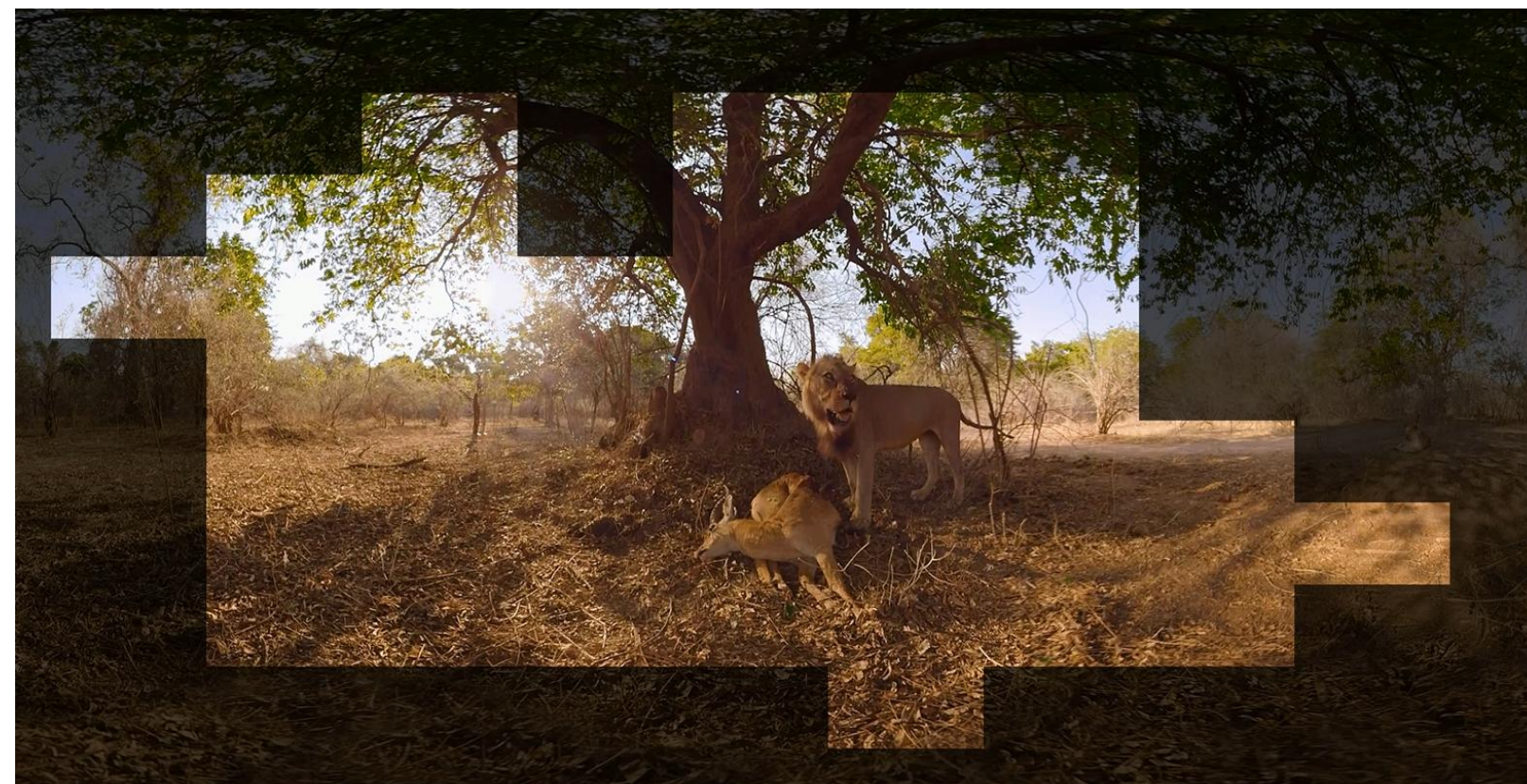


Executive Summary

Virtual reality video streaming demands extremely high bandwidth to deliver immersive, high-quality experiences, often exceeding the capacity of current network infrastructure. This research presents a tile-based streaming approach that significantly reduces bandwidth consumption while maintaining high visual quality for VR video content. By spatially dividing each video frame into independent tiles, the system fetches only the tiles within the user's predicted viewport at high quality, while tiles outside the viewport are not fetched at all. Our implementation, built on a Unity-based VR platform, dynamically determines which tiles to fetch using real-time viewport prediction and network condition monitoring. This approach enables high-resolution VR video delivery over bandwidth-constrained networks by eliminating unnecessary data transfer entirely.

Background

- 360-degree VR video streaming requires transmitting the entire spherical view at high resolution, consuming 4-6x more bandwidth than traditional flat video. Current approaches stream the full sphere at uniform quality, wasting significant bandwidth on regions the user never sees. Tile-based streaming solves this by treating different spatial regions of the video independently, enabling intelligent bandwidth allocation based on where the user is looking.



System Architecture

The system consists of two primary components: a Python Flask server responsible for tile segmentation, encoding, and adaptive bitrate decision-making, and a Unity-based VR client that handles playback, viewport tracking, and quality requests. Each 360-degree video frame is spatially divided into a grid of independent tiles. The server encodes each tile at multiple quality levels and serves tiles based on client requests informed by viewport prediction and available bandwidth.

Table 1. Tile Quality Assignment Strategy

Tile Region			Quality Level	Bandwidth Used
Viewport	High		Full	
Peripheral	Not Fetched		None (saved)	

Methodology

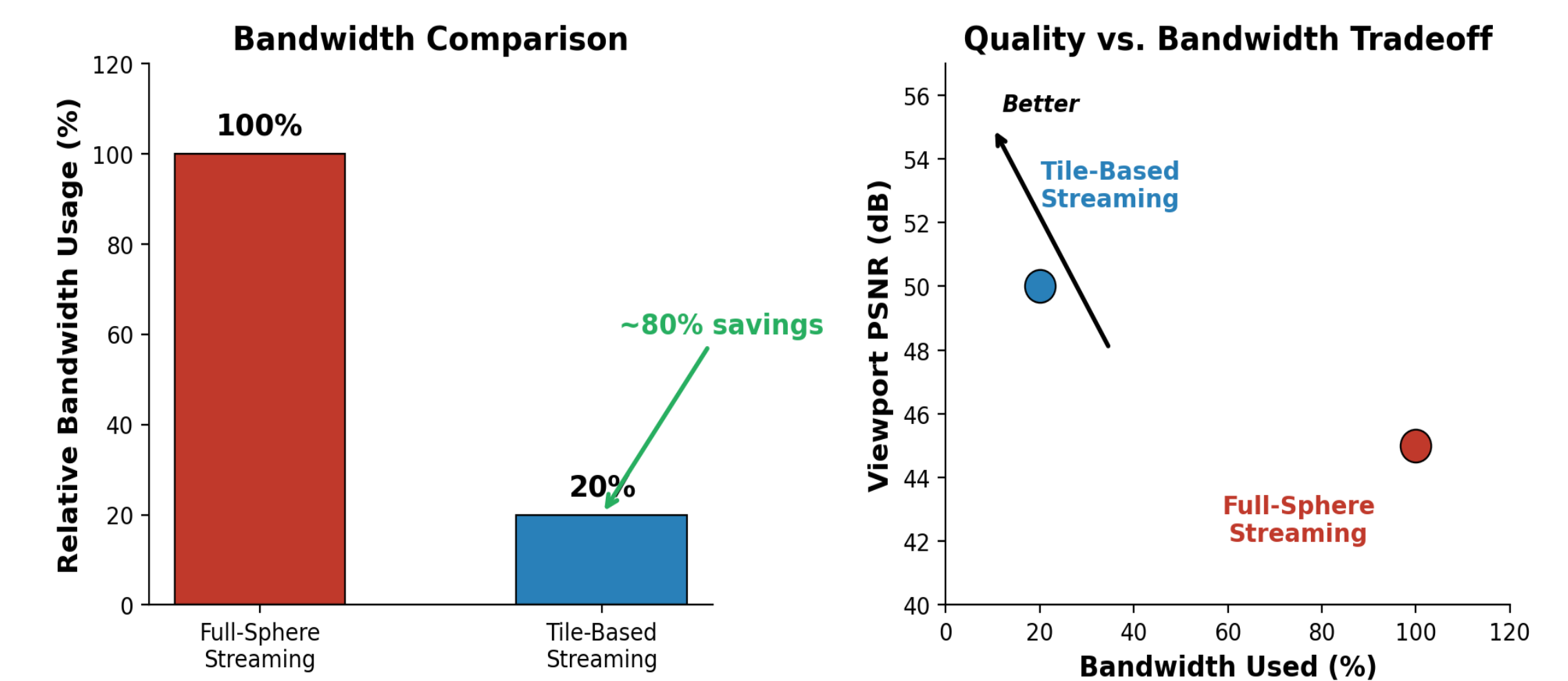
- The tile-based streaming system operates in real time by: (1) predicting the user's viewport direction using head-tracking data from the VR headset, (2) classifying each tile as inside or outside the predicted viewport, (3) monitoring current network throughput to determine available bandwidth, and (4) fetching only the tiles within the viewport at high quality while skipping all other tiles entirely. This selective fetching approach maximizes visual quality where the user is looking while eliminating all bandwidth spent on content the user cannot see. The system logs detailed metrics including per-tile bitrate, viewport accuracy, rebuffering events, and overall bandwidth consumption for evaluation.

Algorithm: Tile-Based Streaming Decision

```
FOR each video chunk:
  1. viewport ← predict_viewport(head_tracking_data)
  2. bandwidth ← estimate_throughput(network)
  3. FOR each tile in frame:
    IF tile is INSIDE viewport:
      FETCH tile at HIGH quality
    ELSE:
      SKIP tile (no bandwidth used)
  4. Render viewport tiles → VR headset
  5. Log metrics (bitrate, accuracy, rebuffering)
```

Results

- Preliminary testing demonstrates that tile-based streaming achieves substantial bandwidth savings compared to full-frame uniform-quality streaming. By fetching only viewport tiles and skipping peripheral tiles entirely, the system eliminates all unnecessary data transfer. Viewport tiles delivered at high quality show no perceptible degradation for the user.



Conclusions

- Tile-based streaming offers a practical and scalable solution to the bandwidth challenges of VR video delivery. By fetching only the tiles within the user's viewport and skipping everything else, the system delivers high visual quality where users are actively looking while using a fraction of the bandwidth required by full-sphere streaming. This approach makes immersive VR streaming feasible over bandwidth-constrained networks. This research is conducted in the MobiSec Lab at UTA under the supervision of Dr. Ming Li.

References

1. Qian, F., Ji, L., Han, B., and Gopalakrishnan, V., "Optimizing 360 Video Delivery over Cellular Networks," ACM ATC, 2016.
2. Hosseini, M. and Swaminathan, V., "Adaptive 360 VR Video Streaming: Divide and Conquer," IEEE ISM, 2016.
3. Graf, M., Timmerer, C., and Mueller, C., "Towards Bandwidth Efficient Adaptive Streaming of Omnidirectional Video over HTTP," ACM MM Sys. 2017.