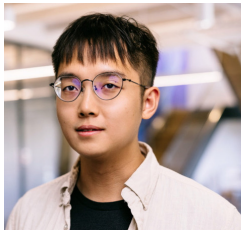
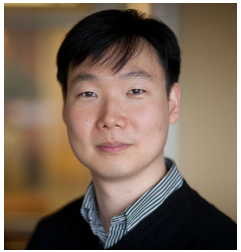
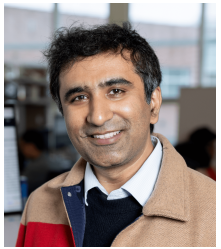
Privatar

Enabling Privacy-preserving Real-time Multi-user VR through Secure Outsourcing



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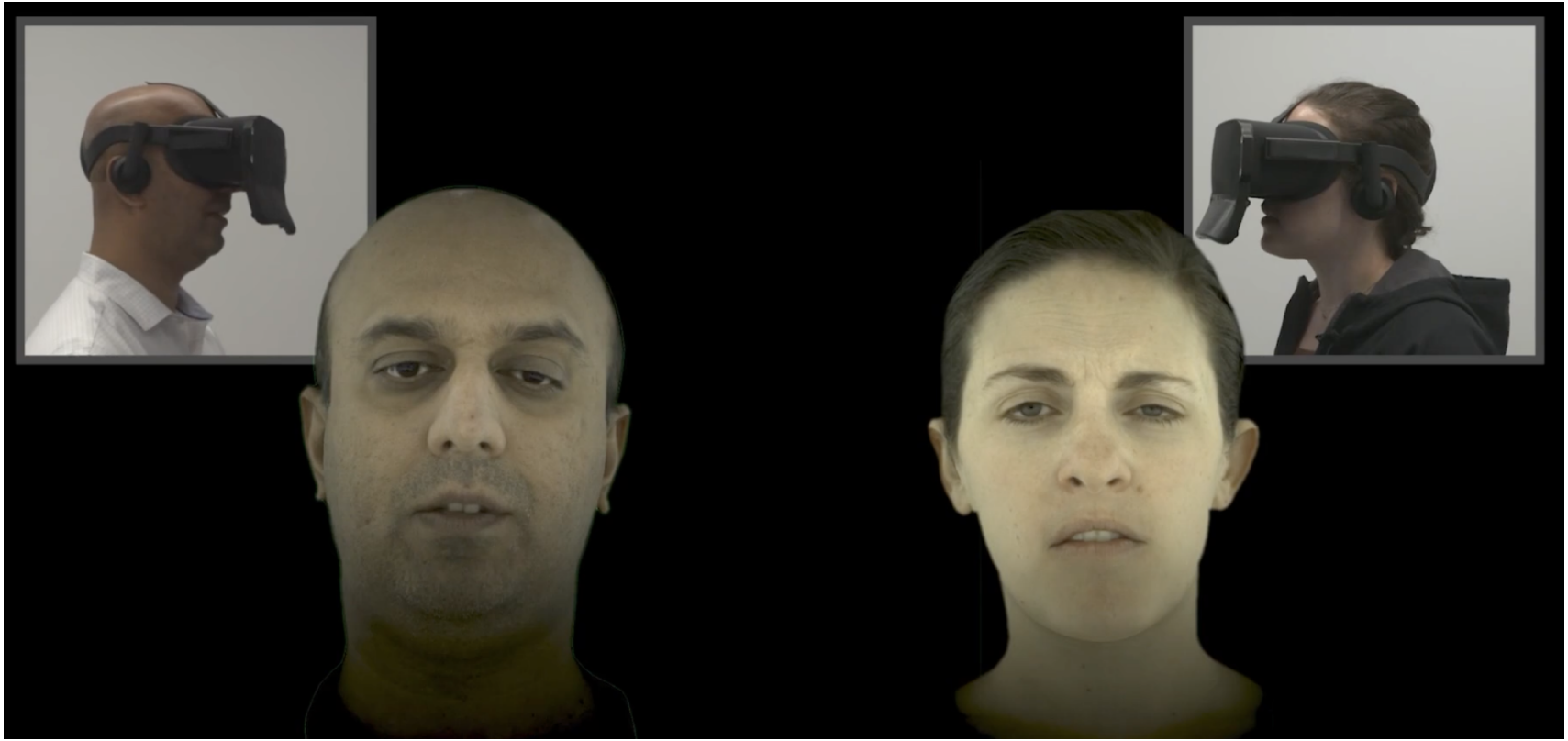
Outlines

- Background and Motivation
- Challenge
- Privatar: Secure Avatar Reconstruction Offloading
- Evaluation
- Conclusion

Application: VR Enables Photorealistic Chat

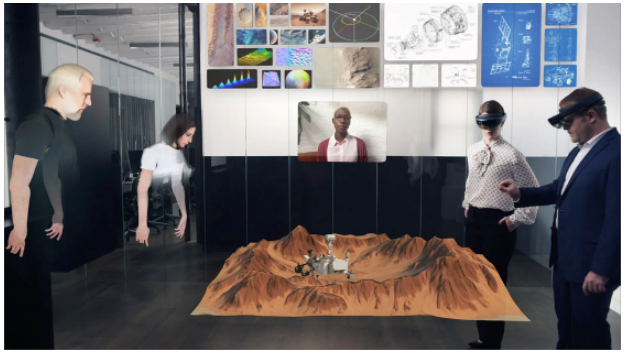


VR Enables Geographically Disjointed Users to communicate.

Application: Realistic VR requires many users!

VR Concert

VR Football Game



Virtual Meeting

Render (>10) Multiple Avatars

Exceed the Compute Capacity of a single VR headset

This Talk: Secure Avatar Reconstruction Outsourcing!

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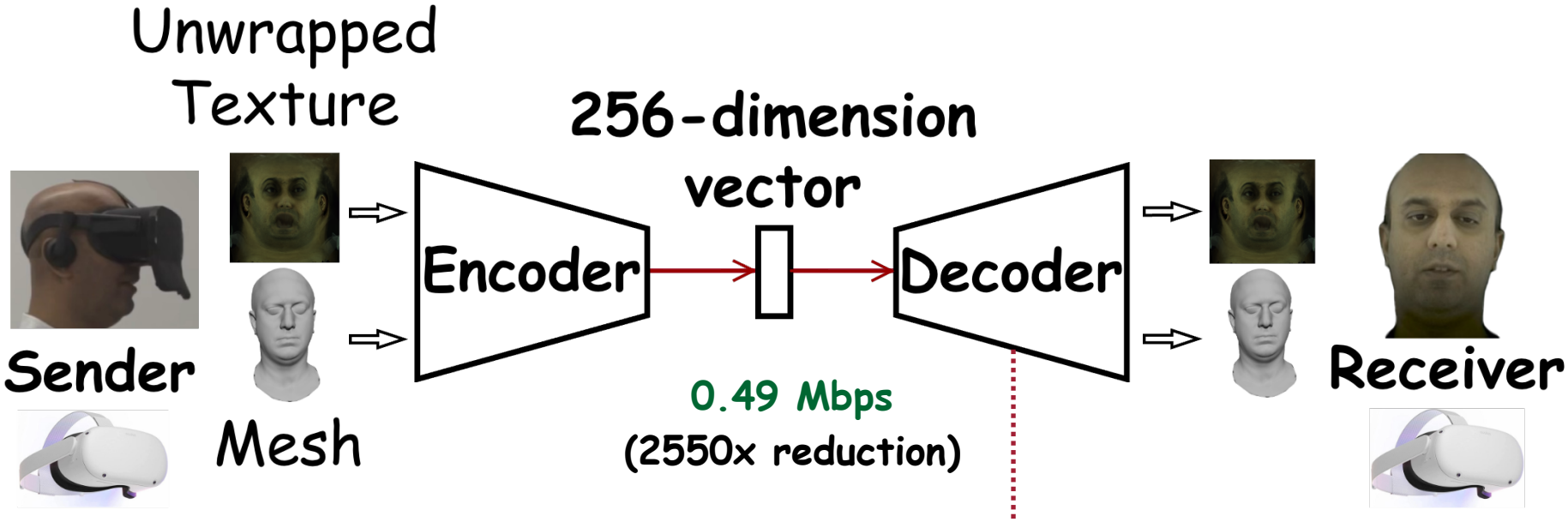
Problem: Limited Compute for Multi-user VR



Compute Bottleneck: 364 GFlops per user

902 GFlops Max Throughput

Problem: only Support <= 2 Users

How to securely outsource avatar reconstruction other devices?

Challenge: Private Data Needs Secure Outsourcing

Unwrapped Texture

Sender

Mesh

Private Data

User Identity, Expression and Emotion

Directly Outsourcing leaks privacy

Challenge 1: Where to outsource?

Challenge 2: What data to outsource?

Challenge 3: How to ensure privacy?

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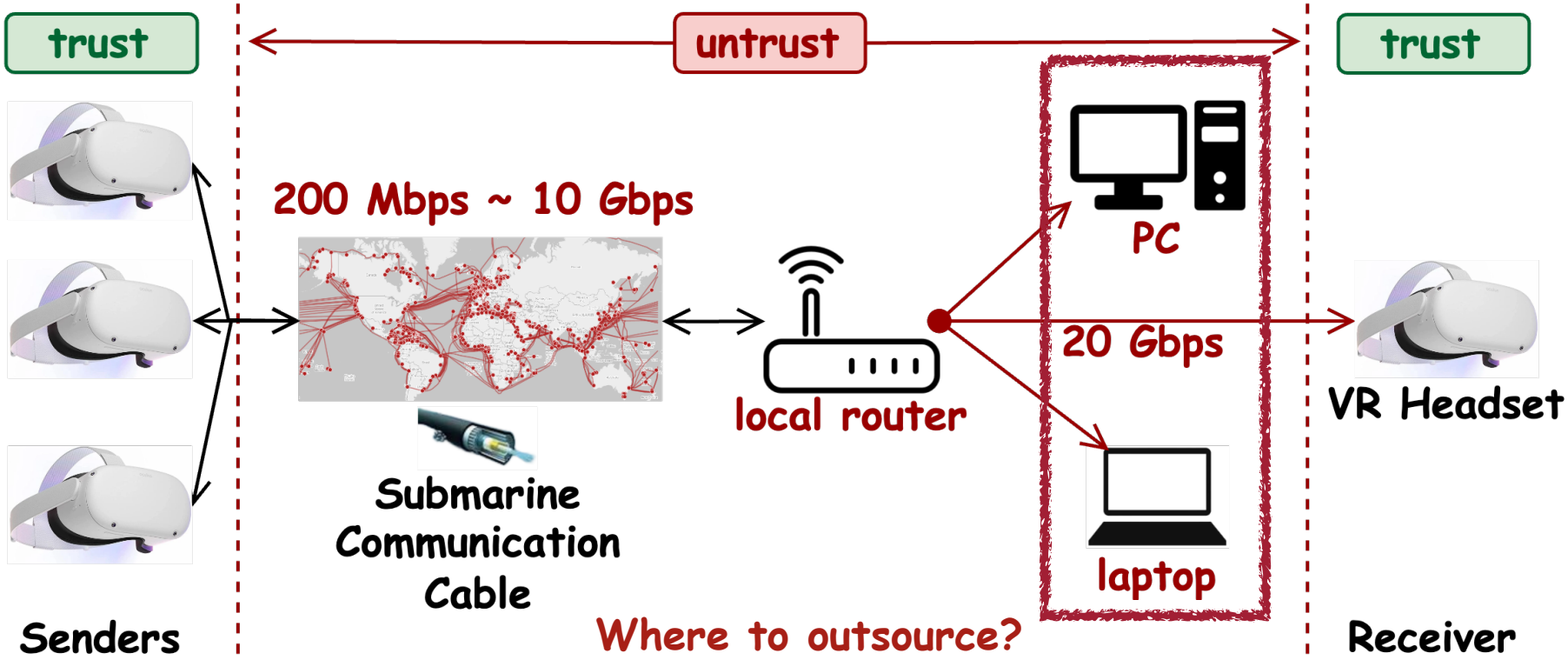
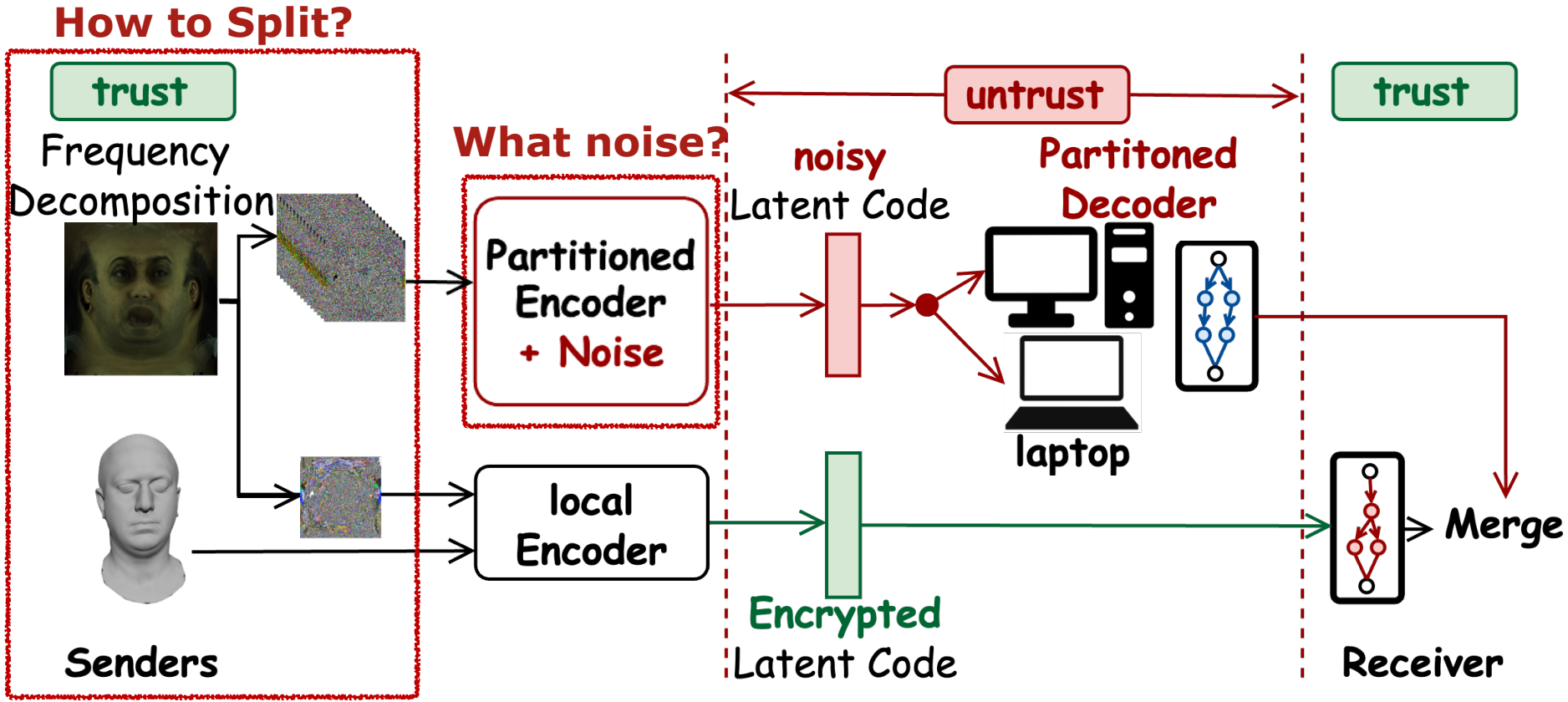
Threat Model and VR System Setup



Untrusted Devices Connected to Local Router (PC, Laptop)

Secure Offloading Partitioned Model and Input



Horizontally Partitions Input and Model and Offloaded One Part

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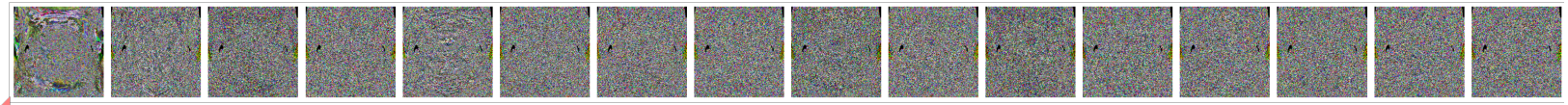
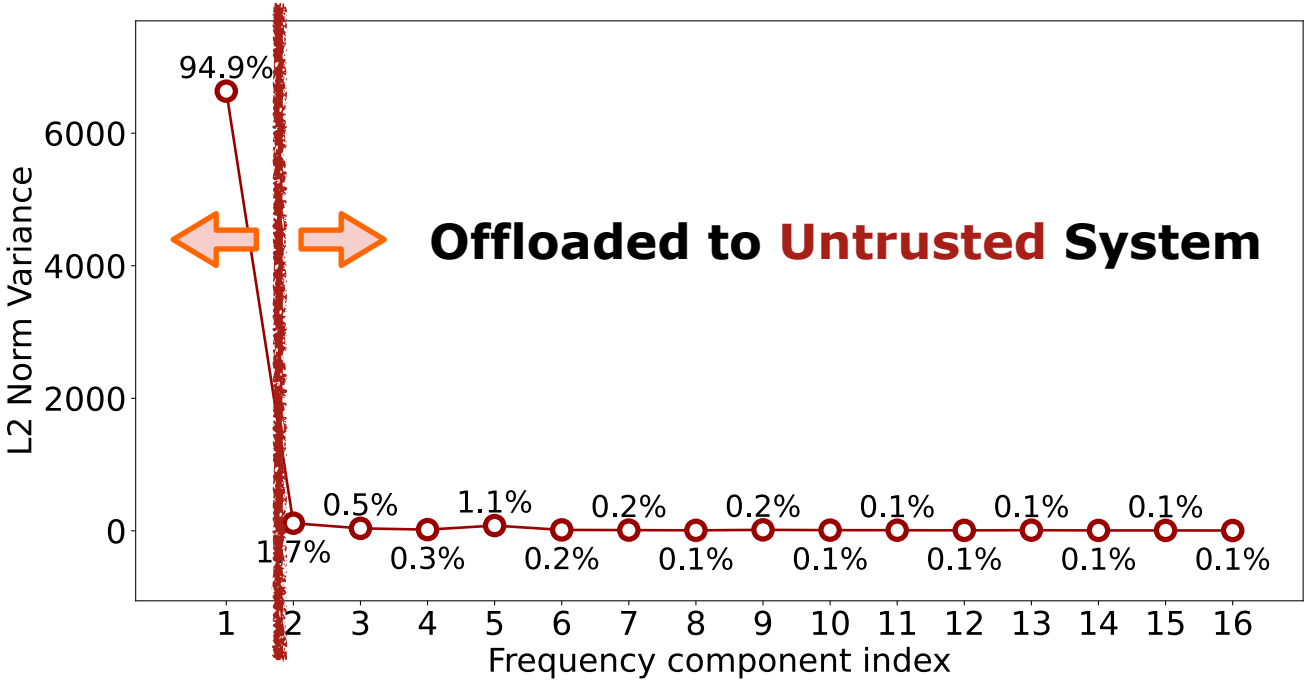
Frequency Splitter: Energy based Partition

Unwrapped Texture (X)



Local Processing



Offloaded to Untrusted System

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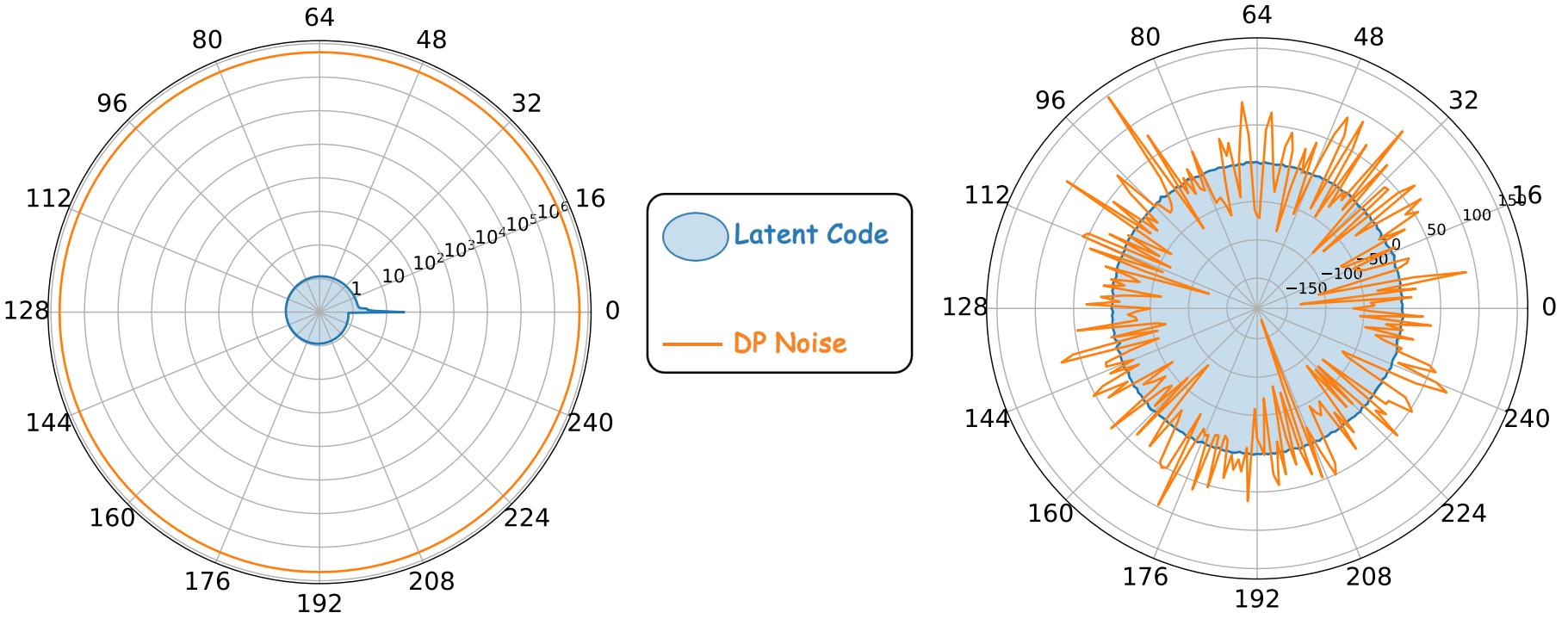
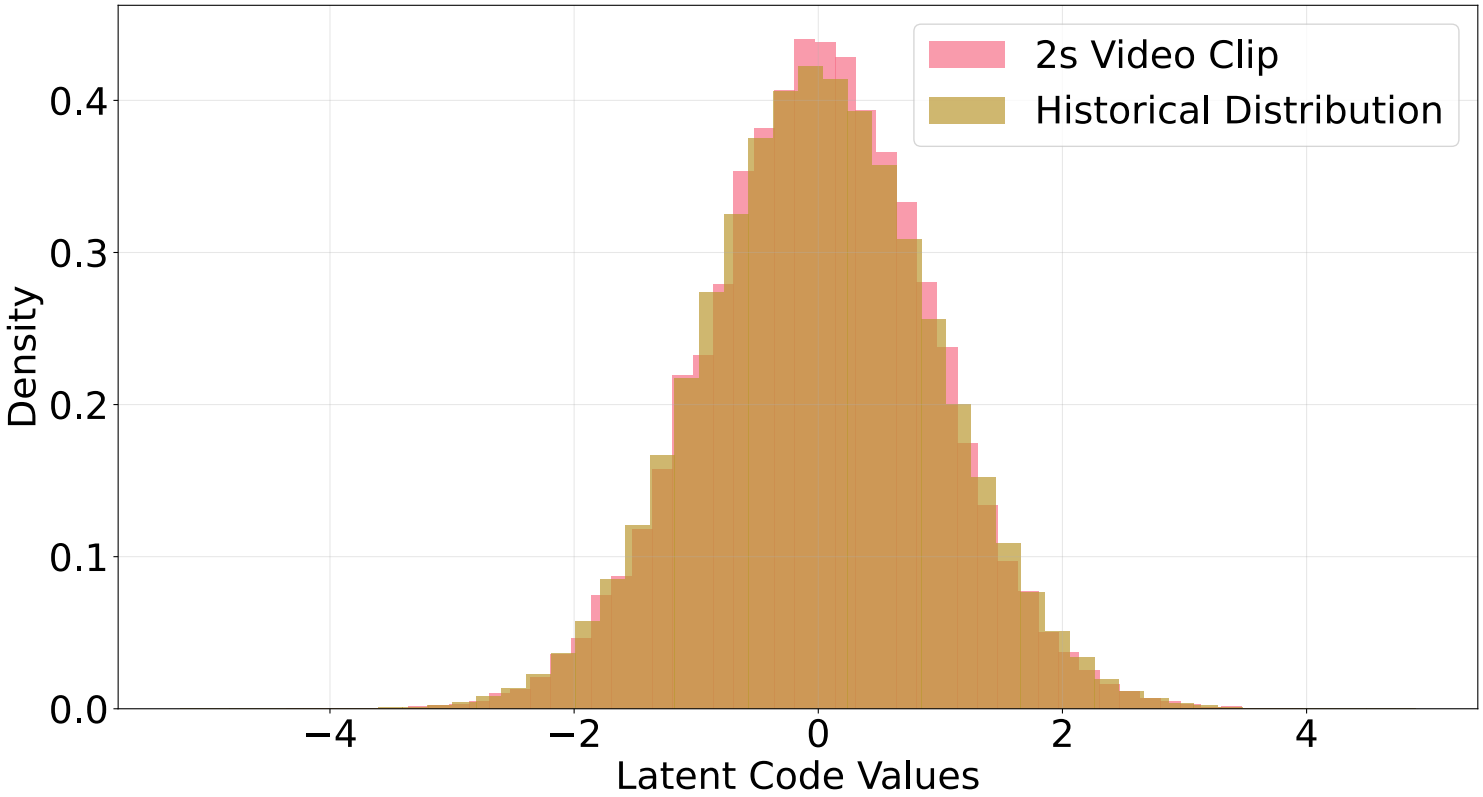
Adding Noise for Provable Privacy Guarantee

For 256D Tensor, Differential Privacy (DP) gives Worst-Case Protection



Ignores Dimensional Differences — But VR Data Not Hit Worst Case

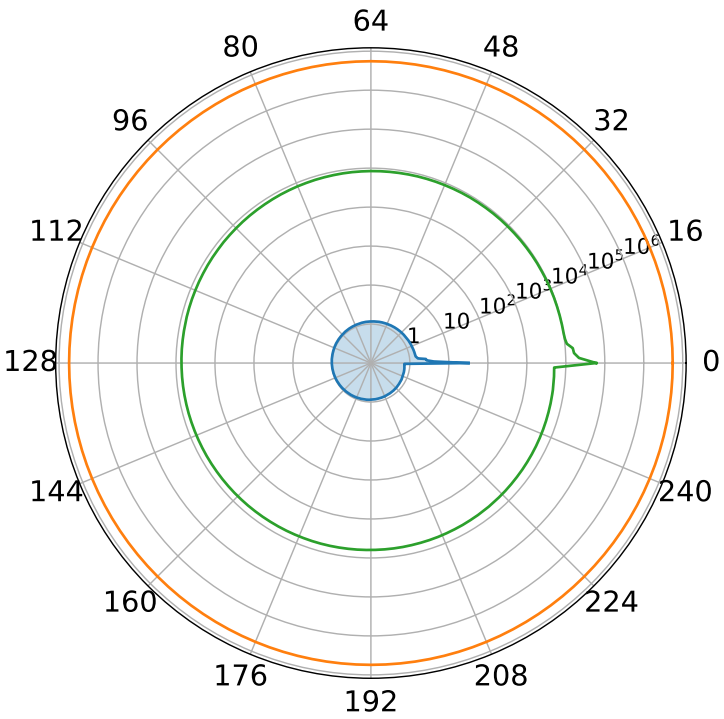
Observation: Slow Statistical Distribution Drifting

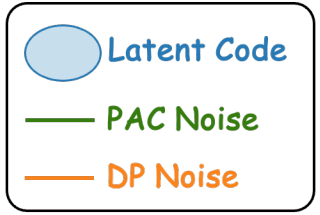


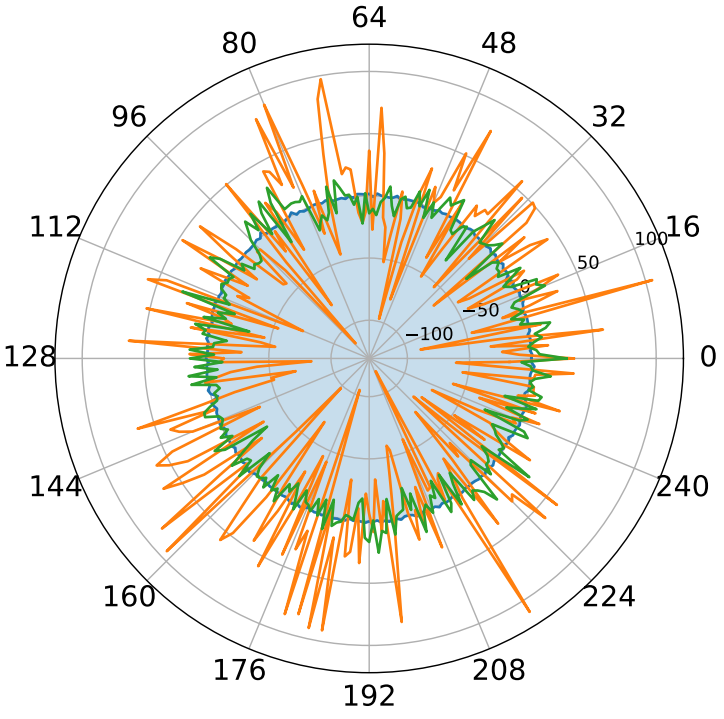
We Could Add Statistical Distribution into Noise Determination!

Adding Noise for Provable Privacy Guarantee

Leverage Statistic Data Distribution to Provable Minimize Noise







Statistical Distribution **Random One Data Sample**

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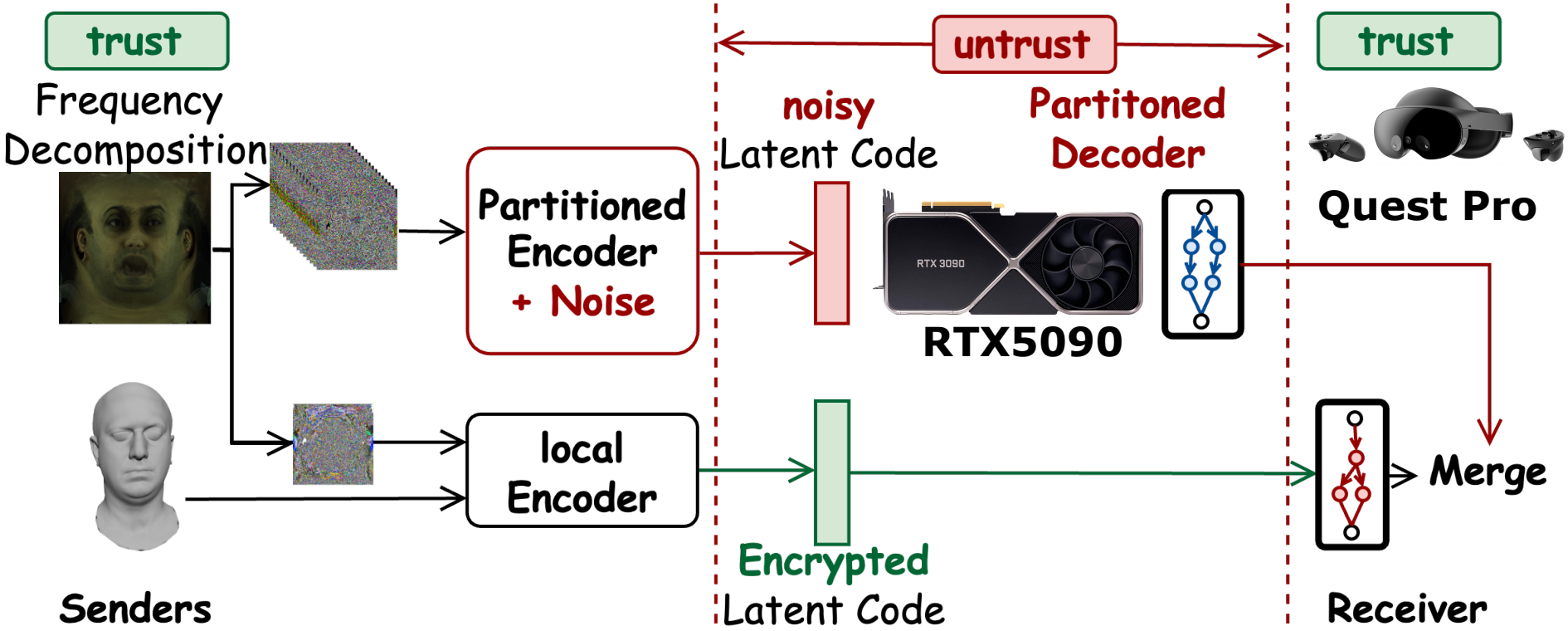
Evaluation Setup

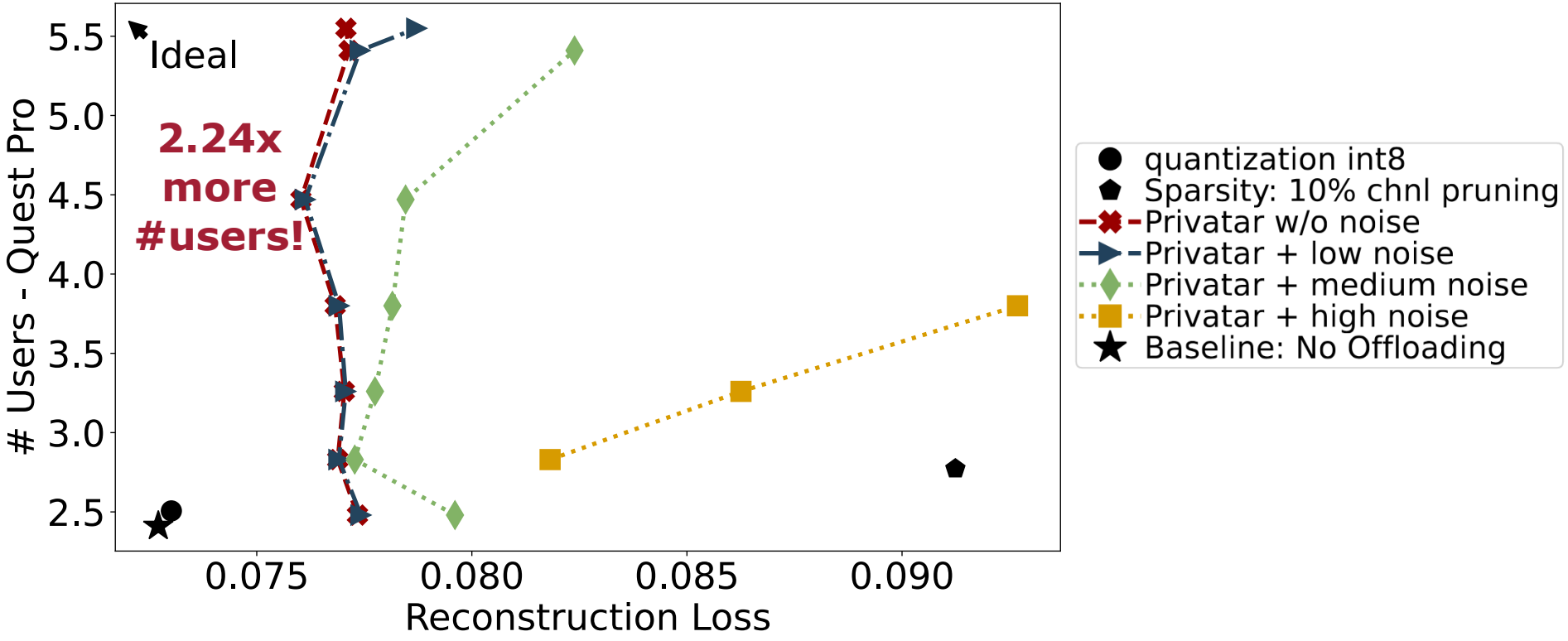


Real Deployed on RTX 5090 and Estimated on Quest Pro

Evaluation: Negligible Quality Loss from Truth

(a) Truth (b) Baseline (c) FO (d) Quantize (e) Sparsity (f) PRIVATAR

Privatar: SotA #user-Accuracy Pareto Frontier



Privatar Offers SoTA #user-Accuracy Pareto-Frontier Curve

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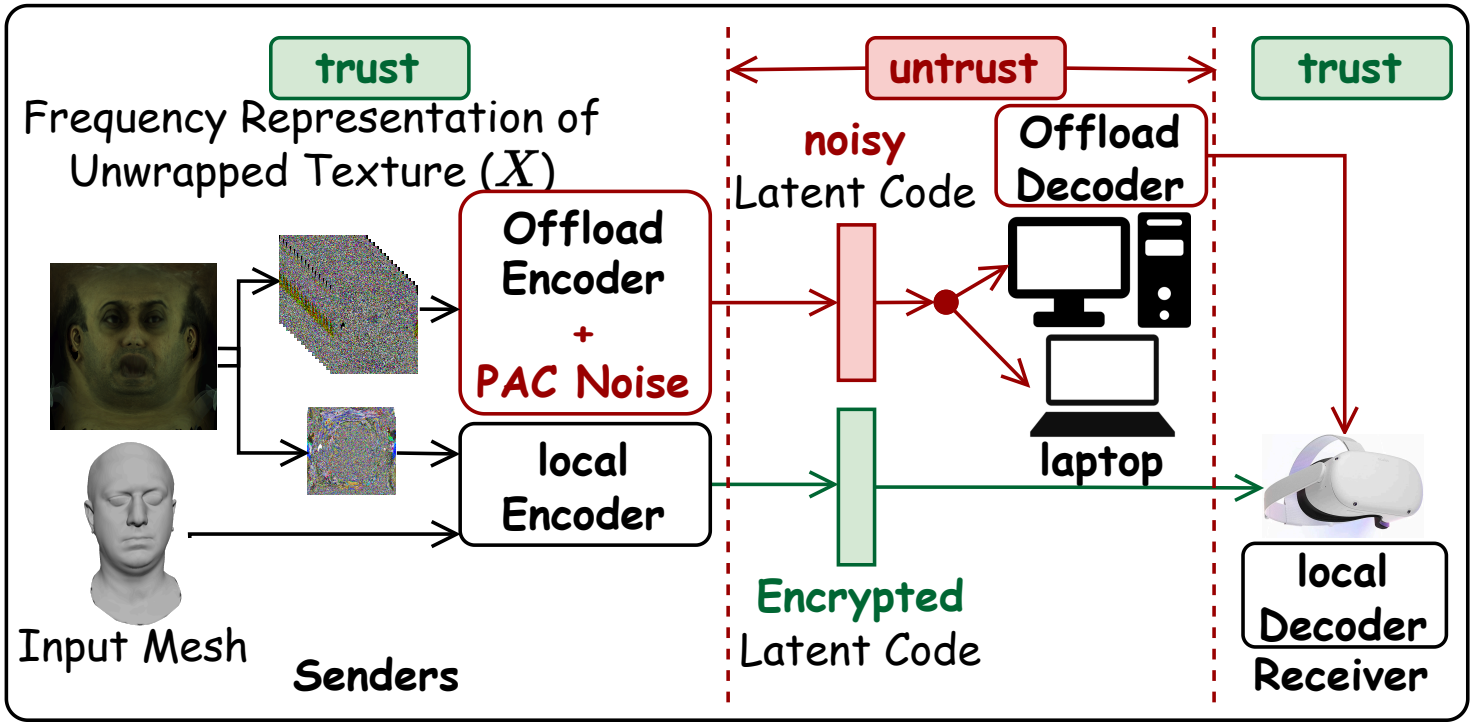
First Secure Outsourcing Avatar Ceconstruction



Paper

Code

What to split? Horizontal Partitioning

How to secure data? Distribution-Aware Minimal Noise