

THE METAVERSE AND EXTENDED REALITY

A first test and measurement perspective

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ROHDE & SCHWARZ

Make ideas real



QUO VADIS, 5G? IS IT TIME FOR 5G BASHING?

FORBES > INNOVATION > CLOUD

The State Of 5G In The U.S. And How It Might Improve

[Link](#) [Sep 2023]

- ▶ Another example: South Korea launched the first 5G network in 2019 but hasn't seen the expected technological transformation due to limited demand for advanced services and a lack of a "killer app" driving adoption¹⁾
 - \$20+ bn investment in 5G infrastructure; some 215,000 base stations (2% support FR2)
 - End of 2022: 28.2 million 5G subscribers, compared to 4G LTE same period: 46.2 million subscribers²⁾
 - ARPU for 4G LTE: rose from 5% to 12% annually, with 5G NR ARPU climbing slowly or is stagnating
 - Nov-2022: Korean government recalls 28 GHz frequency licenses³⁾

³⁾ <https://telecoms.com/518619/korea-recalls-mobile-operators-5g-licences/> [Nov 2022]

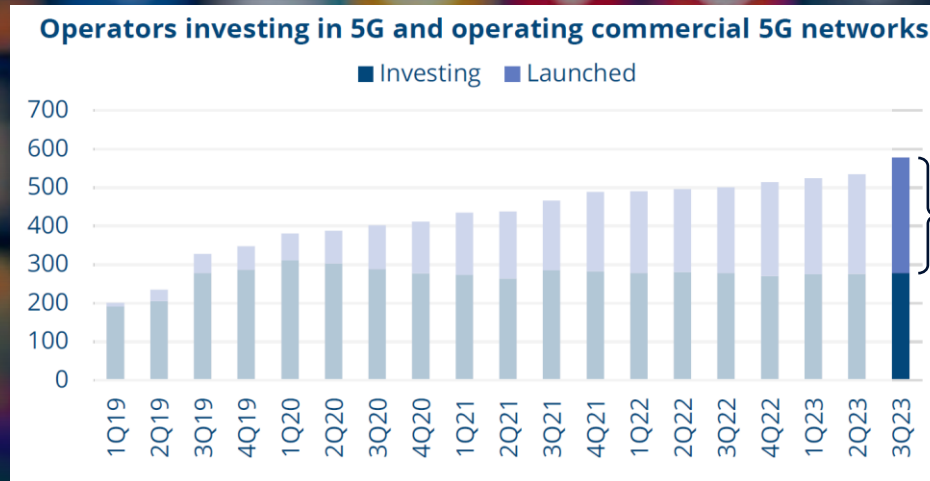
²⁾ <https://www.rcrwireless.com/20230207/5g/south-korea-ends-2022-over-28-million-5g-subscribers> [Feb 2023]

¹⁾ <https://www.reuters.com/business/media-telecom/skoreas-high-speed-5g-mobile-revolution-gives-way-evolution-2022-05-13/> [May 2022]

QUO VADIS, 5G?

IS IT TIME FOR 5G BASHING?

- ▶ HOWEVER and in all fairness, we should not forget that 5G is still in its infant state from a deployment point of view! Not even half of the specification has yet made it to the market. And most of the operators have not yet switched to 'Standalone' (SA) mode:



300 commercial 5G networks worldwide in 114 countries

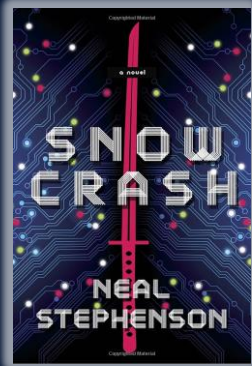
- 121 investing in Standalone mode; 43 operators deployed, launched or soft-launched 'Standalone' mode

- ▶ From a pure consumer perspective, where and what is the “killer” application for 5G?

<https://gsacom.com/download.php?id=16165> [Nov 2023]

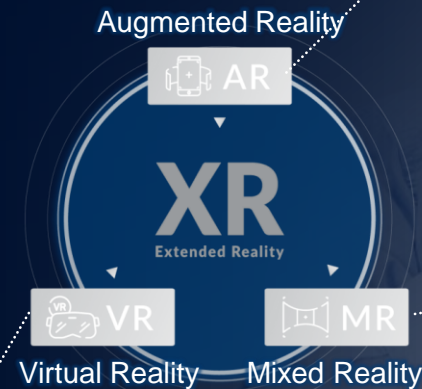
WHAT IS THE METAVERSE?

- ▶ An immersive, persistent, pervasive, interconnected virtual 3D world shaped by extended reality applications where many people can gather to work, shop, play, and socialize.



https://en.wikipedia.org/wiki/Snow_Crash

Users are totally immersed in a simulated digital environment or a digital replica of reality.



AR is one such variant, where digital information is overlaid on images of reality viewed through a device.

MR includes all variants where virtual and real environments are mixed.

DIVERSE SET OF METAVERSE USE CASES

A HIGH-LEVEL OVERVIEW

Training/Education, Healthcare



Collaboration



Digital Twins



Consumer: Gaming, Social



DIVERSE SET OF METAVERSE USE CASES

A HIGH-LEVEL OVERVIEW

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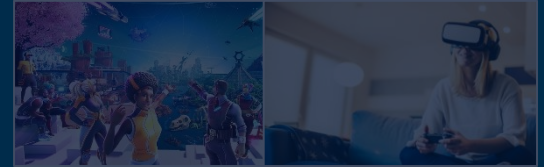
Collaboration



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Consumer: Gaming, Social



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A HIGH-LEVEL OVERVIEW

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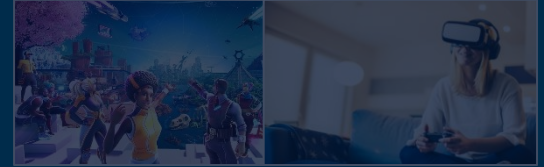
Collaboration



Digital Twins



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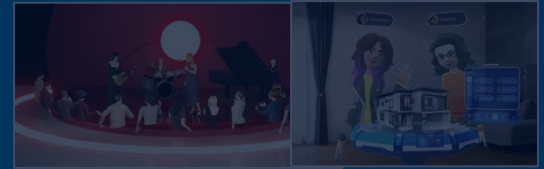
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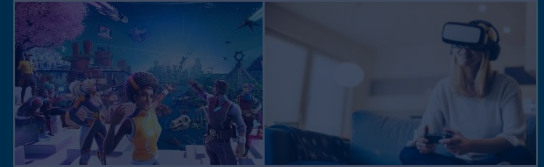
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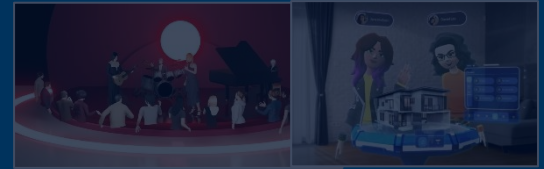
DIVERSE SET OF METAVERSE USE CASES

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Digital Twins



Consumer: Gaming, Social



IS THERE ONE METAVERSE? OR MANY?

“The many-worlds interpretation is the only completely coherent approach to explaining both the contents of the quantum mechanics and the appearance of the world!”

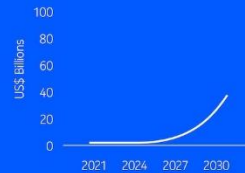
Hugh Everett (1930 – 1982)

Industry is where the metaverse may reach its greatest potential

Source: ABI Research, Evaluation of the Enterprise Metaverse Opportunity, Third Quarter, 2022

Consumer Metaverse

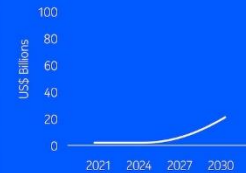
Virtual spaces revenue (global)



- Consumer appeal driven
- Reliant on trends and network effect
- Fragmented monetization, with growth from 2026

Enterprise Metaverse

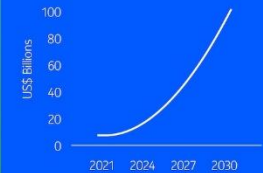
Immersive collaboration and related cloud revenue (global)



- Business value driven
- Solution and device innovation
- Good monetization potential, with growth from 2025

Industrial Metaverse

Digital twin and simulation and industrial extended reality revenue (global)



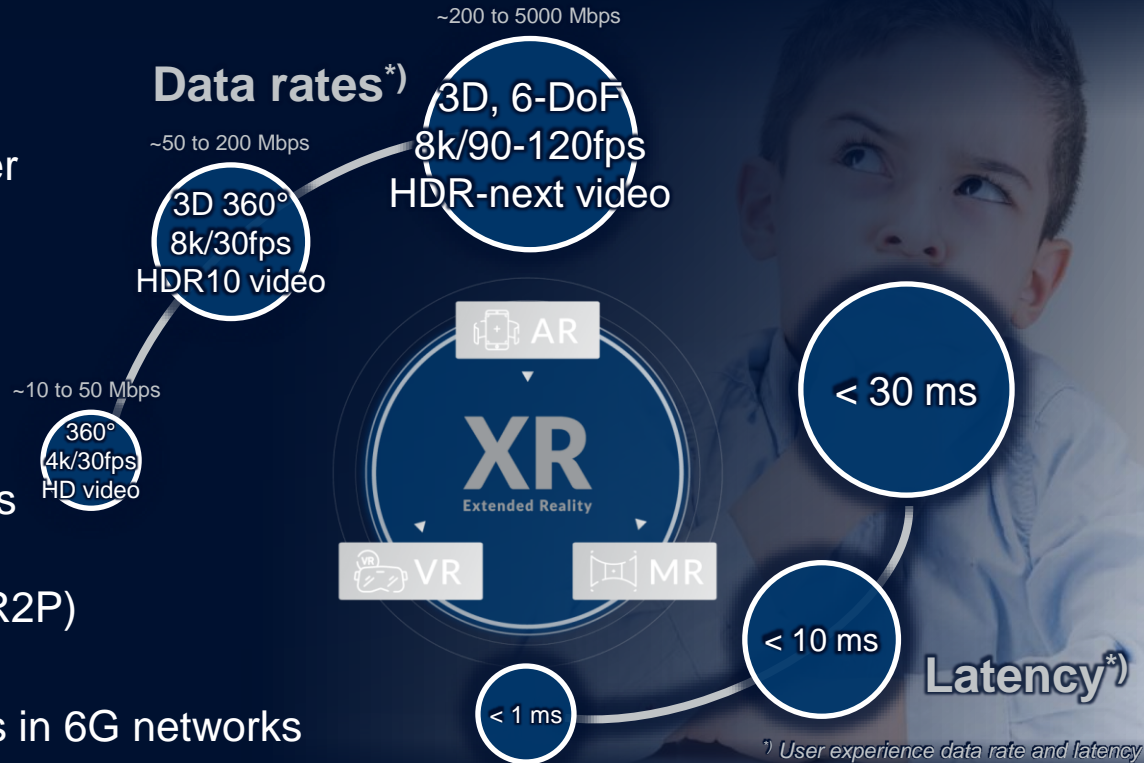
- Operational results driven
- Industrial automation focus
- High monetization potential, with early traction

<https://www.nokia.com/metaverse/industrial-metaverse/the-metaverse-at-work-research/>
<https://www.nokia.com/sites/default/files/2023-02/potential-of-the-industrial-metaverse-market.png>



HOW TO UNLOCK THE FULL POTENTIAL OF THE METAVERSE? WHAT ROLE DOES 5G AND 6G PLAY IN IT?

- ▶ High data rates, low latency
- ▶ Device form factor for consumer applications: small, lightweight, even fashionable; low power consumption
- ▶ Optimized edge processing and split rendering architectures to effectively handle Motion-to-Render-to-Photon latency (M2R2P)
- ▶ Future: delay-aware schedulers in 6G networks



WHERE DO SUCH REQUIREMENTS ORIGINATE FROM?

DATA RATES AND LATENCY

The Distribution Challenge



| Standard | Early VR | Entry-level VR | Advanced VR | Ultimate VR |
|---|-----------------------------|--------------------------------|------------------------------|-----------------------------------|
| Video resolution | 4K 2D video (3840x2160) | 8K 2D video (7680x4320) | 12K 2D video (11520x6480) | 22K 24K 3D video (23040x11520) |
| Monocular resolution | 980x960 (90° FoV) – 240p | 1820x1820 (90° FoV) – 4800p | 3840x3840 (120° FoV) | 7680x7680 (120° FoV) |
| Pixels/degree | 11 | 21 | 32 | 55-60 |
| Colour depth | 8 bit | 8 bit | 10 bit | 12 |
| Compression ratio | 165:1 | 165:1 | 215:1 | 350:1 (3D) |
| Frame rate | 30 | 30 | 60 | 100 |
| Typical video bit rate | 16M | 64M | 265M | 2.18G |
| Typical network bandwidth requirement | 25Mbps | 100Mbps | 398Mbps | 3.28Gbps |
| Typical network latency requirement | 40ms | 30ms | 20ms | 15 |
| Typical network packet loss requirement | 1E-4 | 1.5E-5 | 2E-6 | 1E-7 |

Immersive experiences

- are interactive
- are untethered
- recreate reality

Reality requires significant amounts of audible and visual data to be delivered with very low latency level

5G provides a predictable distribution medium for immersive content

VRIF – Immersive Media Meets 5G – April 2019

| Component | Latency | Location |
|-----------------------|------------|---------------|
| SLAM ¹⁾ | 50...70 ms | AR device |
| Object tracker | 2...5 ms | AR device |
| Game simulation | 2...5 ms | Remote server |
| Rendering | 2...16 ms | AR device |
| AR device | 7...8 ms | AR device |
| Video decoding | 12 ms | Remote server |
| Object detection (OD) | 250 ms | Remote server |

¹⁾ Simultaneous Localization And Mapping

<https://www.ericsson.com/en/blog/2022/11/network-performance-metaverse-5g>
<https://www.vr-if.org/wp-content/uploads/1-2-5-VRIF-Immersive-Media-meets-5G-workshop-1.pdf>

SPECTRUM CONSIDERATIONS FOR THE METAVERSE AND XR DATA RATES



Holographic communications

- Holographic representation is based on volumetric media
- Objects are represented as sets of 3D volume pixels
- Actual image is dynamically rendered from any viewing point angle to the local endpoint
- Typical throughput for a full immersive (16K resolution, 360°) holographic experience: 500Mbps
- Outdoor cell-edge efficiency: 0.45 bits/s/Hz

DL spectrum needs: ~1.1 GHz per network



XR (Extended Reality)

- Immersive XR requires significant data processing that will be mitigated through cloud-based technologies, where content will be stored, rendered, and computed in the cloud
- Fully immersive 16K resolution
- Frame rate minimum: 60Hz and 12-bit pixel representation
- Required throughput: 450Mbps
- Outdoor cell-edge spectrum efficiency: 0.45 bits/s/Hz

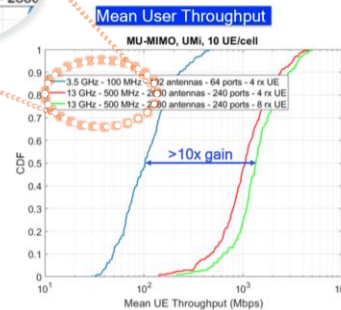
DL spectrum needs: ~1GHz per network

X/Ku: the new capacity band



More than 10x performance gain¹ at 13 GHz DL compared to 3.5 GHz

- 5x BW
- Same aperture
- Higher order spatial multiplexing enabled with larger number of TxRUs



Qualcomm Technologies, Inc. contribution to Next G Alliance Technology Working Group

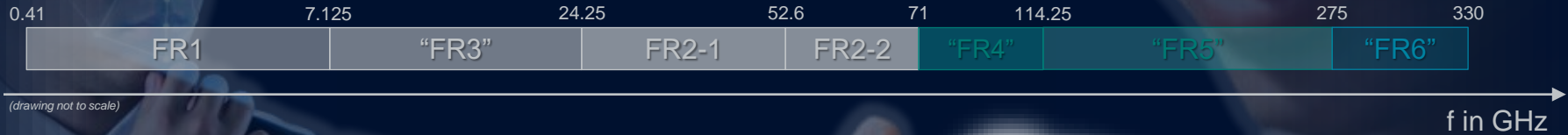
Source: <https://www.nokia.com/about-us/newsroom/articles/spectrum-for-6G-explained/>

Source: Next G alliance, Qualcomm contribution "Advanced Massive MIMO for Upper Mid band" (November 2021)



SPECTRUM CONSIDERATIONS FOR THE METAVERSE AND XR

THz BASED GESTURE RECOGNITION FOR CONTROL AND TRACKING?



- ▶ Use of a THz-based RF transceiver chipset with a phased array antenna (e.g. uniformed linear arrays) to “sense and monitor” the space in front of the person using the AR/VR headset
- ▶ Power and therefore range, is not the limiting factor, but what about resolution, e.g. sub-cm range?
 - Access to wider bandwidths at (sub-)THz frequencies allows finer resolution to detect particular finger, hand, arm and body movements



XR-RELATED FEATURES IN 3GPP RELEASE 15 AND BEYOND

5G NR AIR INTERFACE: URLLC AND POWER CONSUMPTION (1/2)

| Release 15 | Release 16 |
|-------------------------|-------------------------|
| BWP switching | SCell dormancy |
| Downlink Preemption | Cross-slot scheduling |
| | PDCCH Wake-up signal |
| Uplink skipping | Uplink configured grant |
| Mini-slot transmissions | Slot aggregation |
| | Uplink preemption |

XR-RELATED FEATURES IN 3GPP RELEASE 15 AND BEYOND

SYSTEM LEVEL AND CORE NETWORK ASPECTS

| 3GPP working group | XR-related study item / work item description for Rel-17 |
|--------------------|---|
| SA1 | XR (and Cloud Gaming) use cases are outlined in SA1 study item on Network Controlled Interactive Services (TR 22.842) |
| SA2 | Work item on 5G System Enhancement for Advanced Interactive Services (SP-190564) proposes to introduce new 5Q1s to identify the requirements on traffic from SA1 NCIS |
| SA4 | Feasibility Study on Traffic Models and Quality Evaluation Method for Media and XR Services in 5G Systems (TR 26.926) |
| SA6 | Study on application architecture for enabling Edge Application (TR 23.758) |
| RAN1 | Study on XR Enhancements for NR (TR 38.838) |

XR-RELATED FEATURES IN 3GPP RELEASE 15 AND BEYOND

5G NR AIR INTERFACE: URLLC AND POWER CONSUMPTION (2/2)

| Release 15 | Release 16 | Release 17 | Release 18 | Release 19 |
|-------------------------|-------------------------|----------------|--------------------------------------|--|
| BWP switching | SCell dormancy | PDCCH skipping | enhanced cDRX | Consolidation of topics at RAN plenary in Dec'2023 |
| Downlink Preemption | Cross-slot scheduling | | Retransmission-less configured grant | |
| | PDCCH Wake-up signal | | | |
| Uplink skipping | Uplink configured grant | | Low latency mobility | |
| Mini-slot transmissions | Slot aggregation | | QoS-based on multimedia payload | |
| | Uplink preemption | | XR awareness | |



R&S@CMX500
5G One Box Signaling Tester



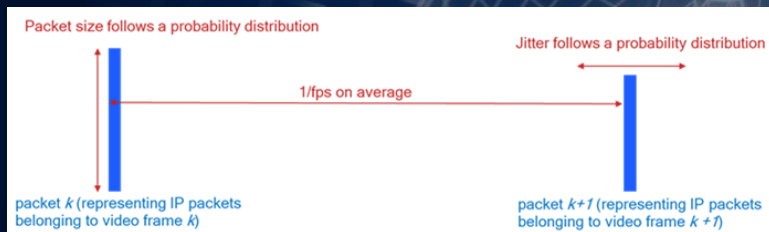
Combination of 3GPP features and other tools, e.g., L4S protocol, OS-specific functionality, specific modem APIs, etc.

| 2022 | | | | 2023 | | | | 2024 | | | | 2025 | | | | |
|-----------------|----|----|----|------|----|----|-------------|--------------|-----------------|----|----|------|----|----|-------------|--------------|
| Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | |
| Rel-18 RAN1 | | | | | | | Maintenance | Rel-19 RAN1 | | | | | | | Maintenance | |
| Rel-18 RAN2/3/4 | | | | | | | Maintenance | ASN.1 freeze | Rel-19 RAN2/3/4 | | | | | | | ASN.1 freeze |

You are here



THE CURRENT CHALLENGE WITH cDRX SINGLE STREAM DOWNLINK TRAFFIC



Source: TR 38.838

Video frame rates correspond to a periodicity that is not an integer and thus does not align with frame a slot durations

► Characterized by

- Packet size
- Packer arrival rate
- Packet success rate
- Packet delay budget (PDP)

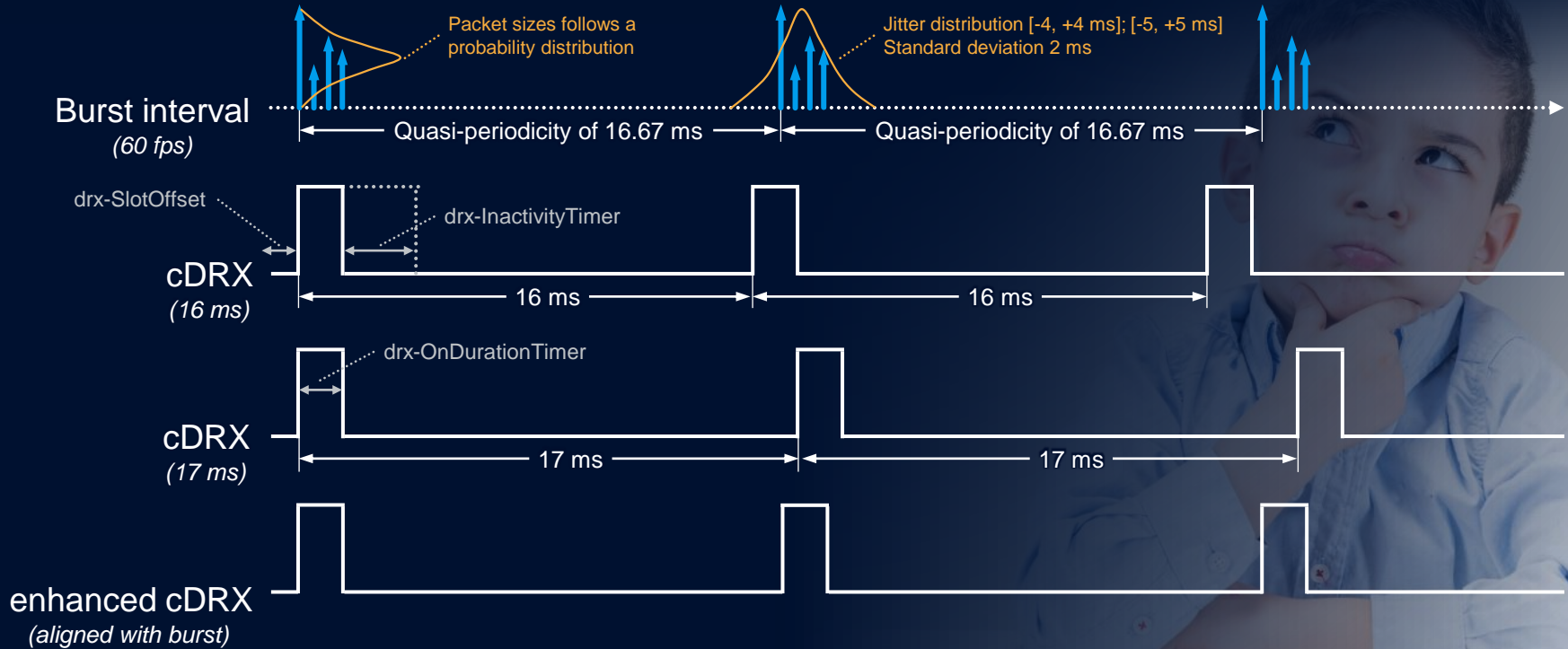
TABLE I
3GPP TRAFFIC MODEL PARAMETERS AND REQUIREMENTS FOR SELECTED XR USE CASES.

| Traffic stream | DL/UL | Use cases | Packet rate | Average data rate | Packet size | Jitter | PDB |
|----------------|---------------------------|--------------------------|----------------------------|--------------------------------------|---|--|-------------------------------------|
| Video | DL | AR | 60 fps, [30,90,120] fps | 30 Mbit/s, 45 Mbit/s, [60 Mbit/s] | Truncated Gaussian, Mean = Av. data rate / (fps * 8) bytes, [STD, Min, Max] = [10.5%, 50%, 150%] of mean | Truncated Gaussian, Mean = 0ms Standard deviation (STD) = 2 ms [Min, Max] = [-4, 4] ms or [-5, 5] ms | 10 ms |
| | | VR | | | | | 8 Mbit/s, 30 Mbit/s, [45 Mbit/s] |
| CG | 10 Mbit/s, [20 Mbit/s] | Optional, same as for DL | | 30 ms | | | |
| Motion/control | UL | AR | 60 fps | 0.2 Mbit/s | 100 bytes | No | 10 ms |
| | | VR | 250 fps | 0.2 Mbit/s | 100 bytes | | |
| | | CG | 250 fps | 0.2 Mbit/s | 100 bytes | | |
| Audio +Data | DL+UL | AR/VR/CG in DL, AR in UL | 100 fps | 0.756 Mbit/s, 1.12 Mbit/s | Av. data rate / (fps*8) bytes | | 30 ms] |

If multiple values given, bold are default values.

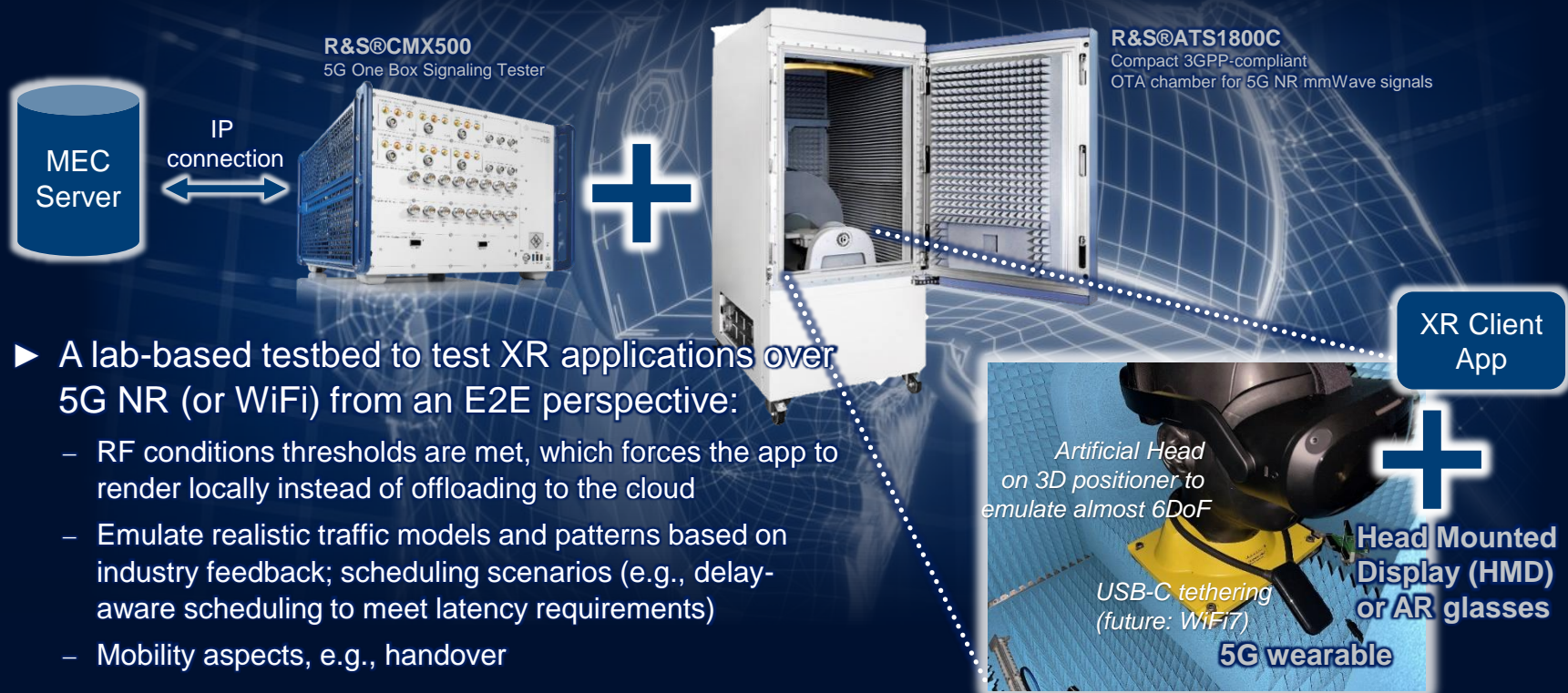
Source: [Standardization of Extended Reality \(XR\) over 5G and 5G-Advanced 3GPP New Radio](#)

ENHANCED cDRX FOR EXTENDED REALITY



LET'S GET OUR TOES WET

PROTOTYPE OF LAB-BASED XR TESTBED AND TEST SUITE



Lab-based 5G testbed for testing extended reality (XR) from an End-to-End (E2E) perspective

PROTOTYPE OF LAB-BASED XR TESTBED AND TEST SUITE

DEMO1: 360 4K VIDEO WITH SLALOM

4k, 360 video from our partner Slalom Consulting stored on internal server, streamed via http to the client (HMD)



R&S@CMX500
5G One Box Signaling Tester



Wireless
5G NR
connection



USB tethered

Neckband and HMD
inside chamber mounted
on the artificial head



Wi Fi

WiFi-to-HDMI adapter
inside chamber, cable
connected via a
feedthrough

HDMI cable



For illustration
only



Rohde & Schwarz

PROTOTYPE OF LAB-BASED XR TESTBED AND TEST SUITE CONFIGURATION AND AUTOMATION OF TESTBED & XR USE CASE



R&S@CMX500
5G One Box Signaling Tester

R&S@ATS1800C
Compact 3GPP-compliant OTA chamber for 5G NR mmWave signals

¹⁾ [Link to CMsequencer brochure](#)



WHAT ARE THESE USE CASES?

3GPP TR 26.928 V18.0.0 (2023-03)

| Core Use Cases and Scenarios | Clause | Use Case from Annex A |
|-------------------------------|--------|--|
| Offline Sharing of 3D Objects | 5.2 | Use Case 1: 3D Image Messaging Use Case 2: AR Sharing Use Case 10: Online shopping from a catalogue – downloading |
| Real-time XR Sharing | 5.3 | Use Case 7: Real-time 3D Communication Use Case 8: AR guided assistant at remote location (industrial services) Use Case 11: Real-time communication with the shop assistant Use Case 17: AR animated avatar calls Use Case 23: 5G Shared Spatial Data |
| XR Multimedia Streaming | 5.4 | Use Case 3: Streaming of Immersive 6DoF Use Case 4: Emotional Streaming Use Case 20: AR Streaming with Localization Registry Use Case 21: Immersive 6DoF Streaming with Social Interaction |
| Online XR Gaming | 5.5 | Use Case 5: Untethered Immersive Online Gaming Use Case 6: Immersive Game Spectator Mode Use Case 22: 5G Online Gaming party |
| XR Mission Critical | 5.6 | Use Case 9: Police Mission Critical with AR |
| XR Conference | 5.7 | Use Case 12: 360-degree conference meeting Use Case 13: 3D shared experience Use Case 14: 6DOF VR conferencing Use Case 15: XR Meeting Use Case 16: Convention / Poster Session |
| Spatial Audio Multiparty Call | 5.8 | Use Case 18: AR avatar multi-party calls Use Case 19: Front-facing camera video multi-party calls |

Source: [3GPP TR 26.928 V18.0.0 \(2023-03\)](#)



**THANK YOU!
QUESTIONS?**

**“No one can whistle a symphony.
It takes a whole orchestra to play it.”**

Halfrod E. Luccock (1885-1960)



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