

March 17, 2022

# Reality Check of Metaverse: A First Look at Social Virtual Reality Platforms

**GAMES: Graphics And Mixed Environment Seminar**

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# Research Overview

## Past Research



**802.11  
Wireless  
LAN**

**[INFOCOM 2009]  
[NSDI 2010]**



**Mobile  
Opportunistic  
Networks**

**[MobiHoc 2012]  
[ICNP 2012]**



**Multipath  
Transport on  
Mobile**

**[CoNEXT 2015]  
[CoNEXT 2016]**



**Network  
Functions  
Virtualization**

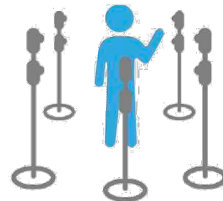
**[SOSR 2015]  
[SOSR 2017]**



**360-degree  
Video  
Streaming**

**[MobiCom 2018]  
[CoNEXT 2019]**

## Ongoing Research



**Volumetric  
Video  
Streaming**

**[MobiCom 2020]  
[MobiCom 2022]  
[NSDI 2022]**



**Mobile  
Augmented  
Reality**

**[Multimedia 2018]  
[HotMobile 2018]  
[VR 2022]**



**Mobile  
Spatial  
Computing**

**[MASS 2020]  
[HotMobile 2022]  
[MobiSys 2022]**



**Collaborative  
Immersive  
Computing**

**[HotNets 2021]  
[CHI 2022]**

# Improving Quality of User Experience and Optimizing Data Traffic

# Metaverse: The Evolution



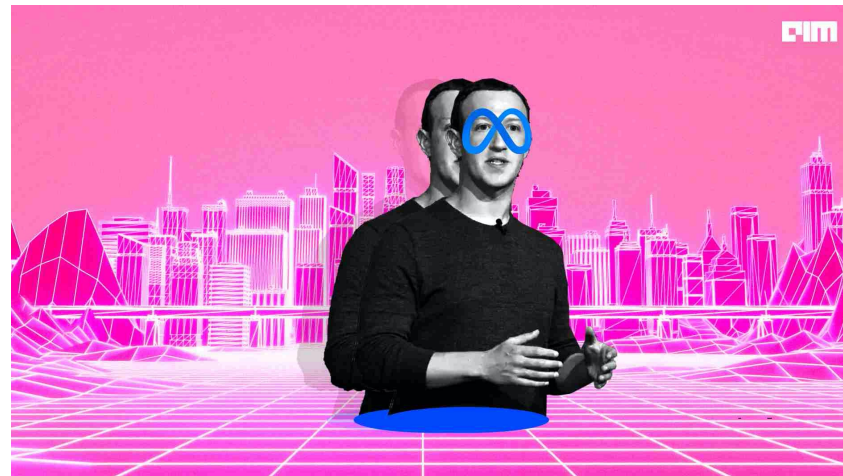
# Metaverse: The Evolution



1990s



2000s

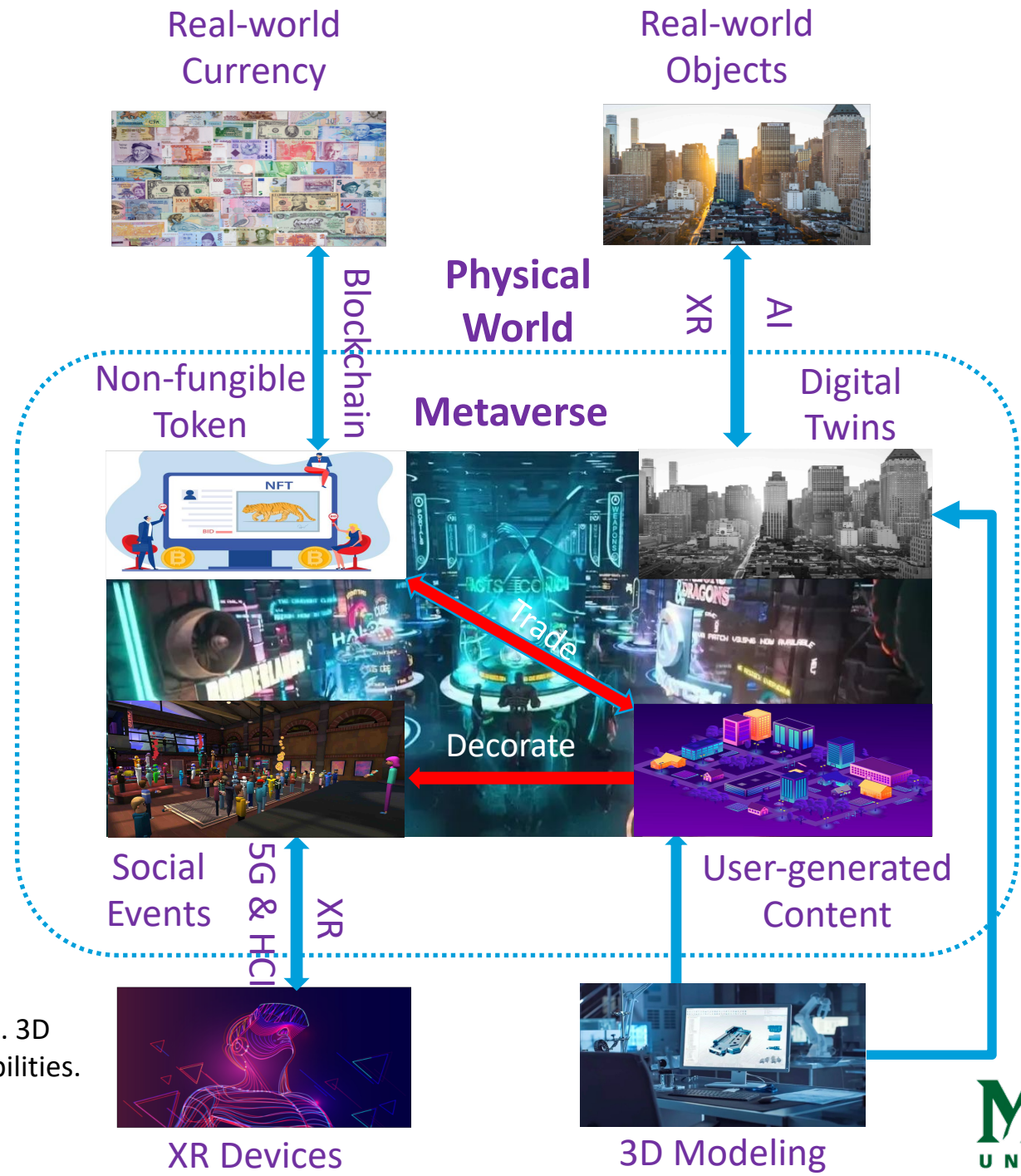
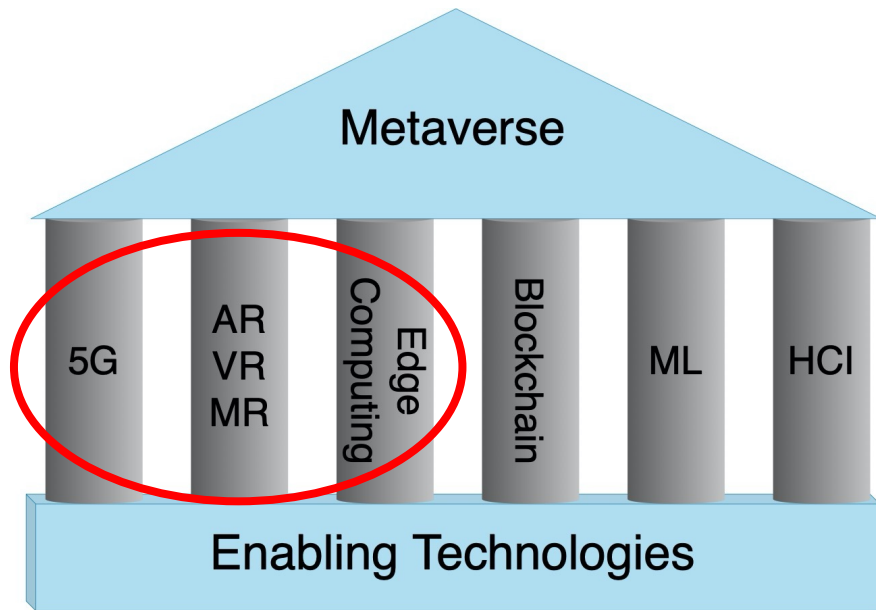


Now



# Today's Metaverse

- ✓ A collection of **3D virtual** worlds connected via the Internet<sup>[1]</sup>



[1] John David N. Dionisio, William G. Burns III, and Richard Gilbert. 3D Virtual worlds and the metaverse: Current status and future possibilities. ACM Computing Surveys, 45(3):34:1–34:38, 2013.

# What is the **Reality** of the Metaverse?

# Social Virtual Reality (VR)





# Motivation

- ✓ Why measuring social VR platforms?
  - Early prototype of the Metaverse
  - Increasing popularity (*e.g.*, hosting conferences<sup>[1]</sup> and supporting dance community<sup>[2]</sup>)
  - Potentially replace online social networks and video conferencing applications
- ✓ Why the selected platforms?
  - Top in the list of existing platforms<sup>[3]</sup>
  - Diversity: Including various features

[1] Julie Williamson, Jie Li, Vinoba Vinayagamoorthy, David A. Shamma, Pablo Cesar. Proxemics and Social Interactions in an Instrumented Virtual Reality Workshop. ACM CHI 2021.

[2] Piitulainen, Roosa; Hämäläinen, Perttu; Mekler, Elisa. Vibing Together: Dance Experiences in Social Virtual Reality. ACM CHI 2022.

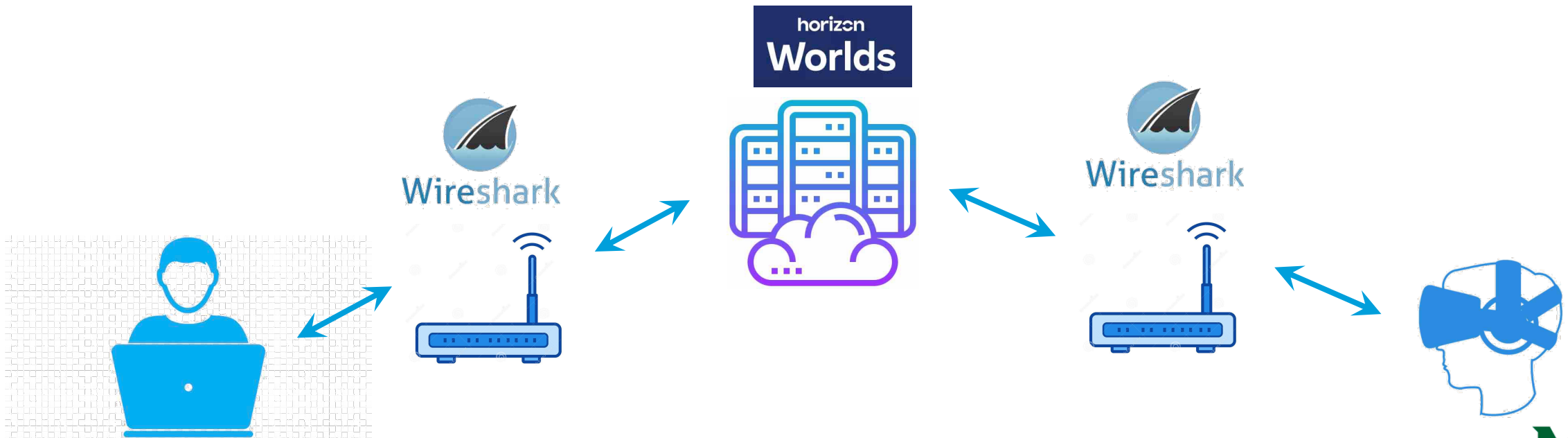
[3] Welcome to the Metaverse: A Comprehensive List of Social VR/AR Platforms and Virtual Worlds. <https://ryanschultz.com/list-of-social-vr-virtual-worlds/>

# What to Measure?

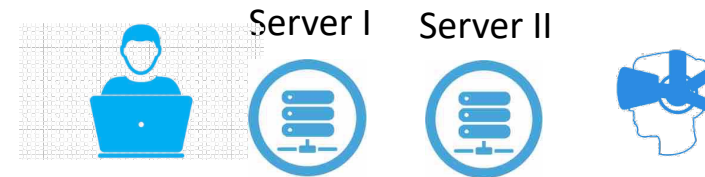
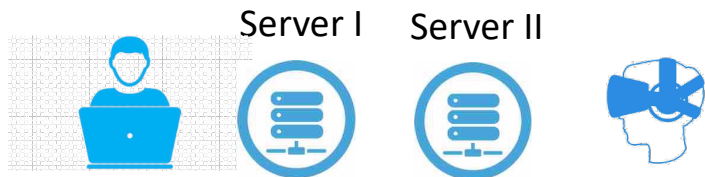
- ✓ Network Data Analytics: Data flow and protocols (*e.g.*, TCP, UDP, WebRTC, *etc.*)
- ✓ Bandwidth: Minimum requirement for basic features
- ✓ Scalability: Communication overhead with increasing number of users
- ✓ Advanced Features: Create and exchange user-generated content
- ✓ End-to-end Latency: From user A's action to display for user B
- ✓ Network Disruption: Bandwidth fluctuation, increased latency, and packet loss
- ✓ Quality of Experience (QoE): Factors affecting user-perceived quality and QoE modeling
- ✓ ... ..

# How to Measure?

- ✓ Capturing network traffic at different vantage points
- ✓ Leveraging existing performance/metrics tools (e.g., OVR for Oculus devices)
- ✓ Instrumenting server/client source code (e.g., Mozilla Hubs)

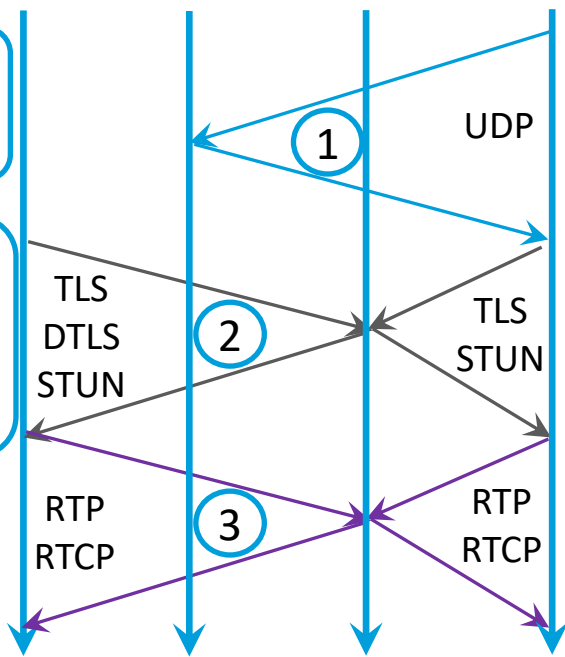


# Protocol Analysis: Workrooms & AltspaceVR



PC users do not exchange virtual content with Server I

Users set up a connection with Server II via TLS (over TCP) and STUN.

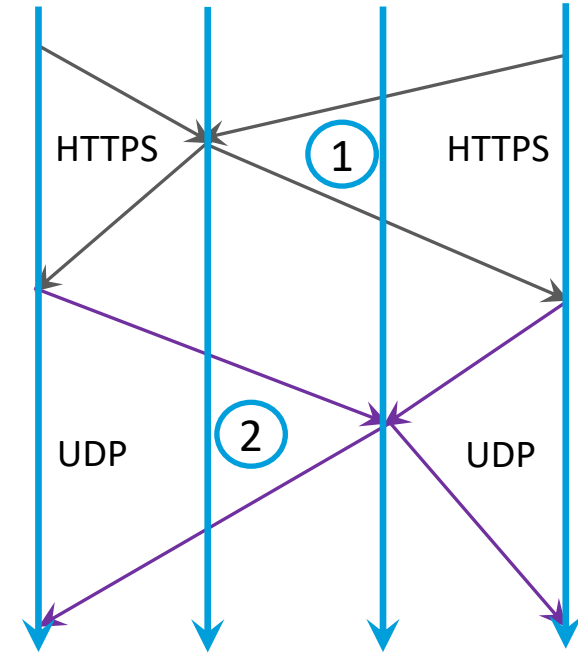


Users load background and keep exchanging virtual content via UDP.

Users keep exchanging multimedia content with Server II via RTP and RTCP.

Users set up HTTPS connection with Server I, load main environment and world content of via HTTPS.

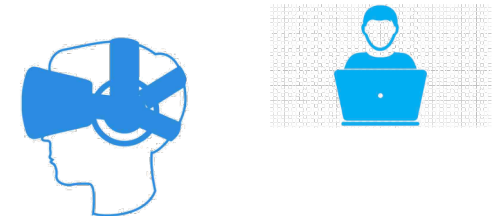
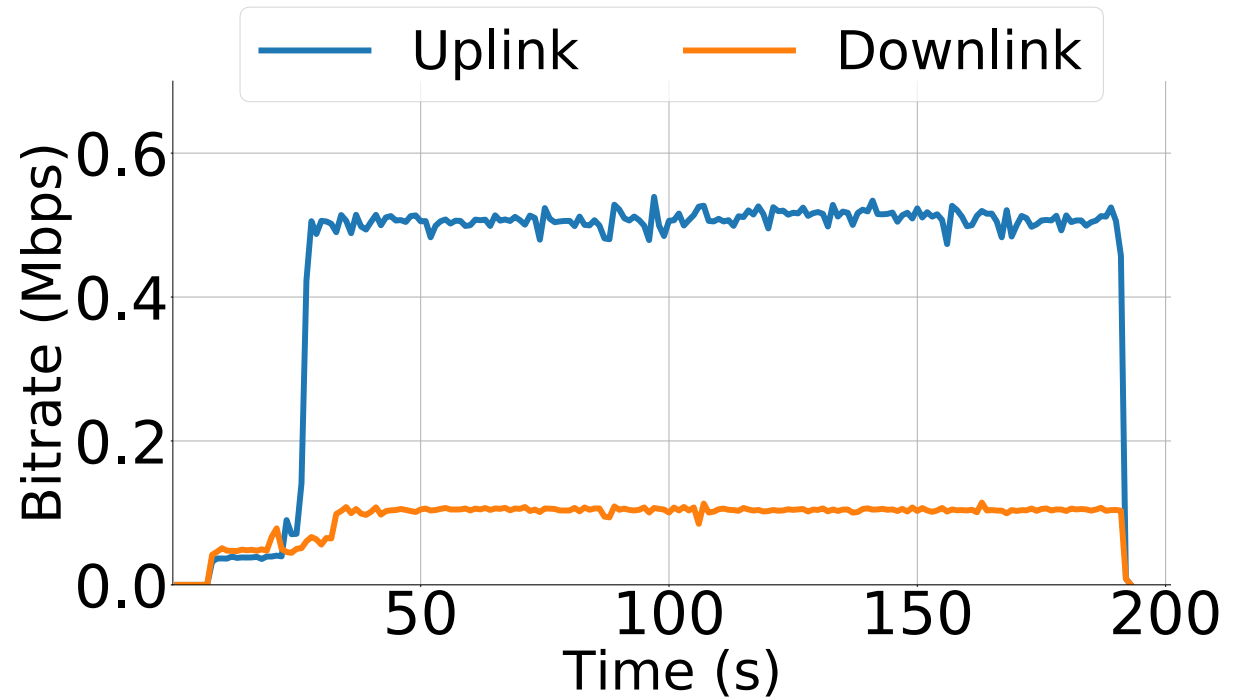
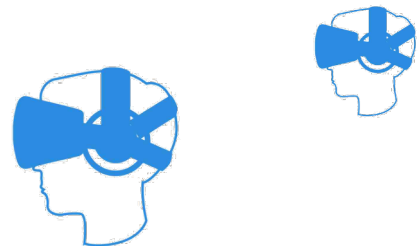
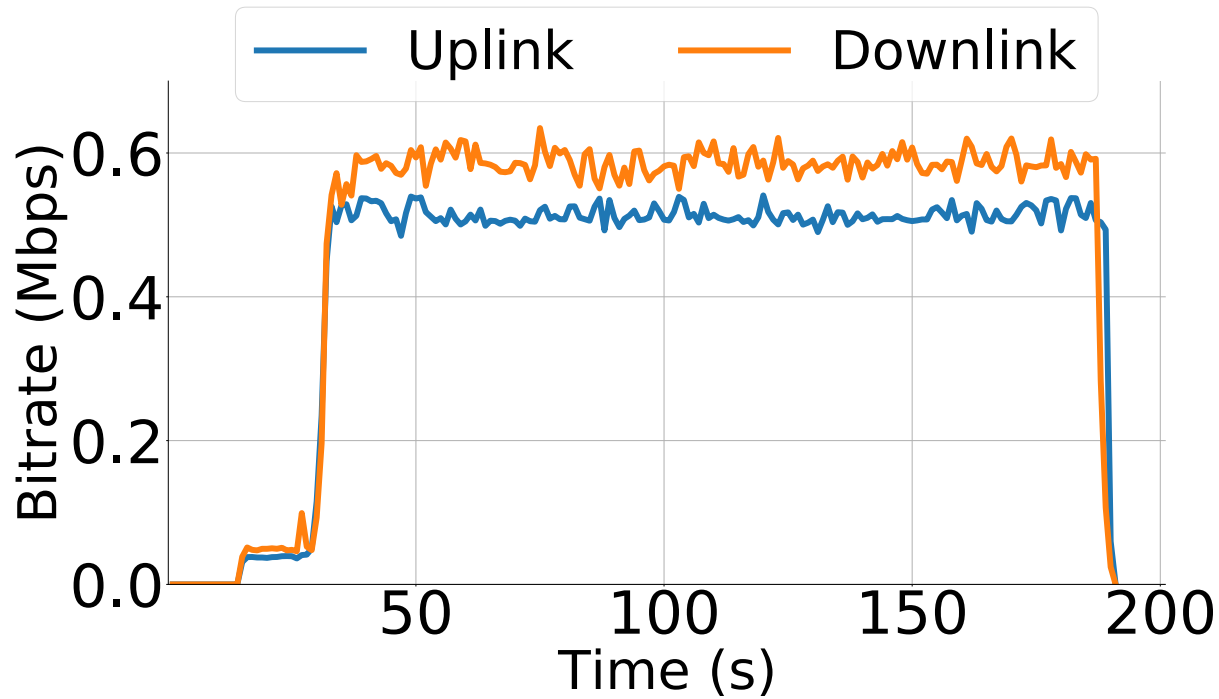
Users keep exchanging content (e.g., audio) with Server II via UDP.



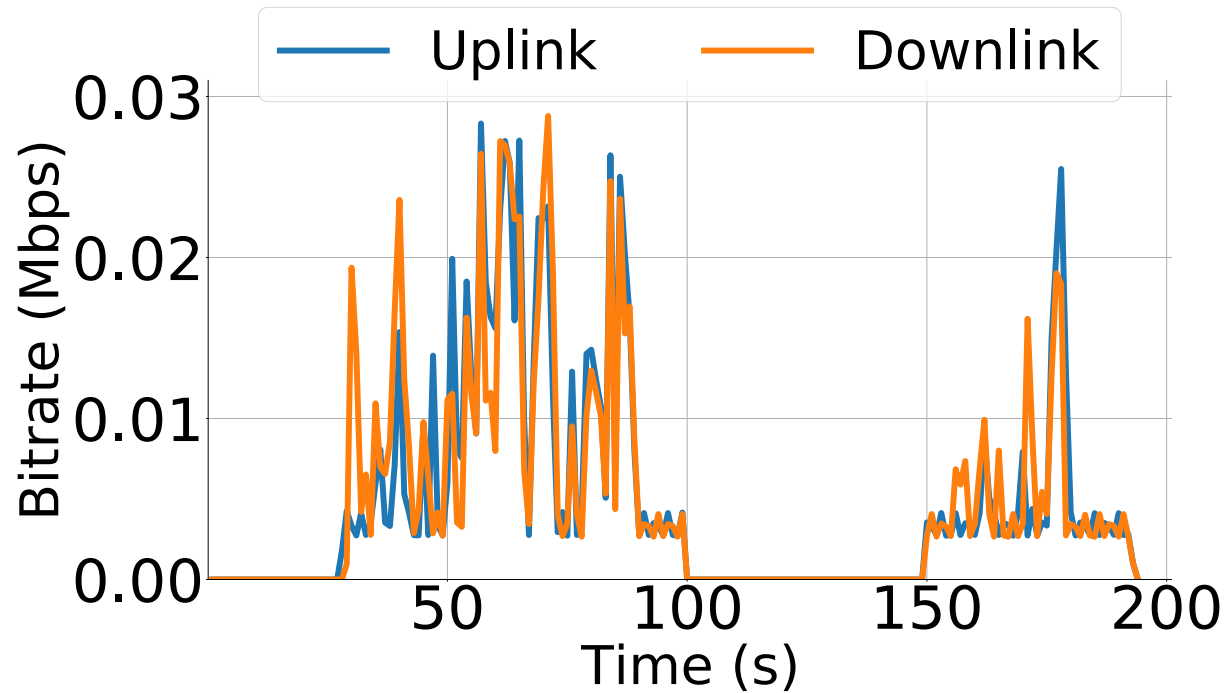
# Protocol and Capacity of Social VR Platforms

Platform	Welcome Page	Content		Max # of Users in One Room
		Virtual Background	User Interaction	
RecRoom	UDP	Pre-download in the App	UDP	40
Horizon Worlds	UDP	Pre-download in the App	UDP	20 (Headset)
VRChat	HTTPS	HTTPS Downloading (first joining)	UDP	40
AltspaceVR	HTTPS	HTTPS Downloading (first joining)	UDP	50
Mozilla Hubs	HTTPS	HTTPS (everytime)	Audio: RTP/RTCP (over UDP) Others: HTTPS	24
Horizon Workrooms	HTTPS	UDP	Audio: RTP/RTCP (over UDP) Others: UDP	16 (Headset) 50 (Total)

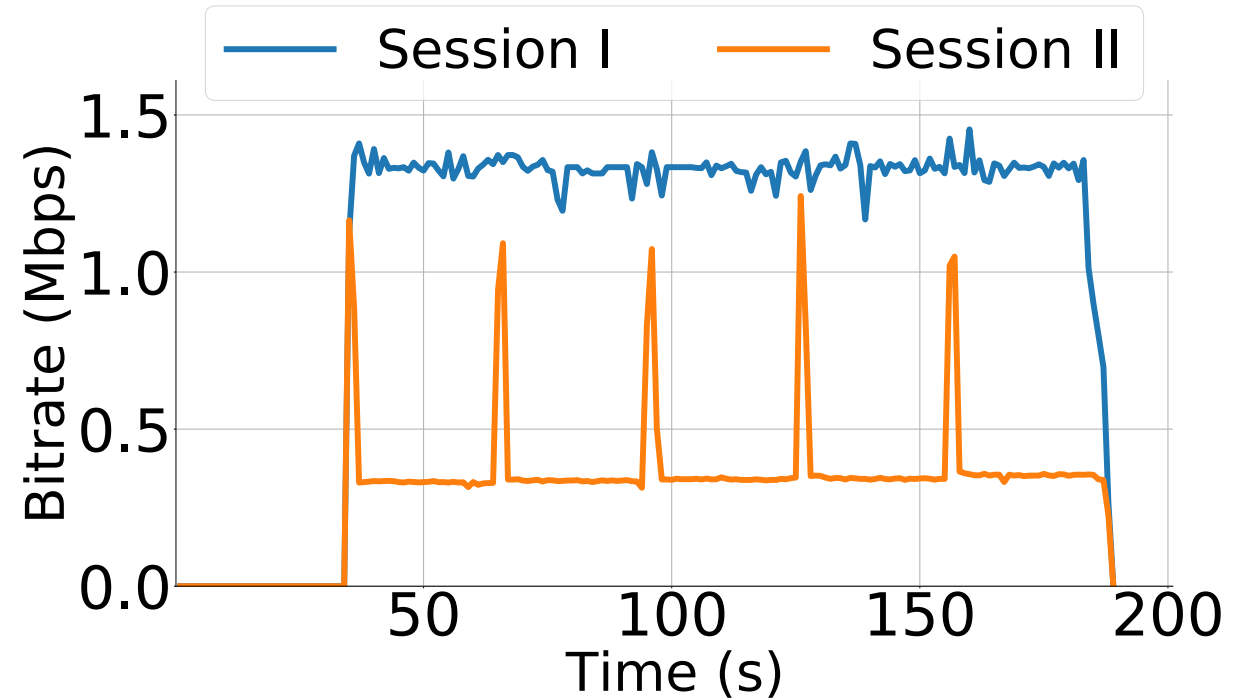
# Data Usage in Workrooms: Virtual Content



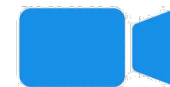
# Data Usage in Workrooms: Multimedia Content



Audio Exchange (mute users from 100 to 150s)



Video Sessions (downlink only, unknown content)



# Data Usage: More Platforms

Platform	Throughput (Two Oculus Quest 2 Users)	
	Uplink	Downlink
Horizon Workrooms	0.5 Mbps (virtual content flow)	2.3 Mbps (virtual content flow: 0.6 Mbps multimedia flow: 1.7 Mbps)
Horizon Worlds	0.7 Mbps	0.4 Mbps
VRChat	0.03 Mbps	0.03 Mbps
AltspaceVR	0.04 Mbps	0.04 Mbps
RecRoom	0.05 Mbps	0.05 Mbps
Mozilla Hubs	0.06 Mbps	0.06 Mbps

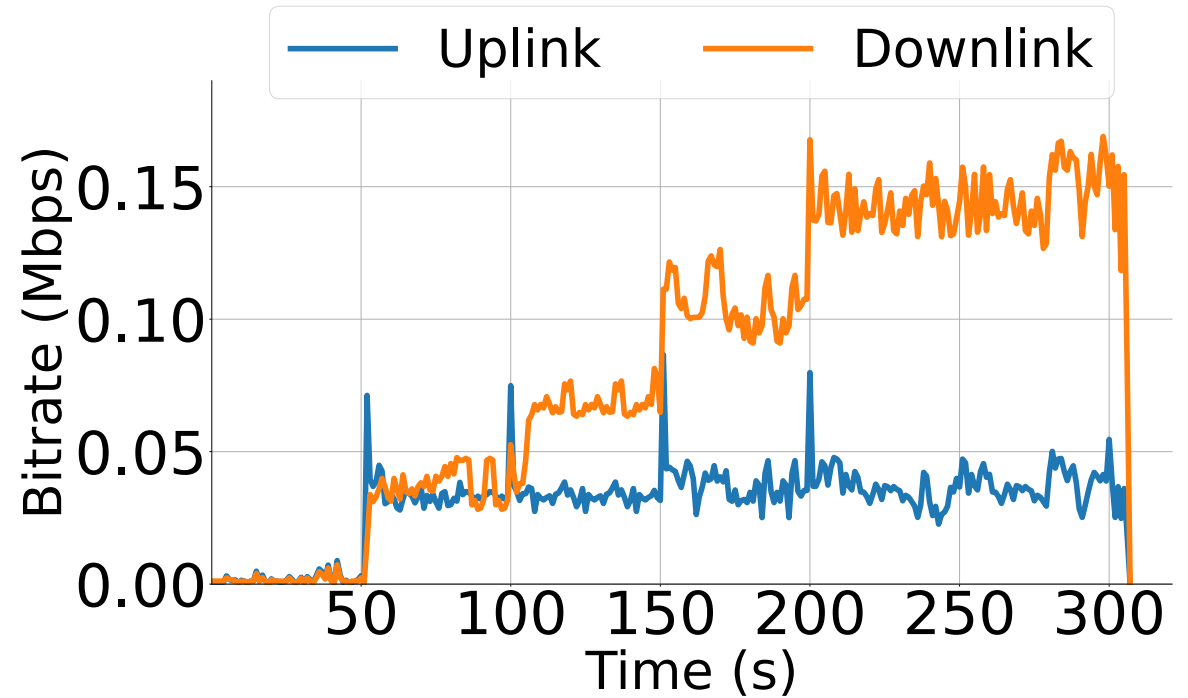
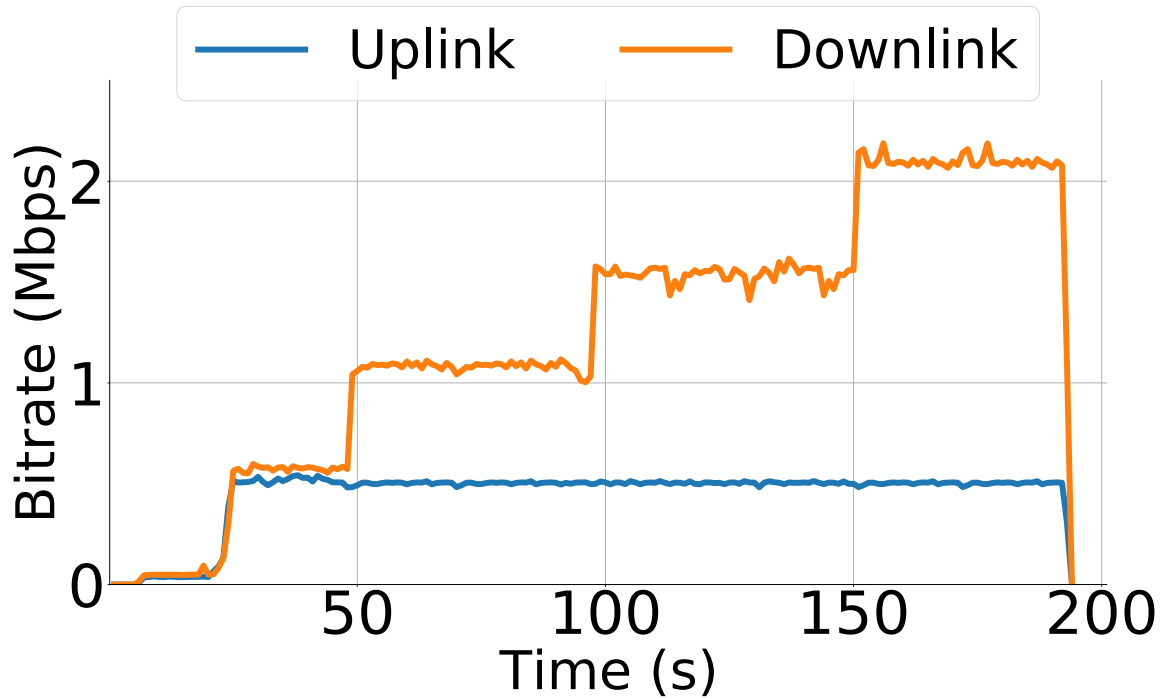


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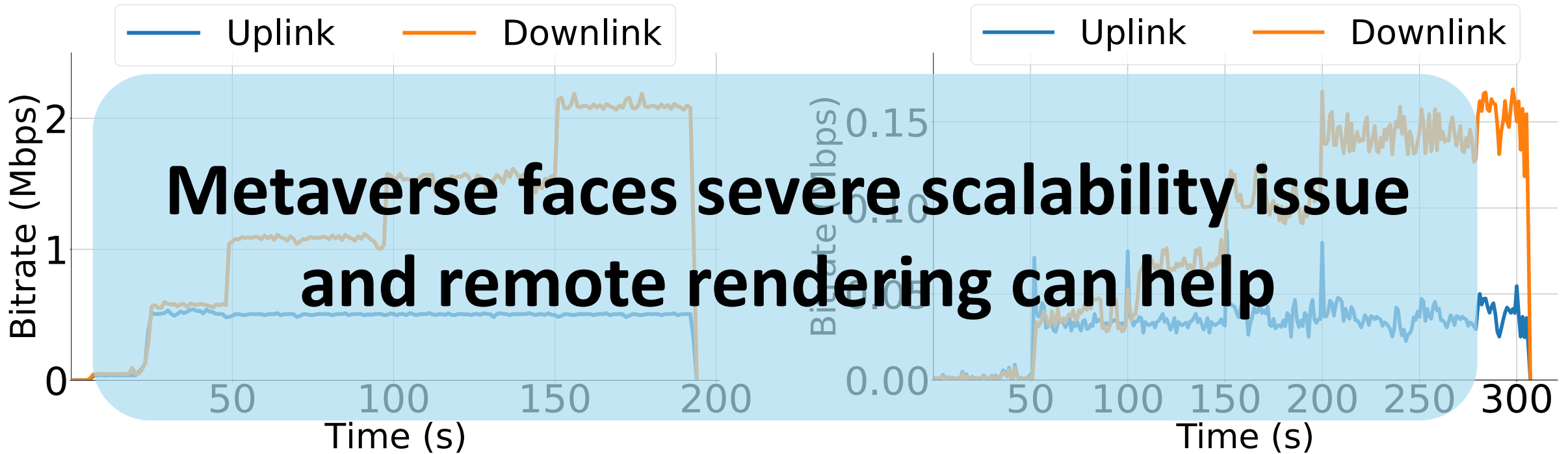
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**Today's Metaverse does not consume lots of data due to low-quality graphics**

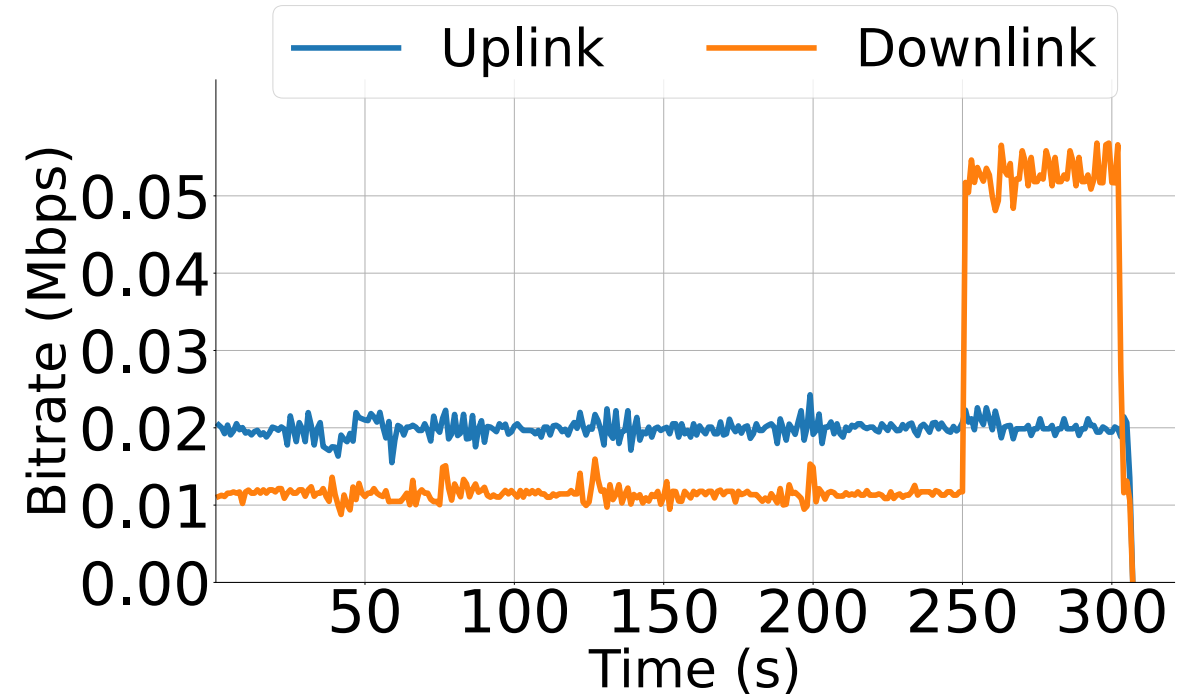
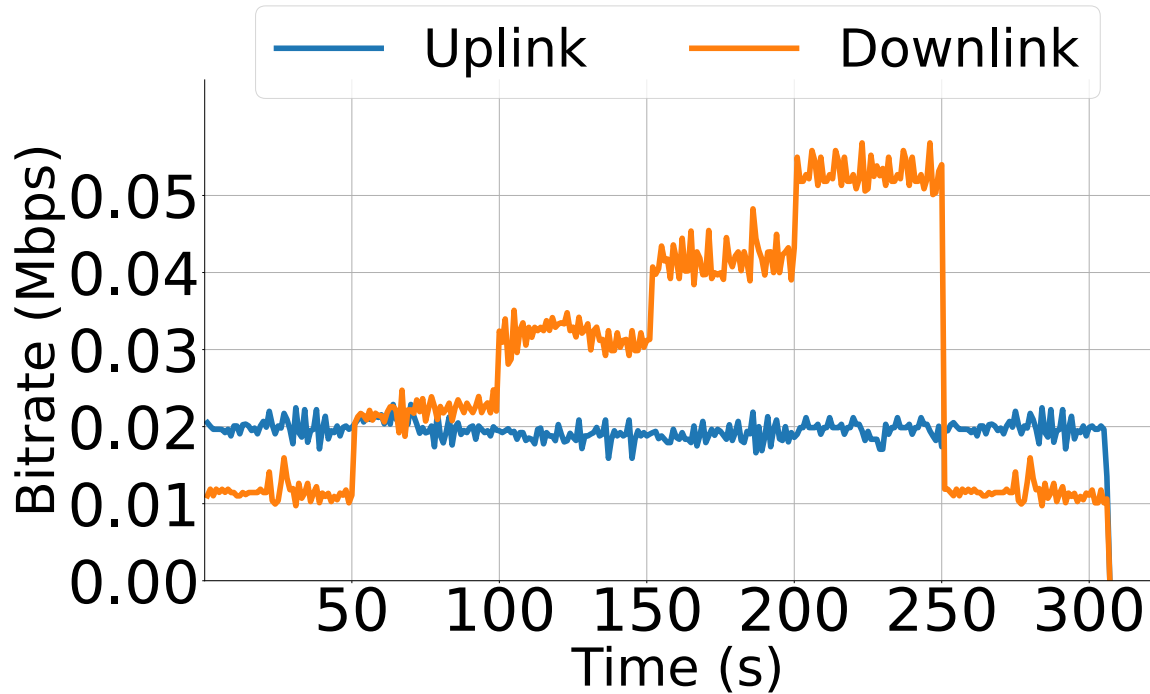
# Scalability



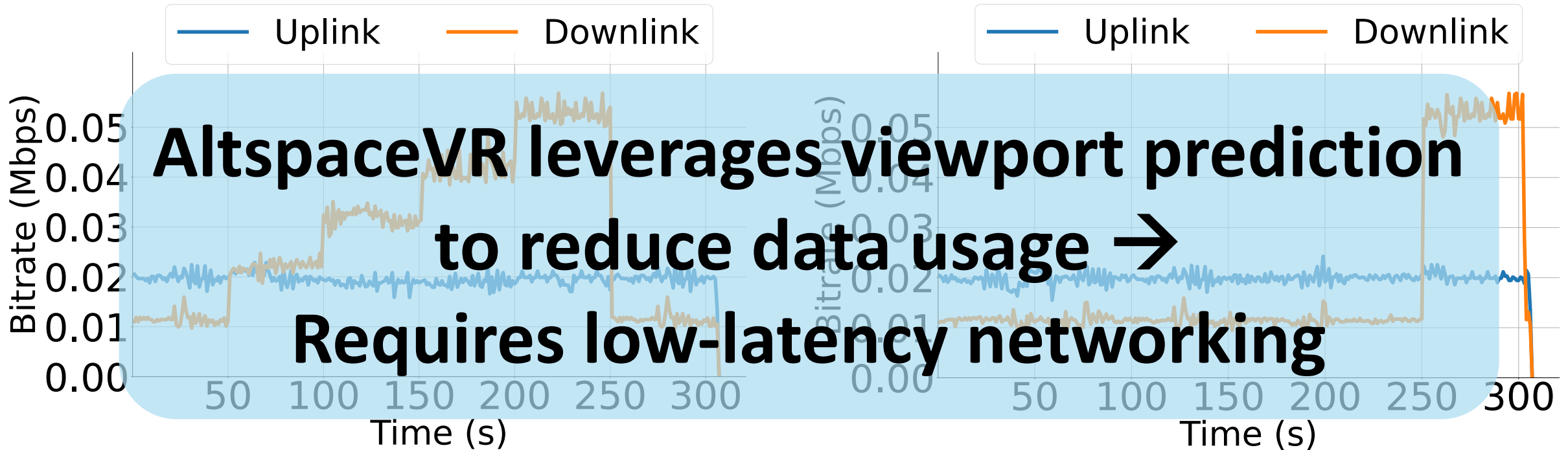
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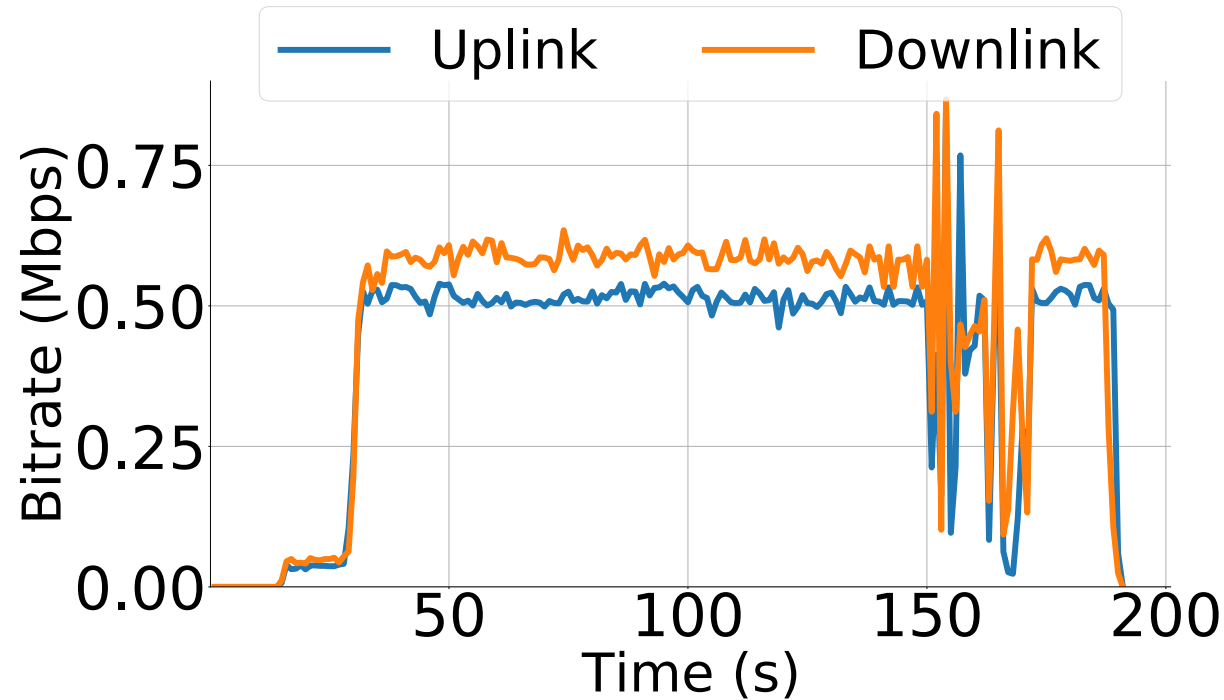
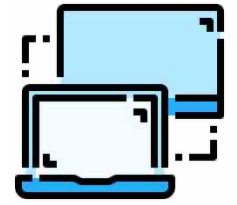
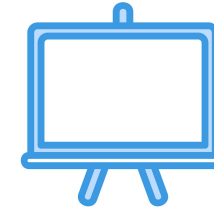
# Scalability: Viewport-adaptive Optimization



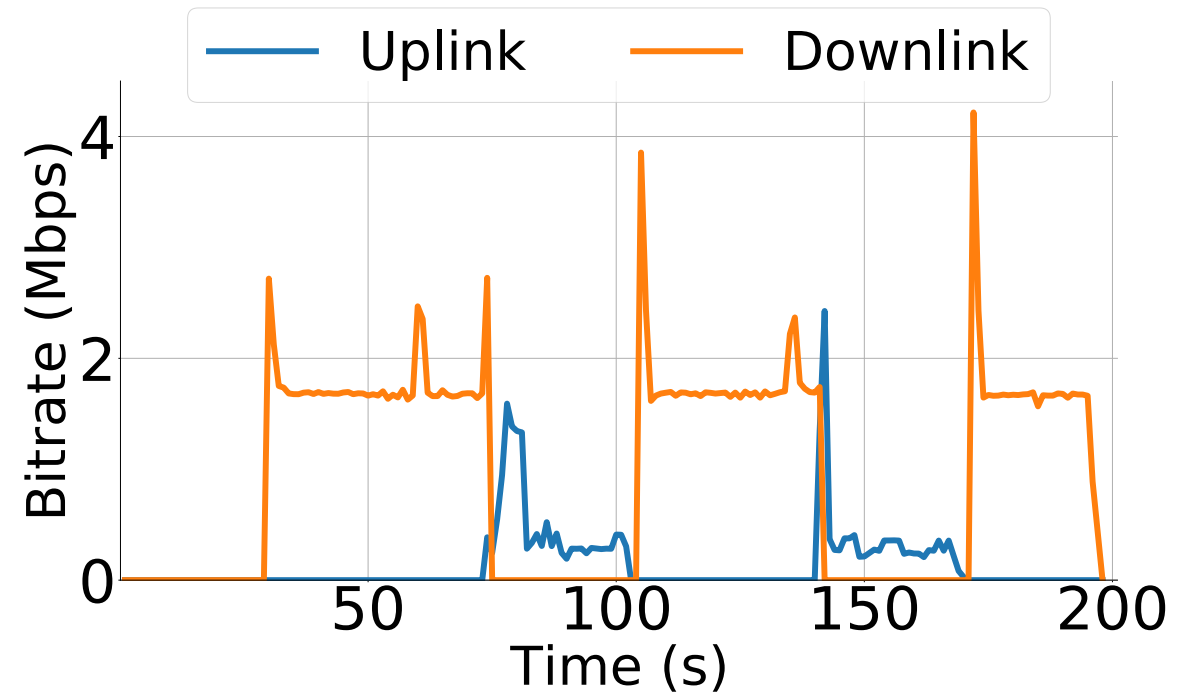
# Scalability: Viewport-adaptive Optimization



# Advanced Features: Workrooms



Virtual Content Flow (enable whiteboard from 150 to 170s)



Multimedia flow (share screen twice starting at 80 and 140s, respectively)

# Conclusion

- ✓ Today's social VR platforms do not consume lots of data (low-quality graphics)
- ✓ Metaverse may face scalability issues with local rendering
- ✓ Ongoing work: Latency, network disruption, advanced features, ...
- ✓ Tremendous opportunities to optimize system design and performance of Metaverse

Ruizhi Cheng, Nan Wu, Songqing Chen, and Bo Han. Reality Check of Metaverse: A First Look at Commercial Social Virtual Reality Platforms. In Proceedings of the 1st Workshop for Building the Foundations of the Metaverse (METABUILD 2022), co-located with the 29th IEEE Conference on Virtual Reality and 3D User Interfaces (VR 2022), March, 2022.

Ruizhi Cheng, Nan Wu, Songqing Chen, and Bo Han. Will Metaverse be NextG Internet? Vision, Hype, and Reality. <https://arxiv.org/abs/2201.12894>