended reality (XR) refers to all real-and-virtual combined environments and associated human-machine interactions generated by computer technology and wearables. It includes representative forms such as augmented reality (AR), mixed reality (MR), and virtual reality (VR) and the areas interpolated among them» (TR 26.928)

Virtual reality (VR) is a rendered version of a delivered visual and audio scene;

Augmented reality (AR) is when a user is provided with additional information or artificially generated items or content overlaid upon their current environment;

Mixed reality (MR) is an advanced form of AR where some virtual elements are inserted into the physical scene with the intent to provide the illusion that these elements are part of the real scene.
5G Media Streaming (5GMS)
5G Media streaming architecture
Potential Edge computing extensions
Study phase XR architecture mapping
Study on eXtended Reality (XR) in 5G
FS_5GXR
Initial study on XR over 5G

Study:
• Define Extended Reality and Terms in 3GPP, including quality-of-experience with XR services
• Collects the technologies in the context of XR and their potential relation to 5G System
• **Collects 23 use cases in the context of XR and 5G** that are analyzed in terms of potential specification needs
• Breaks down the use cases in architectures, functions and interfaces
• Create **specific conclusions on normative work in Rel-17**
• Support other 3GPP groups on the definition of system and radio specifications for XR

Detailed Technical Report completed in March 2020
• TR 26.928: [http://www.3gpp.org/ftp//Specs/archive/26_series/26.928/26928-g00.zip](http://www.3gpp.org/ftp//Specs/archive/26_series/26.928/26928-g00.zip)

The first comprehensive output from 3GPP on XR – Rel-16 (!).
Terms and Definitions

- **3DOF**: Yaw, Pitch, Roll
- **3DOF+**: Yaw, Pitch, Roll, Forward, Backward, Left, Right
- **6DOF**: Yaw, Pitch, Roll, Forward, Backward, Left, Right
- **Windowed 6DOF**: Yaw, Pitch, Roll, Forward, Backward, Left, Right

- **Presence**
- **Tracking**
- **Meshes**
- **SLAM**
- **Point Cloud**
- **Time Warp**
<table>
<thead>
<tr>
<th>No</th>
<th>Use Case</th>
<th>Type</th>
<th>Experience</th>
<th>Delivery</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3D Image Messaging</td>
<td>AR</td>
<td>3DoF+, 6DoF</td>
<td>Upload and Download</td>
<td>Phone</td>
</tr>
<tr>
<td>2</td>
<td>AR Sharing</td>
<td>AR, MR</td>
<td>6DoF</td>
<td>Local, Messaging Download and Upload</td>
<td>Phone</td>
</tr>
<tr>
<td>3</td>
<td>Streaming of Immersive 6DoF</td>
<td>VR</td>
<td>3DoF+, 6DoF</td>
<td>Streaming, Interactive, Split</td>
<td>HMD with a controller</td>
</tr>
<tr>
<td>4</td>
<td>Emotional Streaming</td>
<td>2D, AR and VR</td>
<td>2D, 3DoF+, 6DoF</td>
<td>Streaming, Interactive, Split</td>
<td>Phone and HMD</td>
</tr>
<tr>
<td>5</td>
<td>Untethered Immersive Online Gaming</td>
<td>VR</td>
<td>6DoF</td>
<td>Streaming, Interactive, Split</td>
<td>HMD with a Gaming controller</td>
</tr>
<tr>
<td>6</td>
<td>Video Game Live Streaming</td>
<td>VR</td>
<td>6DoF</td>
<td>Streaming, Split</td>
<td>2D screen or HMD with a controller</td>
</tr>
<tr>
<td>7</td>
<td>Real-time 3D Communication</td>
<td>3D, AR</td>
<td>3DoF+</td>
<td>Conversational</td>
<td>Phone</td>
</tr>
<tr>
<td>8</td>
<td>AR guided assistant at remote location (industrial services)</td>
<td>2D video + AR</td>
<td>6DoF (2D + AR)</td>
<td>Local, Streaming, Interactive,</td>
<td>5G AR Glasses, 5G touchscreen computer or tablet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Conversational</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Police Critical Mission with AR</td>
<td>AR, VR</td>
<td>3DoF to 6DoF</td>
<td>Local, Streaming, Interactive,</td>
<td>5G AR Glasses/Helmet, VR camera/microphone, Audio stereo headset, 5G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Conversational, Group Communication</td>
<td>accurate positioning</td>
</tr>
<tr>
<td>10</td>
<td>Online shopping from a catalogue – downloading</td>
<td>AR</td>
<td>6DoF</td>
<td>Download</td>
<td>AR Glasses, Rendering system, Tablet (or smartphone), Capture device</td>
</tr>
<tr>
<td>11</td>
<td>Real-time communication with the shop assistant</td>
<td>AR</td>
<td>6DoF</td>
<td>Interactive, Conversational</td>
<td>AR Glasses, Rendering system, Tablet (or smartphone), Capture device</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>360-degree conference meeting</td>
<td>AR, MR, VR</td>
<td>3DoF</td>
<td>Conversational</td>
<td>Mobile / Laptop</td>
</tr>
<tr>
<td>13</td>
<td>3D shared experience</td>
<td>AR, MR, VR</td>
<td>3DoF+</td>
<td>Conversational</td>
<td>Mobile / Laptop</td>
</tr>
<tr>
<td>14</td>
<td>6DOF VR conferencing</td>
<td>VR</td>
<td>6DoF</td>
<td>Interactive, Conversational</td>
<td>VR gear with binaural playback and HMD video playback, Call server</td>
</tr>
<tr>
<td>15</td>
<td>XR Meeting</td>
<td>AR, VR, XR</td>
<td>6DoF</td>
<td>Interactive Conversational</td>
<td>Phone, HMD, Glasses, headphones</td>
</tr>
<tr>
<td>16</td>
<td>Convention / Poster Session</td>
<td>AR, VR, MR</td>
<td>6DoF</td>
<td>Interactive, Conversational</td>
<td>Phone, HMD, AR Glasses, VR controller/pointing device, headphones</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>AR animated avatar calls</td>
<td>AR</td>
<td>2D, 3DoF</td>
<td>Conversational</td>
<td>Phone, HMD, Glasses, headphones</td>
</tr>
<tr>
<td>18</td>
<td>Online shopping from a catalogue – downloading</td>
<td>AR</td>
<td>6DoF</td>
<td>Download</td>
<td>AR Glasses, Rendering system, Tablet (or smartphone), Capture device</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Front-facing camera video multi-party calls</td>
<td>AR</td>
<td>3DoF</td>
<td>Conversational</td>
<td>Smartphone with front-facing camera, headset</td>
</tr>
<tr>
<td>20</td>
<td>AR Streaming with Localization Registry</td>
<td>AR, Social AR</td>
<td>6DoF</td>
<td>Streaming, Interactive, Conversational</td>
<td>AR glasses with binaural audio playback support</td>
</tr>
<tr>
<td>21</td>
<td>Immersive 6DoF Streaming with Social Interaction</td>
<td>VR and Social VR</td>
<td>3DoF+</td>
<td>Streaming, Interactive, Conversational, Split</td>
<td>HMD with a controller</td>
</tr>
<tr>
<td>22</td>
<td>5G Online Gaming Party</td>
<td>VR</td>
<td>6DoF</td>
<td>Streaming, Interactive, Split, D2D</td>
<td>HMD with a Gaming controller</td>
</tr>
<tr>
<td>23</td>
<td>Spatial Shared Data</td>
<td>AR</td>
<td>6DoF</td>
<td>Streaming, Interactive, Conversational</td>
<td>HMD, AR Glasses</td>
</tr>
</tbody>
</table>
Device types
Latencies and Delays

The roundtrip interaction delay is therefore the sum of the Age of Content and the User Interaction Delay.

- **User interaction delay** is defined as the time duration between the moment at which a user action is initiated and the time such an action is taken into account by the content creation engine.
- **Age of content** is defined as the time duration between the moment a content is created and the time it is presented to the user.

**Latency Requirements**

- Ultra-Low-Latency applications: roundtrip interaction delay threshold of at most **50ms latency**.
- Low-Latency applications: roundtrip interaction delay threshold of at most **100ms latency**.
- Moderate latency applications: roundtrip interaction delay threshold of at most **200ms latency**.
- Non-critical latency applications: roundtrip interaction delay threshold higher than 200ms latency.

Details in Clause 4.2.2 of TR 26.928
Split Rendering Architecture

Example: Split Rendering

XR Server

- XR Scene Generation
- XR Viewport Pre-Rendering Rasterization

5G Delivery

2D Media Encoding

XR Media Content Delivery

"Edge" -> 5G NR

5G Delivery

2D Media for pre-rendered viewport

Tracking and Sensor Information

XR Device

- 3DOF/6DOF Tracking and XR Sensors
- XR Viewport Rendering (ATW only)
- XR Media Content Delivery
- 2D Media Decoders

Display

MPEG-Khronos Workshop: Streamed Media in Immersive Scene Descriptions
In the short-term:

- Develop a flexible XR centric device reference architecture as well as a collection of device requirements and recommendations for XR device classes based on the considerations in clause 7.2. Device classes should include VR device for 6DoF streaming and XR online gaming (XR5G-V4), as well as AR devices (XR5G-A1, XR5G-A4 and XR5G-A5) => FS_5GSTAR
- Develop a framework and basic functionalities for Single-Buffer Split Rendering for Online Gaming according to the considerations in clause 7.4 => FS_EMSA
- Document typical XR traffic characteristics in TR26.925 based on the initial considerations in this report, in particular clause 7.7 and support other 3GPP groups in designing systems for XR services and applications => FS_XRTraffic
- Address simple extensions to MTSI to support basic XR conversational services based on the considerations in clause 7.5 => Ongoing work item ITT4RT
- Study detailed functionalities and requirements for glass-type AR/MR UEs with standalone capability according to clause 7.6 => FS_5GSTAR
Study on Typical Traffic Characteristics for XR Services and other Media
FS_XRTraffic
Background

Activity launched in May 2020.

The objective of the study includes:

• Collect and document traffic characteristics including for different services, but not limited to
  • Downlink data rate ranges
  • Uplink data rate ranges
  • Maximum packet delay budget in uplink and downlink
  • Maximum Packet Error Rate,
  • Maximum Round Trip Time
  • Traffic Characteristics on IP level in uplink and downlink in terms of packet sizes, and temporal characteristics. XR Services and Cloud Gaming based on the initial information documented in TR26.928 including.

• Provide the information from above including the following services
  • Simple Single Buffer split rendering for online cloud gaming
  • Cloud Gaming
  • Other Traffic Models

Why is it not trivial to obtain such numbers?
Study on 5G Glass-type AR/MR Devices

FS_5GSTAR
Study context and objectives

Study launched in July 2020 with the following objectives

- Provide formal definitions for the functional structures of AR glasses,
- Describe key use cases for AR services over 5G based on in TR 26.928.
- Describe the architecture for media flow relevant to the use cases.
- Identify media (exchange) formats and profiles and where media processing functions occur.
- Identify necessary content delivery transport protocols and capability exchange mechanisms.
- Identify key performance indicators and quality of experience factors.
- Identify relevant radio and system parameters (required bitrates, latencies, loss rates, range, etc.) to support the identified AR use cases and the required QoE.
### Glass type devices

<table>
<thead>
<tr>
<th>Device Type Name</th>
<th>Reference</th>
<th>Tethering</th>
<th>5G Uu Modem</th>
<th>Basic AR Functions</th>
<th>AR/MR Functions</th>
<th>AR/MR Application</th>
<th>Power Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>5G Standalone AR UE</td>
<td>1: STAR</td>
<td>N/A</td>
<td>Device</td>
<td>Device</td>
<td>Device/Split 1)</td>
<td>Device</td>
<td>Device</td>
</tr>
<tr>
<td>5G EDGE-Dependent AR UE</td>
<td>2: EDGAR</td>
<td>N/A</td>
<td>Device</td>
<td>Device</td>
<td>Split 1)</td>
<td>Cloud/Edge</td>
<td>Device</td>
</tr>
<tr>
<td>5G WireLess Tethered AR UE</td>
<td>3: WLAR</td>
<td>802.11ad, 5G sidelink, etc.</td>
<td>Tethered device (phone/puck)</td>
<td>Device</td>
<td>Split 2)</td>
<td>Tethered device</td>
<td>Device</td>
</tr>
<tr>
<td>5G Wired Tethered AR UE 3)</td>
<td>4: WTAR</td>
<td>USB-C</td>
<td>Tethered device (phone/puck)</td>
<td>Tethered device</td>
<td>Split 2)</td>
<td>Tethered device</td>
<td>Tethered device</td>
</tr>
</tbody>
</table>

1) Cloud/Edge  
2) Phone/Puck and/or Cloud/Edge  
3) Not considered in this document
## Use cases for Glass-based AR

<table>
<thead>
<tr>
<th>No</th>
<th>Use Case</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>3D Image Messaging</td>
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<td>AR Streaming with Localization Registry</td>
</tr>
<tr>
<td>15</td>
<td>5G Shared Spatial Data</td>
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<tr>
<td>16</td>
<td>AR remote cooperation</td>
</tr>
<tr>
<td>17</td>
<td>AR remote advertising</td>
</tr>
<tr>
<td>18</td>
<td>Streaming of volumetric video for glass-type MR devices</td>
</tr>
<tr>
<td>19</td>
<td>AR Conferencing</td>
</tr>
<tr>
<td>20</td>
<td>AR IoT</td>
</tr>
</tbody>
</table>
Mapping to the 5G architecture

5G STAR UE

AR Data

AR Scene Manager

Scene Graph Handler

Compositor

Immersive Visual Renderer

Immersive Audio Renderer

AR Runtime

Display

Sensors

Cameras

User Input

AR Data

Media Session Handler

2D Codecs

Immersive Media Decoders

Content Delivery

Media Client

Media Access Functions

5G System (Uu)

Media AF

5G System (gNB)

Media AS

5G System (Server and Compute)

AR/MR Application Provider

AR Scene

Vision Engine/SLAM

Pose Correction

Soundfield Mapping

© 3GPP 2021
Mapping to the 5G architecture

5G EDGAR UE

Cloud/Edge

AR Runtime

Vision Engine/SLAM
Pose Correction
Soundfield Mapping

AR Data

Display

Speakers

User Input

Basic AR/MR Application

Media Session Handler (incl. Edge)

Scene Description Delivery
Content Delivery
Basic Codes

Media Client

Lightweight Scene Manager

Compositor

AR Scene Manager

Immersive Audio Renderer

AR Functions

AR Scene Manager

Setting the 5G architecture

Media Access Function

Content Delivery

Decoders

Scene Description

Media AF

Scene Graph Generator

Immersive Visual Renderer

Immersive Audio Renderer

AR Functions

AR/ MR Application Provider

Media Assets

Semantical Perception

Social Integration

Content Delivery

5G System (Uu)

5G System (Uu)

M4

M5

M8
Still to be done

- Refine the procedures and call flows
- Complete the identification of the content formats and codecs
- List the KPIs and relevant QoE parameters
- Connect with the study on Streaming Architecture extensions For Edge processing (FS_EMSA)
Next steps in XR
Release 18 - 5G Advanced
SA4 Rel-18 Workshop (17th August 21)

- **New Immersive media types and formats definition**
  - 5G video codec & IVAS codec (including ATIAS, Multimedia telephony/MTSI/System support)
  - New media including AR/MR media and sensory input (e.g. Haptics)
  - QoE metrics for these new media types
  - AI-based media enhancements

- **XR (AR/VR/MR and Cloud Gaming) Services**
  - Desire for a unified framework to support all such new services on 5G Core/RAN/UE
  - Should enable collaboration between MNOs and third-party service providers, support OTT services in 5G, follow 5G Media streaming example
  - Unified framework proposed: 5G-RTC architecture
  - For conversational service, consider MTSI extension (DC-MTSI)

- **Media Distribution enhancements**
  - Universal Access / Free to Air
  - Hybrid/Unicast/Broadcast/Multicast media delivery improvements as appropriate
  - Enhancing quality of traditional media (e.g. 2D video with UHD HDR, 8K)
  - Media handling of Personal IoT networks

- **Support Architecture evolutions**
  - Uplink enhancements : A/V Production, Media Contribution
  - Edge Compute: split rendering, network-based media processing

- **Approaches for Rel-18**
  - Focus on 5GMS adoption and stability
  - Establish a consistent Rel-18 plan to address 5G-Advanced service requirements
  - Make sure we focus on commercially relevant features
  - Provide implementation support: Tooling/Software/Interop
  - Leverage deployed multimedia technologies
  - Proposal under discussion to define a Service Media Enabler framework
New Immersive media types and formats definition

- 5G-Advanced video coding (TBD)
- FS_5GVideo (Feasibility Study on 5G Video Codec Characteristics)
- 8K_VR_5G/8K_TV_5G
- IVAS codec / ATIAS / MTSI & System updates
- FS_5GSTAR
- SA1 FS_AMMT
- SA1 FS_TACMM

- New media format for AR/MR (TBD)
- AI/ML model transfer Stage 3 (TBD)
- Feasibility Study on AI/ML Media (TBD)
- Tactile communications Stage 3 (TBD)
XR (AR/VR/MR and Cloud Gaming) Services

- XR QoS, QoE Quality metrics, Split-rendering (TBD)
- XR real-time communications: 5G-RTC (TBD)
- 2D/VR/AR/MR streaming (TBD)
- MTSI extension for XR conversational, ITT4XR (TBD)
Media distribution enhancement & Architecture evolution

5GMS_EDGE (Edge Extensions to the 5G Media Streaming Architecture)
5MBUSA (5G Multicast-Broadcast User Service Architecture and related 5GMS Extensions)
FS_5GMS_EXT (Study on 5G media streaming extensions)
5GMS AF Event Exposure (EVEX)
FS_NPN4AVProd (Feasibility Study on Media Production over 5G NPN)
SA1 FS_PIN

5GMS EDGE, COPE stage 3, Split-rendering (TBD)
Further MBS enhancements: FTA (TBD)
5GMS extensions (TBD): Low latency, Back channel, Slicing...
NPN4AVPROD Stage 3 / 5GMS Uplink Enhancements / APEX (TBD)
Media handling of Personal IoT Networks Stage 2/3 (TBD)
Thank You!

Next steps

- 2nd SA4 Rel-18 workshop (tentative: 3rd Nov. 2021)
  • For collecting more inputs
  • For adding details of identified items
  • Identify the priorities as a result

- 60% agreed Rel-18 plan at SA4#116-e (Nov. 2021)

- 100% agreed Rel-18 plan at SA4#117-e (Feb. 2022)

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Focus on 3GPP SA4
Focus on XR-related activities

Extended Reality (XR) on 5G

2020

- Glass-based AR/MR services
- Study on Streaming Architecture extensions For Edge processing
- Traffic characteristics for XR media
- 3GPP 8K VR Profile for Streaming Media (Release 17)

2021

- Codec for Immersive Voice and Audio Services - IVAS (Release 17)
- Immersive Teleconferencing and Telepresence for Remote Terminals (Release 17)

2022

- Normative Work?
- Study Item
- Work Item

Release 17
Stage 3