Demo Abstract: MExR: Mobile Edge Resource Management for Mixed Reality Applications

Qiang Liu*, S Qi Huang*, Yang Deng and Tao Han
Electrical and Computer Engineering, University of North Carolina - Charlotte, NC, USA
Email: {qliu12, shuang9, ydeng3, tao.han}@uncc.edu

Abstract—Mixed reality (MR) applications not only require low-latency and high-capacity networks to deliver sensor-generated data and virtual holograms, but also demand high-performance computing capability to process data and prepare virtual holograms. Mobile edge computing emerges as a promising networking solution for mixed reality applications. In this demo, we design the MExR system which is a mobile edge resource management platform for mixed reality applications. In this platform, we design and implement the MExR algorithm that manages the traffic load in mobile edge networks and computing workload in edge and cloud servers. We emulate LTE and software-defined network (SDN) in NS-3, manage network performance with the Ryu SDN controller, and design a workload balancing algorithm based on the HAProxy. We develop a real-time MR application using Microsoft hololens and demonstrate the impact of the mobile edge resource management on the MR application. The MExR emulation platform allows the evaluation of various edge networking and computing resource management algorithms for mixed reality applications.

I. INTRODUCTION

Mixed reality (MR), which mixes virtual holograms and the real world, will create new perception and cognition channels that fundamentally affect how people interact with the world [1]. MR applications require low-latency and high-capacity networks to deliver sensor-generated data and virtual holograms prepared by servers. Meanwhile, when interacting with real world, the large amount of data generated from sensors in MR devices should be processed in a realtime fashion to ensure a relevant virtual hologram. The conventional network and cloud infrastructures cannot meet the stringent requirements of MR applications in terms of the network capacity, latency and computation. Mobile edge computing (MEC) is emerging as a new networking paradigm in which the cloud computation is carried at the edge of mobile networks [2].

Although MEC is a promising networking diagram for MR applications, it is challenging to design the networking mechanisms for supporting these application at the edge. The performance of the MR applications depend on both the network quality of services (QoS) and the high-performance computing. When the computation is pushed to the mobile edge, the networking and computation are tightly coupled. On the one hand, the computation functions may compete for limited networking resources at the edge. On the other hand, the network QoS may highly depend on the performance of the computation.

It is desirable to develop an affordable mobile edge emulation platform which allows a comprehensive study of the impact of mobile edge networking mechanisms on the performance of MR applications. In this demo, we design and implement a mobile edge network emulation platform named MExR (Mobile Edge Mixed Reality). The MExR consists of the network emulation platform and an MR application developed using Microsoft Hololens [3]. The network emulation platform is designed by using the NS-3 network simulator [4], HAProxy load balancer [5], and Ryu Software-Defined Network (SDN) controller [6]. This network emulation platform enables dynamic mobile edge networking and computing resource management such as the packet scheduling, mobility management, traffic load balancing, and computing load placement. The MR application, which is developed based on a deep learning framework named Caffe [7], is able to recognize objects in the view of the hololens and then provide detail information about the objects to the user. This application allows us to study the performance of the MR application under different edge networking scenarios.

II. MExR OVERVIEW

Fig. 1 illustrates the design and implementation of the MExR platform.

Microsoft Hololens: We adopt Microsoft hololens as the MR device in the demonstration. Microsoft hololens is bridged to a UE (user-equipment) simulated in NS-3. The UE communicates with the edge and cloud servers via the simulated LTE network and SDN. In this way, we are able to emulate a mobile edge network environment featuring both LTE radio access and edge networks for the MR application. The traffic generated from the MR device will go through the simulated mobile edge network.

NS-3 Simulated Network: In NS-3, we simulate LTE and SDN. The LTE network simulated in NS-3 enables the evaluation of the impact of network resource management algorithms such as the packet scheduling and mobility management on the MR application. The SDN is controlled by the Ryu SDN controller.
controller [6]. Simulating the mobile edge network in NS-3 provides us the flexibility in designing network protocols as well as testing a large-scale network (with many network nodes).

**Ryu SDN Controller:** The Ryu SDN controller is adopted to manage the SDN simulated in NS-3 [6]. The Ryu SDN controller also monitors the traffic load and latency of each path in the network. We implement a weighted shortest path routing algorithm in the Ryu SDN controller. The weight can be assigned as the latency, data rate, or bandwidth of the communication links between openflow switches.

**HAProxy-Based Load Balancer:** We implement the mobile edge resource management algorithm in HAProxy [5]. The HAProxy is designed to monitor the workload of the edge and cloud servers. The server workload information is one of the inputs to the mobile edge resource management algorithm. The network traffic load and latency information provided by the Ryu SDN controller is the other input to the algorithm. Based on these inputs, the mobile edge resource management algorithm selects either edge or cloud server and redirect the service request accordingly.

### III. Demonstration Application

**MR Application:** As shown in Fig. 2, the MR application is developed to allow the user to obtain the detail information of the object in the view of the hololens in a real-time fashion. The application takes the snapshot of the object using the cameras provided in Microsoft Hololens. The snapshot is then sent back to either edge or cloud server for analyzing. A deep learning algorithm based on the Caffe framework [7] is developed to recognize the object in the snapshot. After the object is recognized, the detail information about this object is transmitted back to the MR device via the simulated mobile edge network. The MR application requires both low-latency network and high-performance computing, which is a desirable application for testing mobile edge networking solutions.

![Application Data Flow](image)

**Application Data Flow:** In this demonstration, the traffic load and computing workload are generated from both the MR device and several virtual clients. The service request generated from the MR device first reaches the HAPerX via the simulated LTE network. In the HAPerX, the mobile edge resource management algorithm selects the server that provides the best performance in terms of the service latency. Once the server is selected, the request is directed to the corresponding server via the simulated SDN network. The Ryu controller optimizes the traffic route in the SDN network. The virtual clients are emulated in Linux containers and bridged to UEs in the simulated LTE network. The service requests generated by the virtual clients follow the similar data flow as that of the MR device. These service requests generated by the virtual clients act as the background traffic load and computing workload which change the networking condition and computing workload in the mobile edge network.

**User Interface:** Fig. 3 is a simple user interface of the demonstration. The user interface shows the network latency, CPU utilization, and server selection. The network latency is measured from the MR device to the edge and cloud server, respectively. The CPU utilization reflects the computing workload in both edge and cloud servers. The selected server is highlighted with green color.

![User Interface](image)

Fig. 3. A user interface of the demo application.

### IV. Conclusion

In this demo, we present a mobile edge networking and computing emulation platform named MExR. This platform enables researchers to evaluate the performance of different mobile edge resource management algorithms for supporting mixed/augmented/virtual reality applications. The impact of networking mechanisms such as packet scheduling, mobility management, traffic load balancing, and computing load placement on mixed/augmented/virtual reality applications can be studied by using the MExR emulation platform.

### References


