A Demonstration of QoE Assessment for Cloud-based Social XR Applications over Mobile Networks

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***Abstract*—Cloud-based social eXtended Reality (XR) services are the cornerstone for realizing the promises of the Metaverse. These services hosted either on datacenters or edge, will demand stringent mobile network quality of service (QoS) to operate effectively and provide an acceptable user quality. It becomes fundamental to study how mobile networks QoS factors round-trip time (RTT), packet loss (PL), and jitter affect these services by measuring their effect on users' perceived quality of experience (QoE). Subjective QoE assessment involves carefully controlled laboratory environments to generate the desired conditions between a large set of users. The requirements for a cloud-based social XR service lab-setup are complex: Identify a reliable streaming service, a customizable VR application, emulate network conditions, define activities or tasks for users to perform, collect their data, label it; all while mitigating possible human mistakes. To address these requirements, we present an effective technical setup that can consistently repeat the same conditions between users and that can be easily replicated to other labs conducting cloud-based social XR research.**

***Index Terms*—QoE, Metaverse, Social XR, Cloud Computing, Computer Networks**

I. Introduction

The Metaverse holds the potential to enable global users to connect and work together by collaborating virtually; all stemming from highly immersive applications, capable of evoking users' sense of immersion and embodiment. These applications require intense computation to generate 3D worlds that can reproduce realistic experiences by simulating real-world lighting, physics, sounds, and avatars. Today, consumer-grade and affordable virtual reality (VR) devices, from Apple, Meta, and Microsoft, are embedded with multiple cameras, to allow 6 degrees of freedom (DOF) movement tracking, high-resolution screens and speakers, and batteries to give users wireless and portable experiences. The most significant constraint of these devices lies in their extremely limited computational power, hindering their capacity to execute highly immersive metaverse applications. A solution to this problem persists in offloading metaverse applications and services to the cloud (dataceter or edge), illustrated in Fig. 1. The "Cloud Services" contains virtual machines (VM) to handle virtual 3D scene video rendering, per user connected, and services to support each VR application context: multi-user synchronization, managing user-created assets, among others. Once the VR scene frames are generated they are encoded and sent over mobile networks to users' VR devices connected at home, in public spaces, or on the move. Cloud-based metaverse services have the necessary computational resources to serve millions of connected users around the world anywhere, anytime, with an affordable subscription cost.

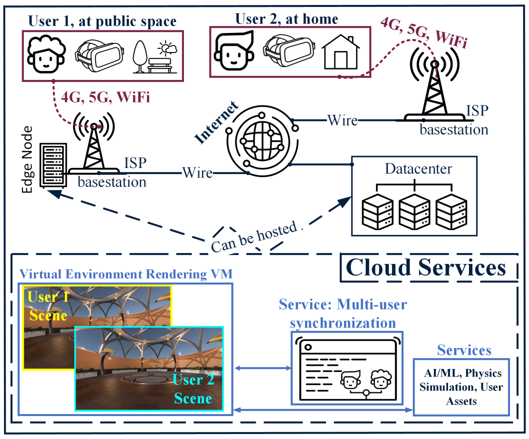


Fig. 1: Concept of cloud-based Metaverse services provided over mobile networks.

Mobile networks, however, may provide an obstacle for provision of metaverse services, due to their heterogeneous behavior. Network conditions such as congestion, wireless network impairments, and handoffs can significantly degrade QoS factors, causing high RTT, PL, and jitter [1], [2]. To deliver this experience with acceptable quality, stakeholders must learn how these QoS factors affect the streaming quality of metaverse applications. The objective QoE metric can capture users' subjective quality perception based on their immersive experiences such as video, audio, and interaction quality [1]. For accurately measuring QoE in the context of cloud-based social XR services over mobile networks, our research team built a technical lab in accordance with ITU-T recommendation P.1320 and P.1301, to emulate cloud-based XR services, network conditions, and sponsor immersive collaborative mutti-user tasks. In this demo paper and at the conference, we showcase a novel experimental setup and results from [2] to effectively measure users' QoE perception for future cloud-based XR services.

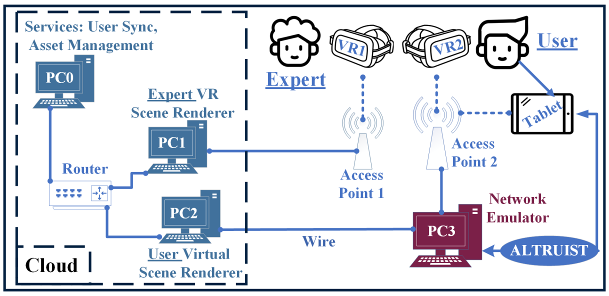


Fig. 2: The experiment setup to emulated network conditions for cloud-based Social XR application.

II. Cloud-based Social XR setup for QoE Assessment

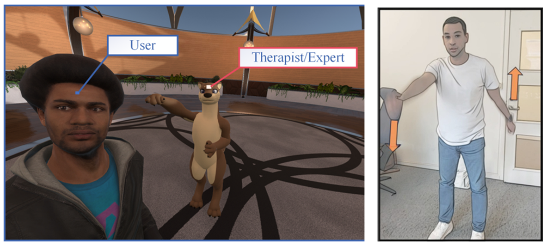
To assess collaboration tasks within a cloud-based social XR context influenced by network conditions, we raised the following requirements:

1) Identify a 6DOF VR application allowing scene and avatar customization, supporting two users connected, with private/local hosting for network QoS control.
2) A cloud-based streaming solution, cable to stream audio/ video, between a computer running the VR application, and the thin-client, i.e. the user VR headset.
3) A controlled network environment capable of systematically emulating mobile network conditions between the users' VR device and the PC hosting the VR application while maintaining stable, low latency among peers outside the emulation path.
4) Ensure reliable data collection for various objective metrics including QoE, and network traffic pcap files.
5) Define activities that would instigate user collaboration, verbal and gesture communication, and that would be easy to perform over time.

To fulfill these requirements we chose Resonite[1], as the Social XR application, which allows collaboration, scene/avatar customization, private server and session hosting, and supports 6DOF. We used commercial SteamVR[2] as the streaming solution to stream the PC Resonite application (video, audio) to the latest Meta Quest 3 VR devices. To do that we use the setup in Fig. 2. We execute cloud services in PC0, namely the Resonite multi-user synchronization, audio synchronization, and 3D assets management (avatar, and scene objects); PC1 and PC2 render the VR scene (created by us) for the participant (e.g. user evaluator) and the expert (the test manager).

For network conditions emulation, we used PC3, positioned in the middle of the streaming path between PC2 and user VR2 device, running NetEm[3] tool. We emulated a range of mobile network conditions including small RTT$\leq$50ms, jitter$\leq$1std, and PL$\leq$2% to account for cloud services, hosted in an edge node. In contrast, we emulate RTT between 75-150ms, jitter 3-6std, and PL=6% to account for these services hosted in a traditional datacenter. We utilized the open-source ALTRUIST tool [3] to manage NetEm. This tool can autonomously invoke NetEm with the appropriate network settings, gather network traffic via Wireshark, present a QoE questionnaire on a Tablet for user opinion data collection, systematically compile, and label the data uniformly across different users.

[1] https://store.steampowered.com/app/2519830 [online: access Sept. 2024]
[2] https://store.steampowered.com/app/250820 [online: accessed Sept. 2024]
[3] https://wiki.linuxfoundation.org/networking/netem [online: Sept. 2024]



(a) VR Avatars (b) Exercise

Fig. 3: Collaborative task

We suggest a physiotherapy task (Fig. 3) to support interactive collaboration in VR, between two participants to communicate and gestures. Users are required to mimic the physical movements of the expert (Fig. 3b), which are performed within the virtual environment (Fig. 3a). The expert engages in verbal chats (in the VR world) with the user, explaining a set of exercises (N=10), eliciting questions regarding users' understanding of the movement, and given constant feedback.

III. Demonstration and Conclusion

In the context of methods for subjective evaluation of cloud-based Social XR applications over mobile networks, we showcase a novel, feasible setup carefully calibrated to emulate cloud-based services, network degradation for both edge and cloud, and collaborative tasks enabling user communication. Our setup can be replicated across multiple labs and has been presented at the Video Quality Expert Group and ITU-T meetings. We welcome conference attendees to wear VR headsets and immerse themselves while learning about the challenges of hosting social XR applications in the cloud and provisioned over heterogeneous access networks.

References

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