



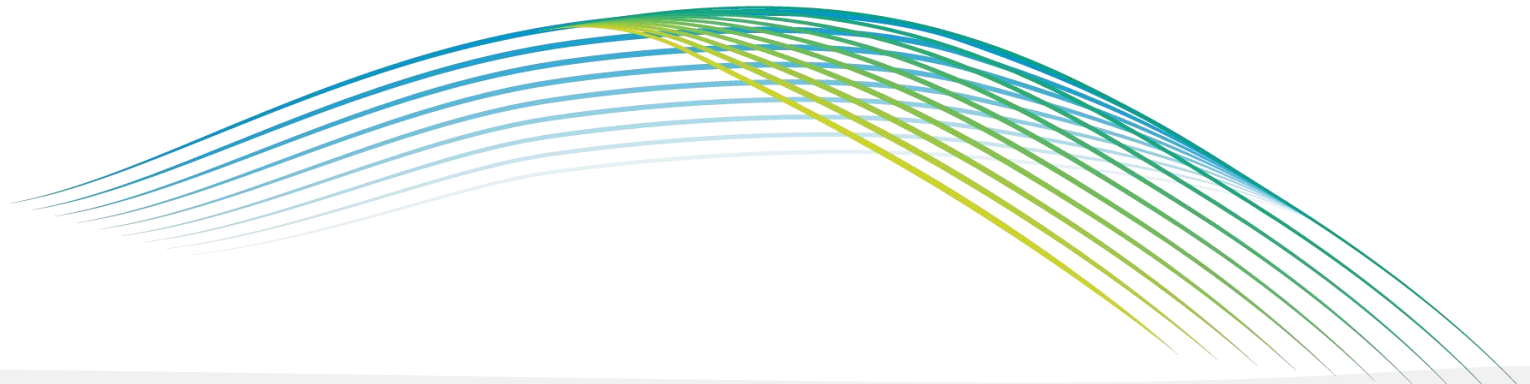
Metaverse
STANDARDS FORUM™



Network requirements and capabilities to support Metaverse applications

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...



Metaverse will be Built on Interoperability Standards

The metaverse combines the connectivity of the Web
with the immersiveness of Spatial Computing
through enabling multiple disruptive technologies to work together
(AI, GPU, XR, Web3, 5G/6G)



Building bridges between
applications to scale beyond a
series of disconnected silos



Depends on
Interoperability



Evolving a platform that is open
and inclusive for all – an
immersive evolution of the web



Pervasive metaverse interoperability will need a constellation of open standards ...
... involving 100s of standards organizations (SDOs)



How can we organize for cooperation on interoperability for the benefit of all?

Where can industry go to engage efficiently with multiple SDOs?

How do SDOs make sure they can reach industry stakeholders?

How can SDOs engage with each other to avoid overlaps, gaps, and needless divergence?

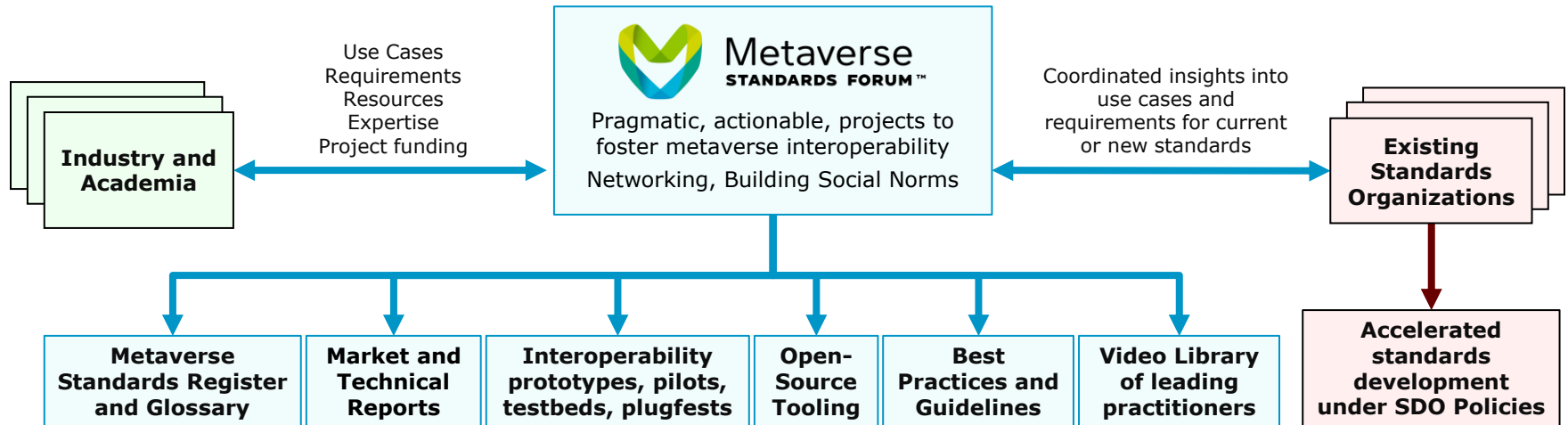
How do open-source projects get visibility into SDOs' plans and industry requirements?

How can we accelerate and fund open source and standard development projects?



How Does the Forum Work?

- The Forum aims to *accelerate the development of metaverse interoperability*
 - The Forum does not create standards itself, but encourages broad standardization cooperation
- A neutral and welcoming venue for all standards organizations and companies to cooperate
 - Open to any organization, free membership tiers, no NDA, no patent licensing obligations
- Pragmatic, active and agile – strongly connected to industry activities
 - Multiple Forum meetings happening almost daily



Forum Domain Groups



3D Interoperability

gITF/USD 3D Asset Interoperability

Cooperation between USD and gITF to increase synergy and reduce duplication of effort, gaps, fragmentation

Interoperable Avatars

Cross-platform avatars and characters for film, gaming, fashion and social platforms

Digital Fashion/Wearables

Clothing (including layering), shoes, hats, accessories

Volumetric Media Interoperability

Capture, transport and display

Digital Twins and Geospatial

Real/Virtual World Integration (Digital twins, IOT)

Constructs to describe and integrate the physical world and created representations

Industrial Metaverse

Enabling collaboration between geographically dispersed teams through virtual environments, expert avatars, digital twins, data visualization, AR/VR and the emerging concept of Shared Reality

Today's
Webinar



Ecosystem Navigation and Discovery

Metaverse Standards Register

Publicly available database mapping the landscape of metaverse-relevant standardization activities, organizations, standards & specifications, use cases, and terms

Technology Stack

Network Requirements and Capabilities

Industry requirements for seamlessly transitioning traffic on multiple wireline and wireless technologies for deploying metaverse applications at scale

3D Web Interoperability

Enable the broadest possible interoperability of Metaverse Content using the Web

XR Device Interoperability

Establishing a platform for facilitating the discussion between identified stakeholders and working on identifying and recommending solutions to XR ecosystem issues to help accelerate the time-to-market, performance, and usage of XR experiences.

Engagement and Education

End-User Technical Troubleshooting

Enabling end-users to ensure reliable metaverse experiences

Metaverse Educational Research

Using the metaverse for education

Accessibility

Ensuring the metaverse is accessible to all

Legal

Asset Management (web3, protection, digital rights)

Digital rights, protection, portability, access, availability

Privacy, Cybersecurity & Identity

Recommendations for responsible innovation that mitigates human and societal harm from objective and subjective privacy risks – including cybersecurity and identity risk management

Ethical principles for the metaverse and its implementation

Define a set of ethical principles and an implementation methodology for the development, use, procurement and commercialization of the metaverse

Ownership and Identity

Decentralized identify and ownership

Use Case Verticals

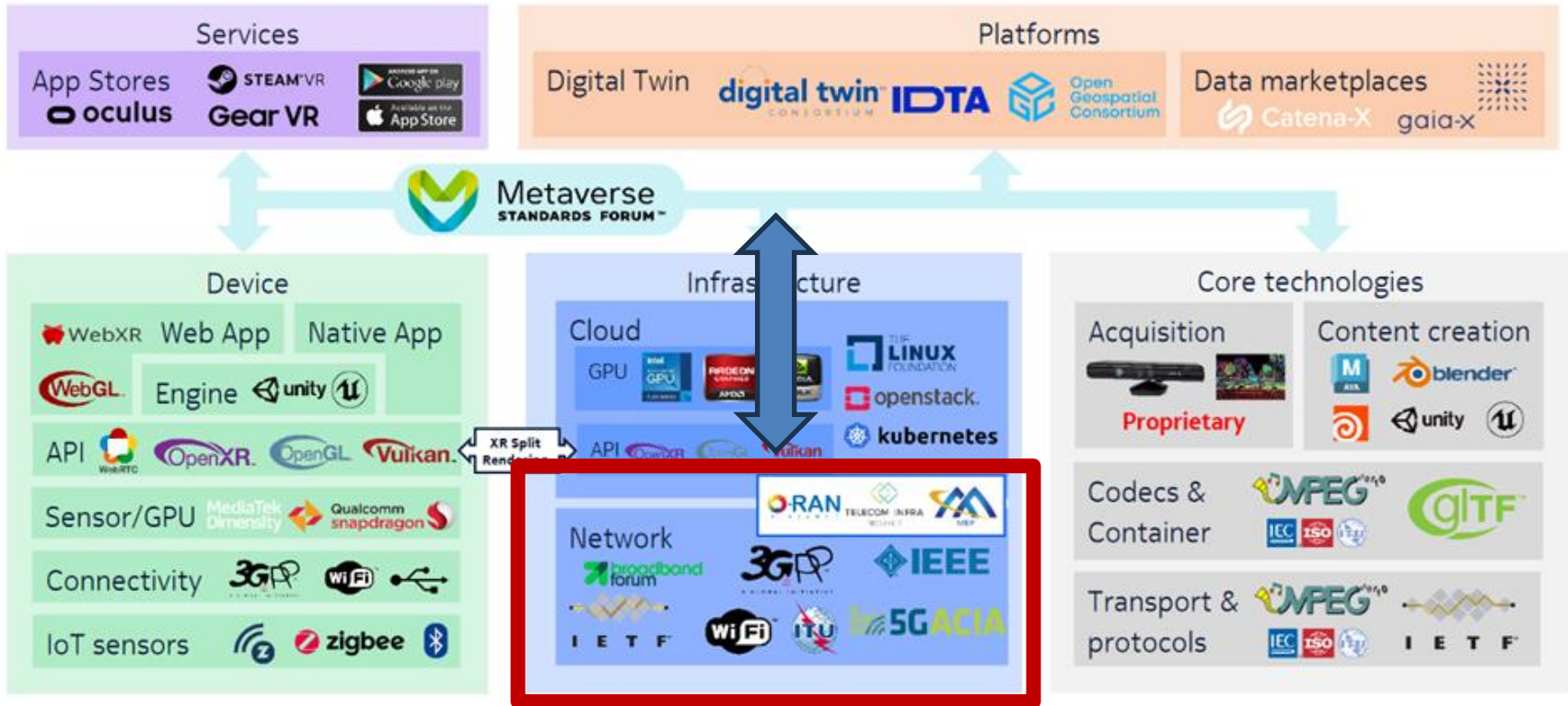
Metaverse Use in the Real Estate Industry

How Metaverses can be used in the real estate industry

Key
Working Groups
Exploratory Groups
Exploratory Group Proposals
Domain Group activities



What we want to achieve : Impact driven, bilateral dialogue with the network infrastructure SDOs



The Network Requirements and Capabilities (NRC) Working Group

Co-chairs : Omar Elloumi (Nokia), Jens Johann (DT)

Goals:

- Collect service and application use-cases
- Identify and describe QoE metrics
- Identity distribution scenarios and architectures
- Identify E2E dataflows and traffic characteristics
- Collect requirements and KPIs
- Analyze features in existing and ongoing standards
- Assess if requirements are addressed, and if any gaps exist

Non-goals:

- NRC is not specifying technologies (protocols, call-flows, ...)



NRC roadmap and deliverable

NRC workplan:

Phases	Description	Status
1	Collect service and application use-cases from the industry.	Done (100%)
2	Classification of use-cases, identification of categories and synergies.	Done (100%)
3	Technical report on network requirements and KPIs for metaverse applications and services (D1)	Done (100%)
4	Technical report on gap & feasibility analysis for metaverse applications and services. (D2)	Done (100%)
5	Conclusions are communicated to relevant organizations.	Ongoing
6	Re-evaluation of the charter	Not started

Now

NRC is now engaged in dissemination and communication with relevant organizations



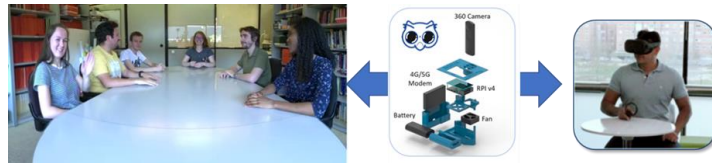
Metaverse use-cases and applications

Diverse set of use-cases, including:

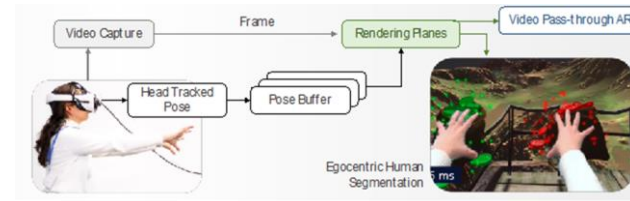
- Maintenance
- Avatars communication
- Local interaction with AI/ML offload
- Immersive telepresence
- Immersive Tele Operated Driving (ToD)
- VR Cloud Gaming
- AR whiteboard
- Virtual and collaborative entertainment



Wiring in a street cabinet



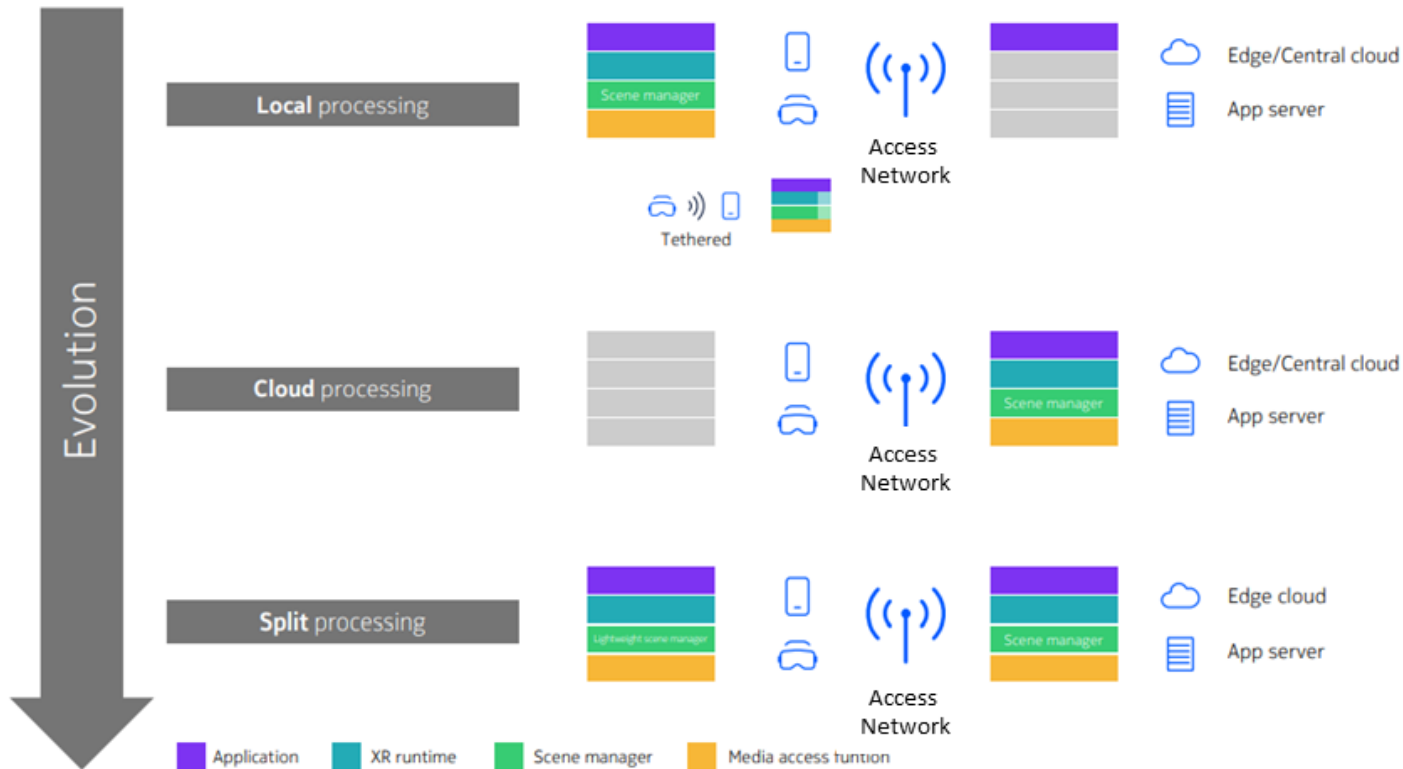
Immersive telepresence



Local interaction assisted by offloaded processing

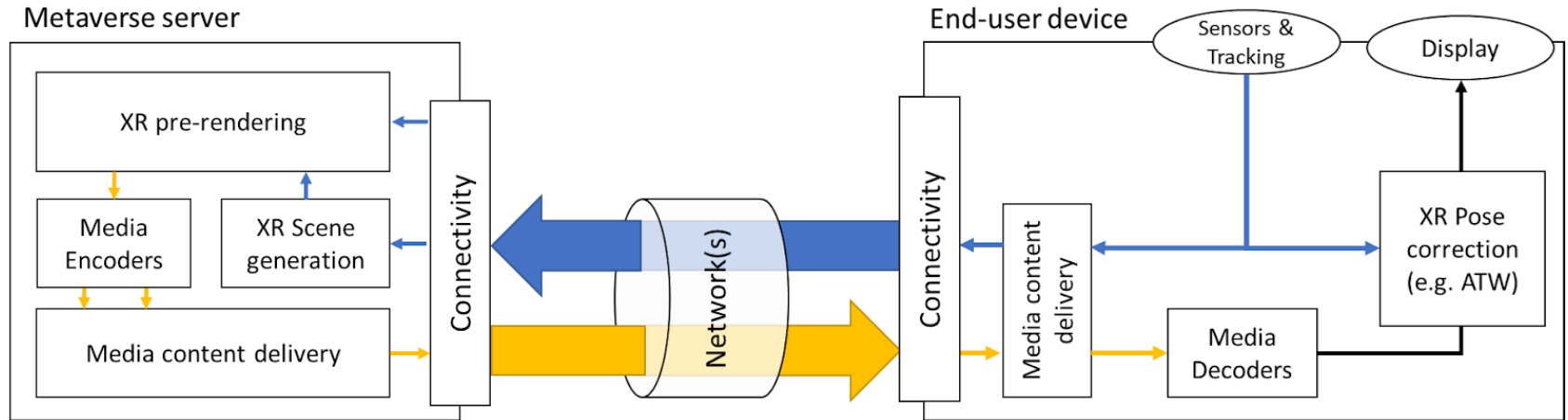


Processing scenarios (1/3)



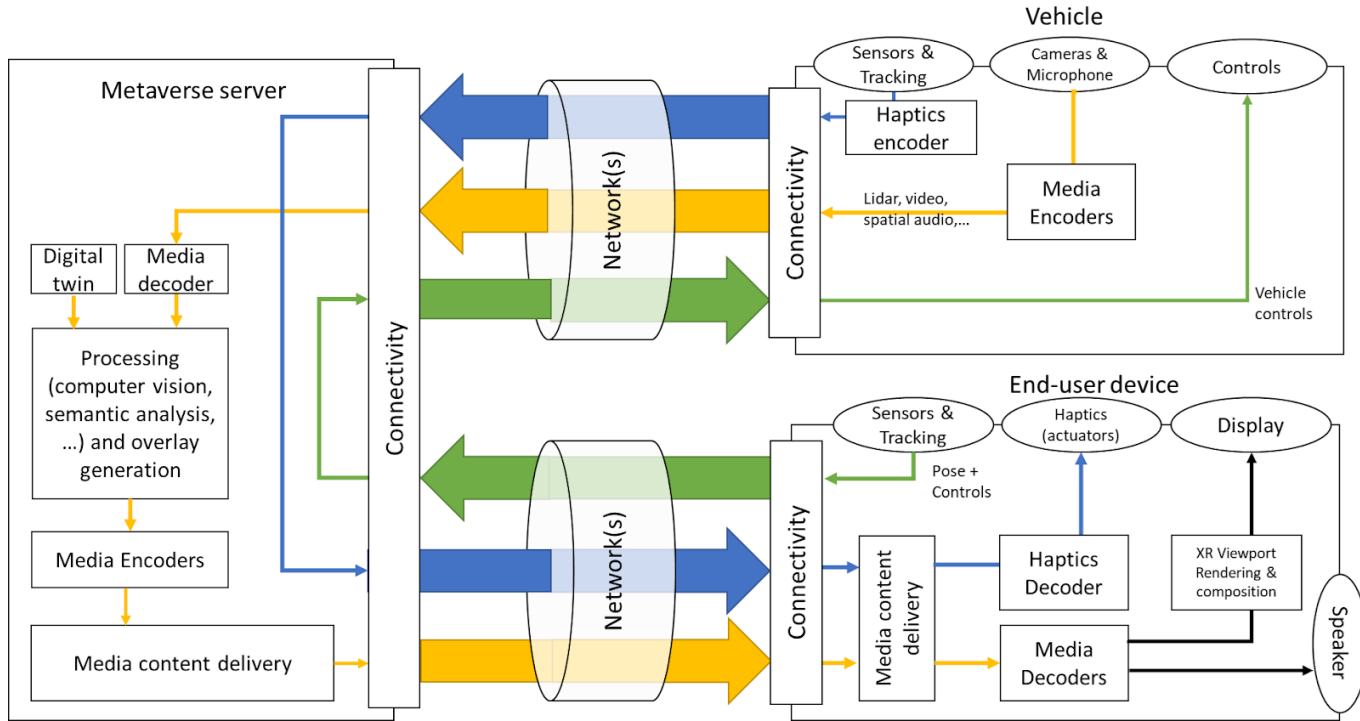
Processing scenarios (2/3)

From classical standalone and split-rendering



Processing scenarios (3/3)

To split-rendering for remote control or collaborative work



Connectivity requirements for metaverse services (1/3)

Split-rendering case for VR cloud gaming (UC6) and Immersive telepresence (UC7)

	Session aspects			Throughput					Latency (worst-case)
	#Users	Device Speed	Distance between users	Video	Audio	Sensors	Haptics	Data	
UC6	[1-100]	Static	Worldwide	Rendering: [6-35]Mbps DL [16,17]	500kbps DL	Pose 500Kbps UL	500kbps DL	Controls: 500kbps UL	<p>“Worst-case” is first person game [10] + [60-100]ms motion-to-render-to-photon [Device] -1ms for sensors and pose acquisition (Note: depend on pose estimation algorithm, see [22])</p> <p>[Server] -(1/Fr)ms for scene generation and rendering (Note: depends on rendering targeted framerate, 16ms for 60fps)</p> <p>[Server] -6ms for GPU encoding [12]</p> <p>[Device] -20ms for decoding (1 frame at 50fps)</p> <p>[Device] -ems for composition and display =~[17-57]ms remaining for the network</p>
UC7	[2-10]	Static	Worldwide	Rendering: 20Mbps DL	500kbps UL 500kbps DL	Pose 500Kbps UL	500kbps DL	Controls: 500kbps UL	



Connectivity requirements for metaverse services (2/3)

Use-cases also bring functional requirements

Functional requirements	Split rendering	Offloaded overlay generation	Standalone rendering	Split rendering for collaborative work	Split-rendering for remote control with haptics
Flexible throughput management, to adapt bitrate to signs of congestion	YES	NO	NO	NO	YES
Prioritization of sub-flows compared to other ones, based on their relative importance	YES	NO	NO	NO	YES
Support punctual high-throughput/low-latency bursts	NO	NO	YES	YES	NO

And network exposure requirements

- Quality on Demand to support carriage of media flows
- Network information/insights to monitor network quality and react upon degradation
- Provisioning/deployment of computing resources at the edge – as close as possible
- Network customization to ensure traffic prioritization for crucial data under congestion
- Accurate location and precise positioning, including indoor, to support real-time services



Connectivity requirements for metaverse services (3/3)

Latency

- Network delay budget (RTT) is from 13ms for most demanding applications
- In general, 20-25ms would satisfy most of the cases

Throughput

- When all components are summed up, around 80Mbps-DL/30Mbps-UL are needed in total for most demanding applications
- In general, 30Mbps-DL/10Mbps-UL would satisfy most of the cases

Network exposure is required to:

- Finely set quality on demand for multimodal applications
- Configure and enable congestion control
- Deploy processing at edge to meet most demanding latency constraints



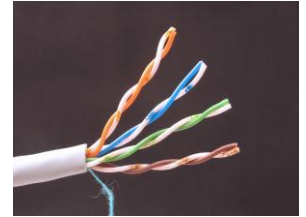
Can the existing networking technologies enable such use-cases and applications to be deployed at scale?



PON



DSL



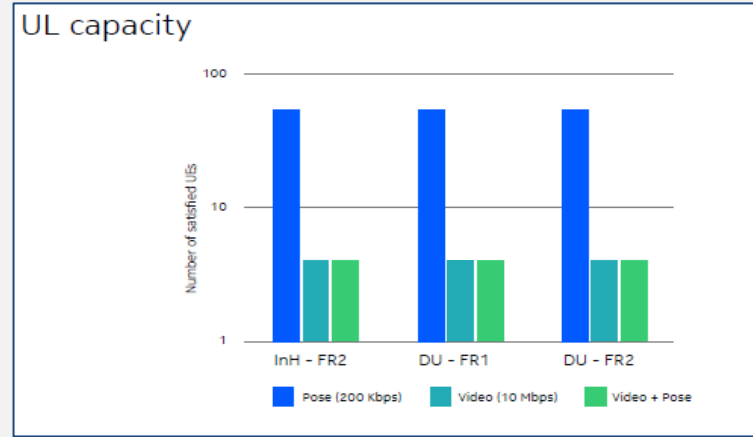
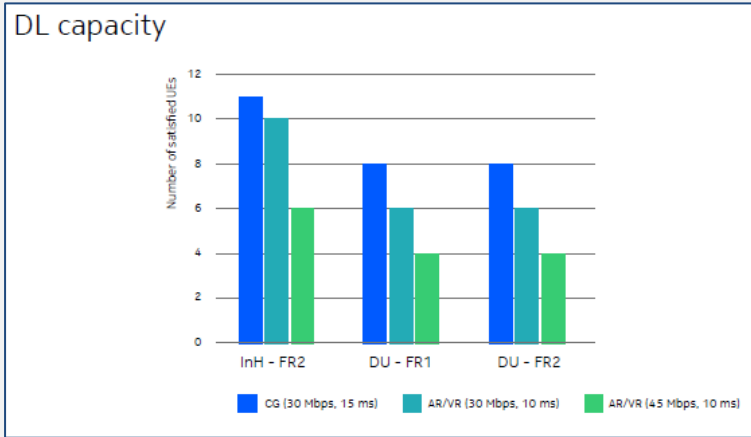
Cable



Gap analysis: Cellular network (1/4)

5G Rel.15/16 can support low XR traffic load of standalone devices - number of users depend on the Packet Delay Budget (PDB), bandwidth requested

Device Power usage not optimized for XR, feature supporting XR mass adoption come in Rel.18



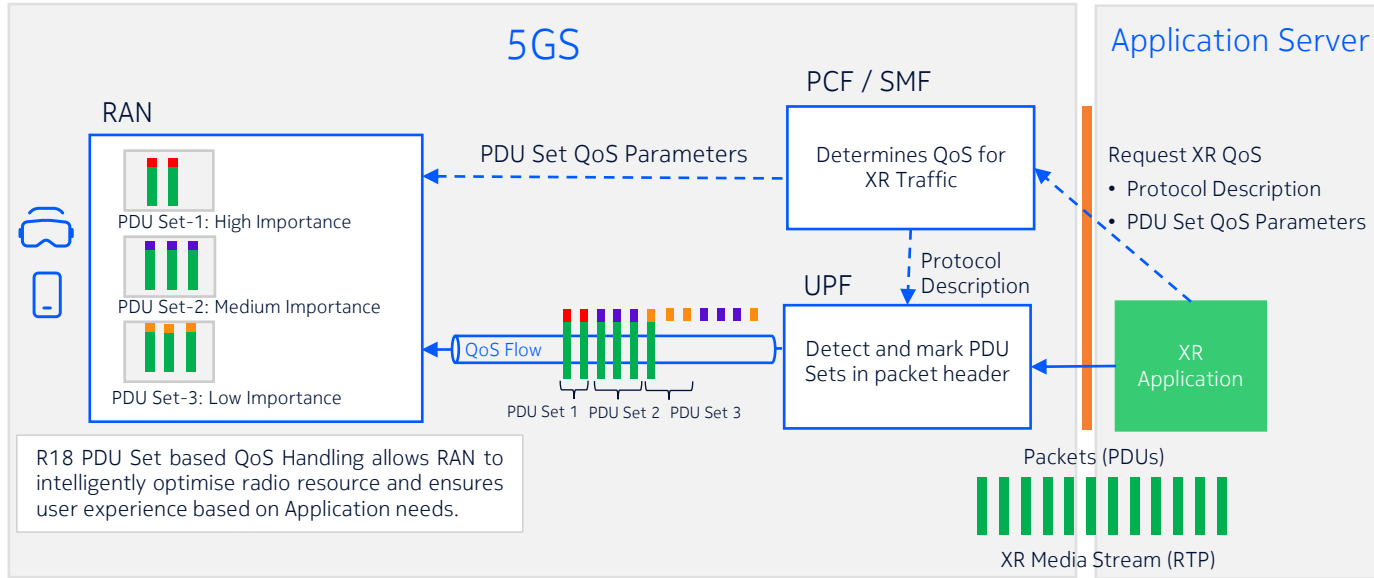
InH = Indoor Hotspot
DU = Dense Urban
FR1: 4GHz, FR2: 30GHz
System bandwidth: 100MHz

- 2022: IEEE paper ([researchgate.net](https://www.researchgate.net/publication/358888888)) : [Extended Reality \(XR\) over 5G and 5G-Advanced New Radio: Standardization, Applications, and Trends](#)



Gap analysis: Cellular network (2/4)

Rel.18 Application Aware QoS



- The 5G CN (UPF) identifies which packets in downlink XR traffic flows form a PDU set. A set can be, e.g., a video frame or a video slice.
- The UPF provides PDU set membership, size and importance info to the RAN over GTP-U.
- RAN is also given PDU Set specific delay budget and error rate requirements (called PSDB, PSER).
- This allows the RAN to schedule the PDUs within a PDU set more intelligently and flexibly compared to individual PDUs

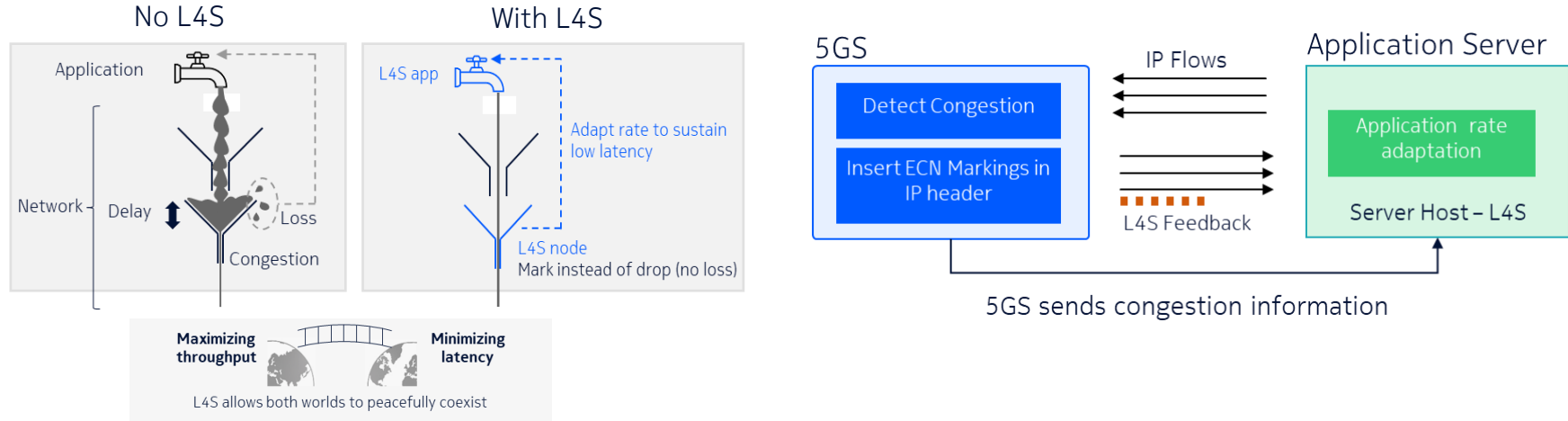
Benefits

- Flexible scheduling improves DL capacity – though minimizing packet loss impact on user experience



Gap analysis: Cellular network (3/4)

3GPP R18 L4S for scalable roll-out of robust low-latency services (UL and DL)

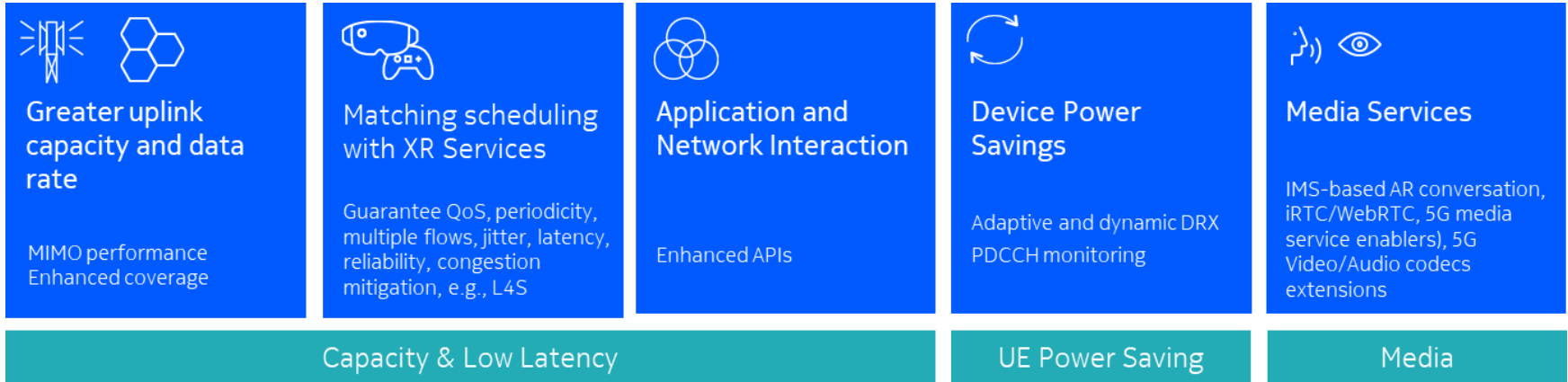


- L4S allows RAN to inform the application directly about the data rate limitations (congestion or coverage bottleneck)
- Application can react to the radio limitations by lowering the data rate before it impacts the application latency
- Data rate adaptation (like Youtube) is available today, but it is slow and kicks-in only when the latency has already increased



Gap analysis: Cellular network (4/4)

In general, all the requirements established in D1 are achievable by 5G. The possible scaling issues are addressed by 5GA, by introducing several enhancements:



Gap analysis: Wi-Fi

For more stringent applications:

- Difficult to obtain required PDB with pre Wi-Fi 6 generations in scenarios with multiple users/applications
- When number of users scales up, XR requires prioritization and admission control, which is fulfilled from Wi-Fi 6, but on busy 2.4GHz and 5GHz bands.
- → Wi-Fi 6E leverages 6GHz, where there are currently no interference problems, and which seems to be the mature enough technology to support metaverse applications

However, it appears in practice that Wi-Fi 6/6E cannot fulfil the latency requirements we've established with average latency measurements around 100ms [1].

- L4S has been demonstrated to provide a solution to address this issue [2]

[1] <https://www-res.cablelabs.com/wp-content/uploads/2024/04/10100006/Impacts-of-WMM-on-Wi-Fi.pdf>

[2] <https://www.nokia.com/about-us/news/releases/2024/04/03/nokia-and-vodafone-conduct-worlds-first-trial-of-l4s-technology-over-an-end-to-end-pon-network/>



Gap analysis: PON (1/2)

Testing GPON, XGS-PON and 25GS-PON:

Technology	Typical throughput (100 Mbps busy hour load, 1:64 split ratio)	Typical DS Latency (without congestion)	Typical US latency (without congestion)
GPON	2 Gbps DS 900 Mbps US	25us (64B) 130us (jumbo)	500us – 1.5 ms
XGS-PON	8 Gbps DS 7.5 Gbps US	25us (64B) 130us (jumbo)	500us – 1.5 ms
25GS-PON	20 Gbps DS 17 Gbps US	25us (64B) 130us (jumbo)	500us – 1.5 ms

PON measurement done on few operators' networks (source: Nokia)



Gap analysis: PON (2/2)

What about congested networks ?

- High performance can still be achieved by leveraging L4S
- L4S maintains near-zero queuing delay
- Demonstrated by Vodafone and Nokia Bell Labs :
 - 1.2ms latency at local ethernet port
 - 12.1ms at WiFi local network termination
 - [Link](#)

PON technologies are capable today of addressing metaverse requirements as a backhaul solution or access network. In an end-to-end solution coupled with another access network, the latter would be the bottleneck. In highly congested networks, PON solutions can support L4S to maintain low latency.



Gap analysis: DOCSIS

Throughput:

- DOCSIS 3.1 supports data rates up to 10 Gbps in the downlink direction and 1.8 Gbps in the uplink direction, shared by the customers of each Service Group.
- DOCSIS 3.1/4.0 could support hundreds of simultaneous sessions.

Latency:

- DOCSIS 3.1 supports active queue management, and are upgradable to support L4S, NQB, and low latency scheduling for particularly latency sensitive upstream services.
- DOCSIS 4.0 supports both active queue management and Low Latency features
- Low Latency DOCSIS deployments can achieve even the most stringent XR latency targets at the 99th percentile, with round-trip times in the range of 1-10ms



Gap analysis: Exposure ecosystem (1/2)

High user-experience requires high interaction with the network, through APIs. We've seen that following functions need to be called:

- Quality on Demand to support carriage of media flows
- Network information/insights to monitor network quality and react upon degradation
- Provisioning/deployment of computing resources at the edge – as close as possible
- Customization to ensure traffic prioritization for crucial data under congestion
- Accurate location and positioning, including indoor, to support real-time services

This is as of today delivered by CAMARA or 3GPP CAPIF/NEF, but how to access those ?

How can applications developers reach those APIs globally ?

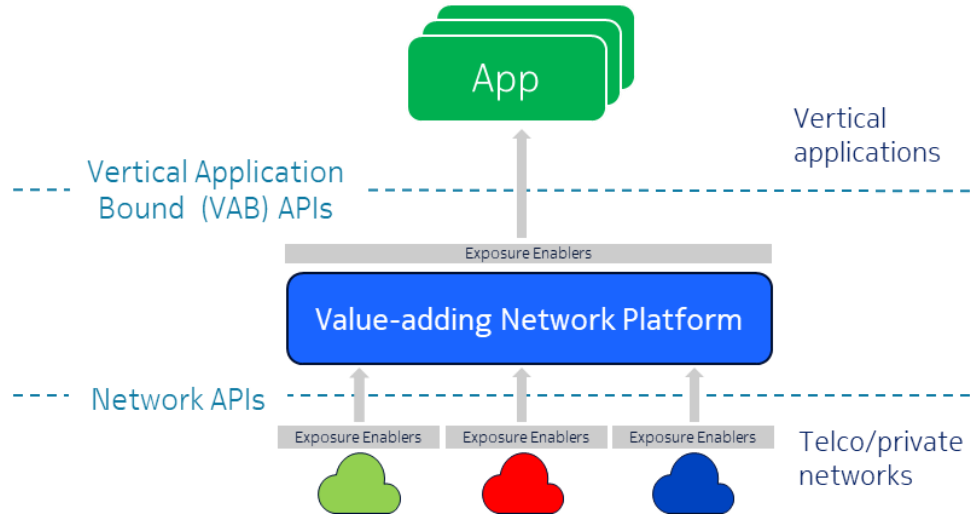
- GSMA Open Gateway identified multiple ways of distributing and accessing APIs
- API roaming or aggregators can play an important role



Gap analysis: Exposure ecosystem (2/2)

There is value in providing intuitive, on-demand, and elastic access to network resources, capabilities and analytics, control and data, while hiding the complexity of the telco capabilities, and opening the network for innovation.

By introducing a Value-adding Network Platform, Telcos or Aggregators can provide vertical application bound (VAB) APIs that deliver simple and contextualized services, focusing on the desired vertical industry outcomes.



Is the open internet ready ? (1/6)

Study has been done on Ookla's global internet speedtest database, which provides:

- Average download/upload speed
- Average latency (RTT)
- Average latency under uplink and downlink load

What we looked at is:

- Per regions mobile & fixed network performance, in average and under load
- Low-density/Rural versus urban/high-density areas networking performance

Note:

- Dataset is providing data from Q1-2019 until now
- Wifi access is merged into fixed data
- 4G and 5G are merged together



Is the open internet ready ? (2/6)

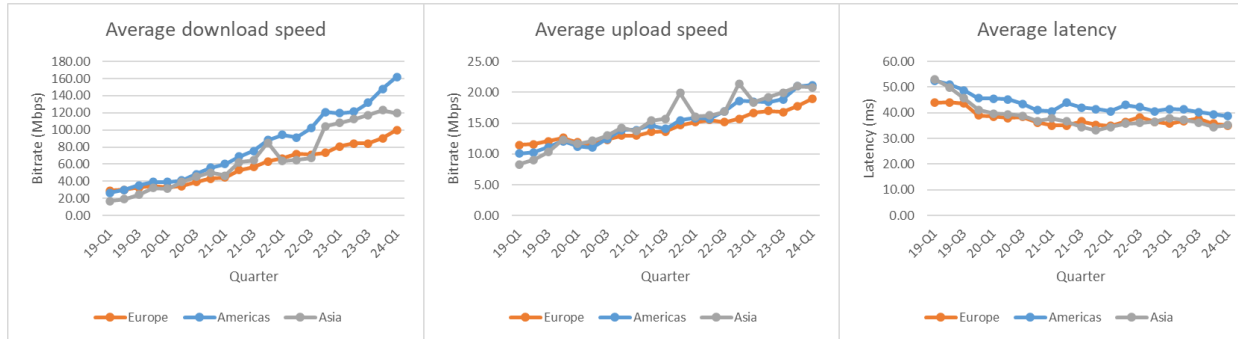


Figure 8: Average performance of internet over mobile network

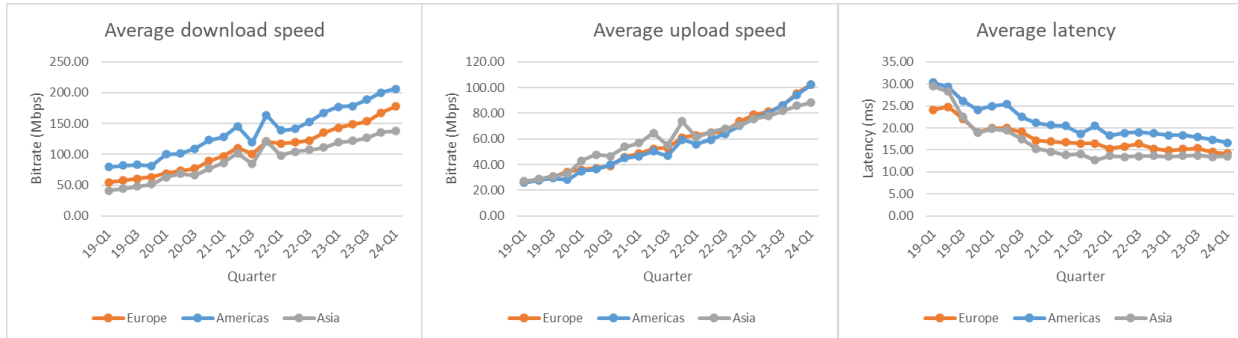


Figure 9: Average performance of internet over fixed network

Today's Internet, on average, is sufficient to deliver most of the metaverse applications over the top, on both mobile and fixed infrastructure

BUT ...



Is the open internet ready ? (3/6)

Table 1: Average latency under load (from 22-Q4 to 24-Q1)

			22-Q4	23-Q1	23-Q2	23-Q3	23-Q4	24-Q1
Europe	Fixed	lat. DL	276.94	265.91	279.29	263.31	250.92	254.83
		lat. UL	435.62	433.77	410.17	394.09	394.81	393.97
	Mobile	lat. DL	984.99	890.00	849.20	847.26	761.75	808.44
		lat. UL	1315.63	1261.53	1231.52	1272.65	1226.17	1153.40
Americas	Fixed	lat. DL	310.81	314.52	316.38	314.00	306.29	300.86
		lat. UL	401.64	399.21	403.71	405.80	403.51	404.33
	Mobile	lat. DL	848.64	850.34	862.97	851.61	854.79	900.07
		lat. UL	1071.31	1073.63	1096.28	1075.92	1034.39	1016.13
Asia	Fixed	lat. DL	283.41	282.34	279.55	268.64	262.21	263.70
		lat. UL	510.25	487.14	478.33	455.39	446.91	453.18
	Mobile	lat. DL	836.16	873.90	873.55	912.86	849.37	880.64
		lat. UL	1124.29	1162.82	1138.85	1143.64	1082.30	1116.85

When filtering out the data to loaded network conditions, it appears that both fixed and mobile networks provide too high latency to support metaverse applications



Is the open internet ready ? (4/6)

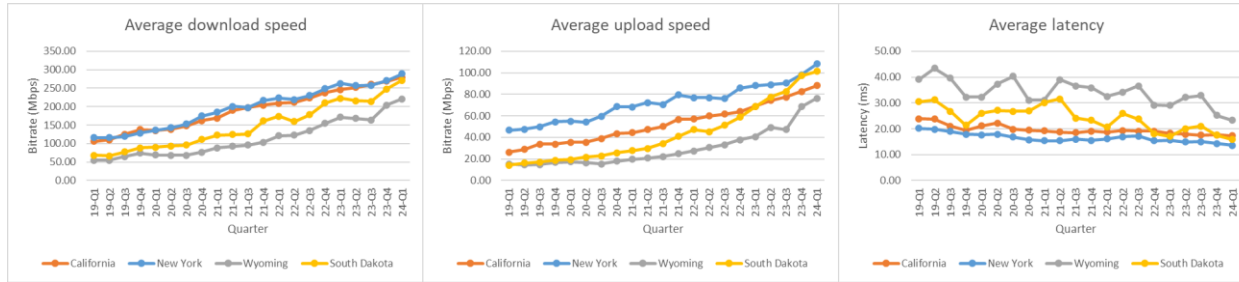


Figure 11: Average performance of internet over fixed network in US states

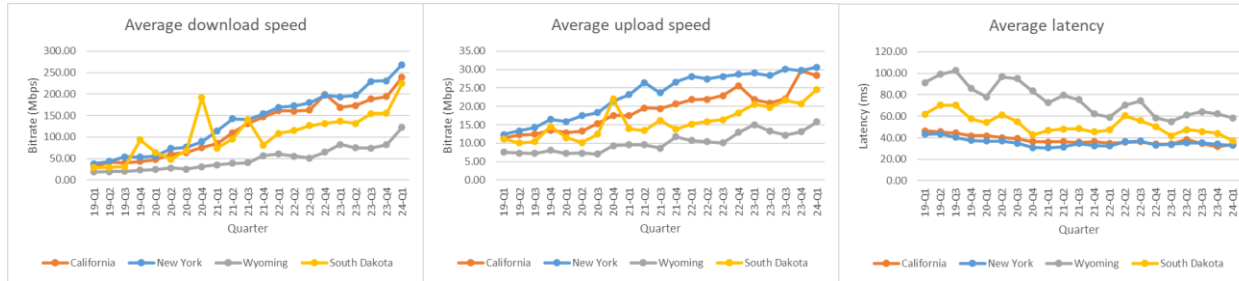


Figure 12: Average performance of internet over mobile network in US states

The disparity between dense urban areas and rural areas is highlighting that remote locations are not compatible today with next generation metaverse services, particularly in terms of latency and upload speed



Is the open internet ready ? (5/6)

In Europe, although average latency measurements do not address most demanding metaverse applications, several countries are already capable of delivering expected network performance, providing low enough latency and high enough upload speed. Those are small countries with few locations concentrating most of the population.

Table 1: Example of European countries ready for most demanding metaverse applications (2024-Q1)

	DL	UL	Latency
North Macedonia	152.557	33.7201	21.0721
Denmark	239.484	30.7403	22.2969
Bulgaria	214.214	30.2402	22.9872
Switzerland	165.952	32.53	23.9475
Croatia	246.31	35.3198	24.0005



Is the open internet ready ? (6/6)

The study shows:

- Round trip latency for wireline access has dramatically dropped over the years to reach an average acceptable level for the identified applications needs (20-25ms).
- Uplink capacity for mobile access has improved but could be a limiting factor for some of most demanding applications. 3GPP has been working on features to enhance uplink capacity in Rel. 18, once they get deployed the uplink throughput should improve.
- Round trip latency for mobile networks is not consistent across countries. In some cases it may not offer the acceptable latency for some applications. Traffic management, e.g. L4S, would be super beneficial to master the round trip latencies and offer levels acceptable to applications. The deployment of edge cloud should also help in bringing the latency to acceptable level.
- During peak hours and under load conditions, neither wireline nor wireless access provide the sufficient performance needed by applications. Without traffic differentiation (e.g. PDU set features in 3GPP Rel.18) or a mechanism to master latency (such as L4S), the current Internet cannot support metaverse applications under load conditions.
- 6G networks must have a significant emphasis on device to application low latency (not ultra low latency) and uplink to bring the performance level on par with wireline.



Conclusion and recommendation (1/2)

Capabilities of networking technologies to support metaverse applications at scale:

- 3GPP: from 5G can cope with connectivity requirements. Additional features in 5GA are necessary to scale up.
- WiFi: from 6E, is a candidate to support metaverse applications. Not enough features to cope with loaded conditions, need for L4S.
- DOCSIS: from 3.1/4.0 can address connectivity requirements. Powerful set of feature for low-latency demanding applications.
- PON: capable today of addressing metaverse requirements as a backhaul solution or access network. L4S is a plus when coupled with bottleneck access point (e.g. WiFi)

It is identified that traffic engineering may not cope with future protocols (HTTP3/QUIC with its full encryption). L4S should be generalized and widely support to enable scaling.



Conclusion and recommendation (2/2)

Ecosystem aspects:

- All applications requires interaction with the network, for quality on demand, congestion control and traffic engineering, and processing deployment
- API ecosystem is complex to manage at a global scale, aggregators can play an important role

Current state of internet:

- Need for more 5G deployment to increase mobile network global performance
- Rural areas may need more edge deployment
- Both fixed and mobile networks cannot sustain metaverse services under load, which advocates for network exposed features:
 - Quality on demand
 - Traffic engineering and congestion control (L4S)





Metaverse

STANDARDS FORUM™

Standards Cooperation for an Open
and Inclusive Metaverse

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