RPT: Re-architecting Loss Protection for Content-Aware Networks

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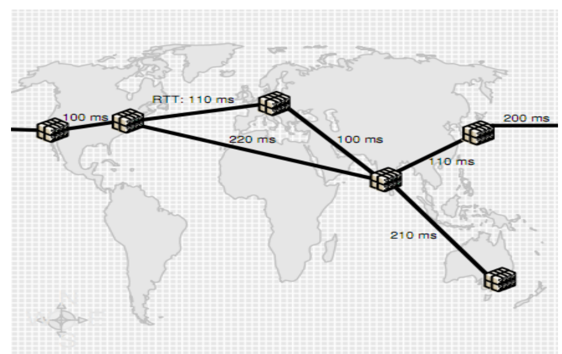
Motivation:
Delay-sensitive communication

Real-time streams:
FaceTime, Skype, on-line games.
Maximum one way latency ~150ms

Soft-realtime intra-data center communication
[DCTCP, D^3]
Response time ~250ms

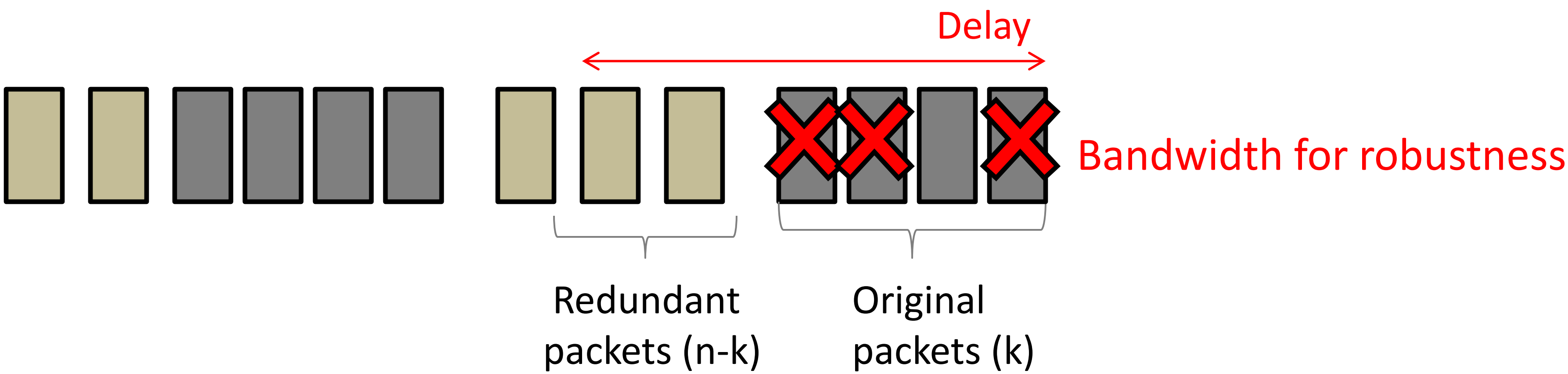


Time critical inter-data center communication
[Maelstrom]

Minimizing data loss in time-critical communication is important, but challenging because of the time constraint.

Loss protection today: Redundancy-based recovery

Forward Error Correction



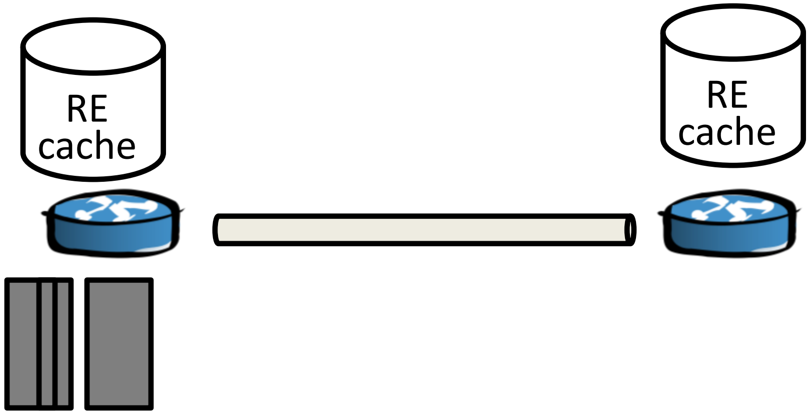
- FEC couples delay with redundancy
- Small batch size makes FEC more susceptible to bursty loss
- Difficult to tune parameters (n and k) [TIP2001,INFOCOM2010]

Amount of redundancy 20%~50% in Skype video[Multimedia'09]

Content-aware networks changes the trade-off of redundancy

Content-aware networks = caching + content-aware processing to remove duplicates

Caching effectively minimizes the bandwidth cost of redundancy



Examples

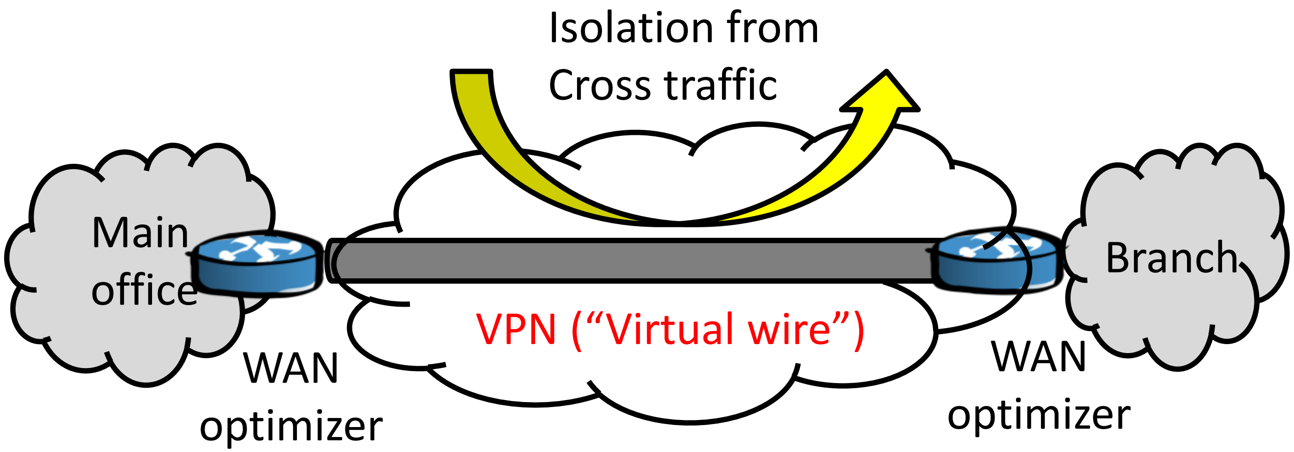
Redundancy elimination (RE) [SIGCOMM'08]

Bandwidth overhead of 100% redundancy: 3%

Content-Centric Networking (CCN) [CoNEXT'09]

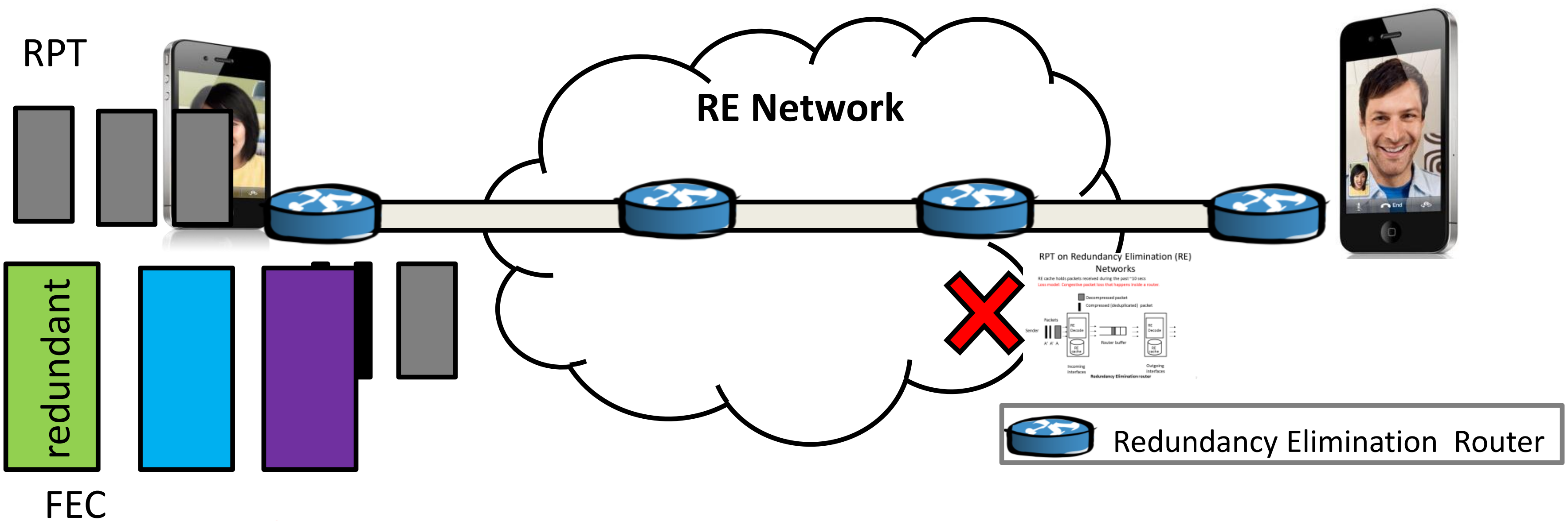
Deployment of content-aware networks

- Product: WAN optimizers (10+ vendors)
  - Cisco, Riverbed, Juniper, Blue Coat Systems
  - E.g., Cisco deployed RE on 200+ remote offices.
  - Corporate networks
    - Riverbed: 50+ corporate customers, datacenter deployments



Redundant Packet Transmission (RPT)

- Introduce redundancy in a way that the network understands



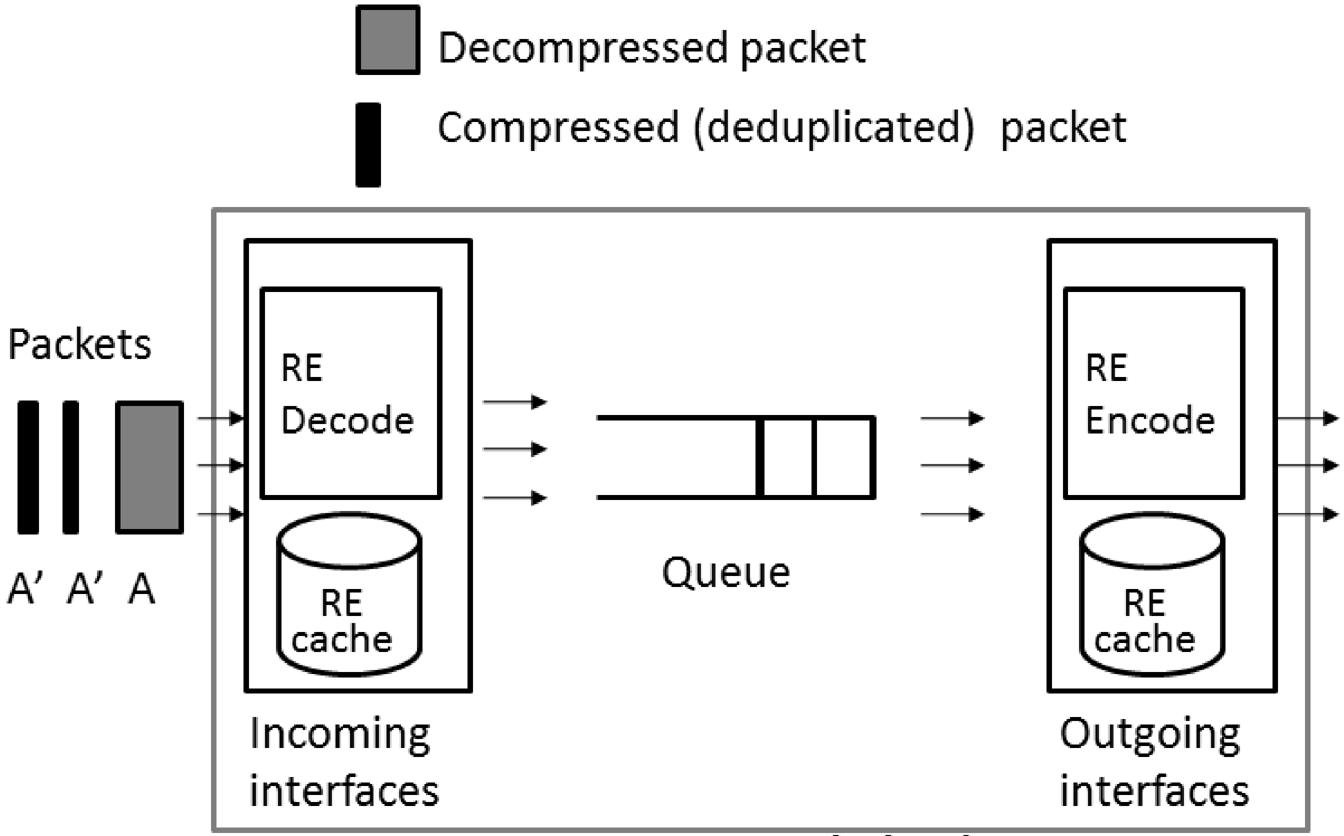
Questions/Challenges

- How do we make sure we retain the robustness benefits?
- How much redundancy is needed? How does it compare with FEC?
- Is this safe to use?

RPT on Redundancy Elimination (RE) Networks

RE cache holds packets received during the past ~10 secs

Loss model: Congestive packet loss that happens inside a router.

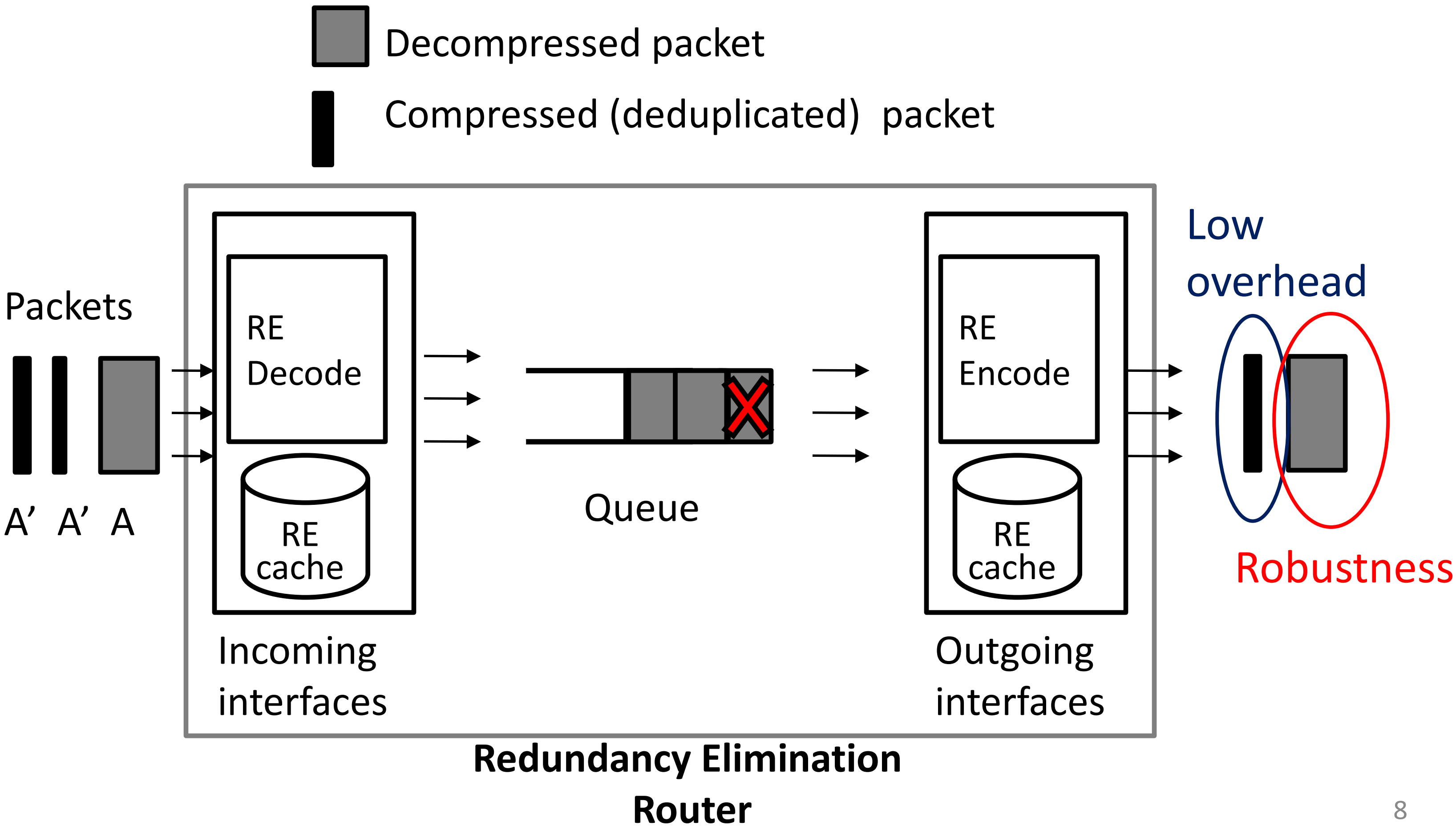


Redundancy Elimination Router

RPT on Redundancy Elimination (RE) Networks

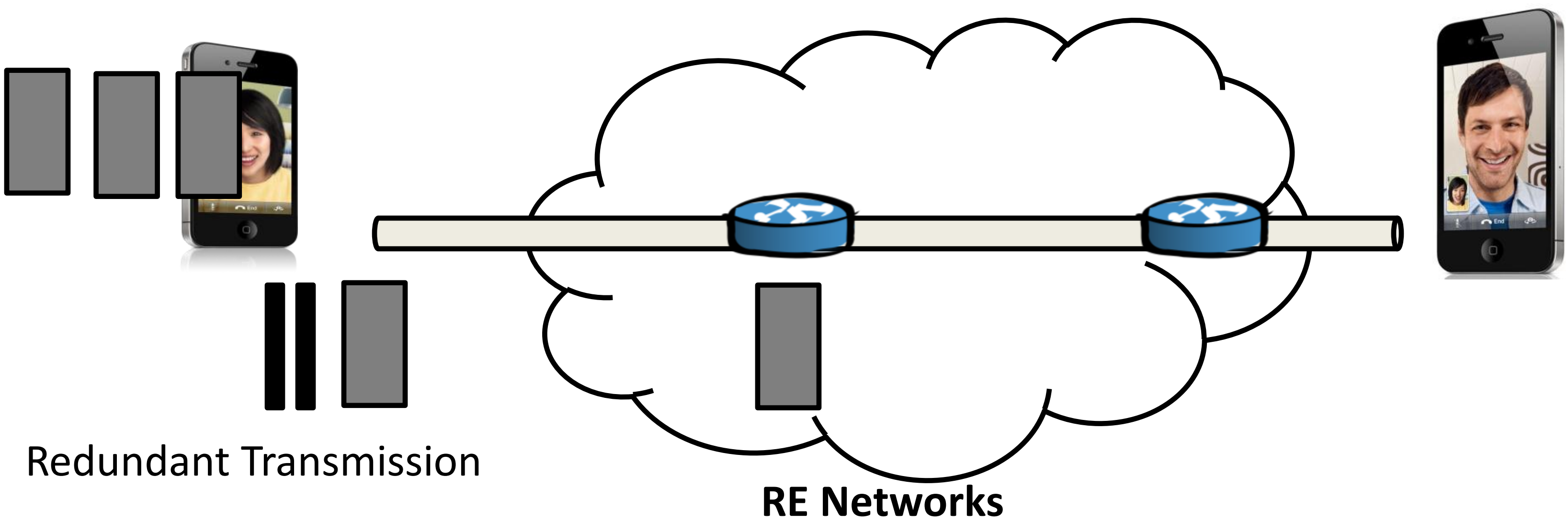
RE cache holds packets received during the past ~10 secs

Loss model: Congestive packet loss that happens inside a router.



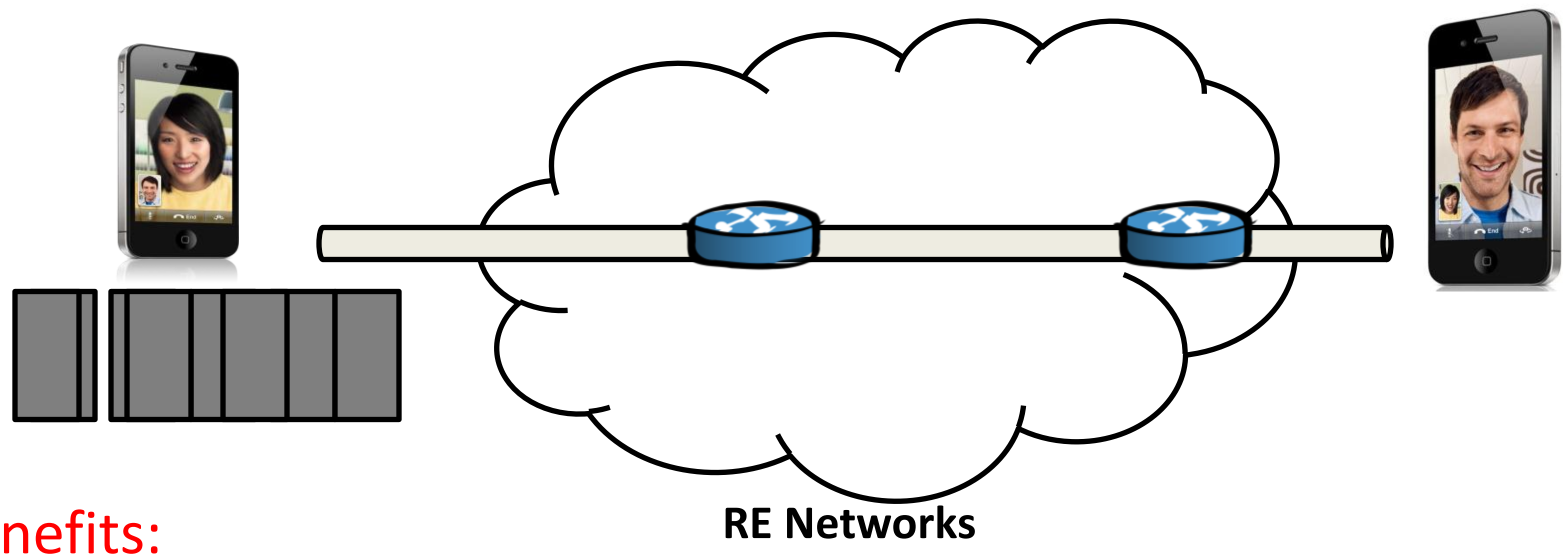
Redundant Packet Transmission

- Introduce redundancy in a way that the network understands



Redundant Packet Transmission

- Introduce redundancy in a way that the network understands



Benefits:

- Retain the robustness benefits of redundancy
- Minimize the bandwidth cost
- Application can signal the importance of data. (Fine-grained control)

A Case Study of RPT

Redundant Packet Transmission (RPT)

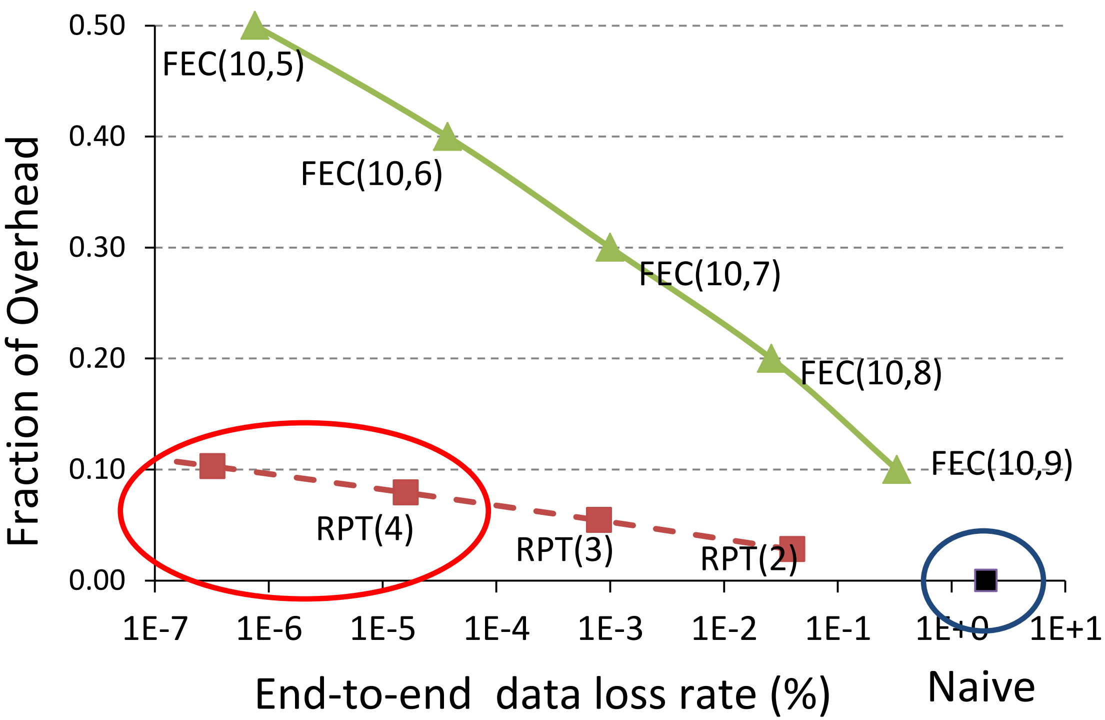
- Send multiple copy of the same packet.
- Send every packet *r* times.
- Applied to live video in RE networks.

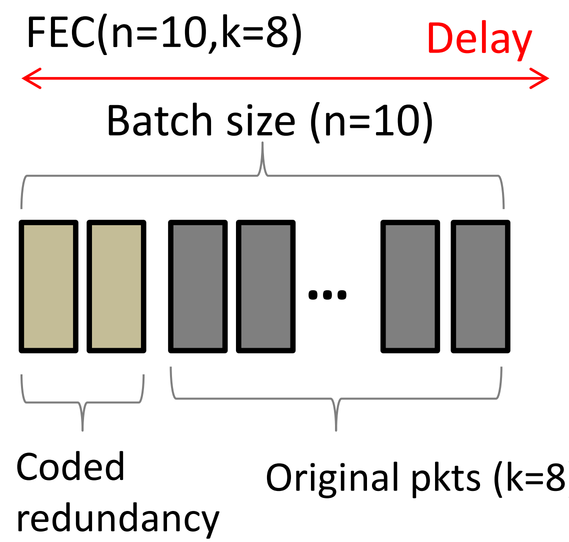
Redundant Packets Transmission

Hop-by-hop RE networks Partially content-aware networks SmartRE networks Networks with link-layer loss Content Centric Networks (CCN)	Time-critical communication

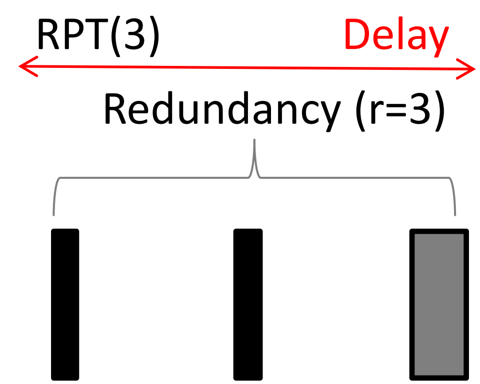
Analytical Comparison with FEC

2% random loss. p = 0.02

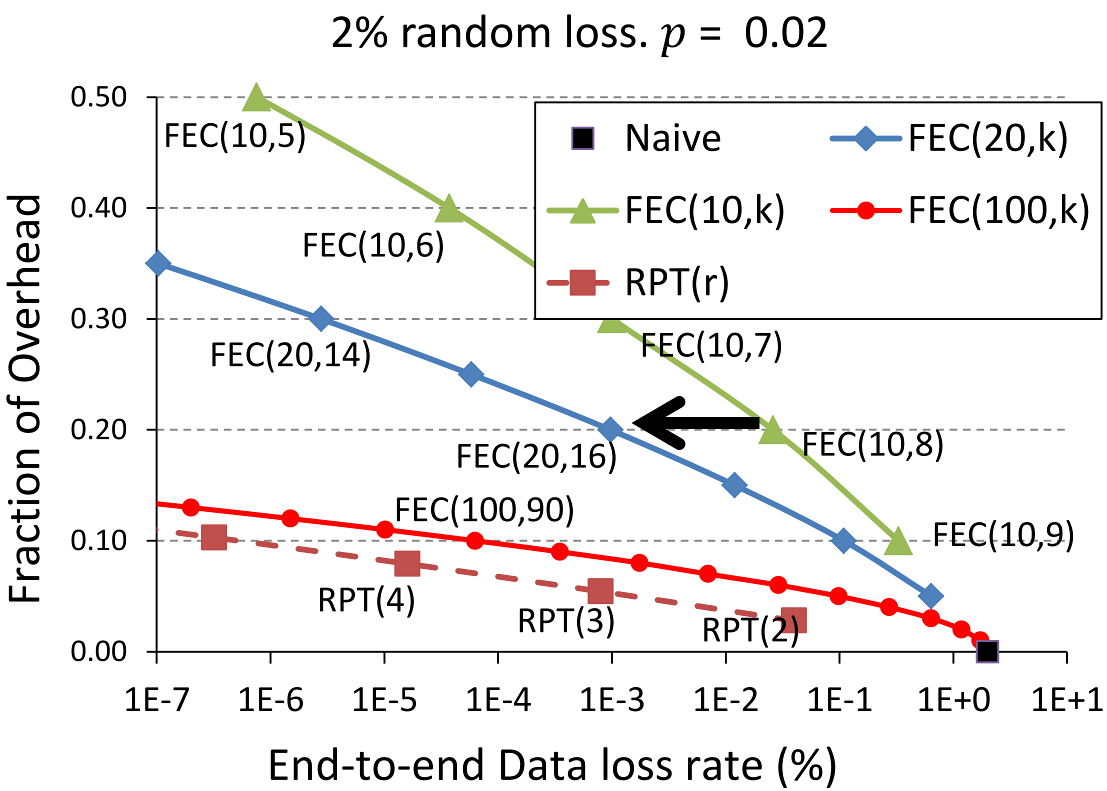


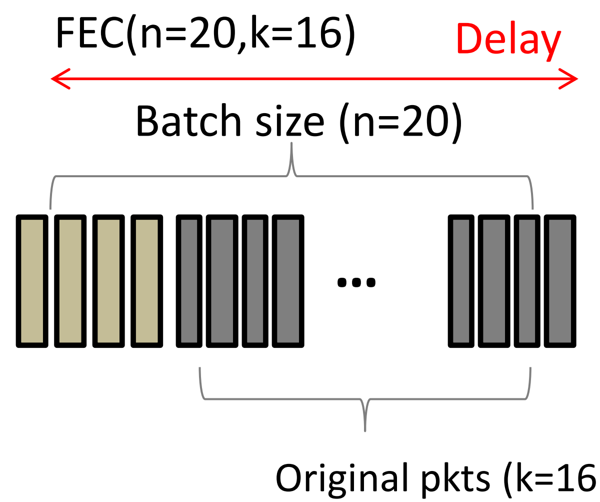


Naive
2% data loss
0 overhead

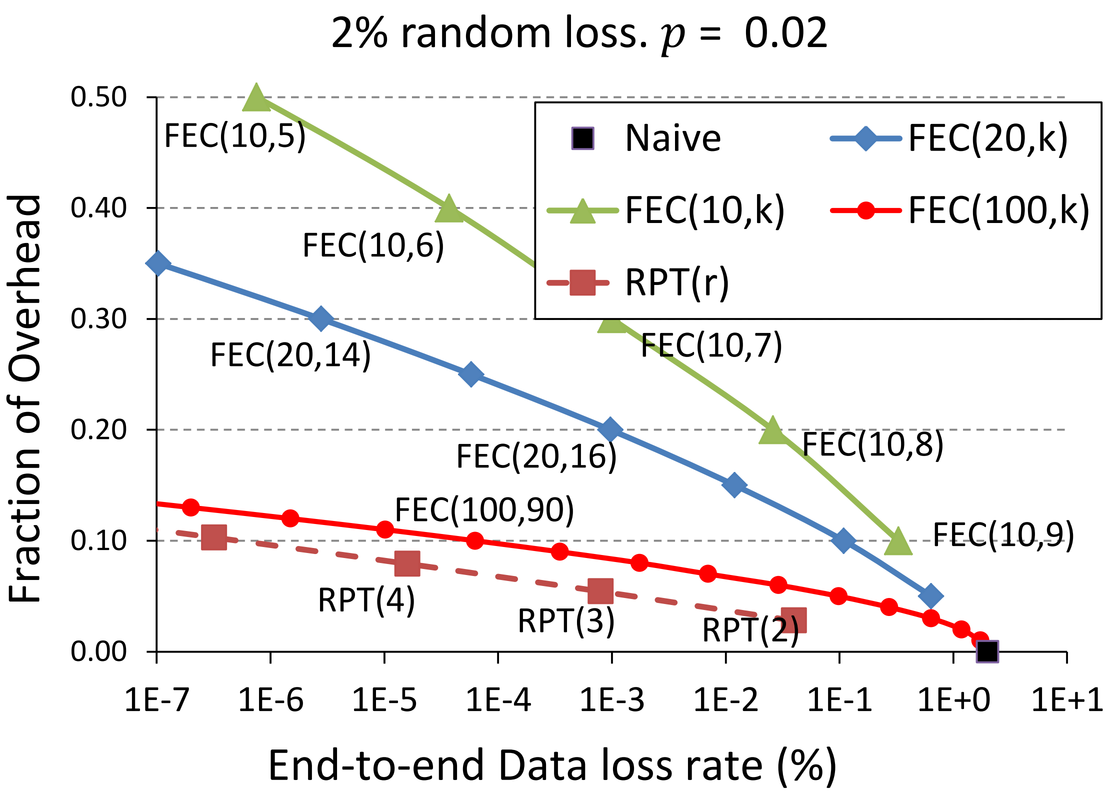


Analytical Comparison with FEC





Analytical Comparison with FEC



Scheme	Max Delay@ 1Mbps
FEC(10,7)	168 ms
FEC(20,16)	300 ms
FEC(100,92)	1300 ms
RPT(r)	**Tunable**

Skype video call 128~300kbps
Skype (HD) 1.2~1.5Mbps

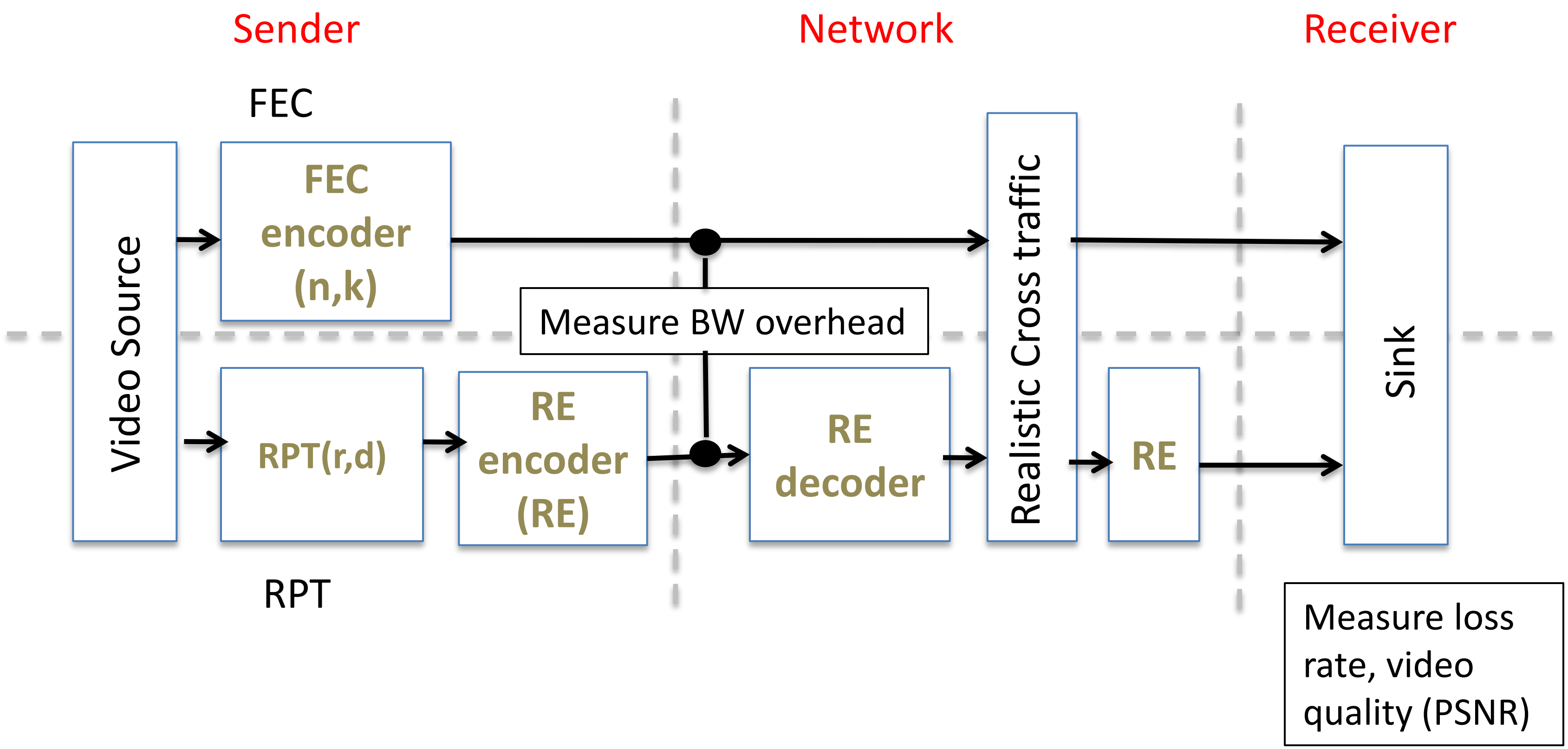
Experimental Evaluation

- Thorough evaluation on 3 different aspects of RPT
  – End user performance
  – Ease of use (parameter selection)
  – Impact on other traffic
- Methodology
  – Real experiment
  – Trace based experiment
  – Simulation

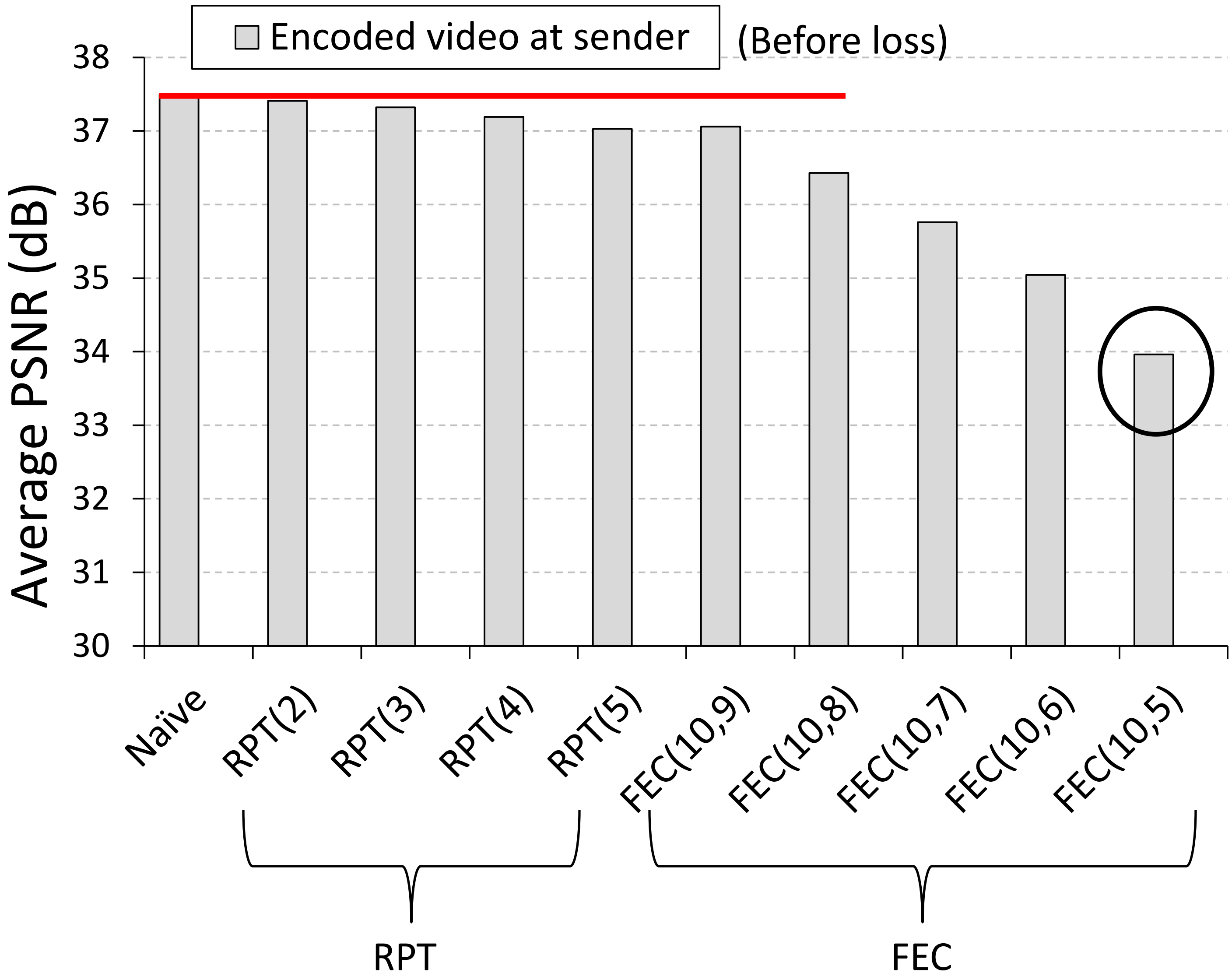
CIF: 352x288

Evaluation Framework

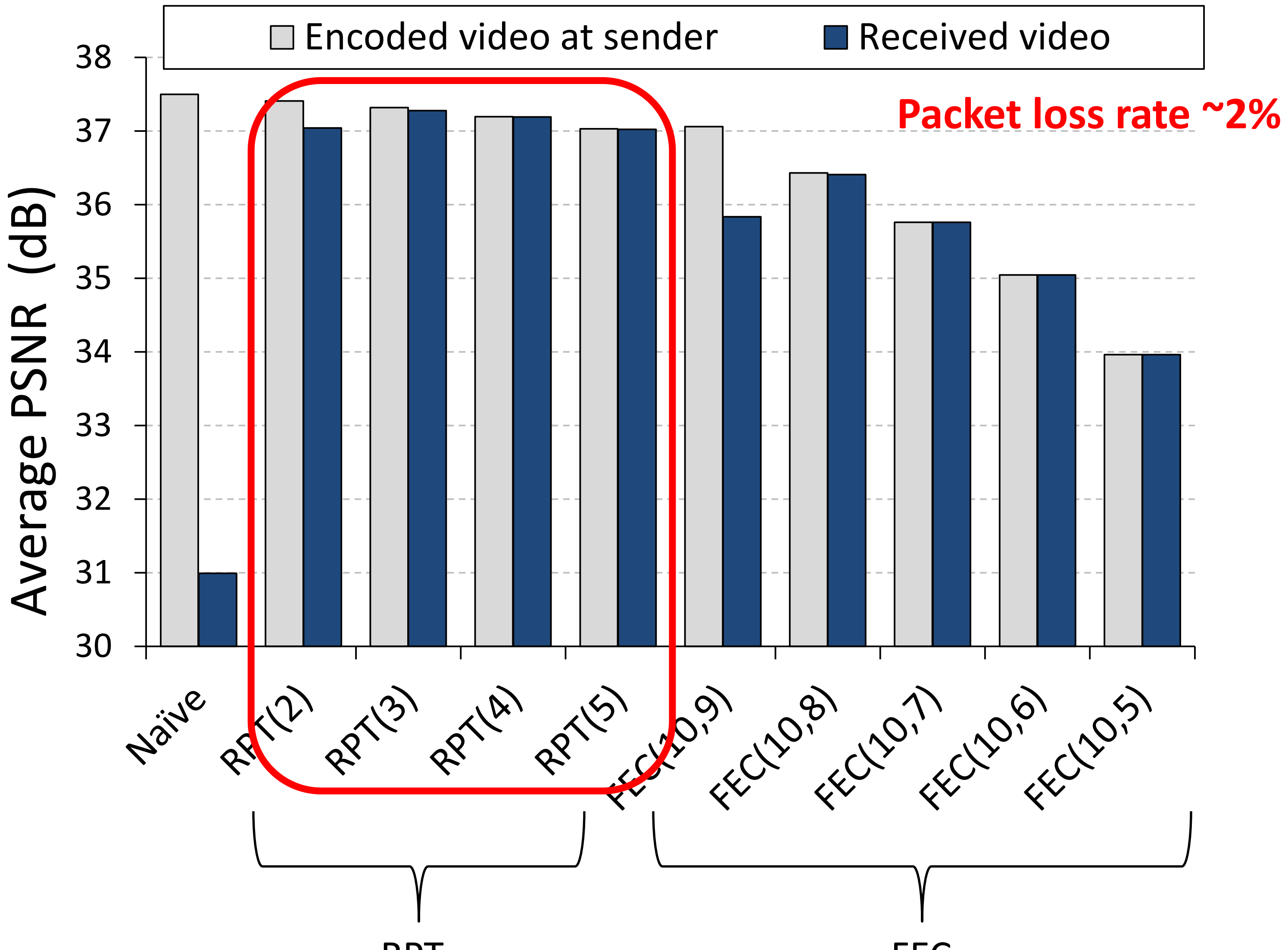
- RE router implementation (Click, NS2)
- Video quality evaluation using evalvid



E2E Performance: Video Quality



E2E Performance: Video Quality



E2E Performance: Video Quality

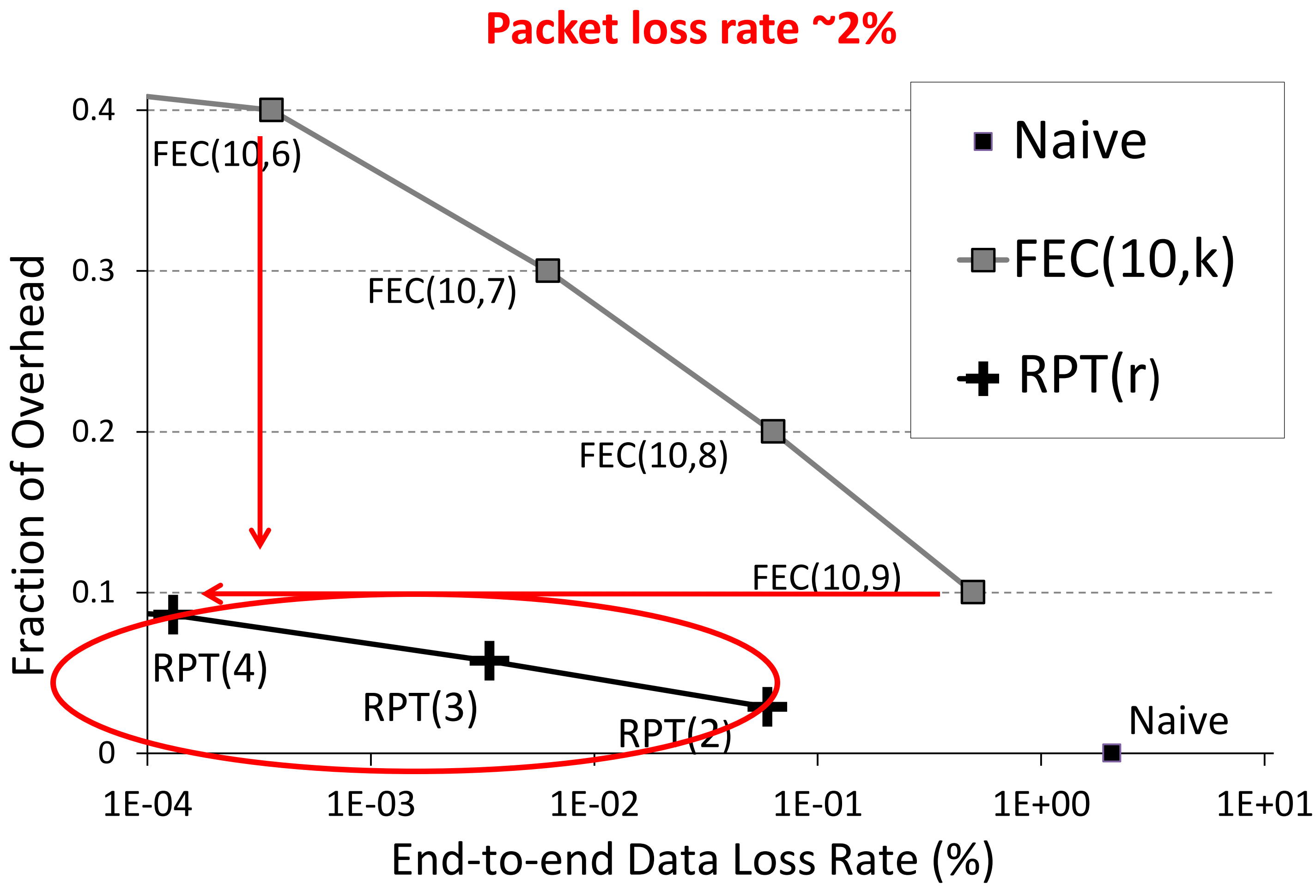
RPT(3) Overhead ~6%

FEC(10,9) Overhead ~10%

Naïve UDP

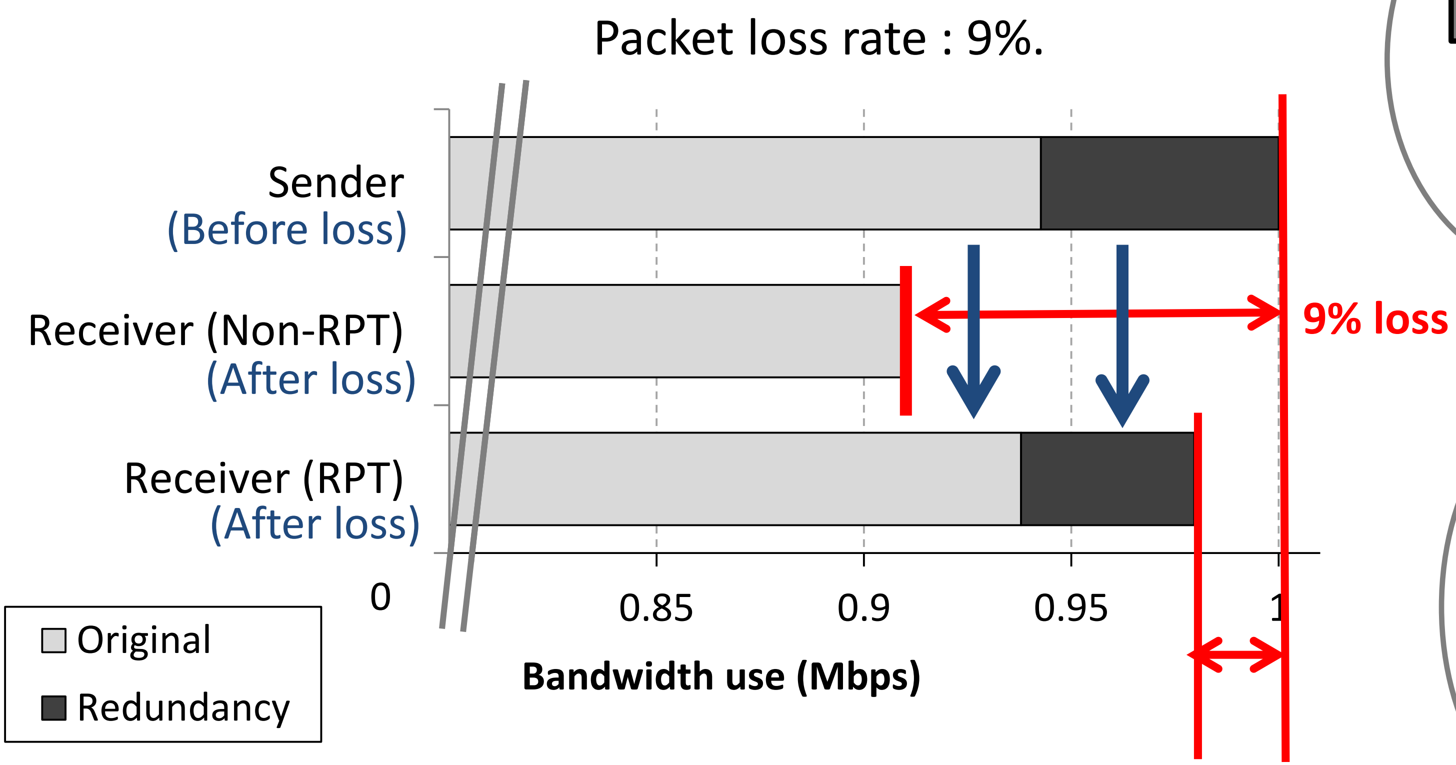
1.8dB ~ 3dB difference in quality

E2E Performance: overhead and robustness

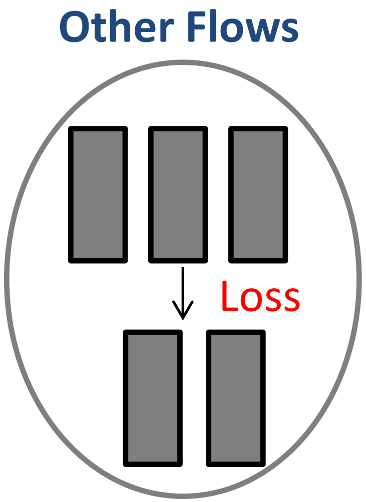


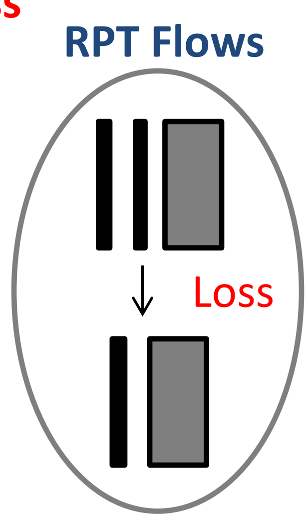
Impact on other traffic

- RPT flows get prioritized.



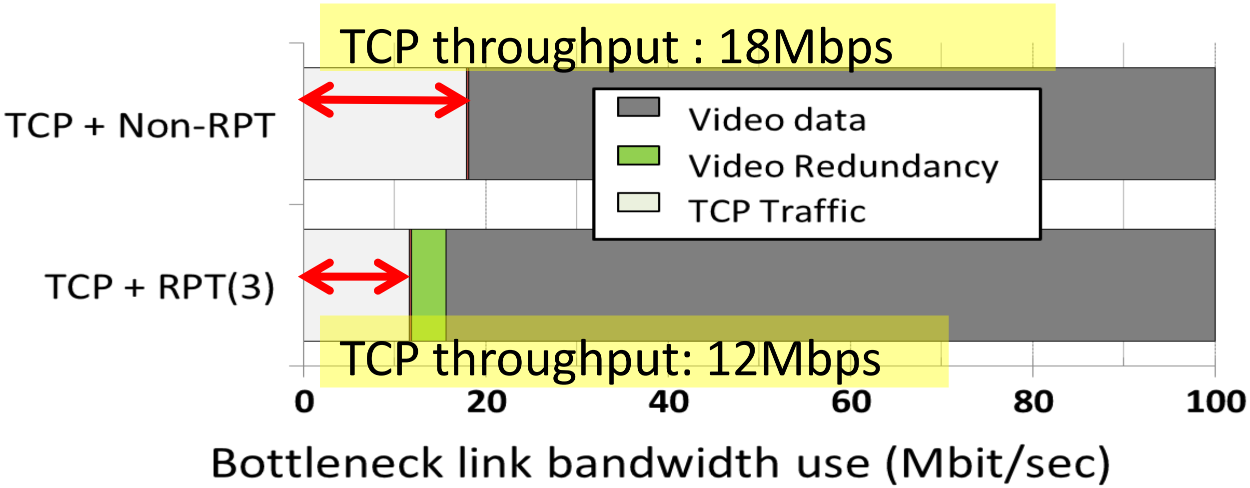
Throughput reduction: 2%





Is flow prioritization a problem?

- Not a problem: Important flows should be prioritized.
- Problem: Unfair bandwidth allocation



- How do provide fairness and robustness at the same time?
  - Core problem: RPT flows are not reacting to congestion.

  →Apply TCP-friendly rate control to RPT.
  - Challenge: correctly accounting for possible changes in loss pattern

Other results in the paper

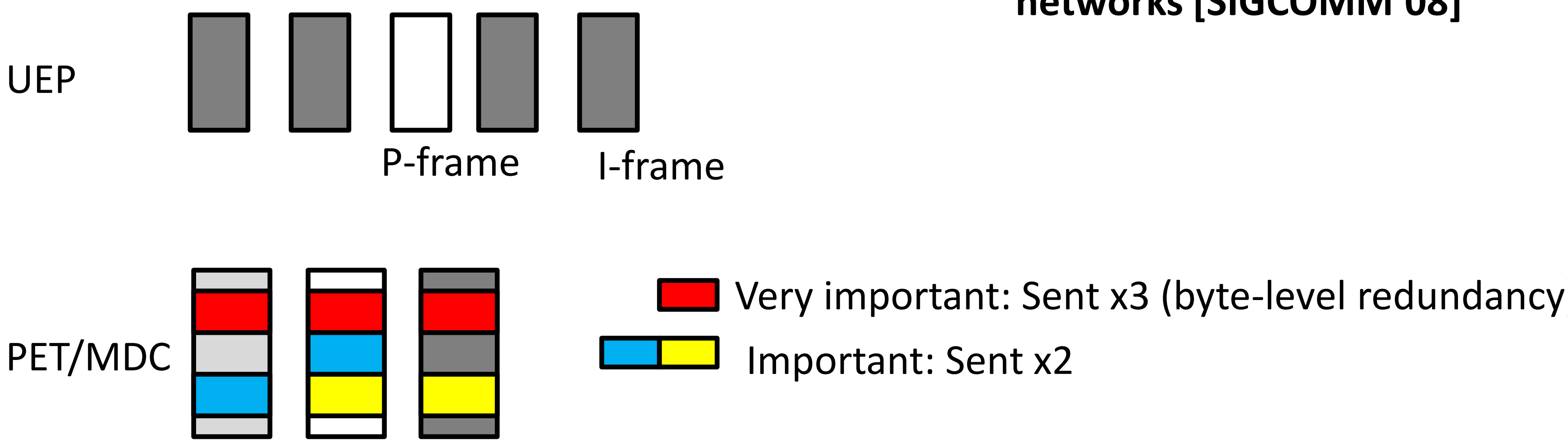
- Demonstration of RPT in a real-world setting
  - E.g., Emulated corporate VPN scenario
- Trace-based experimental results
- Detailed parameter sensitivity study
- Network safety (impact on the network)
- Design and evaluation of TCP-friendly RPT
- Strategies on other content-aware networks

Generalized RPT

- Many sophisticated schemes are enabled by FEC.
  - Priority encoding transmission (PET), unequal error protection (UEP), multiple description coding (MDC)

➔ Prioritization within a flow for graceful degradation of quality

Redundancy elimination networks [SIGCOMM'08]



Conclusion

- Key Idea of RPT: Don’t hide, expose redundancy!
- Key Features
  - High robustness, low overhead → user performance
  - Ease of use: parameter selection, per-packet redundancy/delay control
  - Flow prioritization
- Applicability
  - Applies to delay-sensitive communications in content-aware networks in general.