Robust 360° Video Streaming via Non-Linear Sampling

Mijanur Palash, Voicu Popescu, **Amit Sheoran**, Sonia Fahmy

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360° Video Streaming and Virtual Reality

Multiple sources of
360° videos

37 million 360°
video headsets in US [1]

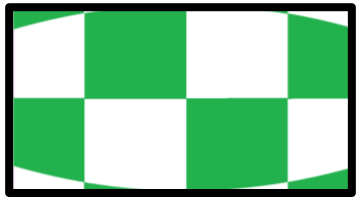
42.9 million users in US
use virtual reality in a month [1]

[1] https://leftronic.com/virtual-reality-statistics/

Challenges in Streaming 360° Video

360° videos require high bandwidth

90



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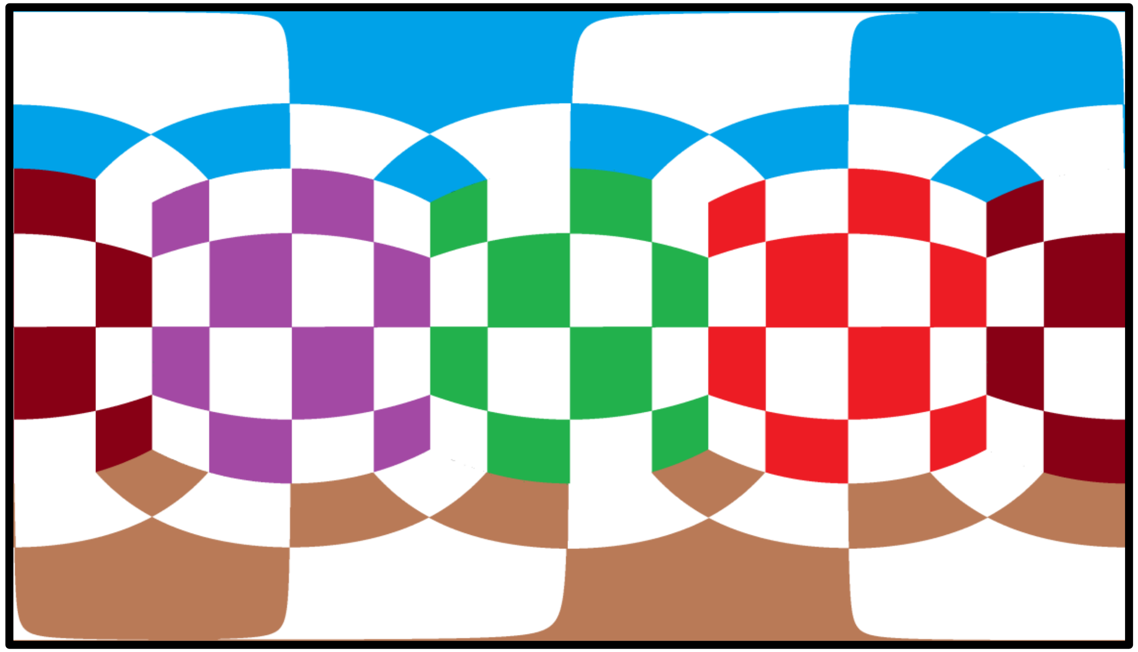
Conventional video

360



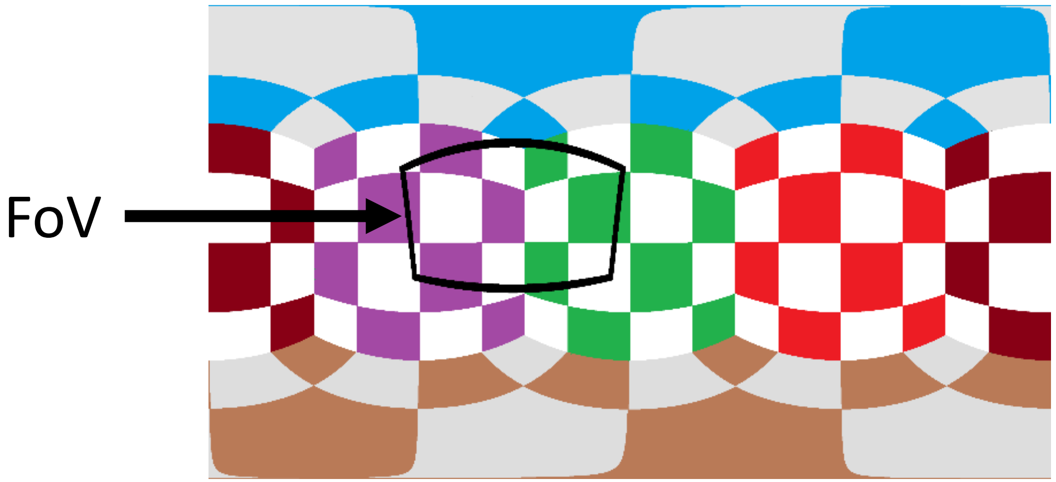
180

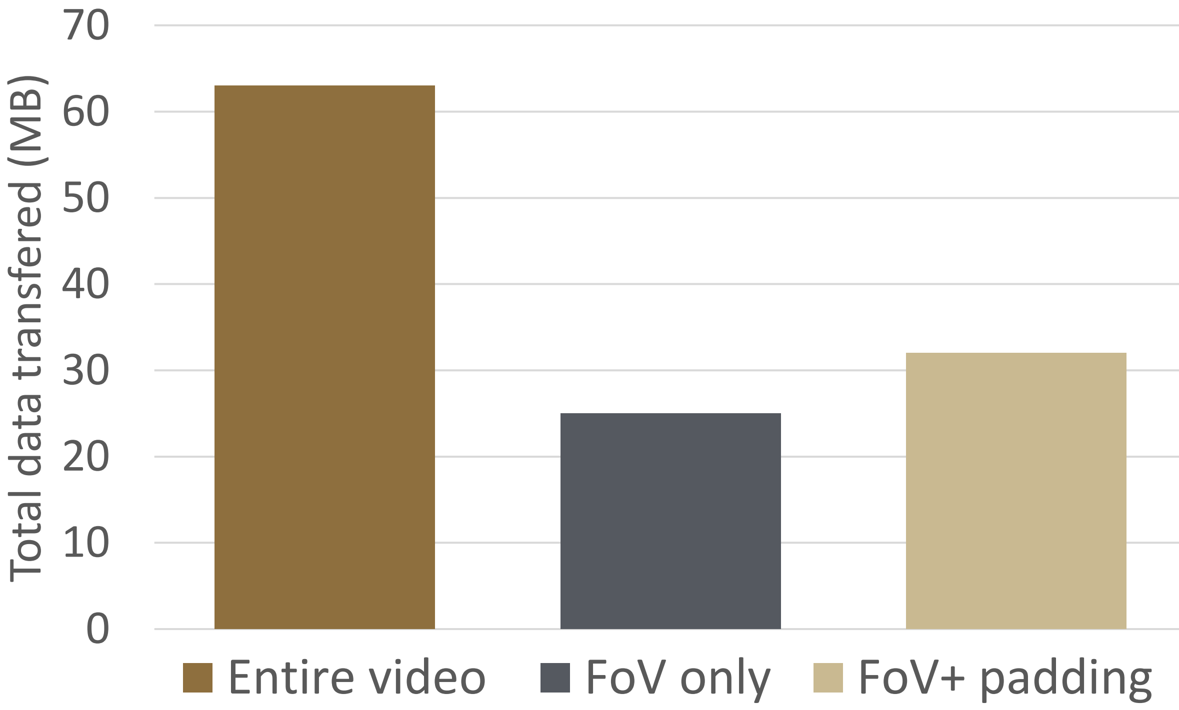
360° Video

State of the Art

360° videos require high bandwidth

- Users only watch a small portion of the video
  - User field of view (FoV)





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State of the Art

- Tiling
  - XIE, X., AND ZHANG, X. POI360: Panoramic mobile video telephony over LTE cellular networks. In Proceedings of CoNEXT (2017).
  - HE, J., QURESHI, M. A., QIU, L., LI, J., LI, F., AND HAN, L. Rubiks: Practical 360-degree streaming for smartphones. In Proceedings of MobiSys (2018).
  - QIAN, F., HAN, B., XIAO, Q., AND GOPALAKRISHNAN, V. Flare: Practical viewport-adaptive 360-degree video streaming for mobile devices. In Proceedings of MOBICOM (2018).
  - ZHOU, C., XIAO, M., AND LIU, Y. ClusTile: Toward minimizing bandwidth in 360-degree video streaming. In IEEE INFOCOM (2018).
  - GUAN, Y., ZHENG, C., ZHANG, X., GUO, Z., AND JIANG, J. Pano: Optimizing 360° video streaming with a better understanding of quality perception. In Proceedings of SIGCOMM (2019).
- Rate adaptation over time
  - e.g., MPC: Yin et al, SIGCOMM 2015.

Observations

- Accurately predicting user FoV is not always possible
  - Errors in prediction can lead to
    - *Missing pixels*
    - *Abrupt changes in quality*
  - Re-fetching the video after correcting FoV prediction is difficult
    - Cellular networks can have high uplink/downlink latency [1]

360° video streaming solutions must be robust to view prediction error

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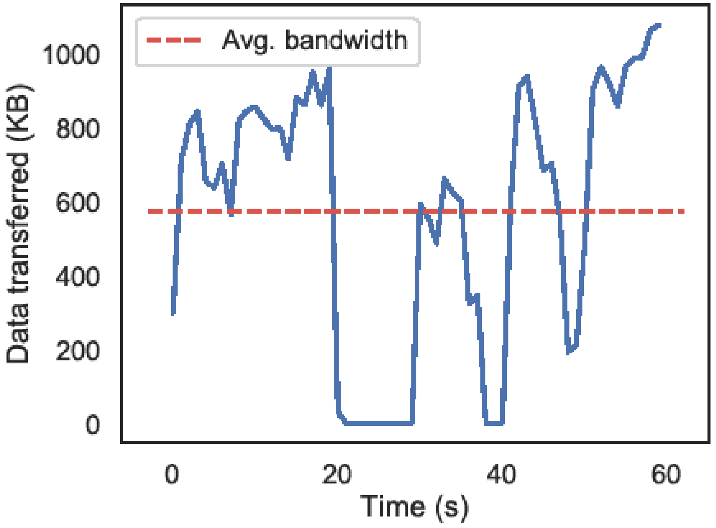
[1] Zhaowei Tan, Yuanjie Li, Qianru Li, Zhehui Zhang, Zhehan Li, and Songwu Lu. 2018. Supporting Mobile VR in LTE Networks: How Close Are We? Proc. ACM Meas. Anal. Comput. Syst. 2, 1, Article 8 (March 2018)

Observations

- Bandwidth fluctuation is common
  - Bandwidth disruption during handovers
- When to pre-fetch?
  - Fetching too early can lead to large view prediction errors
  - Fetching too late can lead to stalls



360° video streaming solutions must be robust to bandwidth fluctuation

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Objectives

- Robustness to view prediction error
- Robustness to transient bandwidth fluctuation
- Decoding and rendering efficiency
  - Support thinner clients without GPUs
- Compatibility with current protocols (H.264 and DASH)

Compressed Rotated Equirectangular (CoRE) 360º Video Streaming

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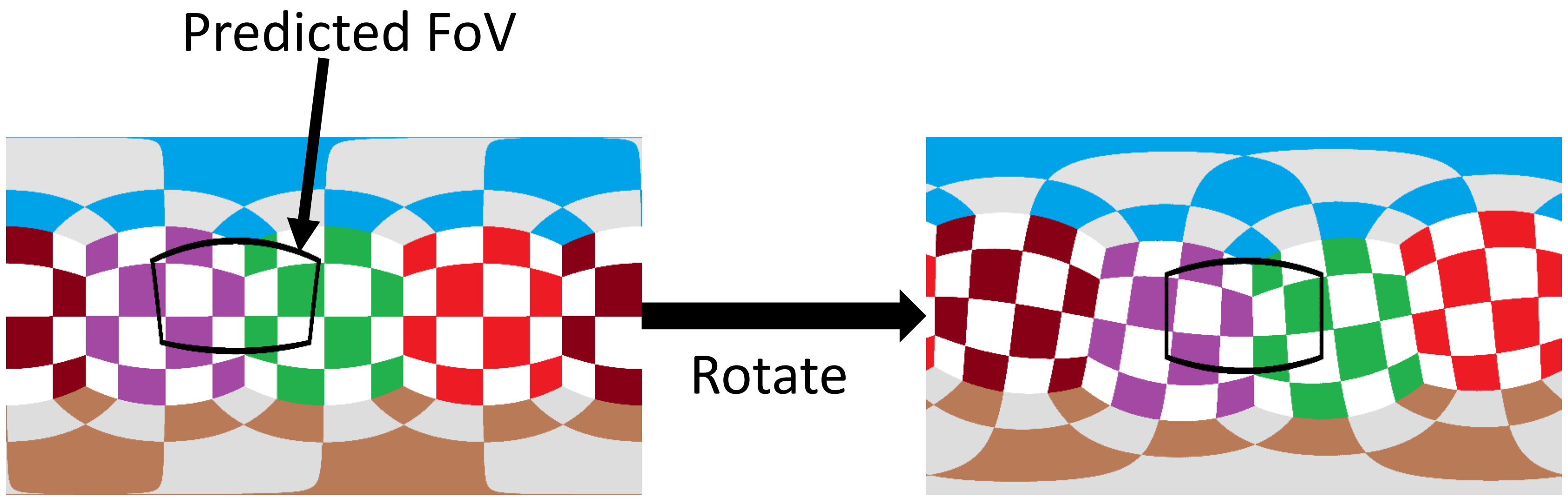
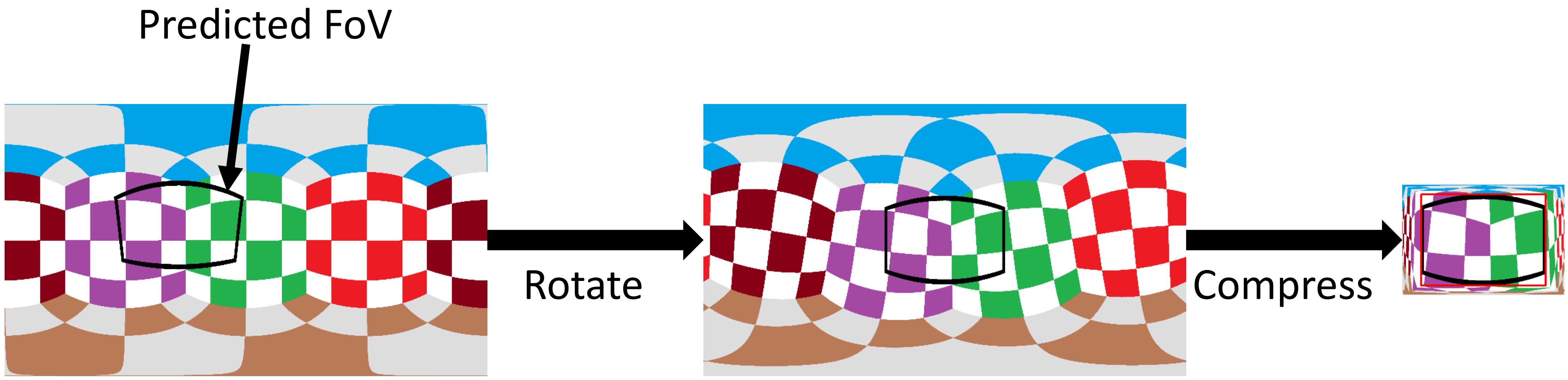
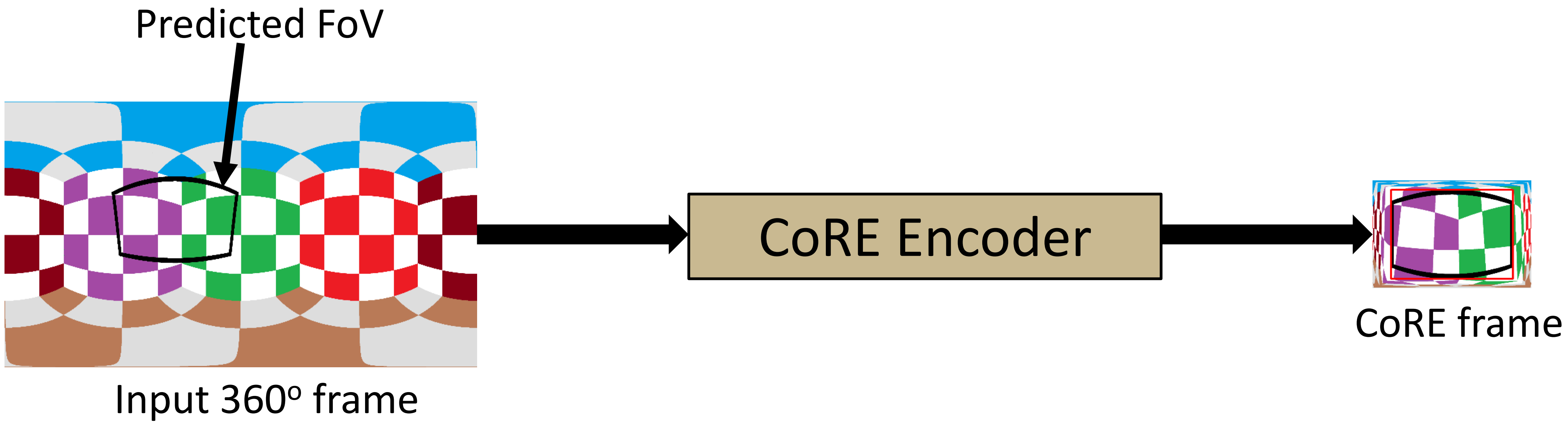
CoRE Encoding: Rotate to center predicted FoV



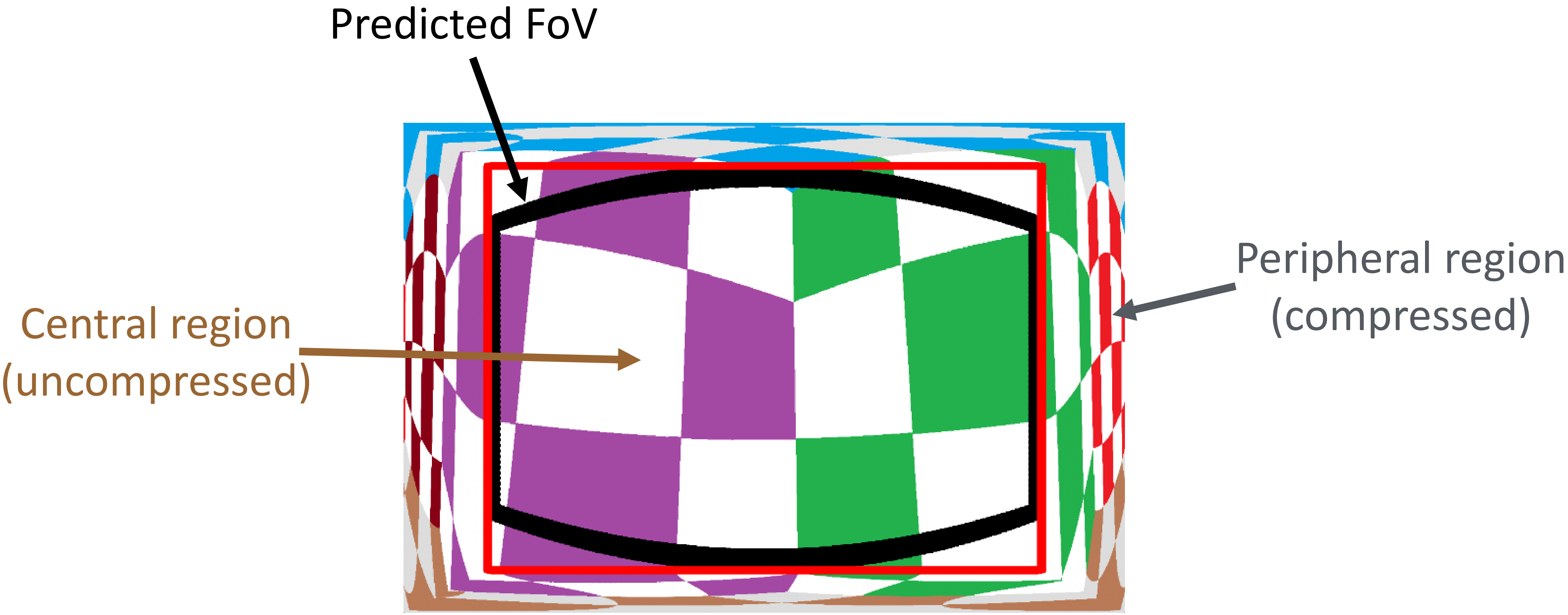
CoRE Encoding: Compress frame periphery



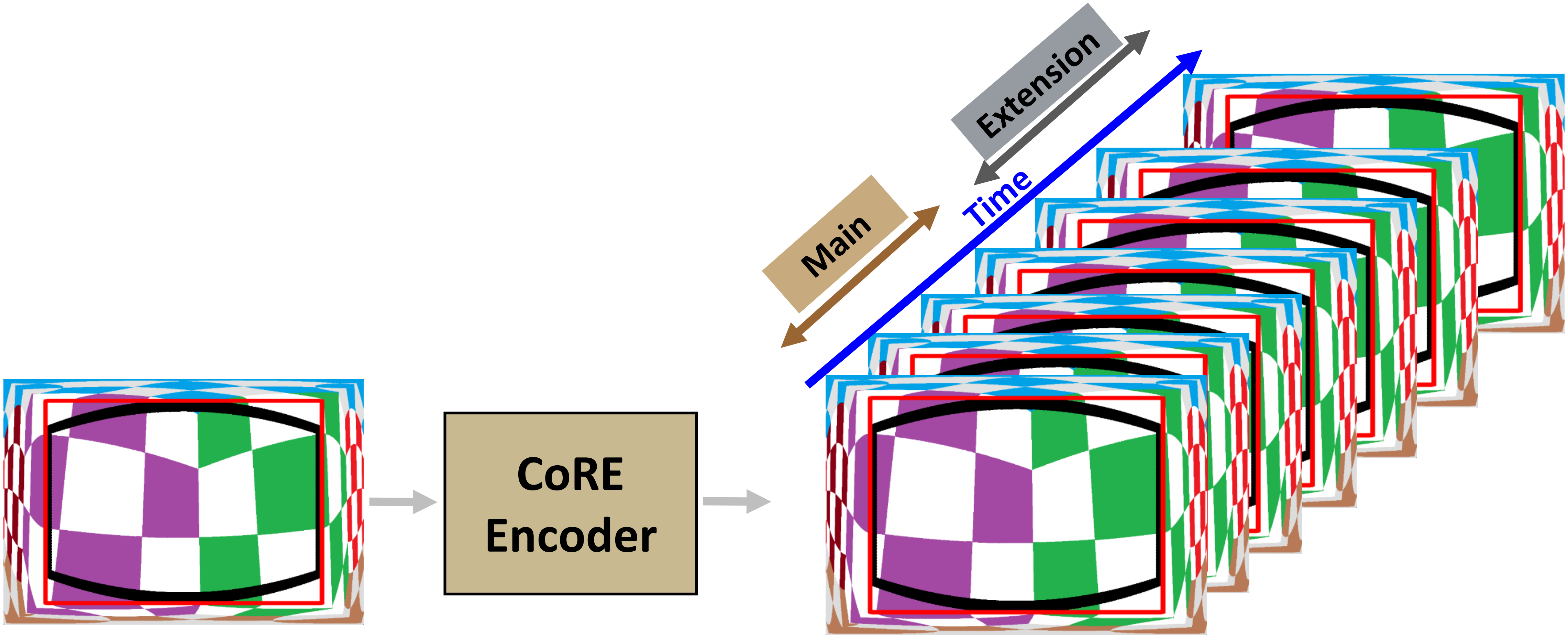
CoRE Encoding: Compress frame periphery



CoRE Frame

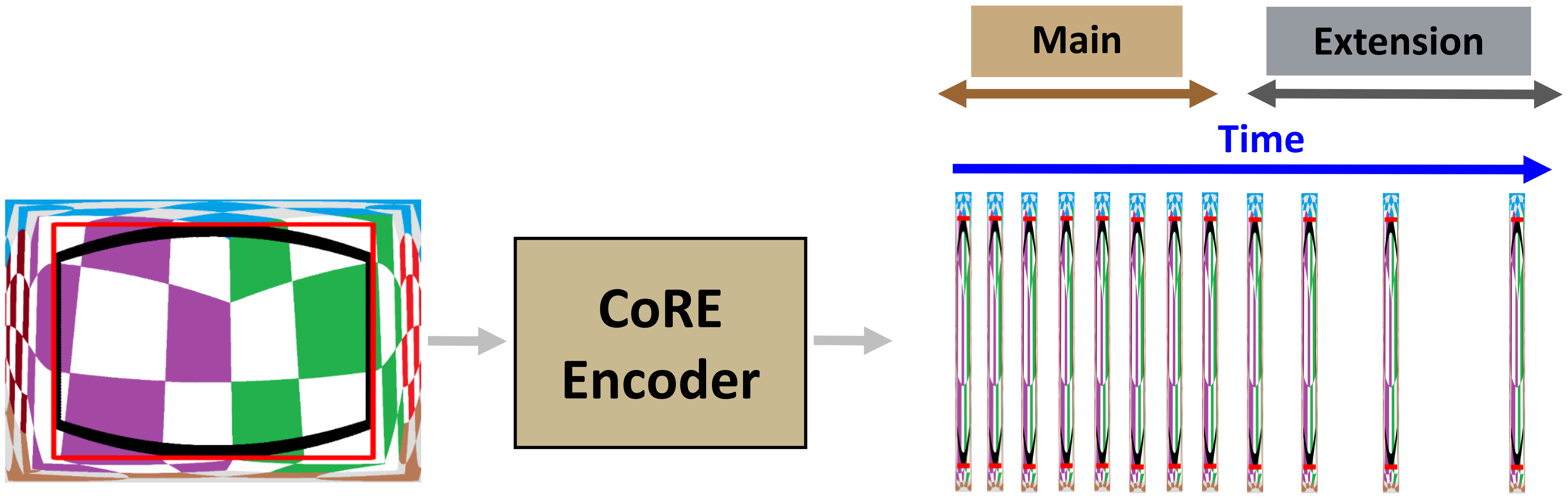

Predicted FoV
Central region
(uncompressed)
Peripheral region
(compressed)

CoRE Encoding



Extension for robustness to bandwidth fluctuation

CoRE Encoding



Extension for robustness to bandwidth fluctuation

- 4s of additional data (1.3x)
- 6s of additional data (1.44x)

TCP RTO-like adaptive prefetching

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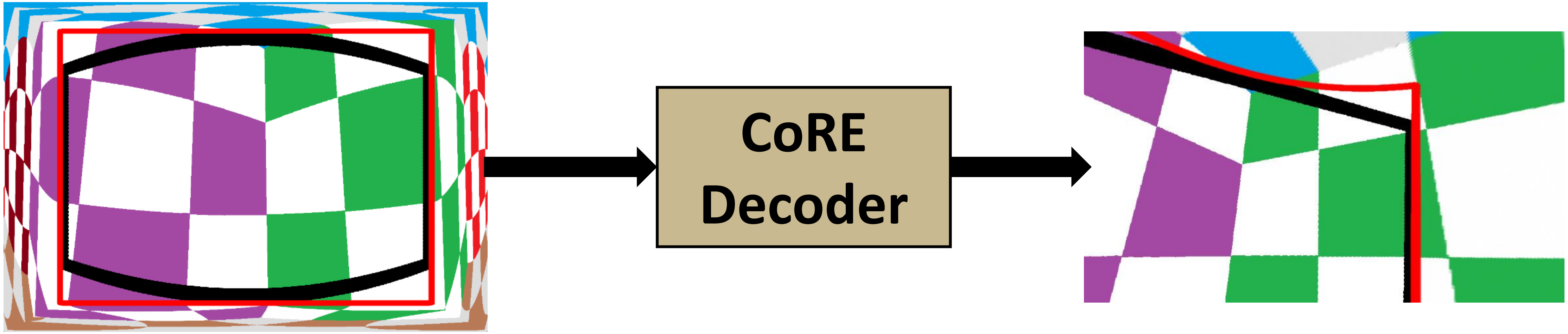
CoRE Decoding



CoRE frame

Output frame

Demonstrations

Experimental Evaluation

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Objectives

- How does CoRE compare to other methods?
  - 4 bandwidth traces
  - 6 videos
  - 25 to 60 head movement traces per video

Method	***Explanation***
FoV only	Field of View only (90° x 48°)
FoV+ 1QL	FoV and padding (20%) of high quality
FoV+ 2QL	FoV high quality, with padding (20%) in lower quality
FoV 360	FoV (high quality) and all remaining tiles in lower quality
FoV+ 360	FoV+padding (high quality) and all remaining tiles in lower quality
CoRE	4s main part (high quality (90°x48°)) and 6s extension part

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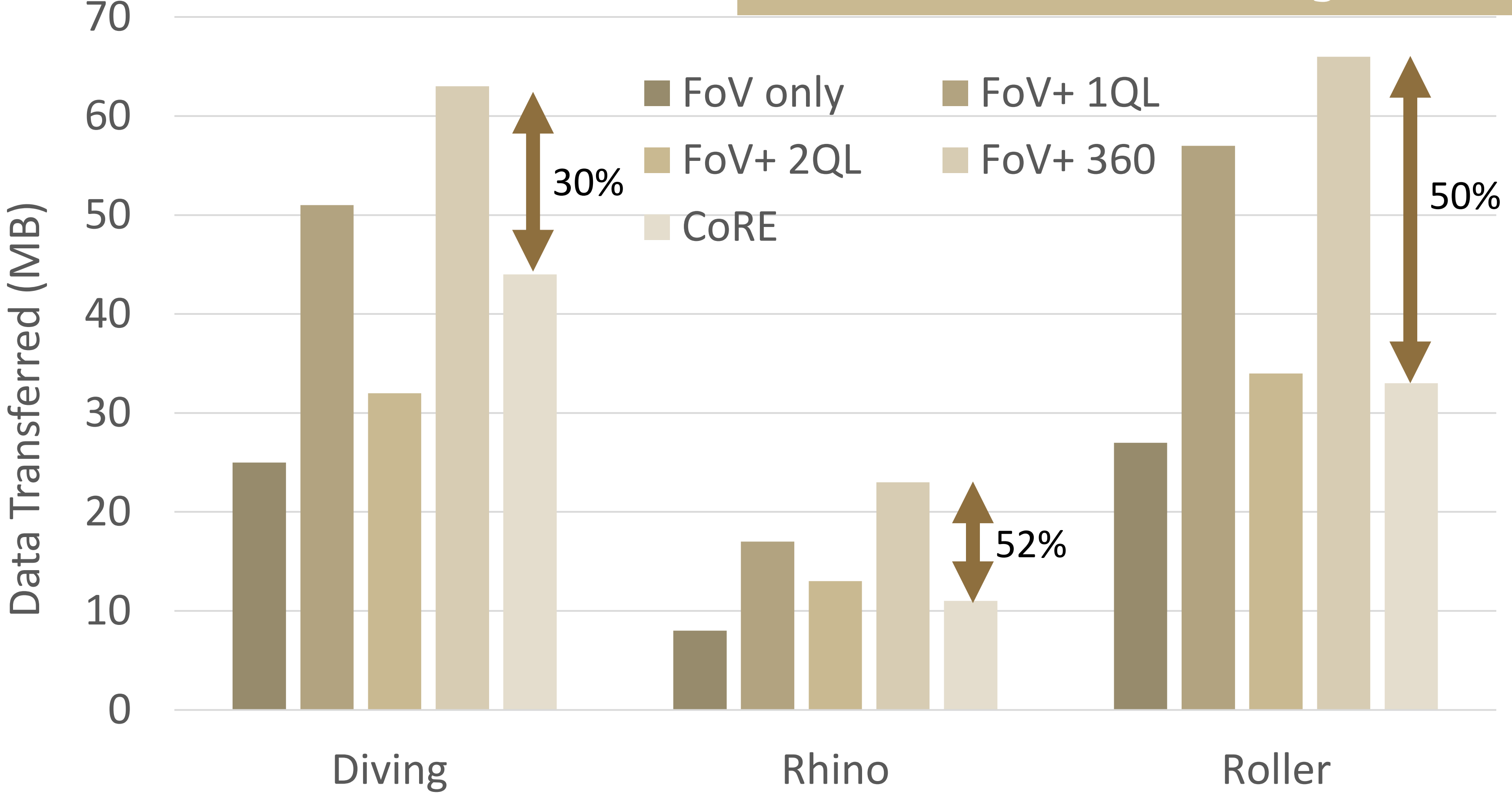
Data Transferred

CoRE transfers significantly less data



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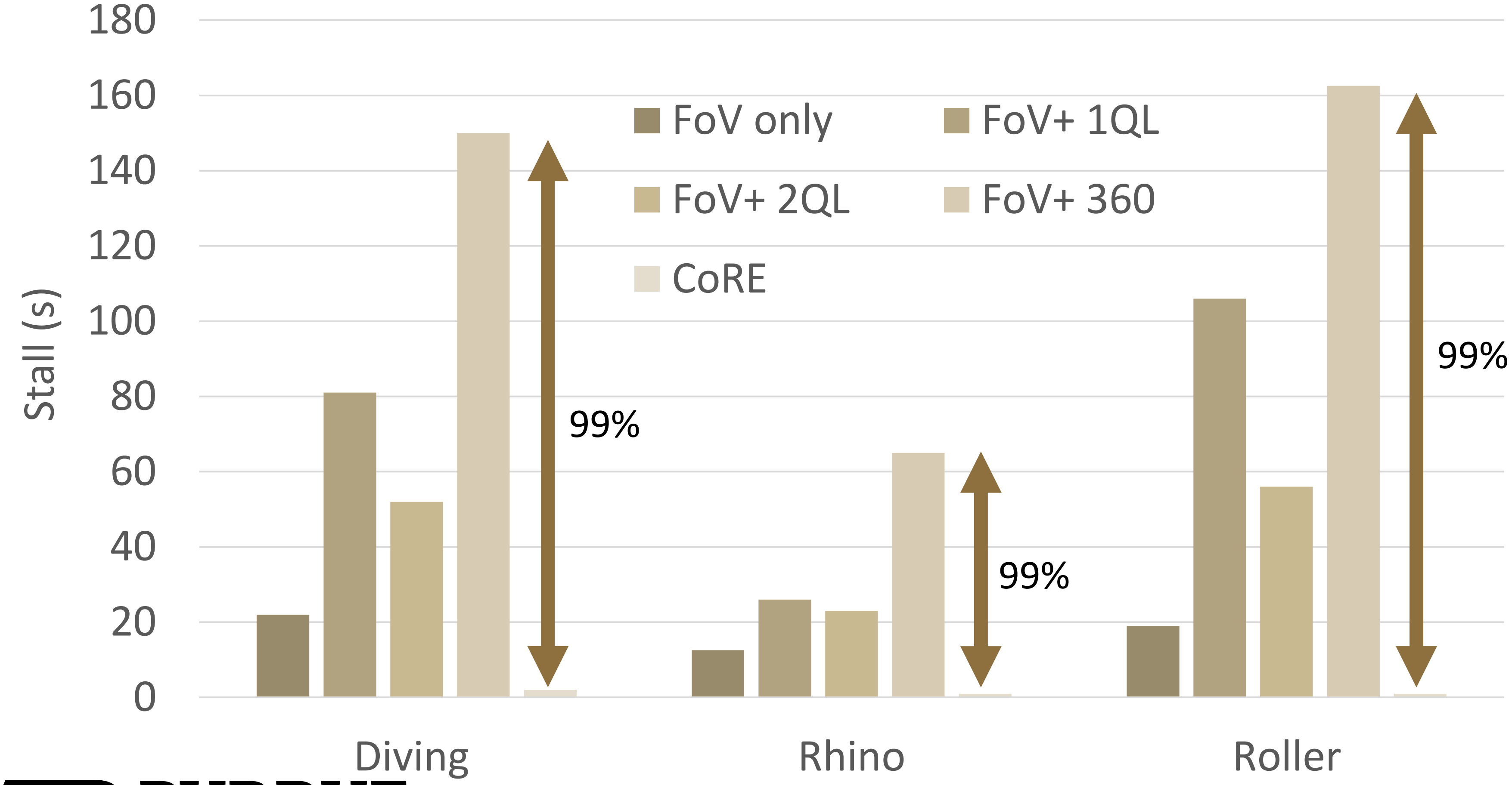
Stalls

CoRE has significantly fewer stalls



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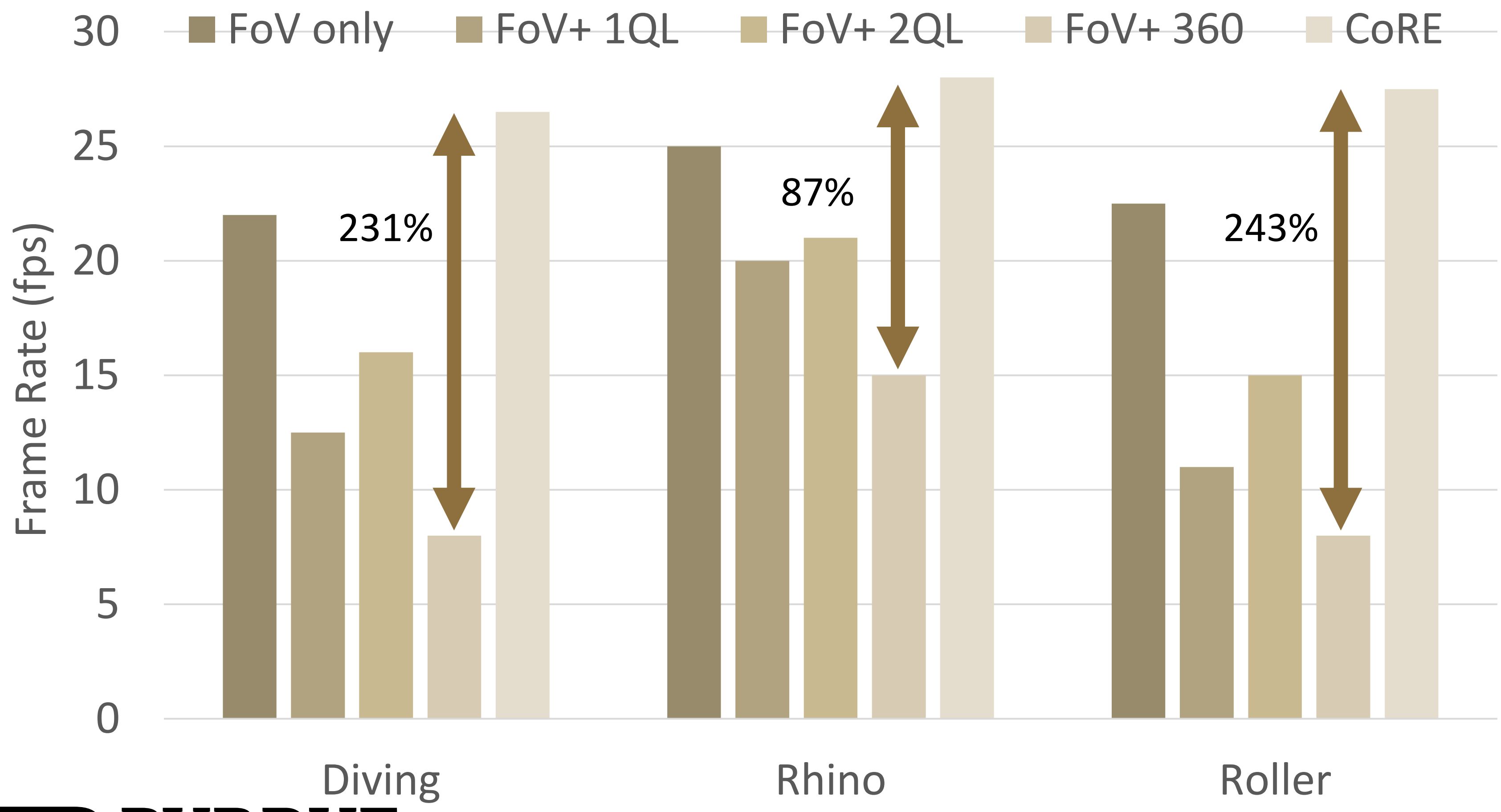
Average Frame Rate

CoRE has significantly higher frame rate



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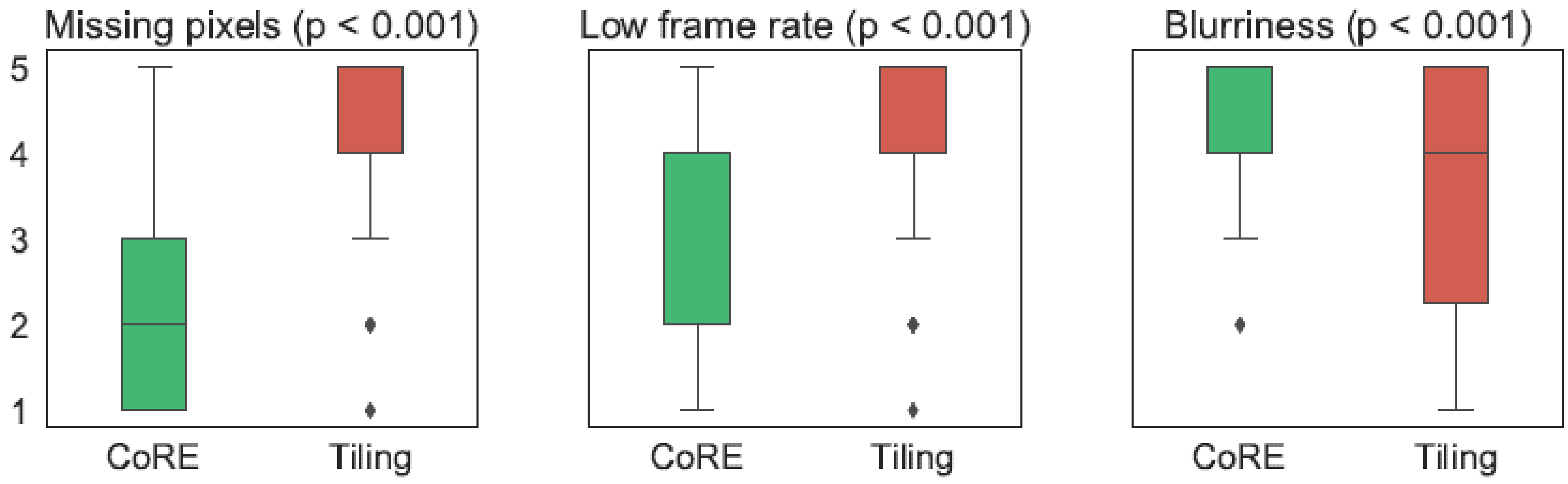
User Study

- Compare CoRE and FoV+ 1QL tiling with 3 videos



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Conclusions

- CoRE is a new approach for 360° video streaming
  - Robust to view prediction errors
  - Robust to bandwidth fluctuation
- CoRE has significantly lower resource requirements
  - Lower energy consumption
- User study shows that CoRE enhances user experience

Much more in the paper ...

- Results with more videos
- Results with more bandwidth traces
  - AT&T, Verizon, and T-Mobile bandwidth traces
- Additional evaluation metrics such as missing pixels
- Comparison of decoding overhead
  - Energy/Time comparison to tiling
- Impact of view misprediction
- Cost/benefit analysis

Thank you

Questions?

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