Agenda

1. **5G vision and status**
   A unified, more capable air interface for the next decade and beyond

2. **5G NR and System design and technologies**
   Based on the 3GPP Release-15 global standard

3. **5G evolution and expansion**
   Rel-16 and beyond

4. **Media and Broadcast in 5G**
   What is happening in the media context?
5G Vision and Status

3GPP Release-15
Leading mobile innovation for over 30 years

Digitized mobile communications
   Analog to digital

Redefined computing
   Desktop to smartphones

Transforming industries
   Connecting virtually everything at the wireless edge

Transforming how the world connects, computes and communicates
Mobile has made a leap every ~10 years

Mobile voice communication

1980s
Analog voice
AMPS, NMT, TACS

1990s
Digital voice
D-AMPS, GSM, IS-95 (CDMA)

2000s
Wireless Internet
CDMA2000/EV-DO WCDMA/HSPA+

2010s
Mobile broadband
LTE, LTE Advanced, Gigabit LTE

2020s
Wireless Edge
5G New Radio (NR)

Efficient voice to reach billions

Focus shifts to mobile data

Mobile broadband and emerging expansion

A unified future-proof platform
A unifying connectivity fabric for society
Like electricity, you will just expect it everywhere

- Multi-gigabit speed
- Scalable to extreme simplicity
- Ultra-low latency
- Virtually unlimited capacity
- On-device intelligence
- Extreme reliability

Scalable to extreme simplicity
Delivering on the 5G vision
Where virtually everyone and everything is intelligently connected
A new kind of network to drive innovation and growth

- Significant connectivity upgrade
- Smartphone tech extending into many industries
- Consumers want 5G smartphones
5G will address the insatiable demand for mobile broadband

Over 60x growth in mobile data traffic from 2013 to 2024

~131B Gigabytes
Monthly global mobile data traffic in 2024

In 2024, ~75% of mobile data traffic from multi-media creation & consumption

In 2024, 25% of mobile data traffic will be carried by 5G networks – 1.3x more than 4G/3G/2G traffic today

Source: Ericsson Mobility Report June 2019
5G is essential for next generation mobile experiences

- Fiber-like data speeds
- Low latency for real-time interactivity
- More consistent performance
- Massive capacity for unlimited data

Mobilizing media and entertainment
Rich user-generated content
Congested environments
High-speed mobility
Connected cloud computing
Immersive experiences
Connected vehicle
Augmented reality

5G
5G NR is a unified, more capable air interface

Diverse services

- Enhanced mobile broadband
- Mission-critical services
- Massive Internet of Things

Diverse spectrum

- Low-bands: Below 1 GHz
- Mid-bands: 1 GHz to 6 GHz
- High-bands: Above 24 GHz (mmWave)

Diverse deployments

10x Decrease in end-to-end latency
10x Experienced throughput
3x Spectrum efficiency
100x Traffic capacity
100x Network efficiency
10x Connection density

Based on ITU vision for IMT-2020 compared to IMT-advanced; URLLC: Ultra Reliable Low Latency Communications; IAB: Integrated Access & Backhaul
Driving the 5G expansion

Future-proof platform

Delivering on the 5G vision

Rel-16 commercialization
Rel-17 commercialization
Rel-18+ evolution

Continue expansion to new verticals, deployments, use cases, spectrum

LTE essential part of the 5G platform

2019 eMBB
- Global smartphone launches
- Fixed wireless access

2020 eMBB expansion
- Beyond smartphone (PC, FWA, ...)
- New markets/regions
- Nationwide coverage & SA migration

Longer term expansion
- Industrial IoT, enterprise, automotive network
- Private networks
- Unlicensed spectrum

1. 3GPP start date indicates approval of study package (study item > work item > specifications), previous release continues beyond start of next release with functional freezes and ASN.1
Comparison of Year 1 announcements

4G: 4 Operators launched
3 OEMs launched

5G: 40+ Operators launching
40+ OEMs launching
5G smartphones

- Lenovo Z6 Pro 5G
- LG V50 ThinQ 5G
- Motorola moto z4/z3 + 5G moto mod
- Nubia Mini 5G
- OnePlus 7 Pro 5G
- OPPO Reno 5G
- Samsung Galaxy S10 5G
- Samsung Galaxy Fold

- Samsung Galaxy Note10+ 5G
- Samsung A90 5G
- Vivo iQOO 5G Edition
- Vivo NEX 3 5G
- Xiaomi Mi MIX 5G
- Xiaomi Mi MIX Alpha
- Xiaomi Mi 9 Pro 5G
- ZTE Axon 10 Pro 5G

Hotspots and CPEs

- Askey
- Inseego
- HTC
- Netcomm
- Netgear
- Nokia
- WNC
- ZTE

5G modules

- Compal
- Fibocom
- Longsung
- Quectel
- Sierra
- Wireless
- SIMcom
- Telit

Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.
5G NR design and technologies

3GPP Release-15
Expanding 5G with the flexible slot-based framework

Efficient multiplex envisioned and future 5G services on the same frequency

**Scalable slot duration**
Efficient multiplexing of diverse latency and QoS requirements

**Forward compatibility**
Transmissions well-confined in freq/time to simplify adding new future features

**Self-contained slot structure**
Ability to independently decode slots and avoid static timing relationships across slots

**Nominal traffic puncturing**
To enable URLCC transmissions to occur at any time using mini-slots
Scalable 5G NR slot duration for diverse latency/QoS

14 OFDM symbols per slot with mini-slot (2, 4, or 7 symbols) for shorter transmissions\(^1\)

Supports slot aggregation for data-heavy transmissions

Efficient multiplexing of long and short transmissions\(^2\)

---

1. As low as two symbols per mini-slot; 2. Symbols across numerologies align at symbol boundaries and transmissions span an integer # of OFDM symbols
5G NR optimized design for massive MIMO

Key enabler for using higher spectrum bands, e.g. 4 GHz, with existing LTE sites

- Exploit 3D beamforming with up to 256 antenna elements
- Accurate and timely channel knowledge essential to realizing full benefits
- Mitigate UL coverage with 5G NR massive MIMO + HPUE

Enabled through an advanced 5G NR end-to-end Massive MIMO design (network and device)

- Optimized design for TDD reciprocity procedures utilizing UL SRS
- Enhanced CSI-RS design and reporting mechanism
- Advanced, high-spatial resolution codebook supporting up to 256 antennas
- New features, such as distributed MIMO

New frontier of mobile broadband – mobilizing mmWave

Multi-Gbps data rates
With large bandwidths (100s of MHz)

Much more capacity
With dense spatial reuse

Lower latency
Bringing new opportunities
Rich media and entertainment for outdoor – augmenting lower bands

More indoor capacity as outdoor mmWave offloads outdoor lower bands

Massive bandwidth for cloud computing

Virtually lag-less experiences – e.g., multiplayer gaming

Dense indoor & outdoor connectivity for venues

New indoor opportunities – e.g., connected enterprises

Fiber-like broadband to the home — fixed mmWave

Beyond smartphones – e.g., smart manufacturing

5G NR mmWave will support new and enhanced mobile experiences

- Fiber-like data speeds
- Low latency for real-time interactivity
- Massive capacity for unlimited data plans
- Lower cost per bit
Showcasing enhanced mobile mmWave user experiences

Advanced Network Simulations
Deploying 28 GHz 5G NR mobile mmWave at Mobile World Congress venue

Ubiquitous coverage via co-siting
Virtually unlimited capacity
Multi-Gbps speed & low latency
More uniform user experience

For a wide range of mobile devices:

Simulation assumes 5G NR mmWave co-siting at actual LTE DAS locations in Fira Gran Via Hall 3, uses 800 MHz spectrum in 28 GHz, and is based on Qualcomm engineering simulation tools.
5G System design and technologies

3GPP Release-15
Non-Standalone (NSA) stepping stone to new core

Fast-to-launch | VoLTE & CS voice

Standalone (SA) for new core benefits

NFV and SDN | VoNR & fallback to VoLTE

5G sub-6GHz

Data and control over 5G NR link

Dual connectivity

4G Radio Network

Data + control over 4G LTE link

5G mmWave and/or sub-6GHz

5G mmWave

Carrier Aggregation

New 5G Next Gen Core

5G sub-6GHz

Data only over 5G NR link

4G Evolved Packet Core

Data only over 5G NR link
5G next Gen Core (NGC) also part of 3GPP Rel-15

Increased flexibility through NFV and SDN – essential to 5G NR expansion

NFV: Network Functions Virtualization; SDN: Software Defined Networking

- Mobile broadband
- Mission-critical control
- Internet of Things

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<th>Flexible biz models and deployments</th>
<th>Dynamic creation of services</th>
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<td>Modular, specialized network functions per service</td>
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<td>Flexible subscription models</td>
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<td>Dynamic control and user planes with more functionality at the edge</td>
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</table>
5G opens door for new Radio Area network (RAN) architecture

Traditional RAN
- The more you distribute
  - Lower front-haul requirements
  - Simplifies support for applications such as IoT and mmWave

Virtual RAN (VRAN)
- The more you centralize
  - Ease of software upgradability
  - Lower investments
  - More scalable

5G
5G Network based on vRAN

Designed for extremely flexible and cost-effective network deployments
5G NR mobility enhancements in 3GPP Release 16+
Delivering higher bandwidth, lower latency, and improved reliability during mobility

Release 15 baseline
Intra and inter RAT\(^1\) handover that enables high-bandwidth, low-latency, and reliable connectivity during mobility

Enhancements proposed for Rel-16
Faster DC/CA access\(^2\), reduced mobility interruption to 0ms\(^3\), faster recovery in failover\(^4\), improved coverage and power consumption

Further enhancements
Enabling independent UL/DL operation, device-centric mobility, extending DC beyond 2 DUs, and further power savings

---

1 Radio Access Technology; 2 Early measurement reporting; 3 With conditional handover; 4 Dual-connectivity role switch and split SRBs;
5G NR standards compliant
Sub-6 + mmWave
Premium-tier smartphones in 2019
A feasible use case for mmWave that provides expedited and low-cost deployment to replace fiber
5G mmWave Fixed Wireless Access

Urban and dense urban deployment

Coverage of up to 1.1 Km distance from base station in urban area with minimum 50 Mbps data rate

Based on CPE height at 6m above ground, 400MHz on 28 GHz, 7:1 TDD Config, light foliage.
5G mmWave Fixed Wireless Access

Rural / suburban deployment

Coverage of up to 1.7 Km distance from base station in rural area with minimum 50 Mbps data rate

Based on CPE height at 6m above ground, 400MHz bandwidth on 28 GHz, 7:1 TDD Config, light foliage.
5G system brings enhanced security and privacy
Building on the proven, solid security foundation of 4G LTE

Flexible framework
To support new devices, use cases, and deployments

Tighter security
To expand protection and increase flexibility

Enhanced privacy
To eliminate communication of unprotected device-specific information

Unified authentication for 3GPP & non-3GPP access (e.g., Wi-Fi), security anchor function, and network slicing

Added user plane integrity protection; lower trust in serving networks to allow for flexible deployment; subscription credentials can be stored in secure hardware element

User permanent identity (e.g., IMSI\(^1\)) and device-specific information are ciphered before being exchanged over the air

1. International Mobile Subscriber Identity

Content Protection
(Laurent Piron, Nagra)
5G evolution and expansion

3GPP Release-16 and beyond
5G NR is expanding to new use cases and verticals
Ongoing innovation through 5G releases

Enhancing broadband and enabling new verticals

5G Release 17+

- High-precision positioning
- Direct communication
- Mission-critical design
- New deployment models

5G Release 16: building upon and expanding the foundation

- Advanced power saving and mobility
- Unlicensed spectrum

5G Release 15: foundations of 5G

- 4G foundations

Continuing pipeline of high value, foundational IP

- Smartphones and beyond
- Automotive
- Fixed Wireless and enterprise
- Industrial IoT
### Continued evolution to deliver on the 5G vision

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<th>Rel-16</th>
<th>Rel-17: Likely candidates</th>
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<td>Established 5G NR technology foundation</td>
<td>Expanding to new use cases and industries</td>
<td>Continued expansion and enhancements</td>
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#### Initial focus: eMBB – enhanced mobile broadband services
- Initial focus: eMBB – enhanced mobile broadband services
- 5G core network
- 5G NR IIoT with eURLLC
- 5G NR Cellular V2X
- 5G NR in unlicensed spectrum
- Enhancements to 5G NR IIoT
- Expand sidelink e.g., V2X reliability, P2V, IoT relay
- Unlicensed spectrum across all use cases
- Positioning across use cases
- Continuous evolution to deliver on the 5G vision

#### Advanced channel coding
- Advanced channel coding
- Sub-6 GHz with massive MIMO
- LTE integration
- 5G broadcast
- 5G massive IoT
- Positioning across use cases
- New spectrum above 52.6 GHz
- NR-Light e.g., wearables, industrial sensors
- Centimeter accuracy e.g., IIoT with mmWave

#### Mobile mmWave
- Mobile mmWave
- Scalable OFDM-based air interface
- Flexible framework
- eMBB evolution
- IAB – integrated access/backhaul
- Continuation of Rel-15 projects, others
- Continued eMBB enhancements
- More capable, flexible IAB
- Rel-15 deployment learning, XR, drones, others

#### Source sample text
- Expanding to new use cases and industries
- Continued expansion and enhancements
5G is a connectivity fabric for virtually everything
On-device AI use-cases today
But we can do more with 5G
On-device AI
Augmented by edge cloud
Process data at the source to scale and make sense of a digitized world

Past
Cloud-centric AI
AI training and AI inference in the central cloud

Today
Partially-distributed AI
Power efficient on-device AI inference

Future
Fully-distributed AI
With lifelong on-device learning
Enriched user experiences, new use case, new verticals

Distributed functionality

- Longer latency
  - Big data/aggregated value
  - Content/storage/AI/processing

- 5G low latency
  - Customized/local value
  - Content/storage/AI/processing

- Compute, vision, sensing
  - AI powered use cases
  - Internal AI optimizations

On-premise control for ultra-low latency

On-device intelligence assisted by cloud

Distributed processing, like boundless XR

New services

Cloud computing, storage, instant access

Low-latency gaming

Real time assisted services like voice UI
5G Core Technologies

- Orchestration and Virtualization (NFV) – de-couple logical function from hardware
- Slicing – logical end-to-end networks tailored to customer needs
- Mobile Edge Computing (MEC) – resources where they are needed (especially for URLLC)
- API Exposure – 3rd party access to 5G services
- Service Based Architecture (SBA) – stateless, open, flexible
- Harmonized Protocols & Access Agnostic – generic solutions with integrated support for fixed networking, 5G satellite access, ...
- 5G Media Streaming
- New Media (Virtual Reality, Extended Reality, ...)
- Specific ‘vertical industry support’: Broadcasting, Mission Critical Communications, Vehicle to Everything, Industrial Automation, Future Railway Mobile Communication System, ...

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Media and Broadcast in 5G
Rel-16 Work and beyond
5GMSA

5G Media Streaming Architecture
5GMSA (5G Media streaming architecture)

• Summary
  ◦ Defines a significantly more modular set of enablers (compared to PSS) for downlink and uplink streaming services
  ◦ MNO and 3rd party Media Downlink Streaming Services with relevant functions and interfaces
  ◦ MNO and 3rd party Media Uplink Streaming Services based on the non-IMS FLUS architecture
  ◦ Procedures in include: Progressive Download, DASH-based Streaming and Uplink Streaming

• Other
  ◦ Enables different deployments with various degrees of integration between 5G MNOs and Content Providers
  ◦ Usage of 5G specific features such as network slicing and edge computing envisioned

• Interested companies
  ◦ Ericsson, Qualcomm, Enensys, Samsung, KPN, Sony, AT&T, Orange, BBC, others

• Status
  ◦ WI was nominally completed in June ´19, but significant corrections happening
5GMSA (5G Media streaming architecture)

- Key functional scenarios for downlink streaming are:
  - Progressive Download
  - Live and On-Demand DASH-based Streaming
  - Consumption Reporting
  - Network Assistance
  - QoE Reporting
  - Dynamic Policies based on AppFilters and Slicing

- Interfaces of relevance:
  - M1d (5GMSd Provisioning API)
  - M2d (5GMSd Ingest API)
  - M3d (Internal and NOT SPECIFIED)
  - M4d (Media Streaming APIs)
  - M5d (Media Session Handling API)
  - M6d (UE Media Session Handling APIs)
  - M7d (UE Media Player APIs)
  - M8d: (EXTERNAL and NOT SPECIFIED): unspecified application interface, which is used for information exchange between the 5GMS Aware application and other components.

Ingest technologies
Imed Bouazizi, Qualcomm)

Low-Latency streaming challenges and opportunities (Nicolas Weil, AWS Elemental)
5GMS3
5G Media Streaming Stage 3
5GMS3 (5G Media Streaming stage 3)

• **Summary**
  ◦ Based on the 5GMS Architecture specified in TS 26.501, creates new 5G Media Streaming (5GMS) stage 3 specifications and update existing ones to come up with a modular but consistent set of specifications enabling deployment of multimedia streaming services.
  ◦ New specifications for:
    • 26.511: 5G Media Streaming (5GMS); Profiles, Codecs and formats
    • 26.117: 5G Media Streaming (5GMS); speech and audio profiles
    • 26.512: 5G Media Streaming (5GMS); Protocols
  ◦ Potentially update specification for DASH and video profiles.

• **Other**
  ◦ Work considers existing work from external specifications and industry organizations such as DASH-IF, MPEG and CTA WAVE as well as input from key industry players on their requirements and usage scenarios for media streaming over 5G.
  ◦ The work also considers aligning with existing industry efforts on testing, conformance and reference tools.

• **Status**
  ◦ WI scheduled for completion Mar ’20, but expected to use an extension until Jun ´20
5GMS3 (5G Media Streaming stage 3)

• Selected Key Issues
  ◦ Network Assistance: radio or core network based
  ◦ Video codec status: make HEVC mandatory?
  ◦ Audio codecs: AAC, EVS - enough? EVS how?
  ◦ Playback requirements: CTA WAVE Device Playback?
  ◦ Streaming Ingest: Provisioning and Ingest based on DASH-IF Ingest Specification
  ◦ Media Player APIs: dash.js based
  ◦ Media Session Handler APIs: TRAPI-based
  ◦ Streaming Format: DASH & CMAF
  ◦ Low-Latency Streaming: LL-DASH & chunked CMAF
  ◦ Encryption and DRM: CMAF and anything else?
• Can only serve as baseline for future work
  ◦ Unicast
  ◦ Multicast
  ◦ XR integration

New codecs
(Thierry Fautier, Harmonic)
Network Slicing in 5G

• Network Slicing:
  ◦ Allows MNOs to completely isolate traffic for a particular service
  ◦ Customized traffic routing and handling, QoS treatment, and charging policies

• Network Slicing as a Service
  ◦ Content and service providers may opt for a network slice for their traffic
  ◦ This can be setup through SLAs with the MNO or directly using the offered Nmf interface by the NSMF

• Example Use Cases:
  ◦ Binge On: fixed QoS, sponsored traffic
  ◦ Game and AR Streaming: edge processing
Network Slicing for Media Distribution

• UE requesting Network Slice
  ◦ UE uses traffic filters information from the session to identify which slice to use for the traffic
  ◦ Filters may include FQDN, IP addresses, or Application Identifier
  ◦ UE establishes or modifies the PDU session that will be used for the traffic
  ◦ Alternatively, Network may also trigger the establishment or modification of the PDU session

• QoS and Charging rules
  ◦ PCF uses pre-stored rules for the network slice to determine the QoS Profile and the charging policy
  ◦ Dynamic variations can be handled by a Media AF
Edge Processing in 5G Network Slice

• Traffic Routing:
  ◦ Through appropriate Filtering rules, traffic is routed to an edge network (e.g. LADN)
  ◦ Through appropriate DNS resolution, an Application Server is selected in the LADN
  ◦ If no AS instance is running, AF together with Orchestrator launch a new instance of the AS

• Slice Configuration:
  ◦ AS criteria and requirements
  ◦ DNS resolution rules
  ◦ AF configuration to manage AS

Cloud computing, edge computing, and media on cloud (Imed Bouazizi, Qualcomm)
enTV and MBMS
Terrestrial broadcast for next-gen digital TV delivery
Building upon a strong 3GPP technology foundation

**eMBMS defined for LTE starting in Rel-8/Rel-9**, improving coverage and efficiency

**eMBMS enhancements in Rel-12 include MOOD² and expansion to MCPTT³**

Enabling terrestrial broadcast and expanding to new services; Meeting 7/10

5G Broadcast requirements⁴ in Rel-14

Further enhancements⁵ to fully satisfy 5G broadcast requirements

Target market focused on **Cellular operators**

Target market expanded to **Broadcasters**

3GPP Rel-14 (completed)

3GPP Rel-16 (on the way)

Enabling terrestrial broadcast and expanding to new services; Meeting all 5G Broadcast requirements⁴ in Rel-16

3GPP Rel-14 (completed)
Terrestrial broadcast for next-gen digital TV delivery
enTV¹ – part of 3GPP Rel-16 – meets terrestrial TV broadcast requirements

Radio access enhancements

- Longer range
  New 1-symbol numerology with longer 200us CP² to support 15 km ISD³

- More broadcast capacity
  Supports dedicated broadcast network with 100% eMBMS carrier allocation

- More deployment flexibility
  Single network for mobile and fixed devices with enhanced support for rooftop reception

- Better efficiency
  New subframe design reduces overhead in dedicated broadcast transmissions

System layer enhancements

- Receive only mode
  Delivery of free-to-air content to devices without SIM/service subscription

- Transport only service
  TV broadcasters can deliver content in native format without transcoding

- Standardized interface
  Content providers can deliver media over LTE with a unified framework

- Shared broadcast
  Multiple operators can serve users on a common broadcast carrier

Rel-16 adds in addition
- ~15km ISD (optimized for higher speeds, e.g. audio)
- 50km ISD+ (rooftop reception, limited outdoor depending on Tx power)
- 250km ISD (TBC)

¹ enTV
² CP
³ ISD

Broadthinking 2019
ETSI JTC Broadcast

ETSI TS 103 720: 5G Broadcast System for linear TV and radio services

- A single overview and system specification that profiles and restricts existing 3GPP specifications in the context of 5G in order to enable the deployment of linear TV and radio services.
- The work item is aligned with ongoing 3GPP standardization work, in particular the "LTE-based 5G terrestrial broadcast"
- Main features
  - radio network comprising only MBMS-dedicated cells as transmitters;
  - Receive-Only-Mode (ROM) devices and UEs supporting FeMBMS [x23.246] as receivers;
  - A down-stripped EPS dedicated to TV and Radio Services with E-UTRAN;
  - A down-stripped MBMS User Service [x26.346] dedicated to TV and Radio Services;
  - A set of MBMS-APIs [x26.347] that permits to use third-party service layers.
## Rel-17 Multicast Broadcast Considerations

### LTE MBMS

**Initial Service Targeted**
- Video Content and Streaming

**Focus on one type of service**
- Joint Transport/Service Layer

**Service independent of unicast**
- Separate core network

**Service oriented architecture**
- Functionality at the core network
- Reliability, unicast/Broadcast decision
- Security also on application layer

**Service oriented architecture**
- Flow identified by TMGI (service)
- Maps to MBMS bearer

### 5G Mixed Mode

**Multiple Services Targeted**
- C2VX, public safety, I-IoT, IP Multicast

**Multiple Services with different characteristics**
- Common Transport/Separate Service Layer

**Service have unicast and broadcast components**
- Transport integrated with 5GS unicast

**Enable high reliability + low latency**
- Functionality provided at the transport
- RAN Reliability, unicast/Broadcast decision
- Security: encryption at either RAN or UPF

**Transport oriented architecture**
- Flow identified by MB-QoS flow ID
- Maps to Radio Bearer in RAN
DAHOE

Support of hybrid DASH/HLS over MBMS
DAHOE (support of hybrid DASH/HLS over MBMS)

• Summary
  ◦ CMAF (Common Media Application Format), uses fragmented MP4 (a.k.a. fMP4) as segment format based on the ISO base media file format, supported both by DASH and HLS. This way the same segments can be referenced both by DASH MPDs and HLS playlists. Such content is referred to as hybrid DASH/HLS service.
  ◦ Distribution of HLS-based CMAF and hybrid services over MBMS is expected to be supported
  ◦ Based on Rel-12 AppService concept already introduced by QC
  ◦ Two approaches possible: DASH-distribution and HLS conversion in MBMS client, 2 manifests distributed

• Other
  ◦ hybrid DASH/HLS service is an important concept and should be well defined

• UE impact
  ◦ Updates to MBMS client necessary to support one or both modes

• Interested companies
  ◦ Apple, ENENSY, Ericsson, Samsung, Qualcomm

• Status
  ◦ WI will be completed in Mar ´20
DAHOE (support of hybrid DASH/HLS over MBMS)

• DASH Amd.1 CMAF work and CTA WAVE
  ◦ This allows to generate content once using an MPD as manifest and do a conversion to other streaming formats such as HLS in the network, for example in a proxy of edge cache or also for example in an end device that includes a streaming client, for example and HLS player.

• Conversion tools based on this format are available and will updated according to this specification:
  ◦ JavaScript based conversion in the client here: http://vm1.dashif.org/DASHtoHLS/
  ◦ server-side conversion using a PHP script. Source code at: https://github.com/waqarz/DASH-to-HLS-Playback
FS_5GXR

eXtended Reality (XR) in 5G
FS_XR5G (eXtended Reality (XR) in 5G)

• Summary
  ◦ 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

• Other
  ◦ The study is supported by a workshop, for a summary please refer to S4-191019

• UE impact
  ◦ Nothing immediately, but defines device types for XR, including VR and AR

• Interested companies
  ◦ Qualcomm, Ericsson, Orange, KPN, LG Electronics, Fraunhofer HHI, Intel, Fraunhofer IIS, Samsung, Facebook, Xiaomi, Nokia, Tencent, Oppo, AT&T

• Status
  ◦ SI expected to be completed in Mar ’20
  ◦ Normative work in Rel-17
Terms and Definitions

- **3DOF**
- **Windowed 6DOF**
- **6DOF**
- **3DOF+**

- **Presence**
- **Time Warp**
- **SLAM**
- **Tracking**
- **Meshes**
- **Point Cloud**

**Images:**

1. 3DOF diagram showing Yaw, Pitch, and Roll.
2. Windowed 6DOF diagram showing additional movements.
3. 6DOF diagram showing full range of movements.
4. 3DOF+ diagram showing expanded movements compared to 3DOF.
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<td>3DoF+, 6DoF</td>
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<td>Streaming of Immersive 6DoF</td>
<td>VR</td>
<td>3DoF+</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>2D screen or HMD with a controller</td>
</tr>
<tr>
<td>6</td>
<td>Video Game Live Streaming</td>
<td>VR</td>
<td>6DoF</td>
<td>Streaming, Split</td>
<td>Phone</td>
</tr>
<tr>
<td>7</td>
<td>Real-time 3D Communication</td>
<td>3D, AR</td>
<td>3DoF+</td>
<td>Conversational</td>
<td>5G AR Glasses, 5G touchscreen computer or tablet</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, Conversational</td>
<td>5G AR Glasses/Helmet, VR camera/microphone, Audio stereo headset, 5G accurate positioning</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, Conversational</td>
<td>5G AR Glasses/VR Glasses, Rendering system, Tablet (or smartphone), Capture device</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>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>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>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 and Power Considerations

<table>
<thead>
<tr>
<th>XR Type Number</th>
<th>XR Device Type Name</th>
<th>Tethering Examples</th>
<th>5G Uu Modem</th>
<th>XR Engine Localization</th>
<th>Power Supply</th>
<th>Typical Max Avail Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR5G-P1</td>
<td>Phone</td>
<td>n/a</td>
<td>XR device</td>
<td>XR device or split</td>
<td>Internal</td>
<td>3-5 W</td>
</tr>
<tr>
<td>XR5G-V1</td>
<td>Simple VR Viewer wired tethering</td>
<td>USB-C</td>
<td>External</td>
<td>External</td>
<td>External</td>
<td>2-5 W</td>
</tr>
<tr>
<td>XR5G-V2</td>
<td>Simple VR Viewer wireless tethering</td>
<td>802.11ad/y, 5G sidelink, etc.</td>
<td>External</td>
<td>External</td>
<td>Internal</td>
<td>2-3 W</td>
</tr>
<tr>
<td>XR5G-V3</td>
<td>Smart VR Viewer wireless tethering</td>
<td>802.11ad/y, 5G sidelink, etc.</td>
<td>External</td>
<td>XR device or Split</td>
<td>Internal</td>
<td>2-3 W</td>
</tr>
<tr>
<td>XR5G-V4</td>
<td>VR HMD Standalone</td>
<td>n/a</td>
<td>XR device</td>
<td>XR device or Split</td>
<td>Internal</td>
<td>3-7 W</td>
</tr>
<tr>
<td>XR5G-A1</td>
<td>AR Wearable standalone</td>
<td>n/a</td>
<td>XR device</td>
<td>XR device or Split</td>
<td>Internal</td>
<td>2 - 4 W</td>
</tr>
<tr>
<td>XR5G-A2</td>
<td>Simple AR Wearable wired tethering</td>
<td>USB-C</td>
<td>External</td>
<td>External</td>
<td>External</td>
<td>1-3 W</td>
</tr>
<tr>
<td>XR5G-A3</td>
<td>Simple AR Wearable wireless tethering</td>
<td>802.11ad/y, 5G sidelink, etc.</td>
<td>External</td>
<td>External</td>
<td>Internal</td>
<td>0.5 - 2 W</td>
</tr>
<tr>
<td>XR5G-A4</td>
<td>Smart AR Wearable wireless tethering</td>
<td>802.11ad/y, 5G sidelink, etc.</td>
<td>External</td>
<td>XR device or Split</td>
<td>Internal</td>
<td>0.5 - 2 W</td>
</tr>
</tbody>
</table>
Architecture Examples

Identifying interfaces, APIs, formats, protocols

- Rendering-centric architectures
- Other architectures look at AR localization or network-based rendering
- Identified an initial set of latency, bandwidth and reliability requirements
A new era in distributed processing

Essential on-device processing
- Optimized under strict power, thermal, size constraints
- Premium experiences today that continuously improve

Split rendering

Augment by edge cloud processing
- Significant higher power envelope—beyond PC class
- Augment on-device rendering with edge cloud rendering

5G
- Low latency
- High capacity
- Reliable link

Complex XR workloads
- Compute intensive
- Complex confluences
- Real-time
- Always-on
- Latency sensitive

Challenging XR form factor
- Thermally efficient for sleek and ultra-light
- Long battery life for all-day use
- Storage/memory bandwidth
Wrap Up
5G enabled capabilities not possible when 4G was defined

Efficient TDD spatial design
Flexibility, lower latency, reciprocity-based massive MIMO, new feedback/pilot_measurements

Scalable numerology
Low, to mid, to high mmWave bands, deployment types

Hardware enablers
Such as faster baseband processing

Mobile mmWave
Overcoming an “impossible challenge”

Continuous research, technology breakthroughs, new architectures, distribution of processing/AI/content,...

Technology leap for new capabilities and reduced cost
5G is the innovation platform for the next decade

A unified future-proof platform

Delivering on the 5G vision

New deployments, new spectrum, new use cases, new verticals,…

Some future requirements only possible on a new platform

Market needs: enhanced/emerging/unknown services to 5G

Vision forming

6G

Historically 10 years between generations

Next technology leap for new capabilities and reduced cost

Continued evolution

Research: for 5G enhancements and for next generation leap

Technology breakthroughs, hardware progress, new architectures, distribution of processing/AI/content,…
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