High-performance vehicular connectivity with opportunistic erasure coding

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Connectivity on-board vehicles

Increasingly common

- Provided by many public transit agencies
- And by corporations

Riders love the facility

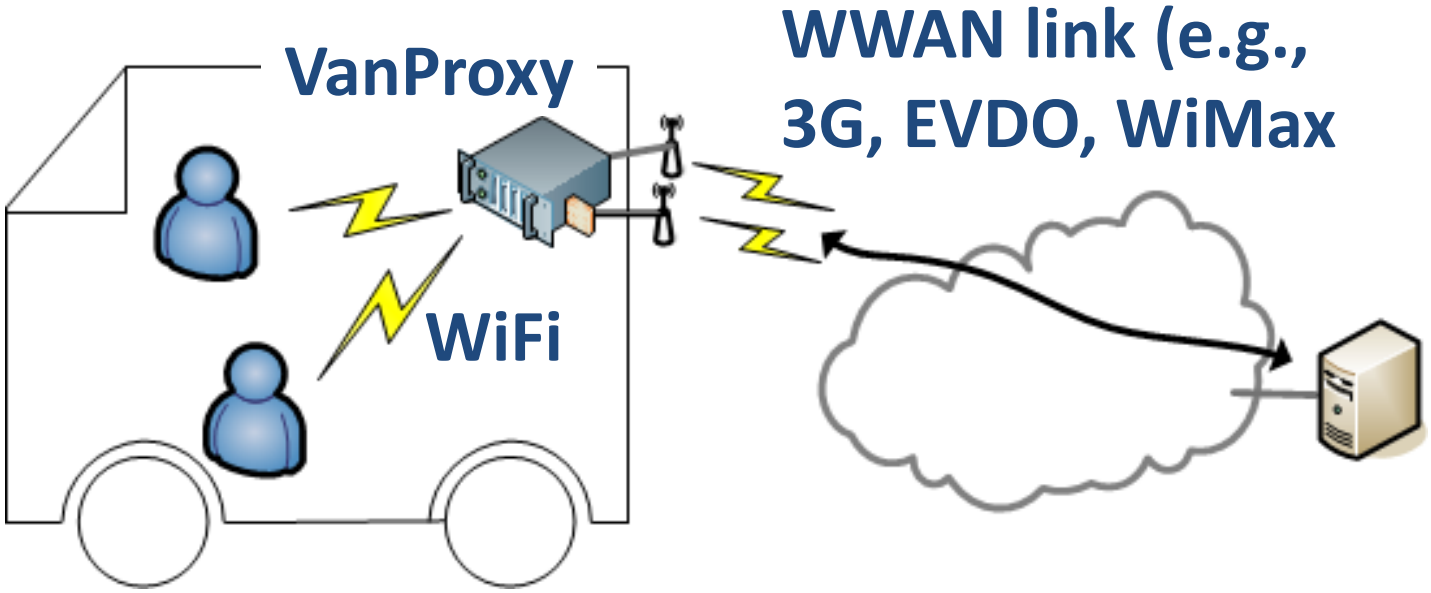
- Boosts ridership

But performance can be poor

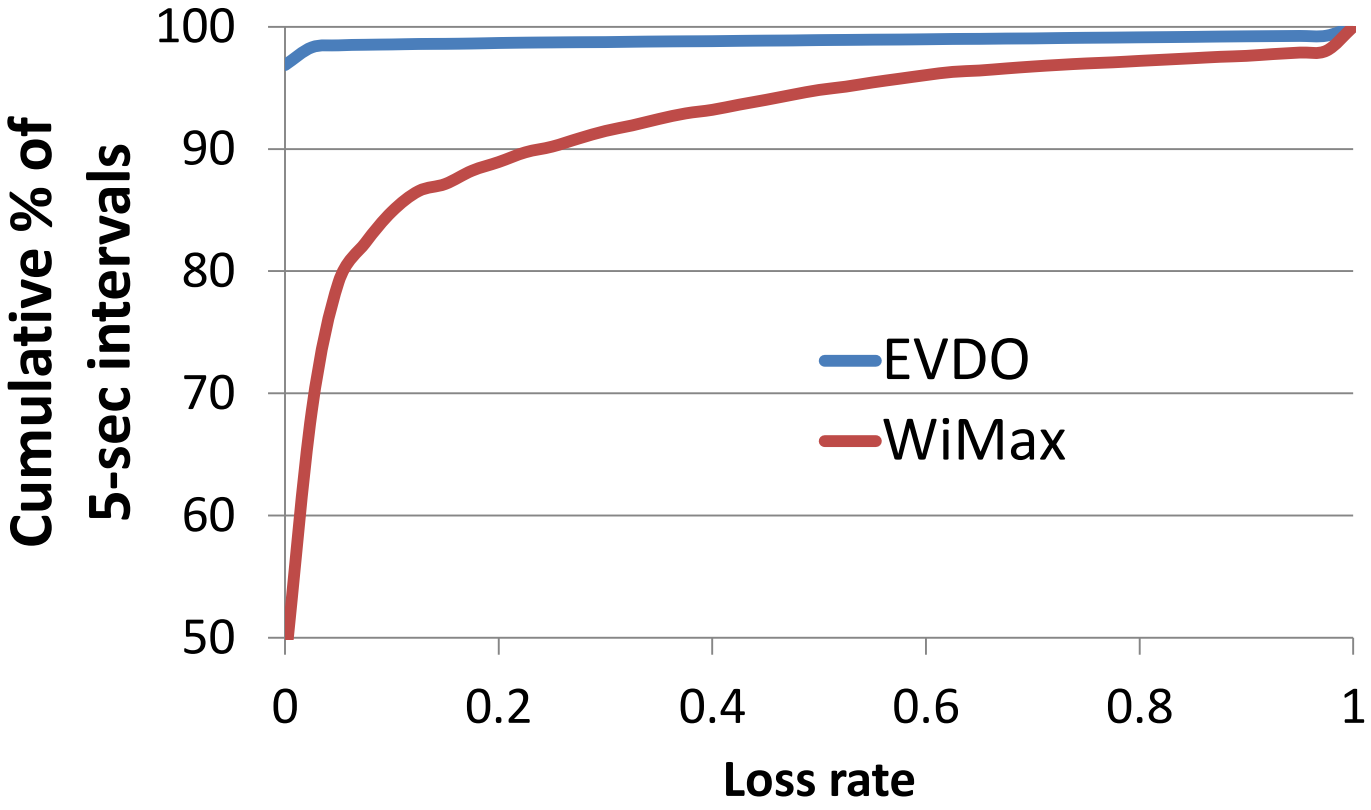
Expectation setting by service operators:

- "there can be lapses in the backhaul coverage or system congestion"
- "cancel a failed download and re-try in approximately 5 minutes"

Vehicular connectivity uses WWAN links



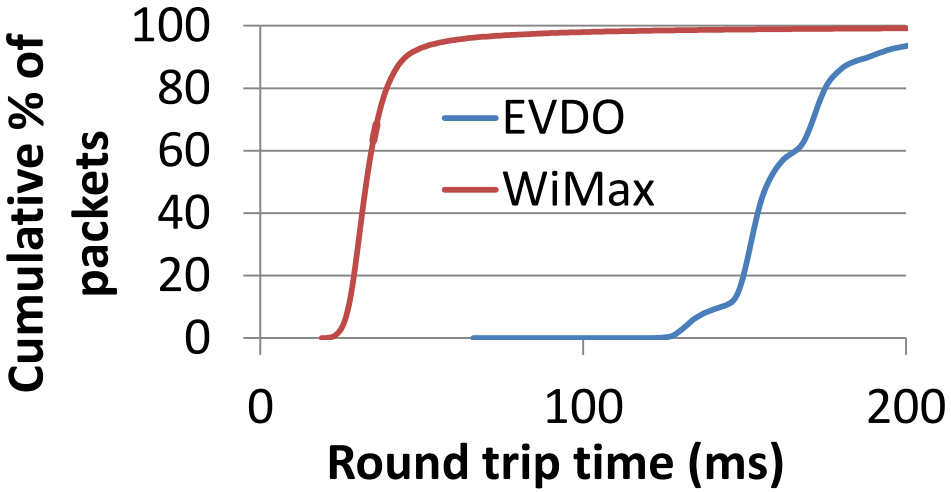
Vehicular WWAN connectivity is lossy



Methods to mask losses

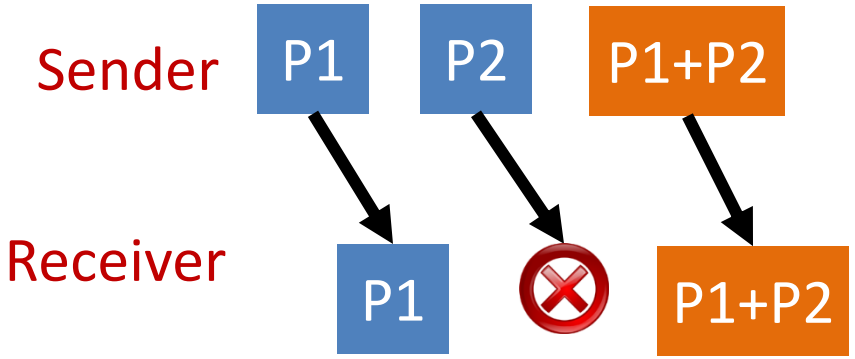
Retransmissions (ARQ)

– unsuitable for high delay paths



Erasure coding

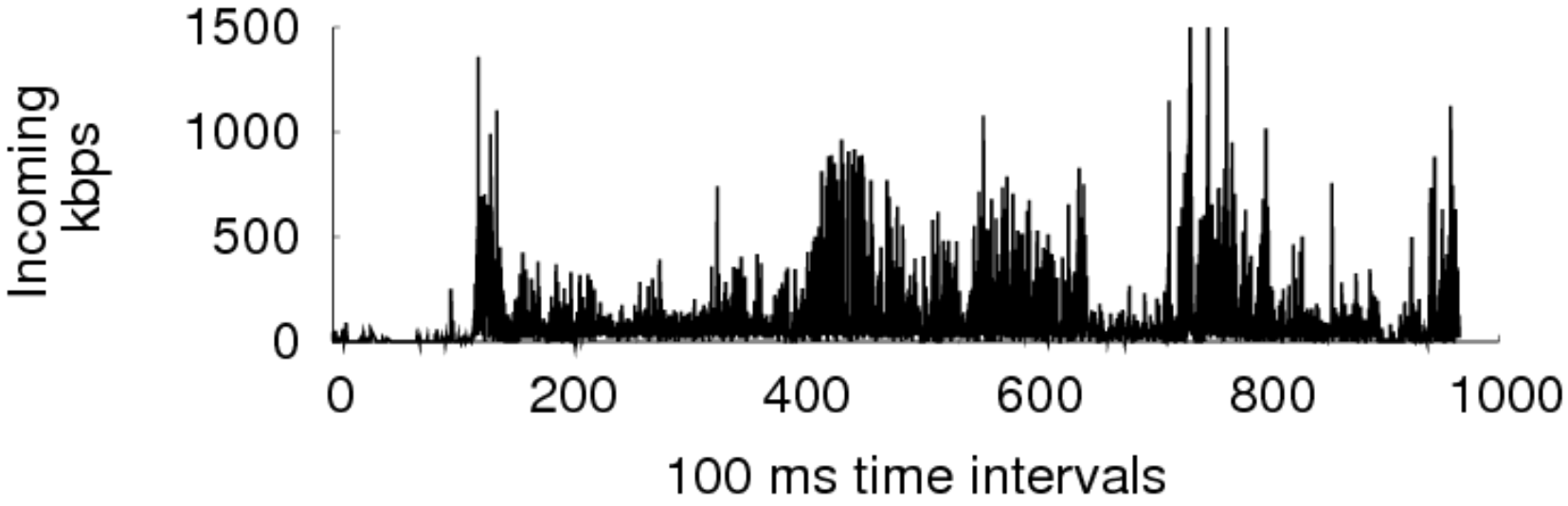
– existing methods are capacity-oblivious



Opportunistic erasure coding (OEC): A new erasure coding method

Use *all* spare capacity for redundancy

Challenge: highly bursty traffic



OEC: Transmission strategy

Send erasure coded packets *iff* the bottleneck queue is empty

- Data packets are sent right away

Properties:

- Dynamically adjusts coding redundancy to match "instantaneous" spare capacity
- Delays data packets by at most one packet

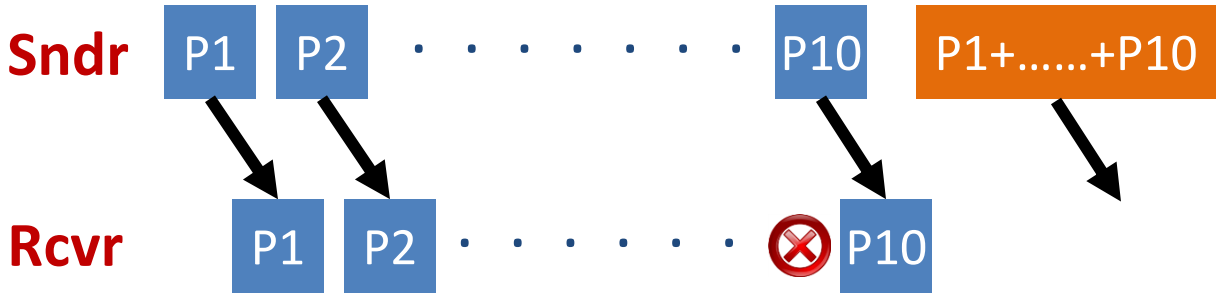
OEC: Encoding strategy

Conventional codes are not appropriate

- Need redundancy level to be known in advance

Greedy encoding: each coded packet maximizes the amount of new information at the receiver

- XOR $\frac{-1}{\ln(r)}$ of W packets



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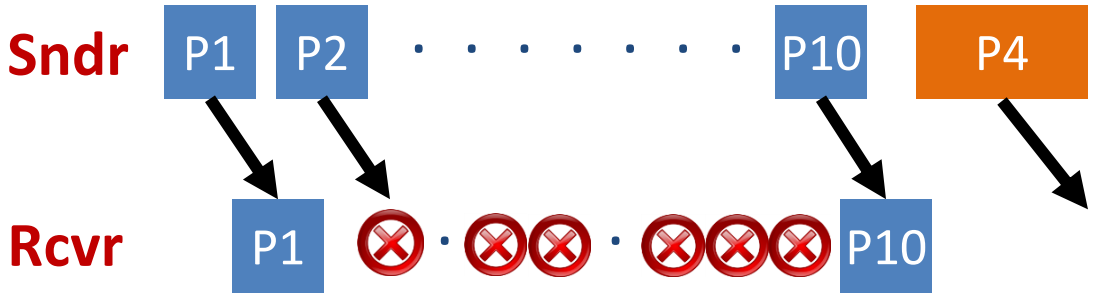


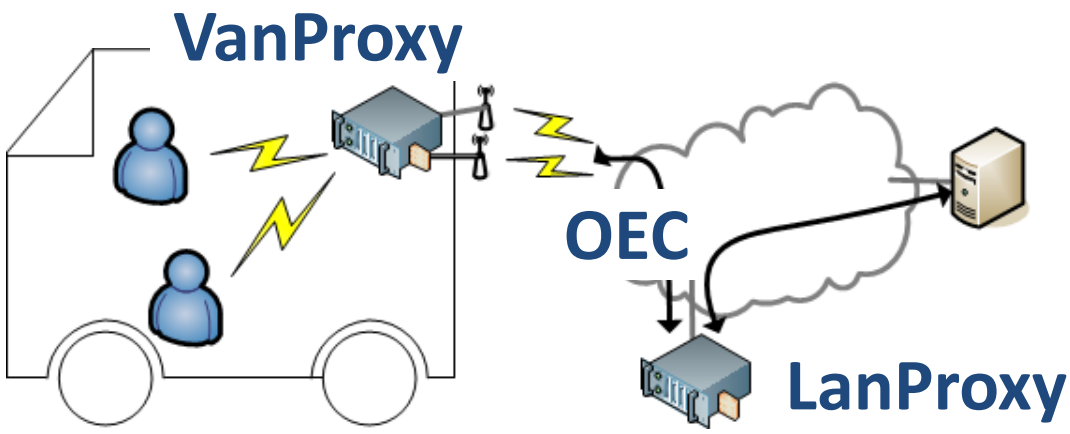
OEC properties

Greedily maximizes goodput with each packet transmission (coded or data)

Retains this property even when traffic is striped across multiple paths

- Combine with delay-based path selection

PluriBus: OEC for moving vehicles



OEC needs	PluriBus estimates
Fraction of received packets	Path loss rate
Queue length	Path capacity
Least-delay path	Propagation delay diff.

On aggressive use of spare capacity

Paths are not busy all the time in practice

WWAN charges are likely a small fraction of operating cost for transit operators

Media access protocol isolates users from each other

Evaluation

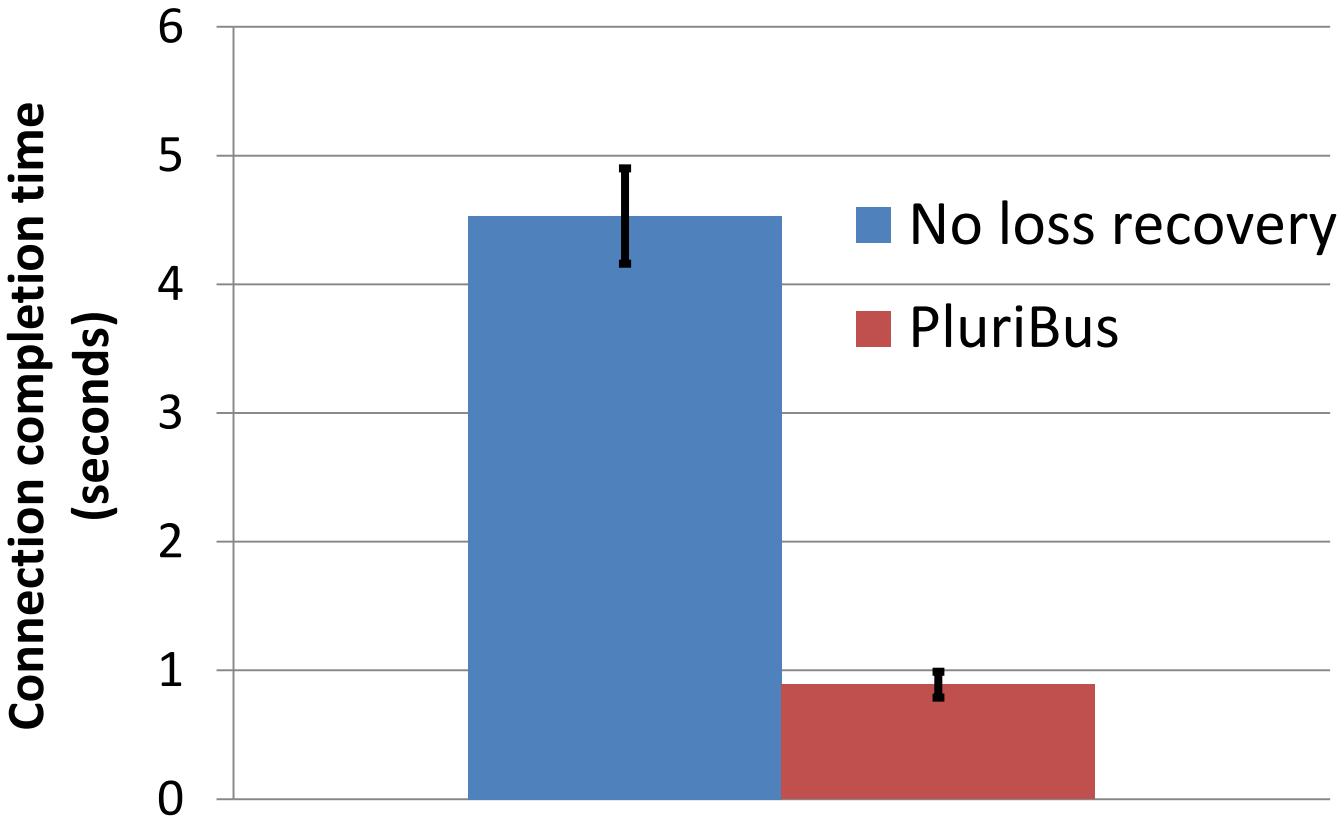
Deployment on two buses plying on MS campus

- Two WWAN links on each: EVDO and WiMax
- Real conditions
- Trace-driven workload

Emulation

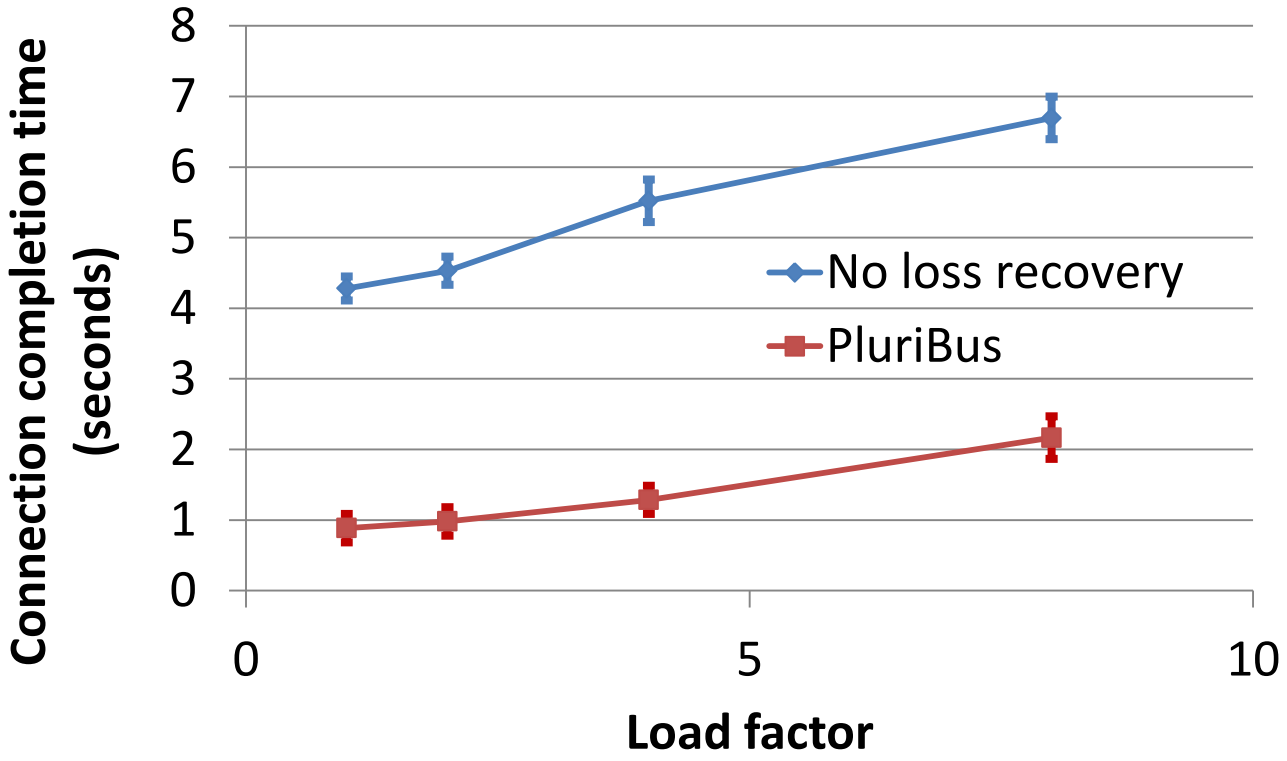
- Repeatability and controlled conditions
- Allows consideration of different environments

PluriBus improves performance by 4x



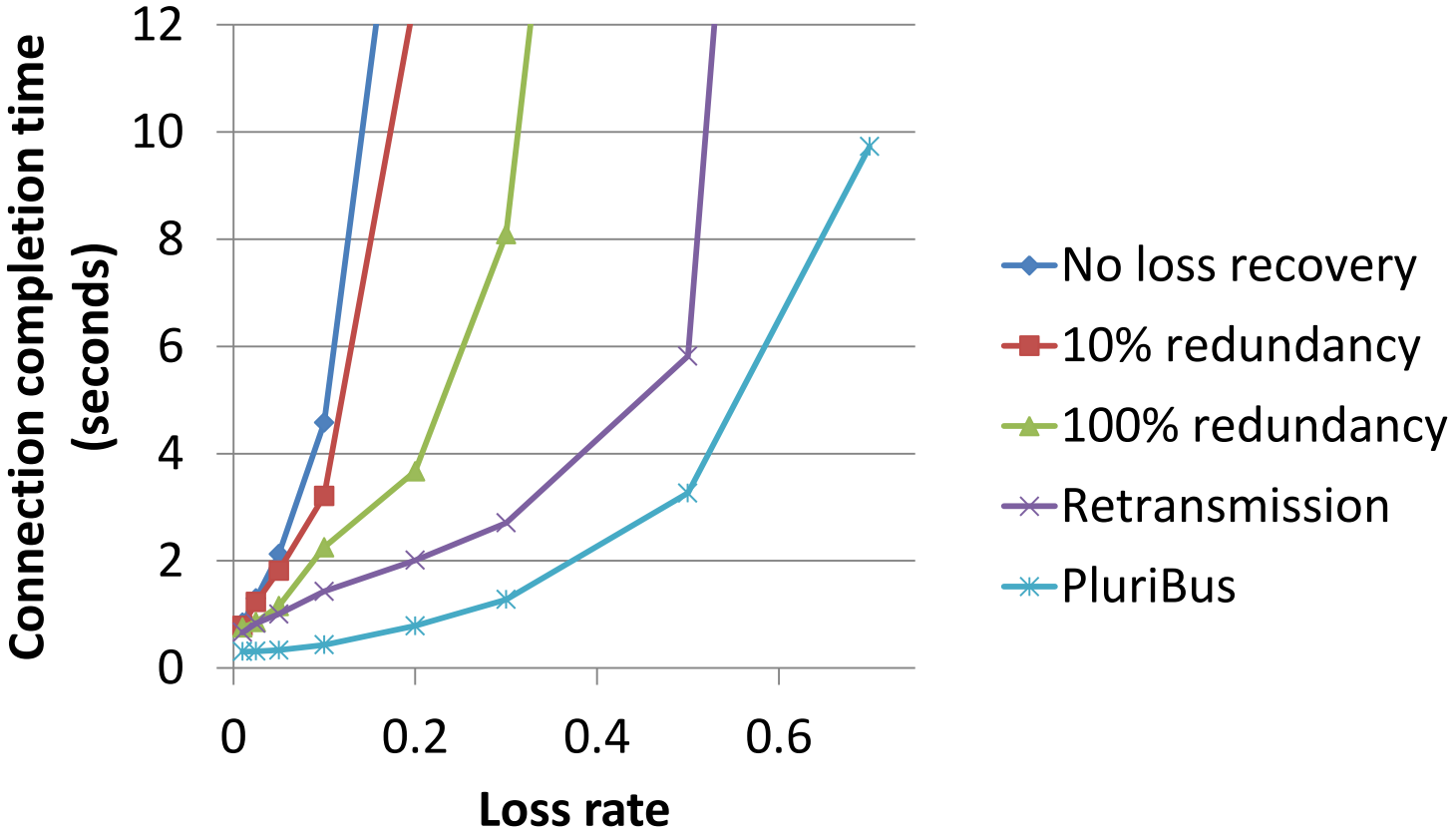
[Results based on deployment]

PluriBus improves performance even when load increases multifold



[Results based on deployment]

PluriBus outperforms other loss recovery methods



[Results based on emulation]

Other results in the paper

Loss rate estimation error is low

- The impact of any inaccuracy on OEC is minimal

Path delay estimation error is low

- Important to account for queue build up

Fraction of coded packets reduces with load

- 67% → 35% when load is increased 8x

Summary

OEC is a new erasure coding method to mask losses while using all spare capacity

- Opportunistic transmissions
- Greedy encoding

Its application to the vehicular context reduces connection completion time by 4x