An Interactive and Immersive Remote Education Platform based on Commodity Devices

Jiangong Chen* Feng Qian† Bin Li*

*Department of ECBE, University of Rhode Island, Kingston, Rhode Island, USA

†Department of CSE, University of Minnesota - Twin Cities, Minneapolis, Minnesota, USA

Motivation

- High demand for remote education, especially under the context of the pandemic
- Virtual Reality (VR) – more interactive and immersive experiences

Remote Education

Virtual 3D World

- Main challenges:
  - High-quality panoramic image rendering: typically, 2560x1440 pixels and 60 FPS
  - Synchronization among users: smooth interactions

Wired V.S. Wireless

Wired VR Headset

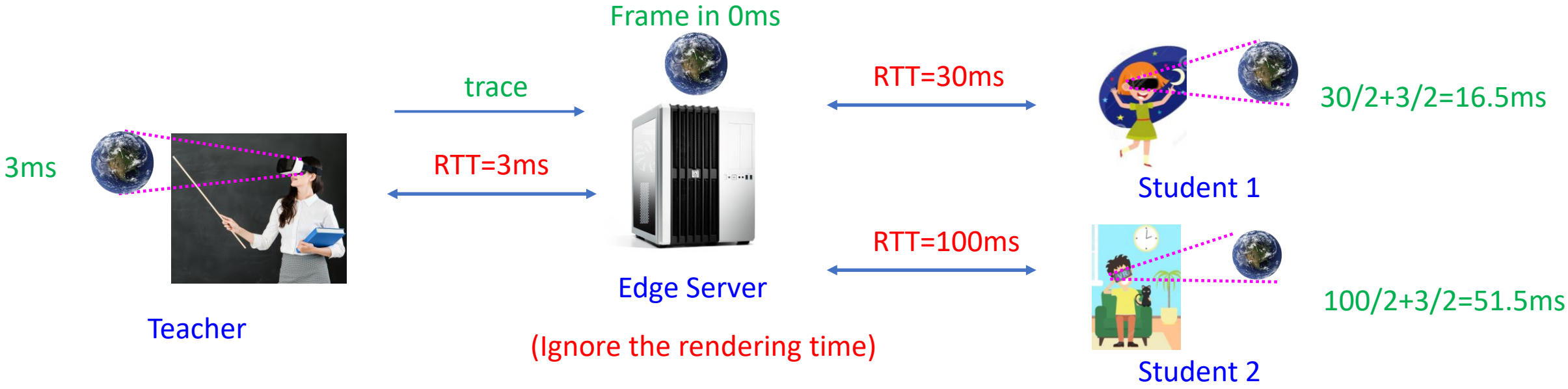
- High computation capability
- Multi-Gbps link transmission rate
- Low flexibility

Wireless VR Headset

- Low computation capability
- Limited wireless bandwidth
- High flexibility

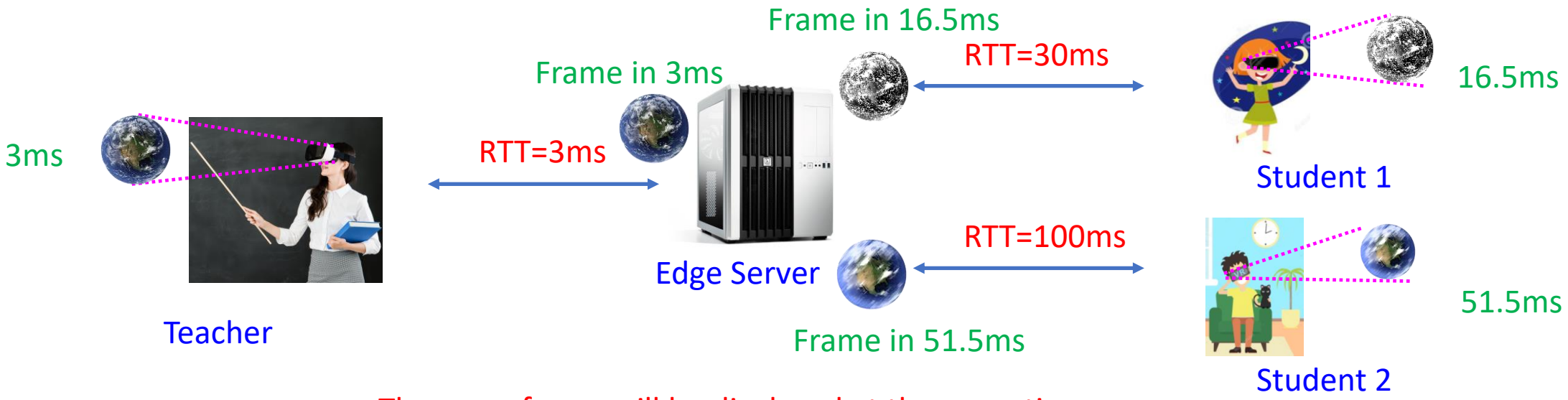
Synchronization

- The same view among teacher and students
- The teacher controls the movement
- The students can interact with the teacher



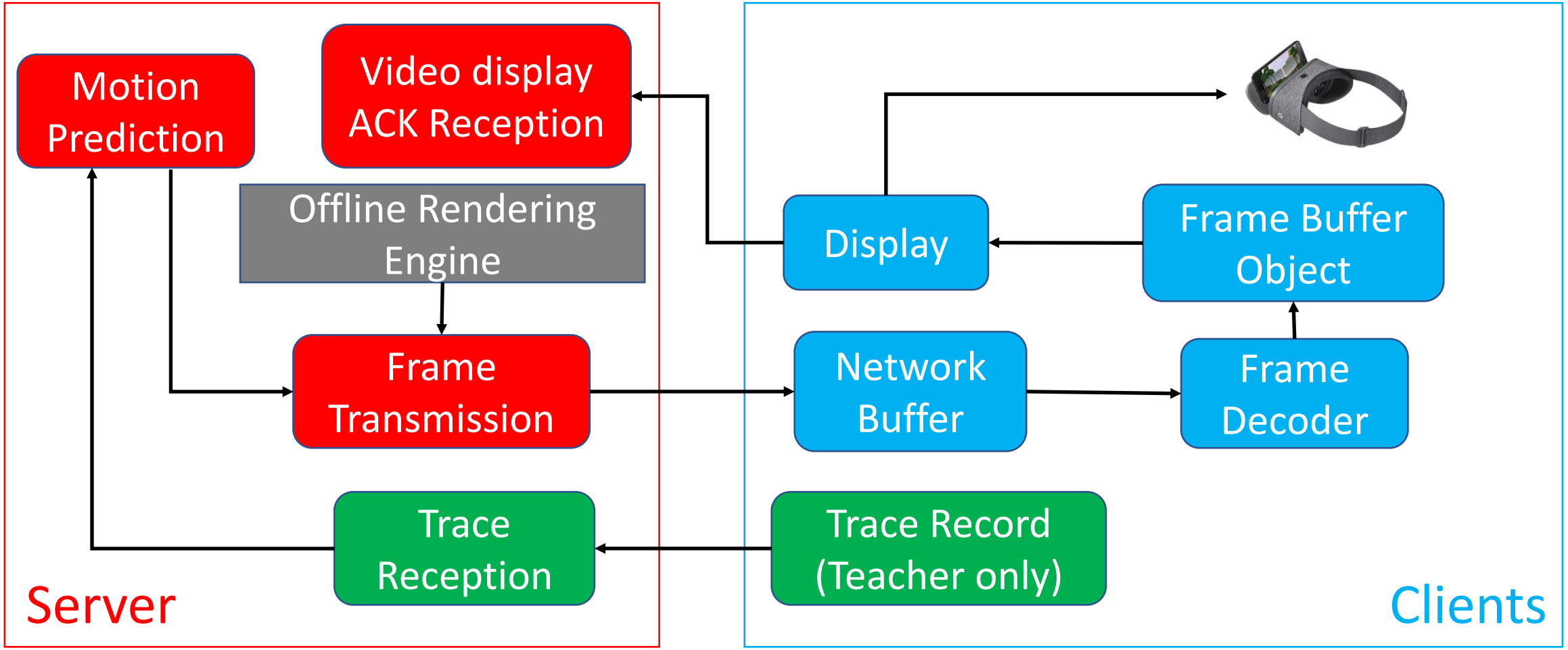
Synchronization (Cont')

- If the server knows the trace in the future, it can send diverse frames based on the RTT to different clients instead of the frame corresponding to the current time slot



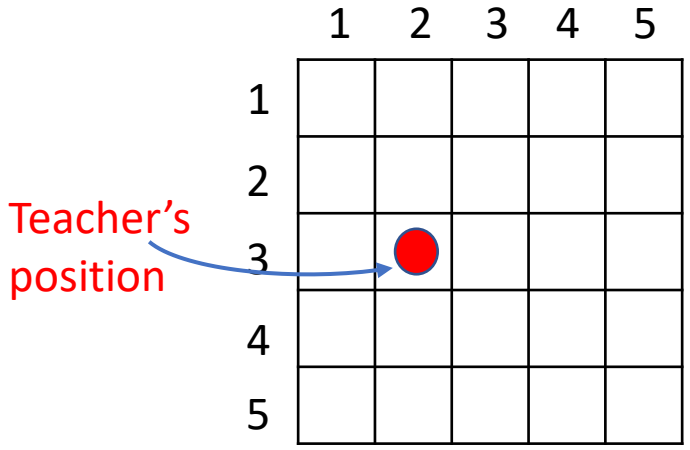
The same frame will be displayed at the same time
At each time slot, they can share the same view

System Architecture

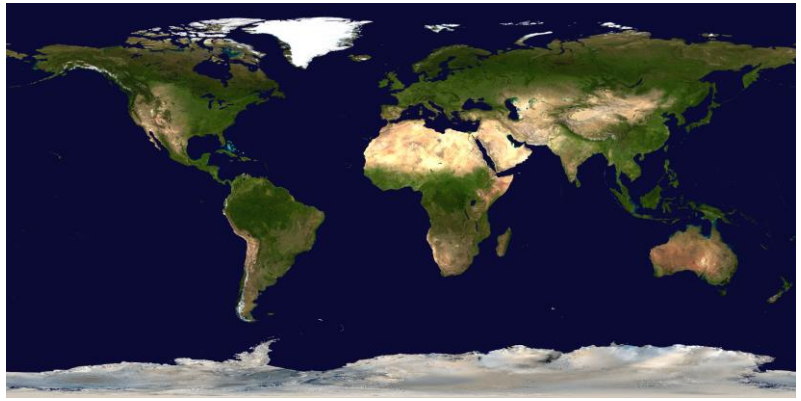


Offline Rendering Engine

- Split the VR world into grids
- Offline generate all panoramic frames in each grid
- Use equirectangular projection to process the panoramic frame
- Compress the frames using the H.264 codec



Grid world



Earth in equirectangular projection

Server and Clients

- **Server**:
  - Deliver both the pose (6DoF, from the teacher) and the rendered frame to both the teacher and students
  - Utilize motion prediction to alleviate the asynchronization problem
    - predict the future positions as the same as the last position
    - use the Autoregressive Process (AR) model to predict the future orientation
  - Collect the display time of each frame for each client
- **Clients**:
  - Always wait for frames from the server
  - Send ACK to the server when a frame is displayed
  - Periodically send sampled pose to the server on the teacher client

Prototype

Edge Server

Ethernet

Teacher

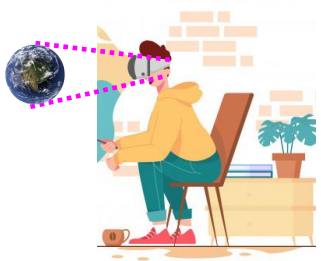
WiFi

Router

Internet

More students…

Bluetooth



Student 1

WiFi

Router

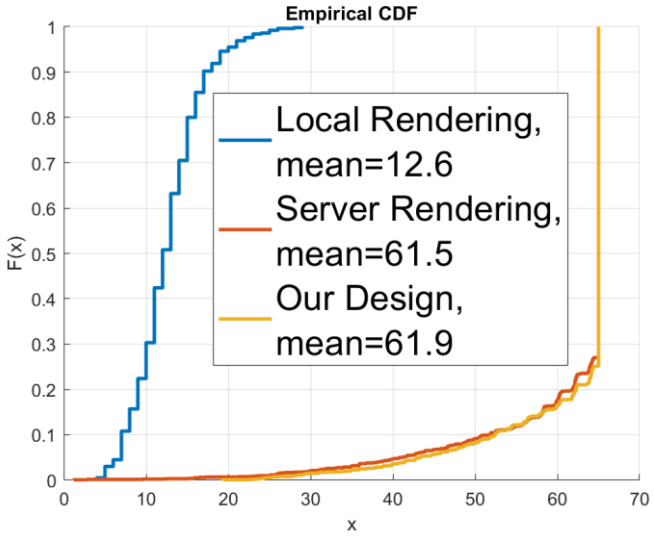
Router

WiFi

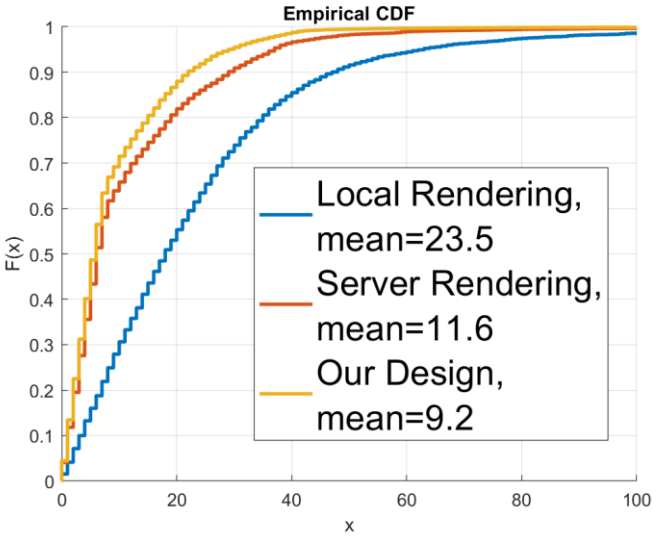
Student 2

Evaluation

- 5 users
- Add extra RTTs by Linux TC: 0,10,20,30,40ms
- 3 methods: Local Rendering, Server Rendering, Our Design
- Frame Rate: displayed frames per second
- Frame Latency Difference: display time difference of similar frames between the teacher and the students



Frame Rate



Frame Latency Difference

Conclusion

- Develop a VR-based remote education platform using commercial off-the-shelf mobile devices
- Provide high-resolution (2560×1440pixels) panoramic content to the clients with a high frame rate (60 FPS)
- Utilize motion prediction to mitigate the impact of heterogeneous RTTs between clients and the server
- Evaluation results show at least 60% and 20% synchronization improvement compared to existing methods, respectively
- A demo video can be found at https://www.ele.uri.edu/~jiangongchen/demo/VRDemo.mp4

Thank you!