Enforcing End-to-end Security for Remote Conference Applications

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Remote Conference Applications

腾讯会议 Tencent Meeting

Signal

zoom

jitsi

webex by cisco

Microsoft Teams

Online learning

Business

eHealth

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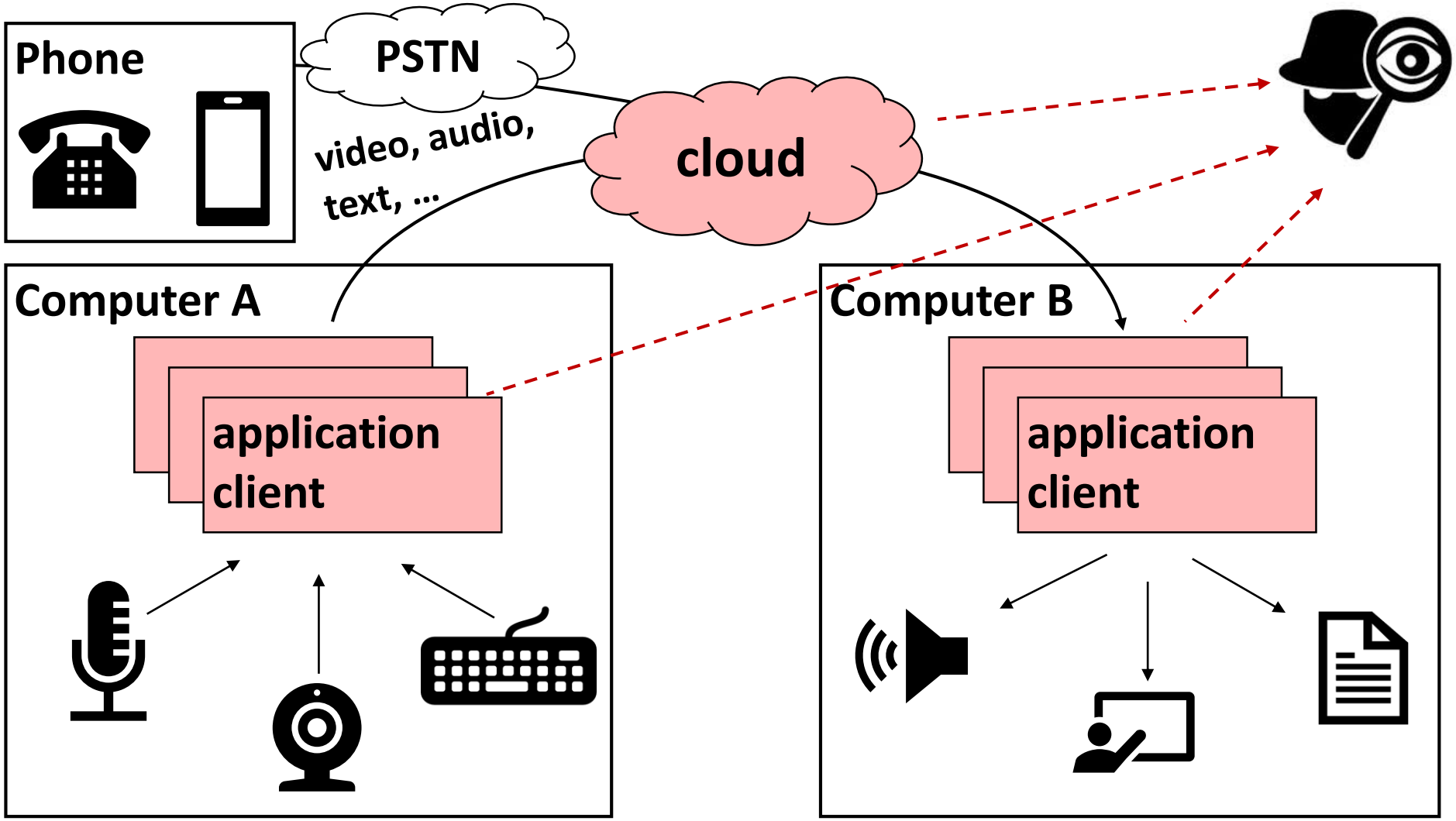
Threats in Conference Applications

- In 2020, Zoom gave user data to Facebook and Google without user's consent[1]
- In 2022, an ex-Amazon employee was convicted of hacking Capital One and stealing data of over 100 million people[2]

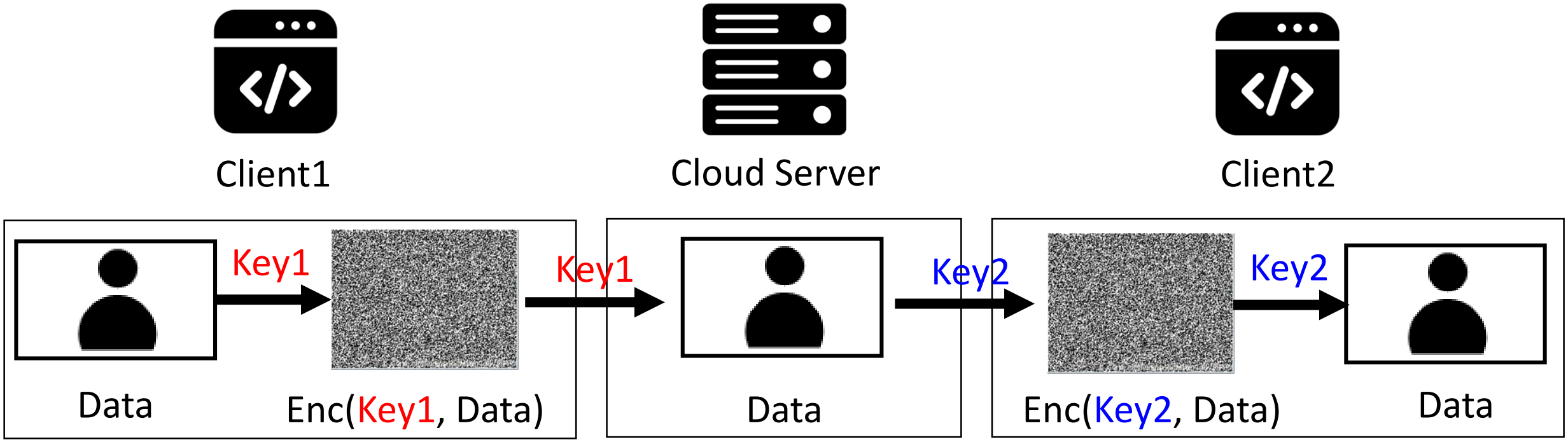
[1] "Zoom is being sued for allegedly handing over data to Facebook," https://www.businessinsider.com/zoom-sued-allegedly-sharing-data-with-facebook-2020-3, Business Insider. 2020.
[2] "Ex-Amazon employee convicted of hacking Capital One and stealing data of over 100 million people," https://www.insider.com/ex-amazon-worker-convicted-of-hacking-capital-one-and-stealing-data-2022-6, Insider. 2022.

Threats in Conference Applications



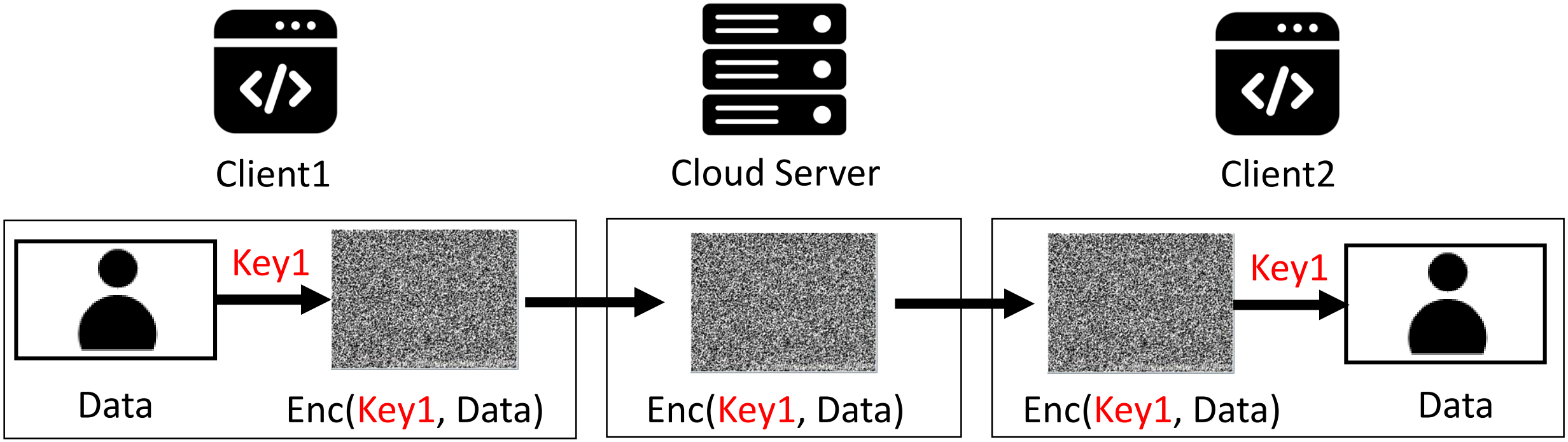
Background - Secure Transmission Schemes

- Point-to-point encryption (P2PE)
  - Encryption keys are negotiated with the cloud
  - User data is transparent to the cloud



Background - Secure Transmission Schemes

- End-to-end encryption (E2EE)
  - Encryption keys are negotiated among clients
  - User data is confidential to the cloud



Limitations of Current E2EE Solutions

- Proprietary Implementations
  - Lack of effective auditing methods
  - Lack of trust from the general public[1]
- Open-source Implementations
  - Lack of rich features
  - Limited market share
- Lack of support for dial-in access

[1] R. Abu-Salma, E. M. Redmiles, B. Ur, and M. Wei, “Exploring user mental models of End-to-End encrypted communication tools,” in 8th USENIX Workshop on Free and Open Communications on the Internet (FOCI 18). Baltimore, MD: USENIX Association, Aug. 2018.

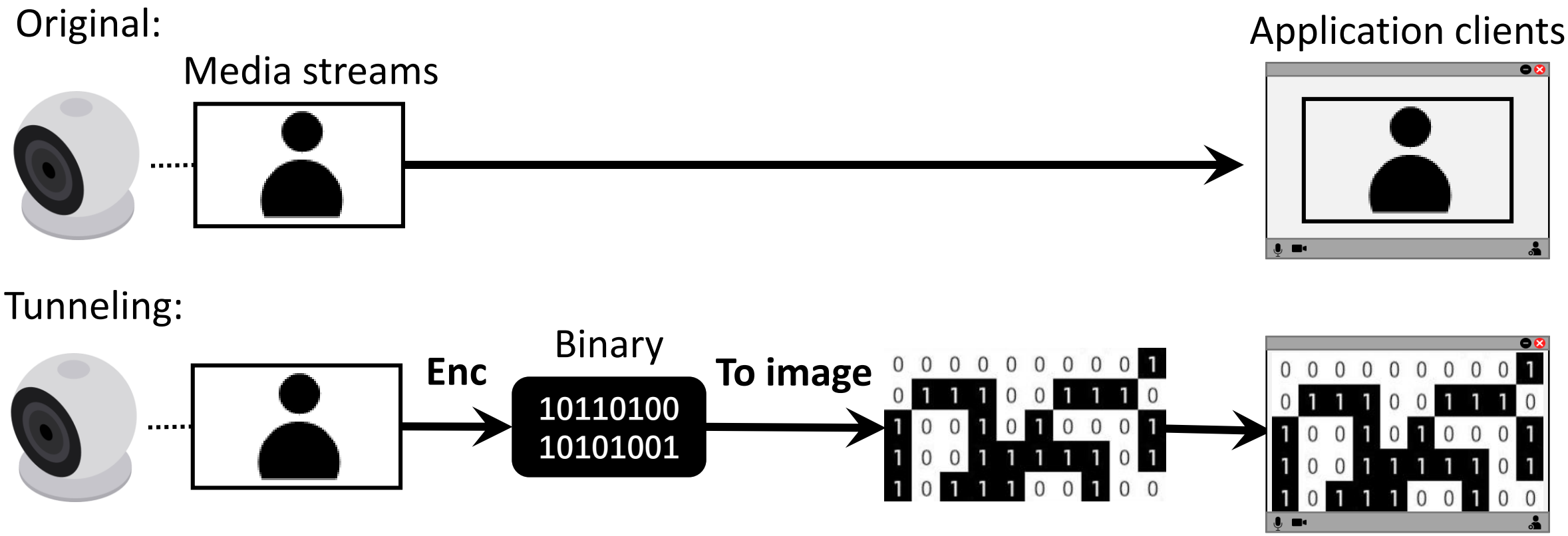
Design Goals

- Threat model: the adversary is a network attacker who can access, replay, and generate arbitrary on-path data and key information
  - *e.g.* Malicious insider, cloud service provider, external adversary

- We want to design a tool to enhance conference applications
  - Achieve E2EE security
  - Ensure compatibility
  - Preserve functionality

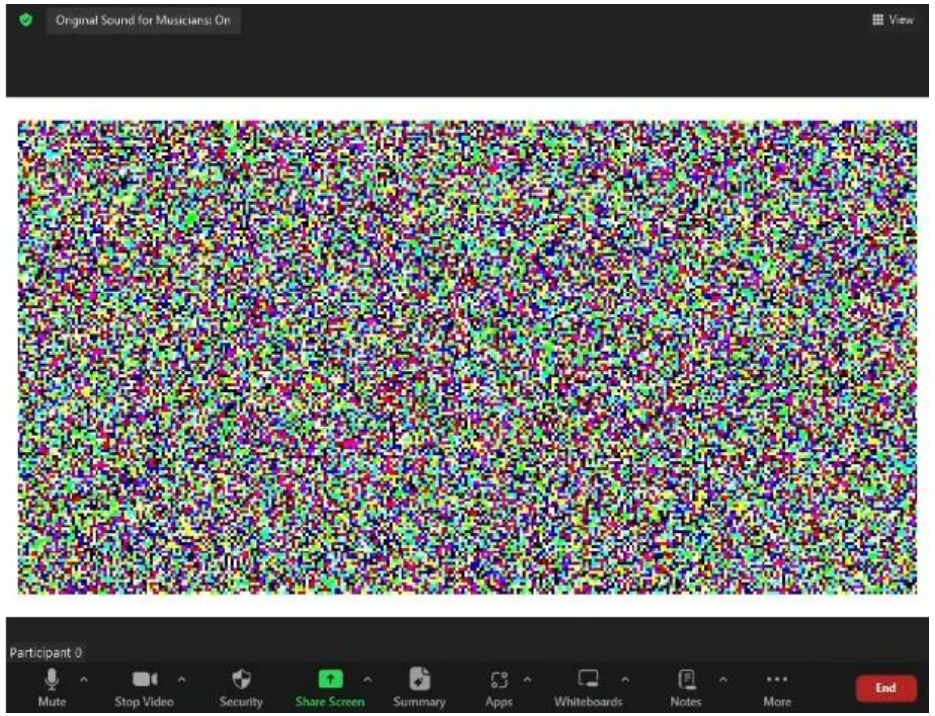
Approach - Media Tunneling

- Basic idea: use E2EE key to encrypt the media streams before they are acquired by the application clients



Demo

Original / Recovered Client UI



Client UI under Protection

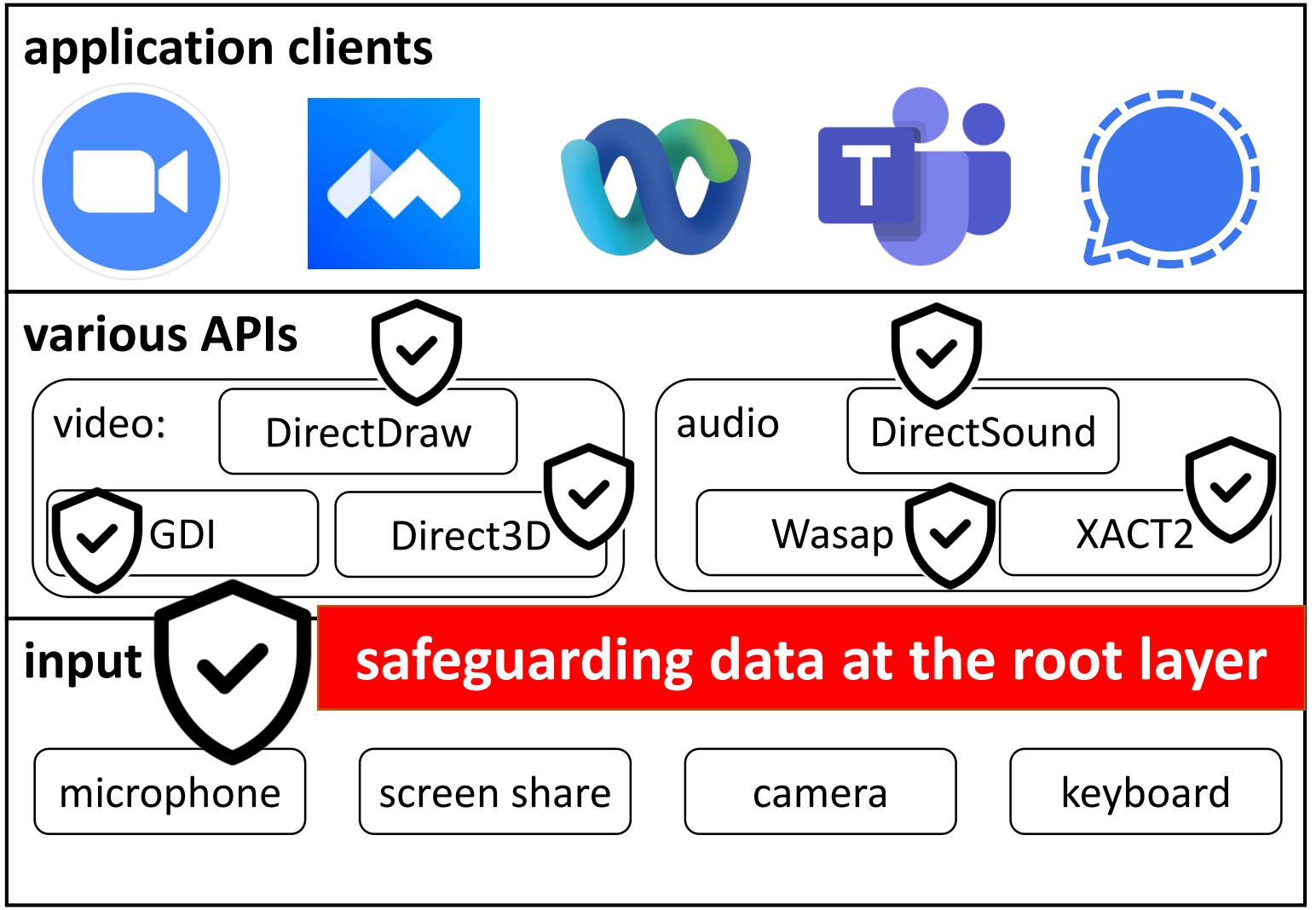
Challenges - E2EE Media Tunneling

1. Be compatible for various clients
   - Conference applications utilize distinct I/O interfaces for data retrieval

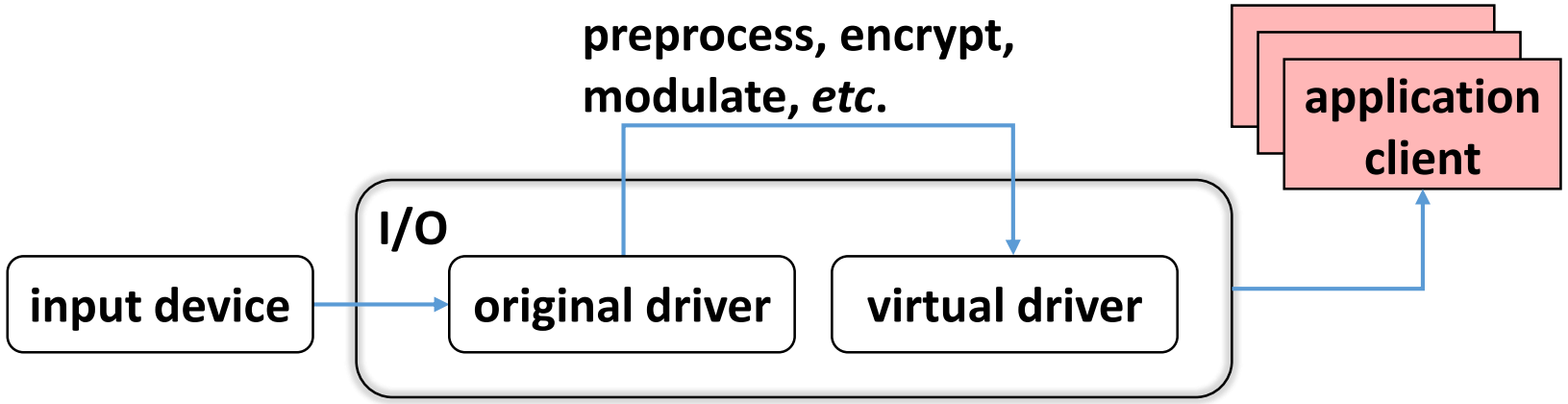
2. Resist lossy compression
   - Conference applications perform lossy compression on transmitted data, corrupting the decryption of ciphertext

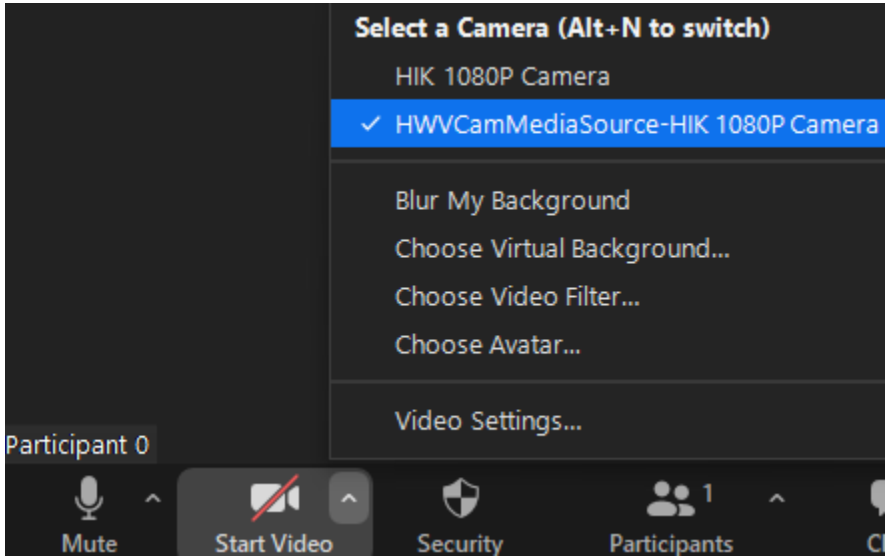
3. Support dial-in access
   - No generic data links to phone clients

Challenge 1 - Be Compatible for Various Clients



Solution - Virtualization





- Virtual device:
  - Virtual camera
  - Virtual display buffer
  - Virtual microphone
  - Virtual speaker

Challenge 2 - Resist Lossy Compression

Left: original

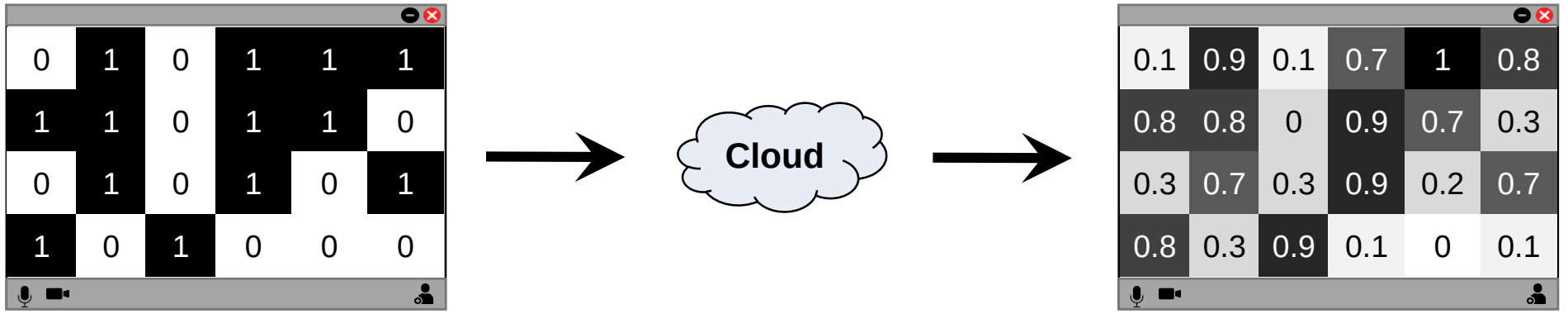
Right: compressed

Photo Sources: dreamstime.com with RF license

Challenge 2 - Resist Lossy Compression

Lossy channel: the media data will be lossy compressed before being transmitted to the remote side

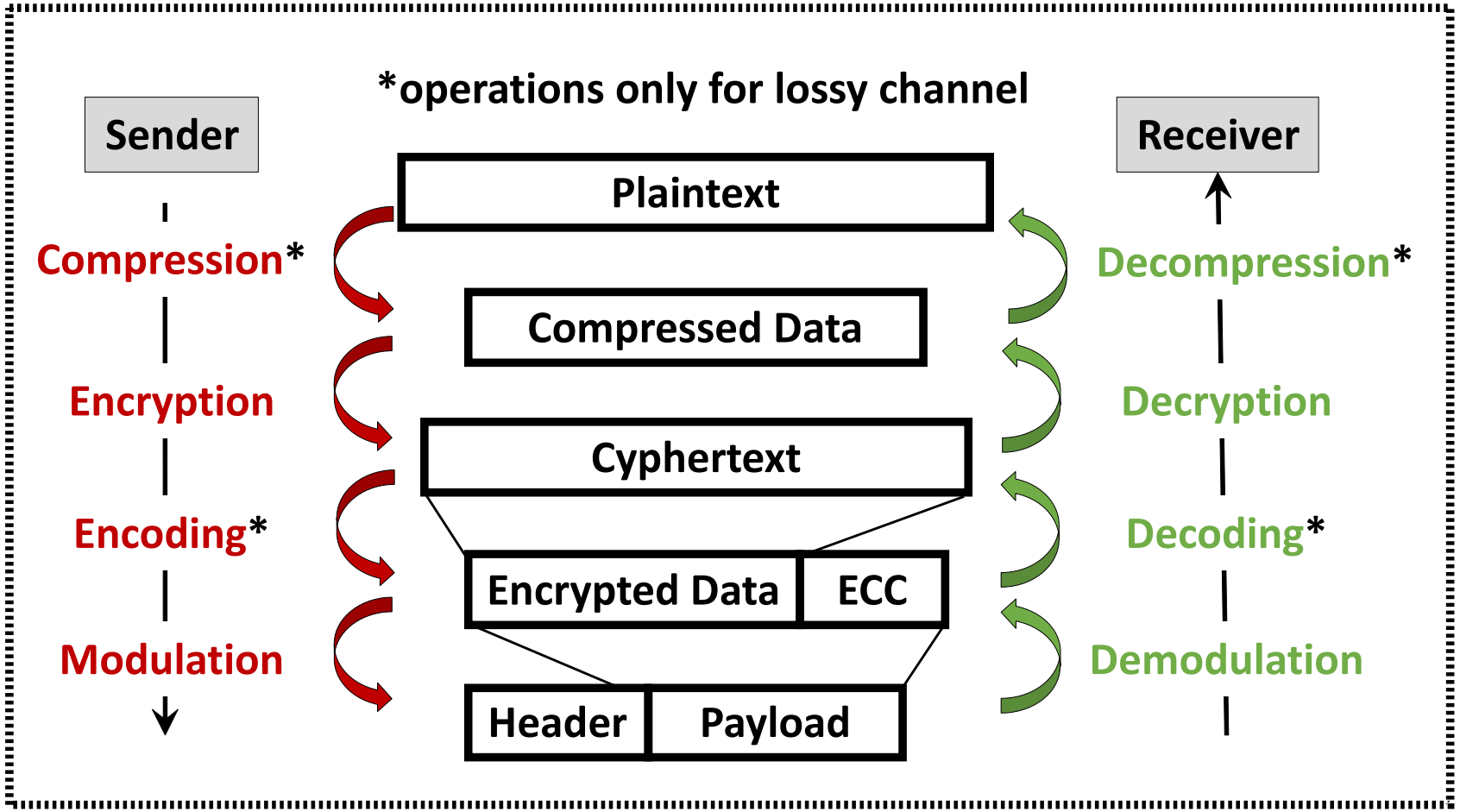
- *e.g.* Video, audio



Sender's client

Receiver's client

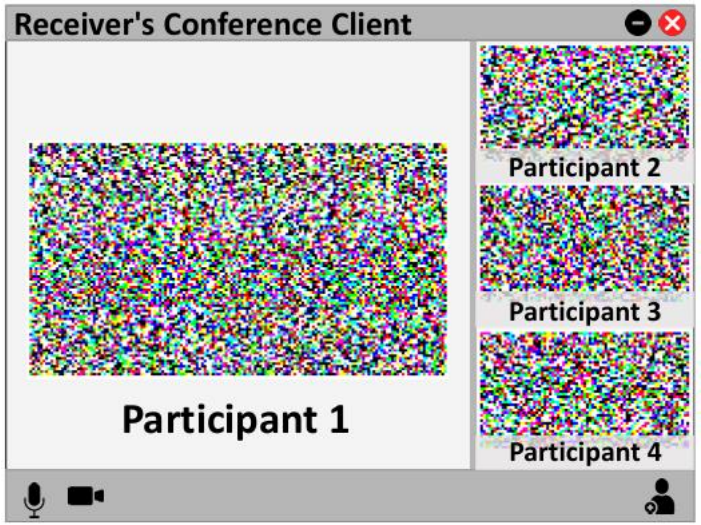
Solution – ECC Encoding and Modulation



Example - Video Channel Modulation

(a) Original Video Frame

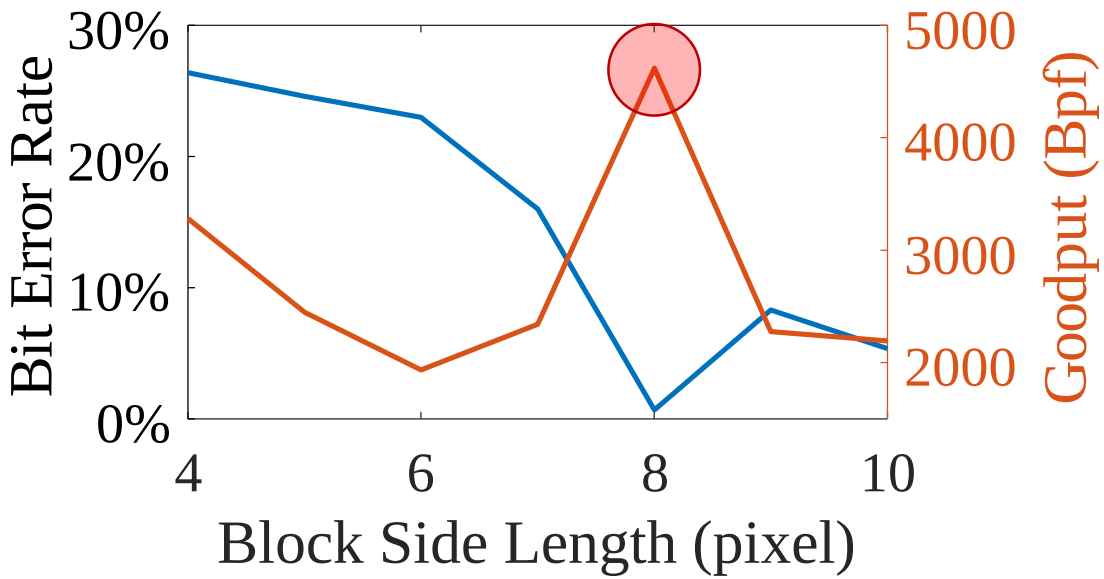
(b) 2D Barcode Structure



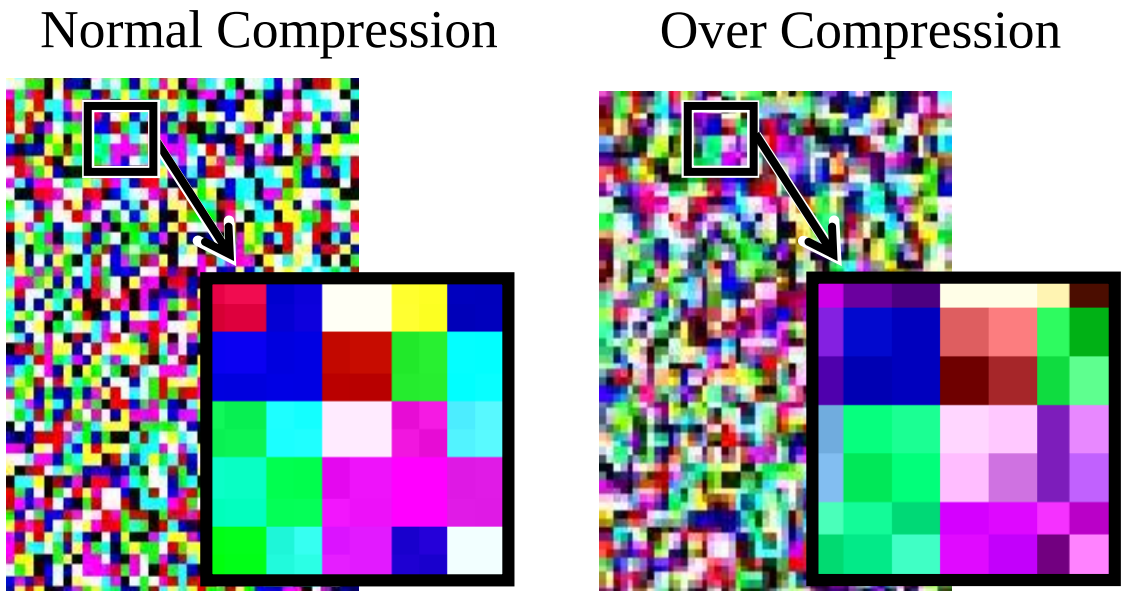
(c) Client UI

(d) Recovered and Recomposited Client UI

Results - Video Quality



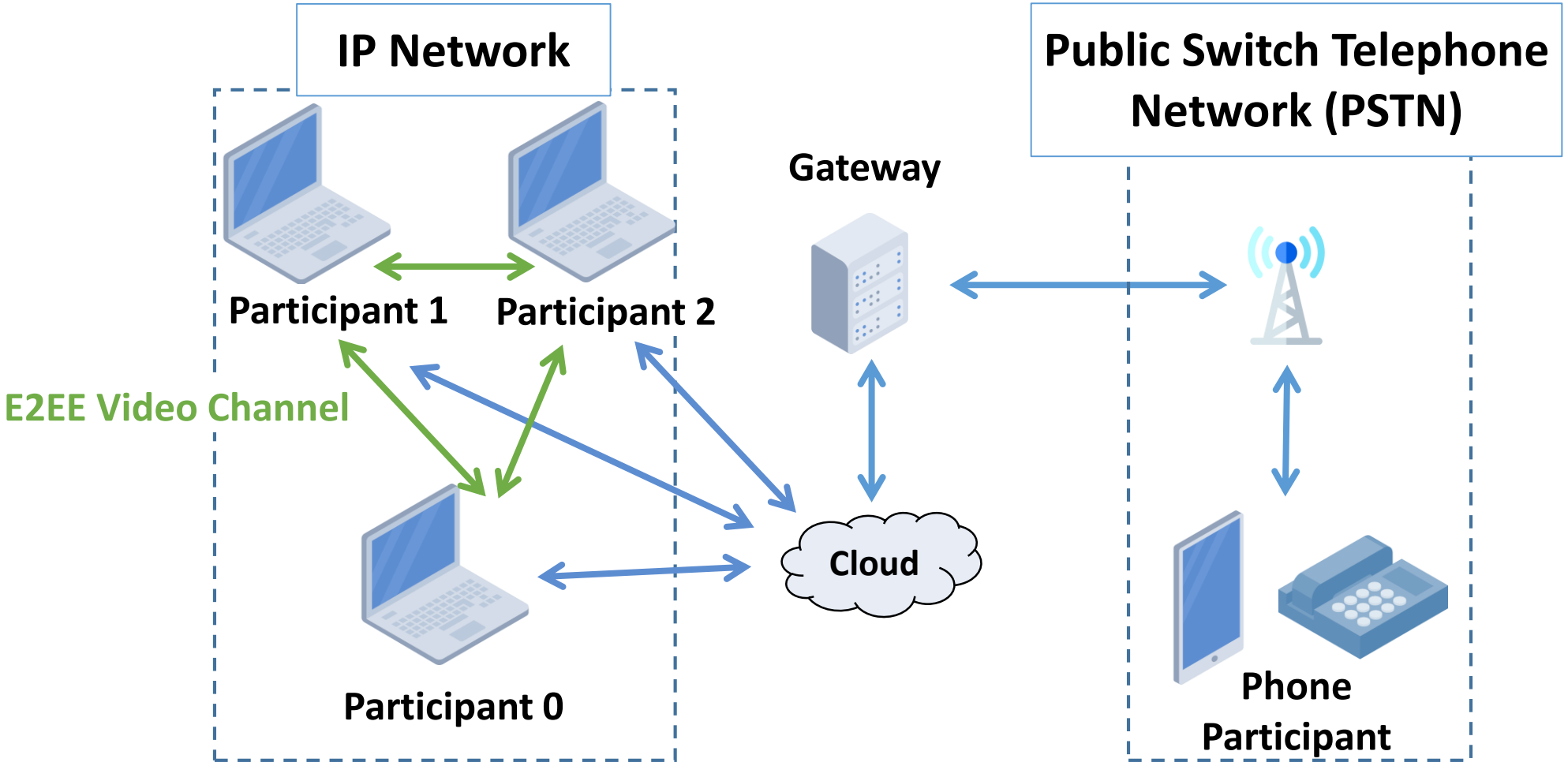
(a) BER, Goodput v.s. Block Size



(b) Over Compression Situation

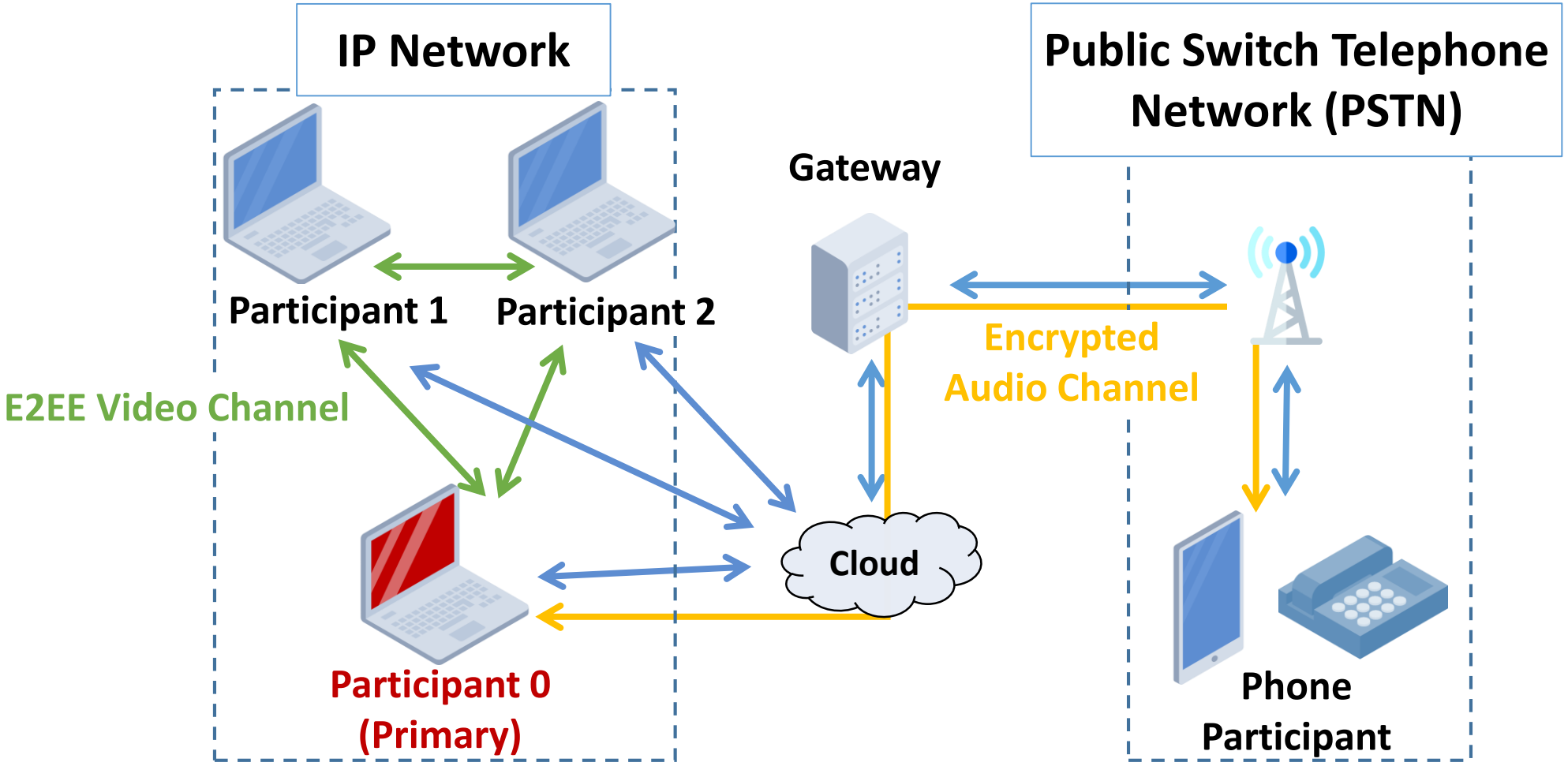
Challenge 3 - Support PSTN Dial-in Access

- Architecture of IP and PSTN hybrid conference



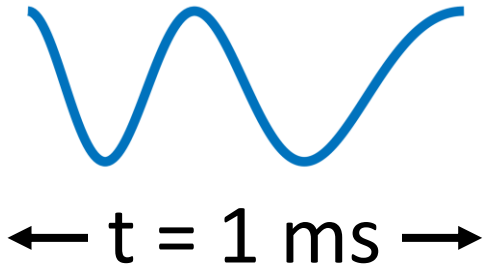
Solution - Relay Participant

- Introduce a primary participant to relay audio streams between IP network and PSTN



Example - Audio Channel Modulation

- Bit ‘1’: f0 = 2200 Hz to f1 = 1800 Hz
- Bit ‘0’: f0 = 800 Hz to f1 = 1200 Hz
- Resynchronization: Utilize chirps to resist sample offsets

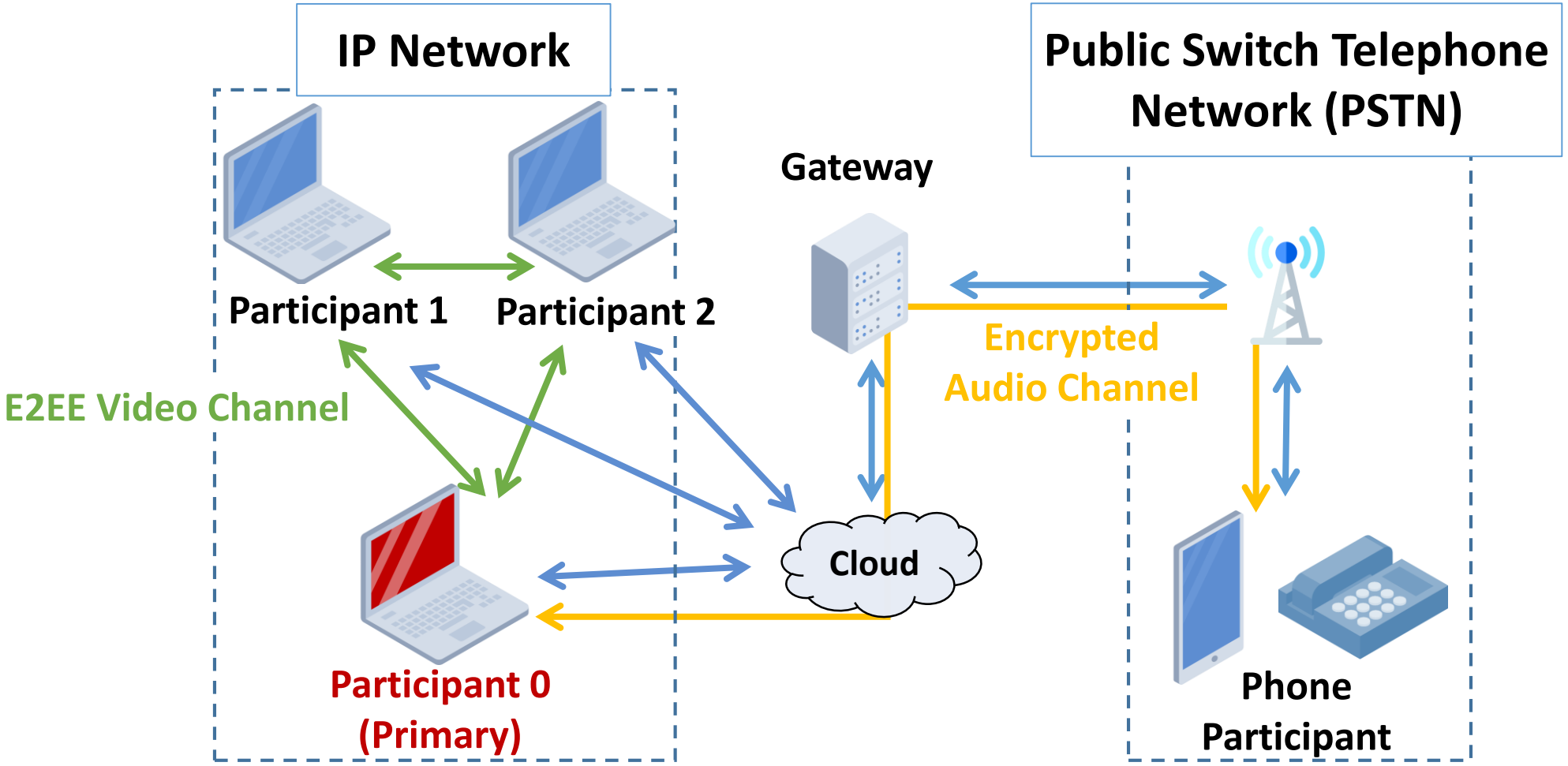


(a) ‘1’ waveform

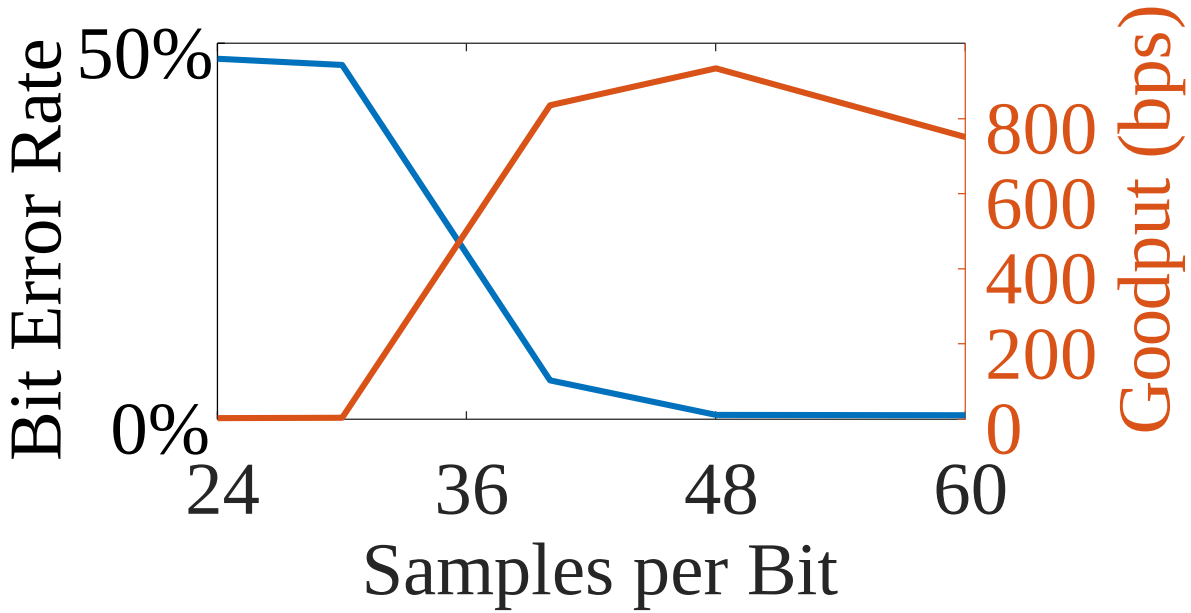
(b) ‘0’ waveform

Solution - Relay Participant

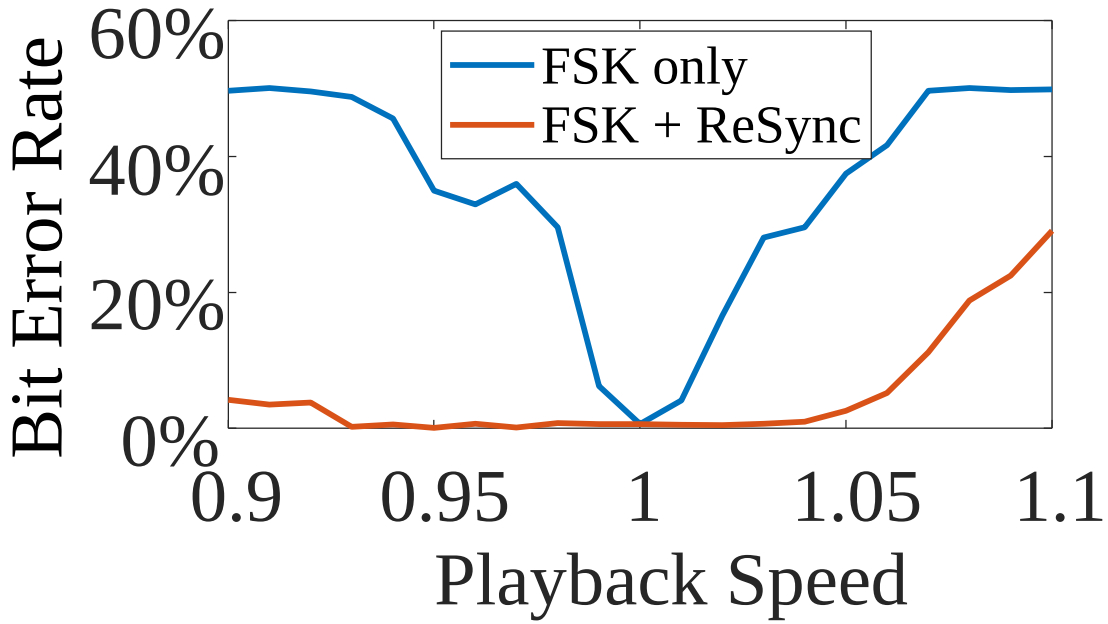
- Introduce a primary participant to relay audio streams between IP network and PSTN



Results – Audio Quality



(a) BER, Goodput of Audio Tunnel



(b) Performance of ReSync

Summary

- Propose a practical software layer in the host system to enforce end-to-end encryption on conference applications
- Build a lightweight I/O virtualization framework to enhance the compatibility and isolate private data from conference applications
- Propose methods to transmit data within conference applications against lossy compression

Thank You !