Improving Re-healing Time in Sparse Networks with Road-Side Units

Andre B. Reis
Susana Sargento
Ozan K. Tonguz

universidade de aveiro
theoria poiesis praxis

instituto de telecomunicações

Carnegie Mellon

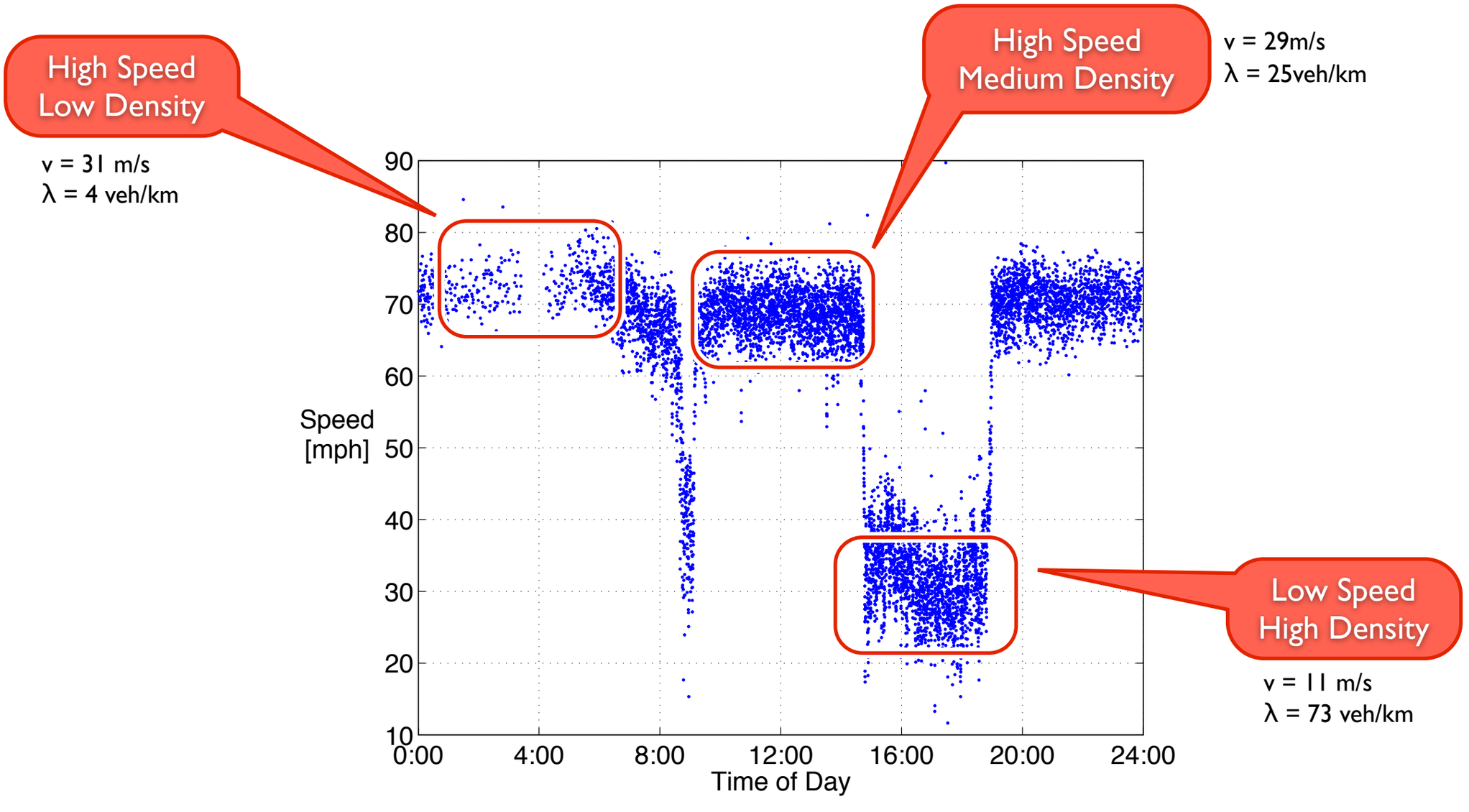
Electrical & Computer ENGINEERING

The issue at hand

- Market penetration is a limiting factor in the usefulness of a vehicular network
  - Initial deployments of VANETs will have to deal with low numbers of vehicles with radios
  - We're still many years away of having every vehicle equipped with a radio
- Even with 100% market penetration, sparse networks are bound to appear
  - Studies show late-night traffic is sparse and leads to disconnected VANETs
- Disconnection causes many issues: poor routing, protocol breakage, severe delays… which limit network's usefulness

How bad is sparse traffic?

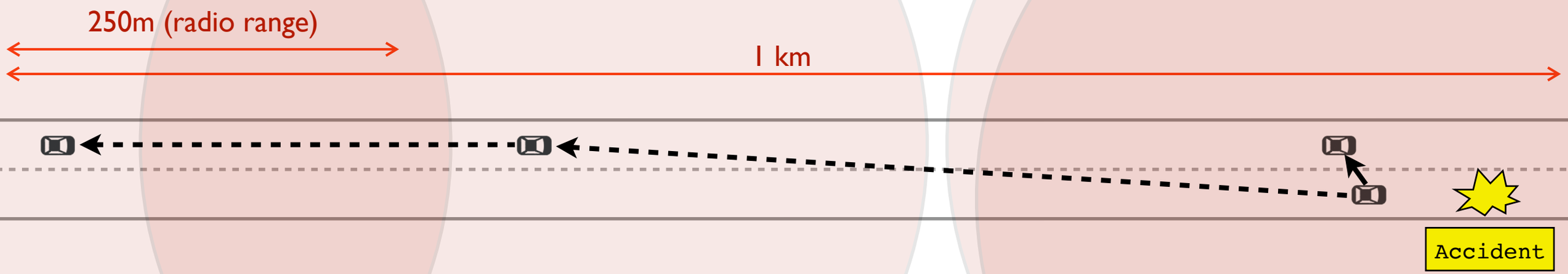
- Dual-loop detector on Interstate-20 (I-20) freeway
- Inter-vehicle spacing follows an exponential distribution (for < 1000 veh/h)



N. Wisitpongphan, O.K. Tonguz *et al.*, "*Routing in Sparse Vehicular Ad Hoc Wireless Networks*", IEEE JSAC, 2007.

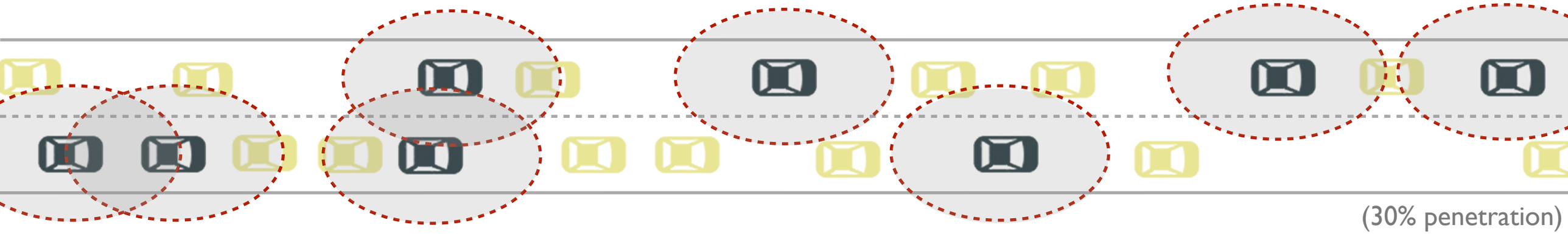
How bad is sparse traffic?

Low Density
(1 a.m. — 3 a.m.)
4 veh/km



Sparse Networks

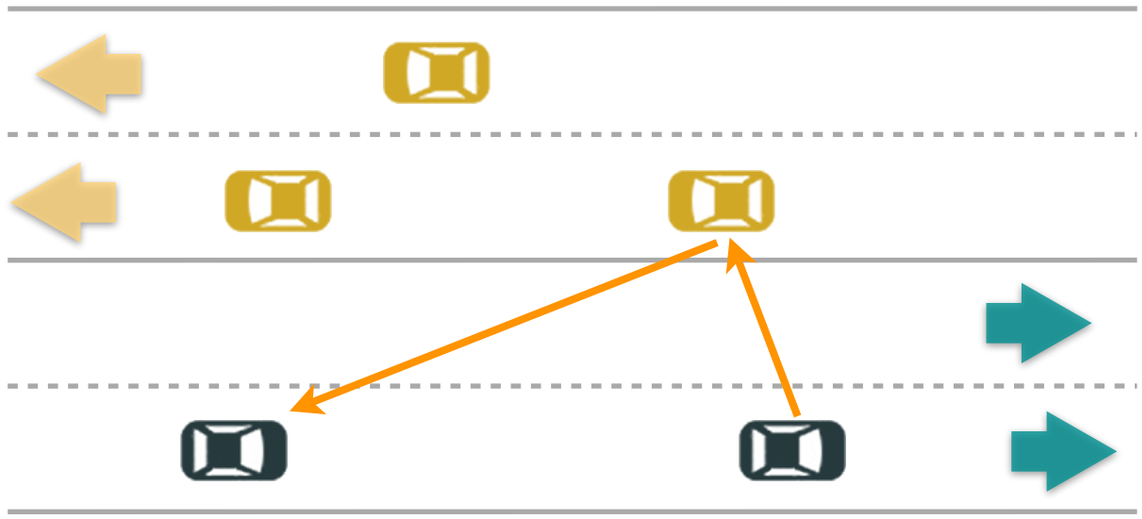
low density of vehicles → severe disconnection
low market penetration →



(30% penetration)

Re-healing Time

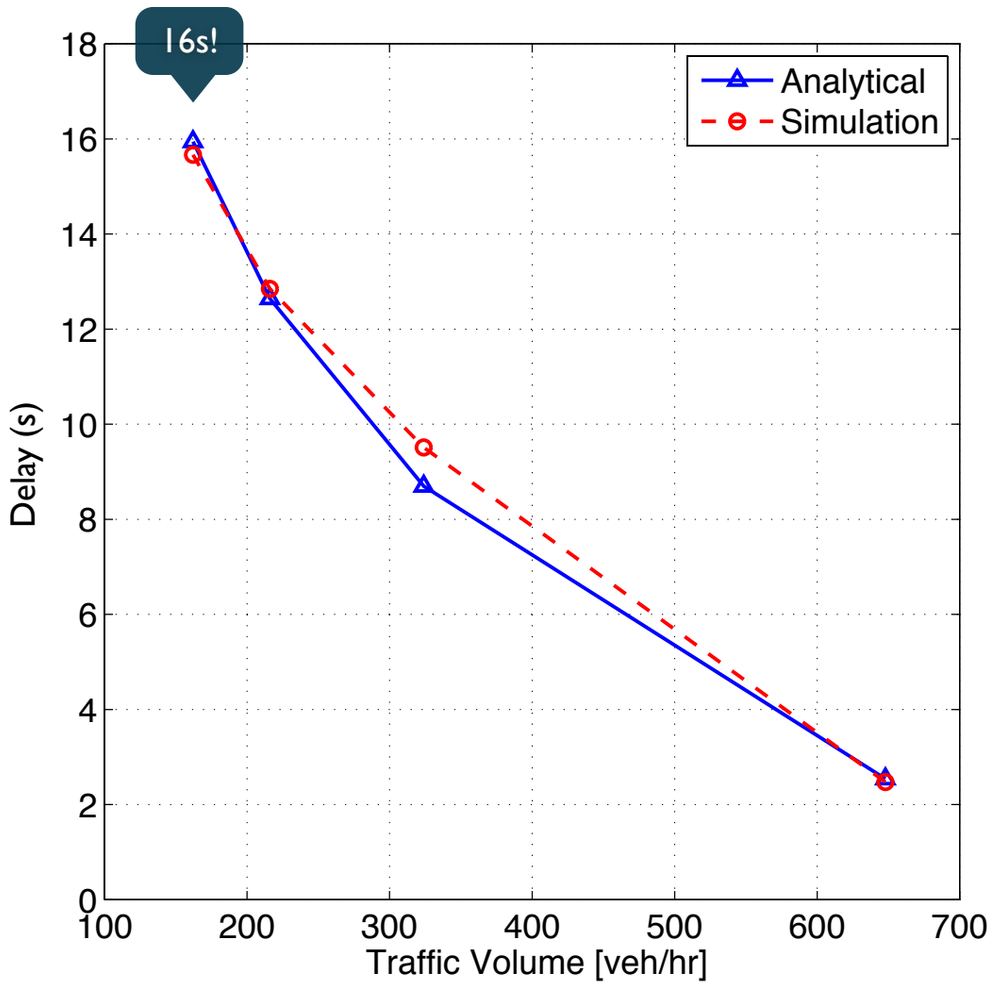
- A way to transmit messages is via the opposite-lane vehicles
- Defined as ‘re-healing time’



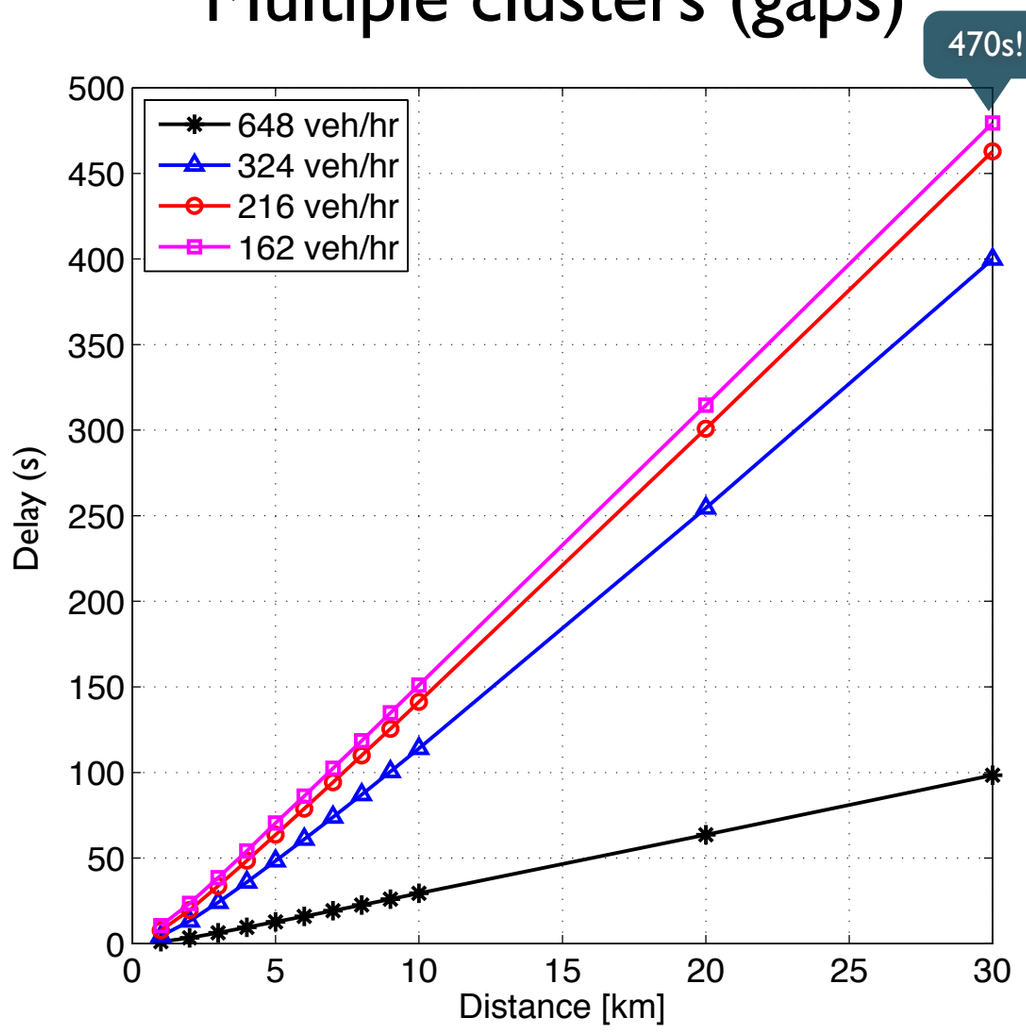
Re-healing Time

no-RSU original model

Single gap only



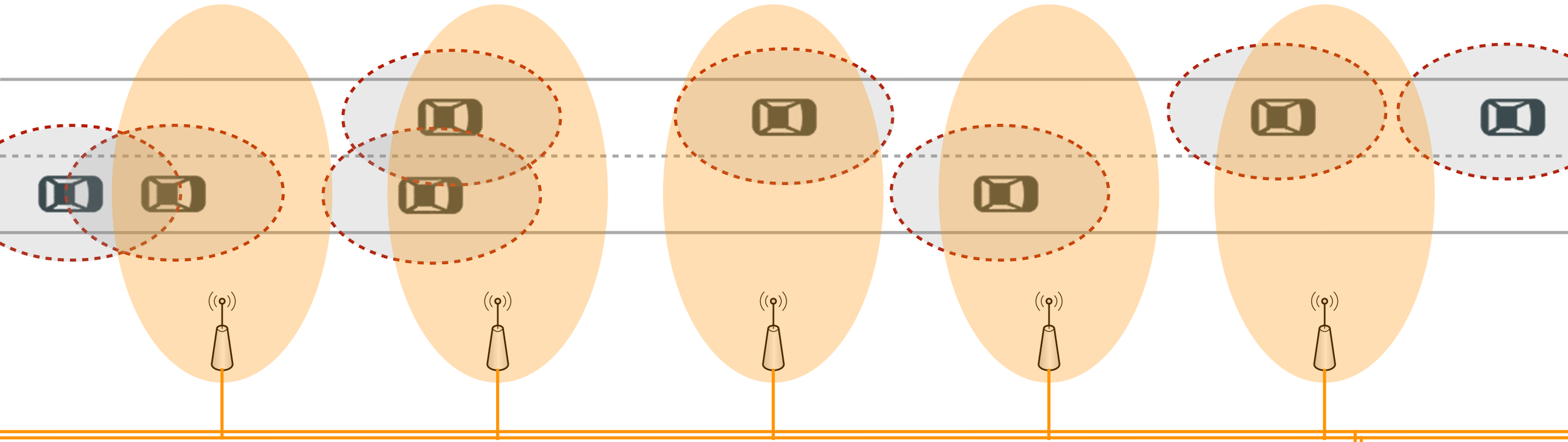
Multiple clusters (gaps)



Road-Side Units

- To improve connectivity, deploy fixed road-side units (RSUs) along the path
- RSUs can cost more, and be better positioned than on-board units ...

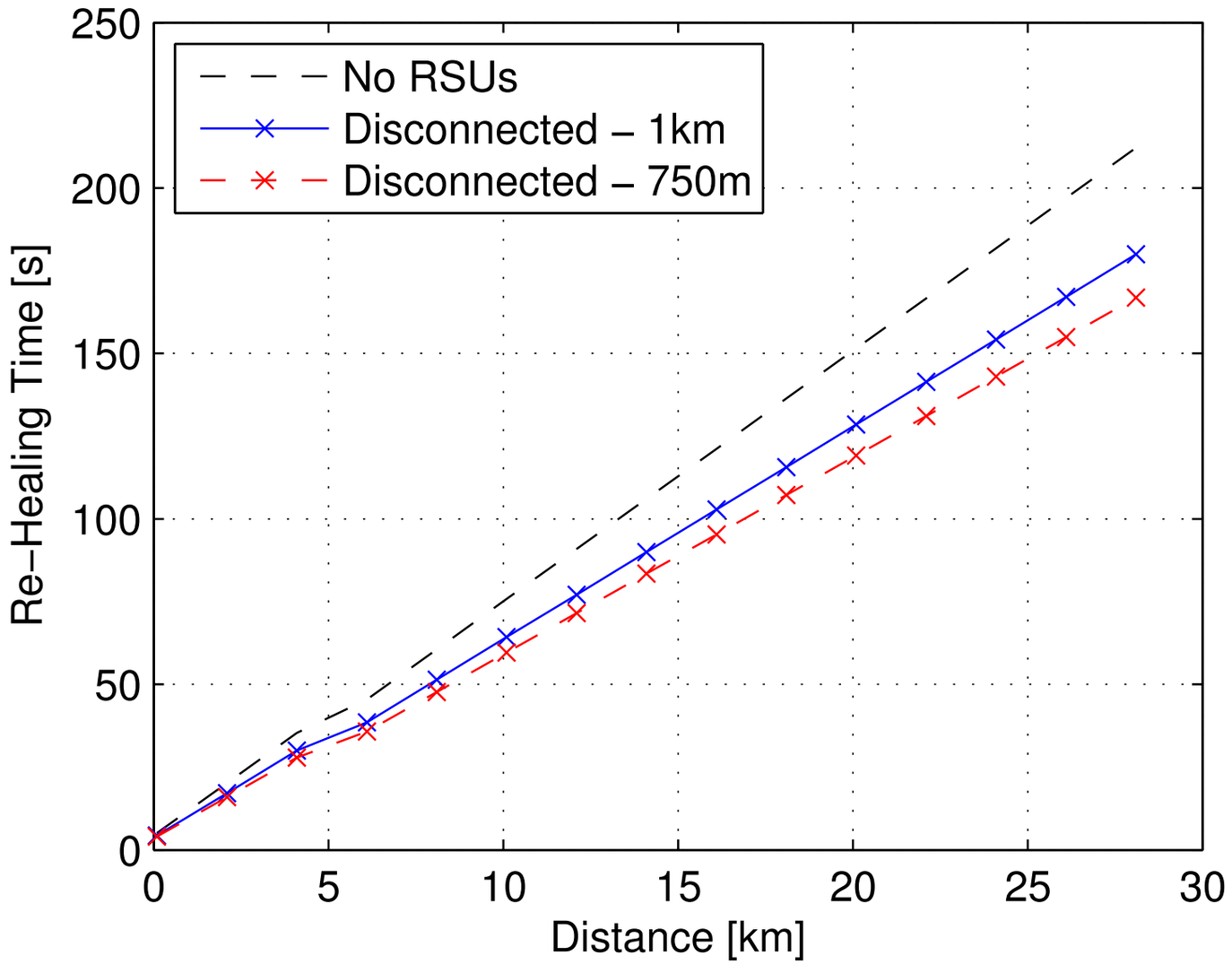
  ... which means better hardware, and better radio range than the vehicles



- A backbone connecting the RSUs can bring:
  - Faster message transmission
  - Access to WANs

Multi-gap re-healing time

accumulated re-healing time
vs. distance to destination



no RSUs

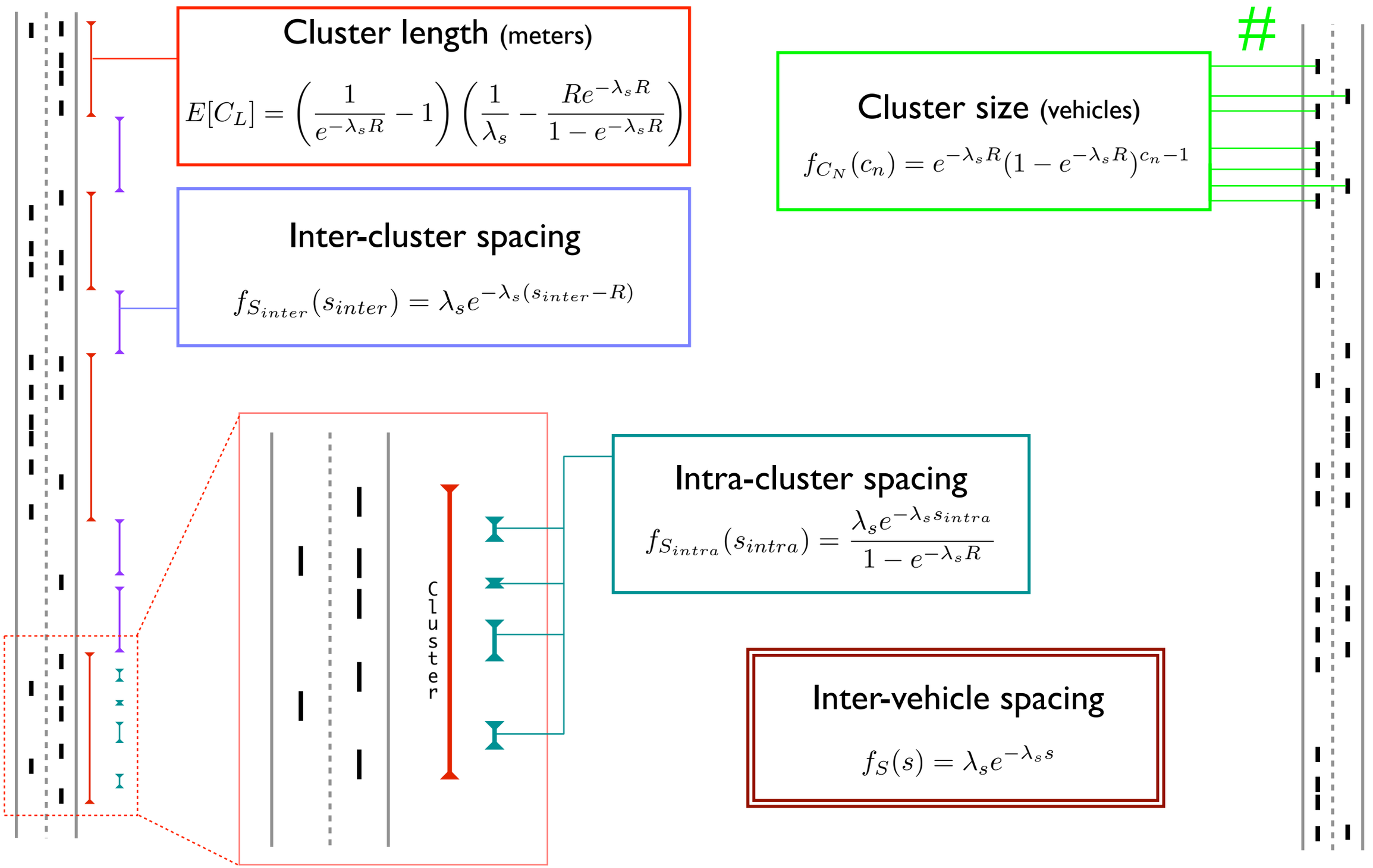
minor gains with disconnected RSUs

Goal

- Develop models that characterize the re-healing time for:
  - Disconnected RSUs
  - Connected RSUs

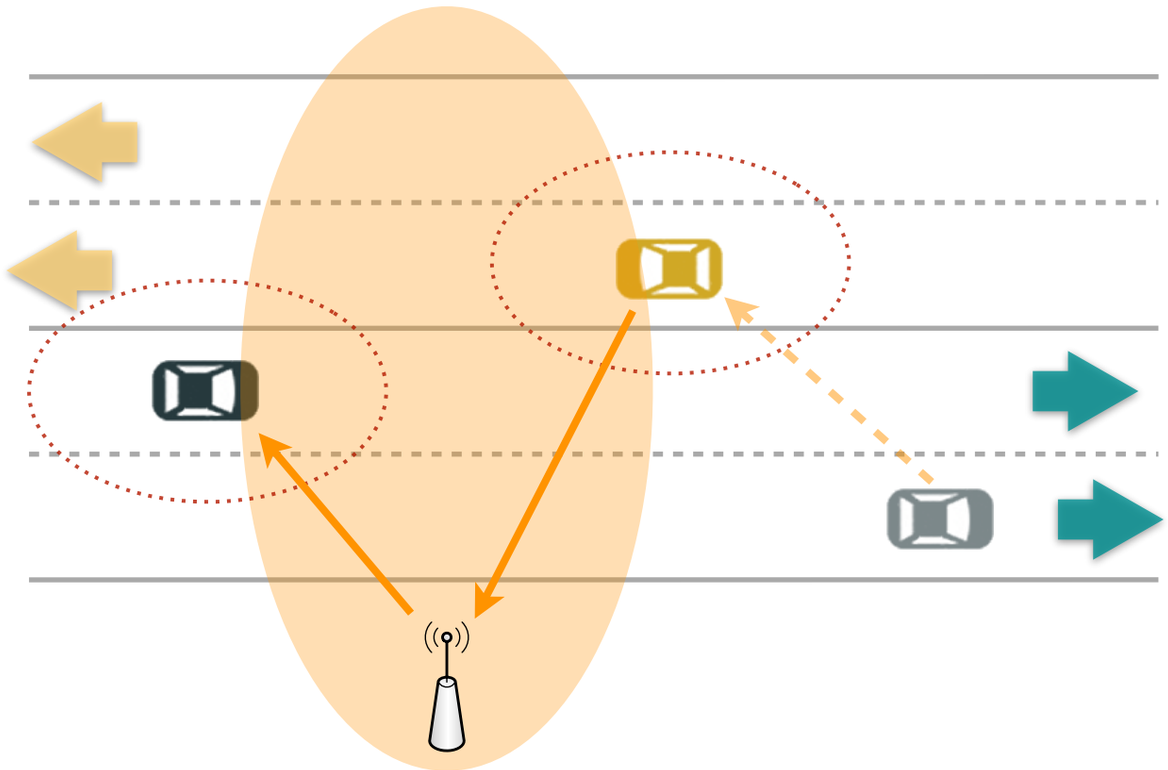
- Model must allow input of essential parameters:
  - Vehicle and RSU radio range
  - Traffic density, vehicle speed
  - Distance between RSUs

Base Traffic Model



Disconnected RSUs

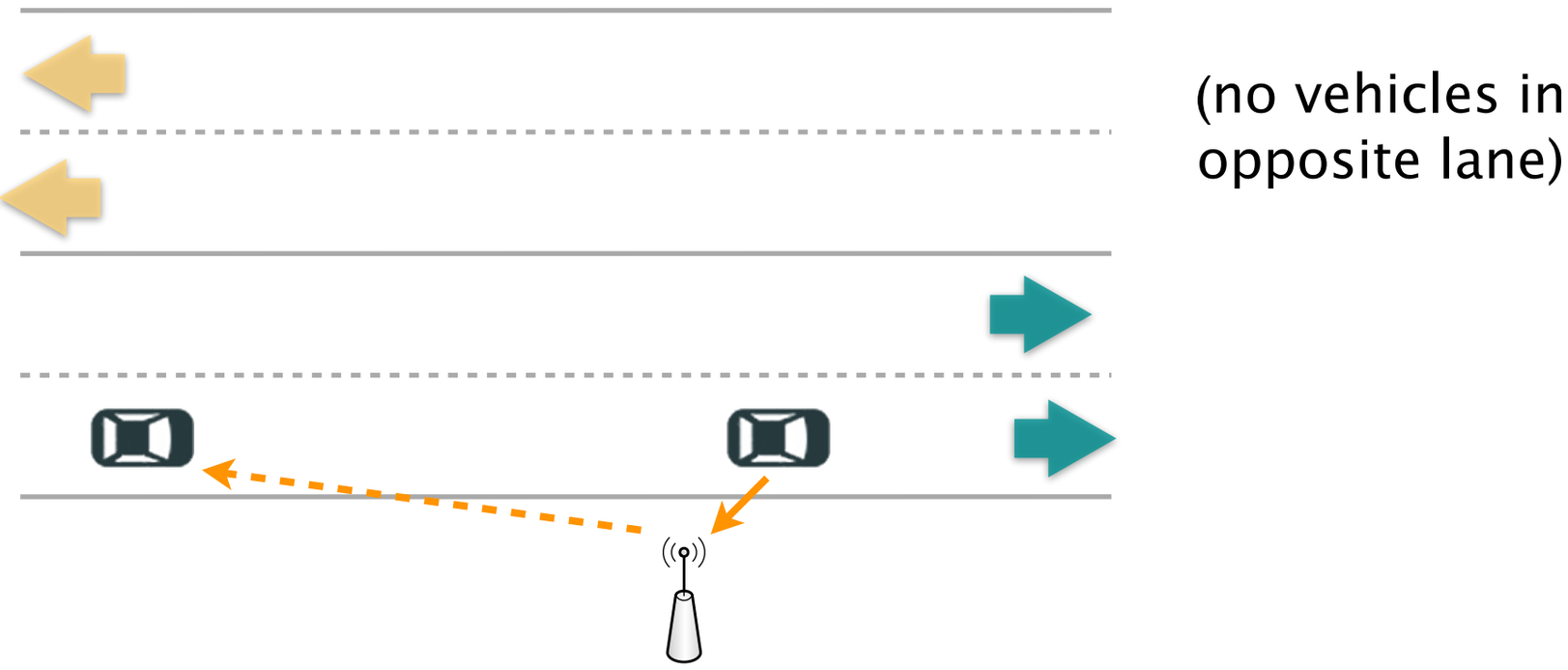
RSU as a radio bridge



- Re-healing time improved by including the average distance ‘gained’ by having the RSU transport the message

Disconnected RSUs

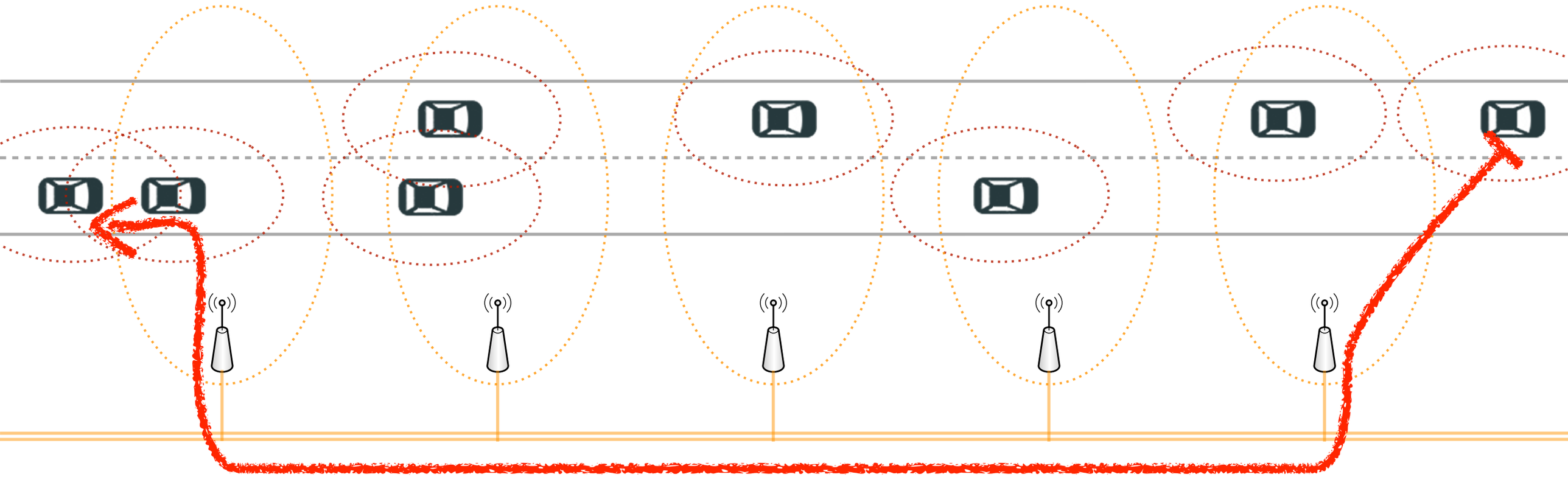
RSU as a message carrier



- RSU can carry the message faster than an opposite-lane vehicle

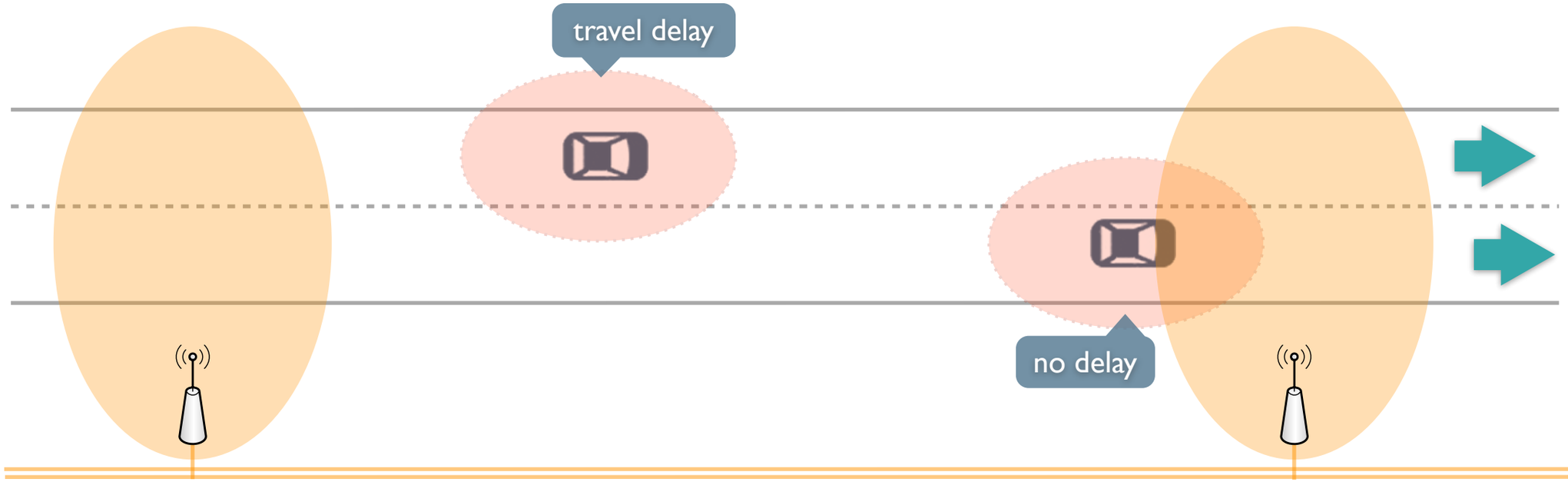
Connected RSUs

RSU is almost always the message carrier



Connected RSUs

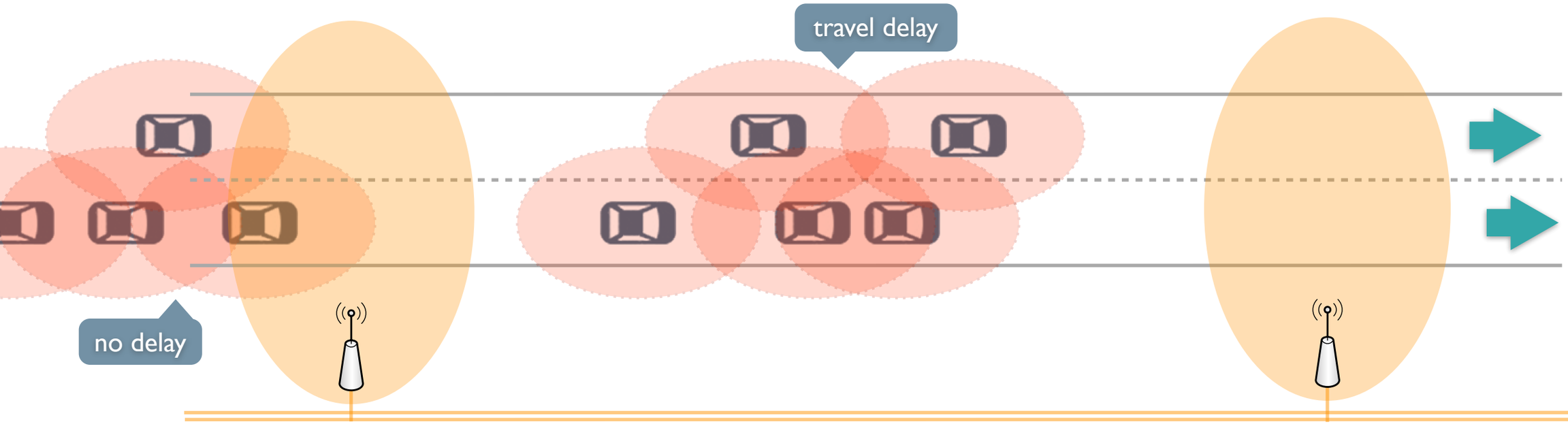
Single vehicle



- Vehicle can be either in range or not in range of an RSU
- No delay when under direct coverage (transmission delay between RSUs is negligible)

Connected RSUs

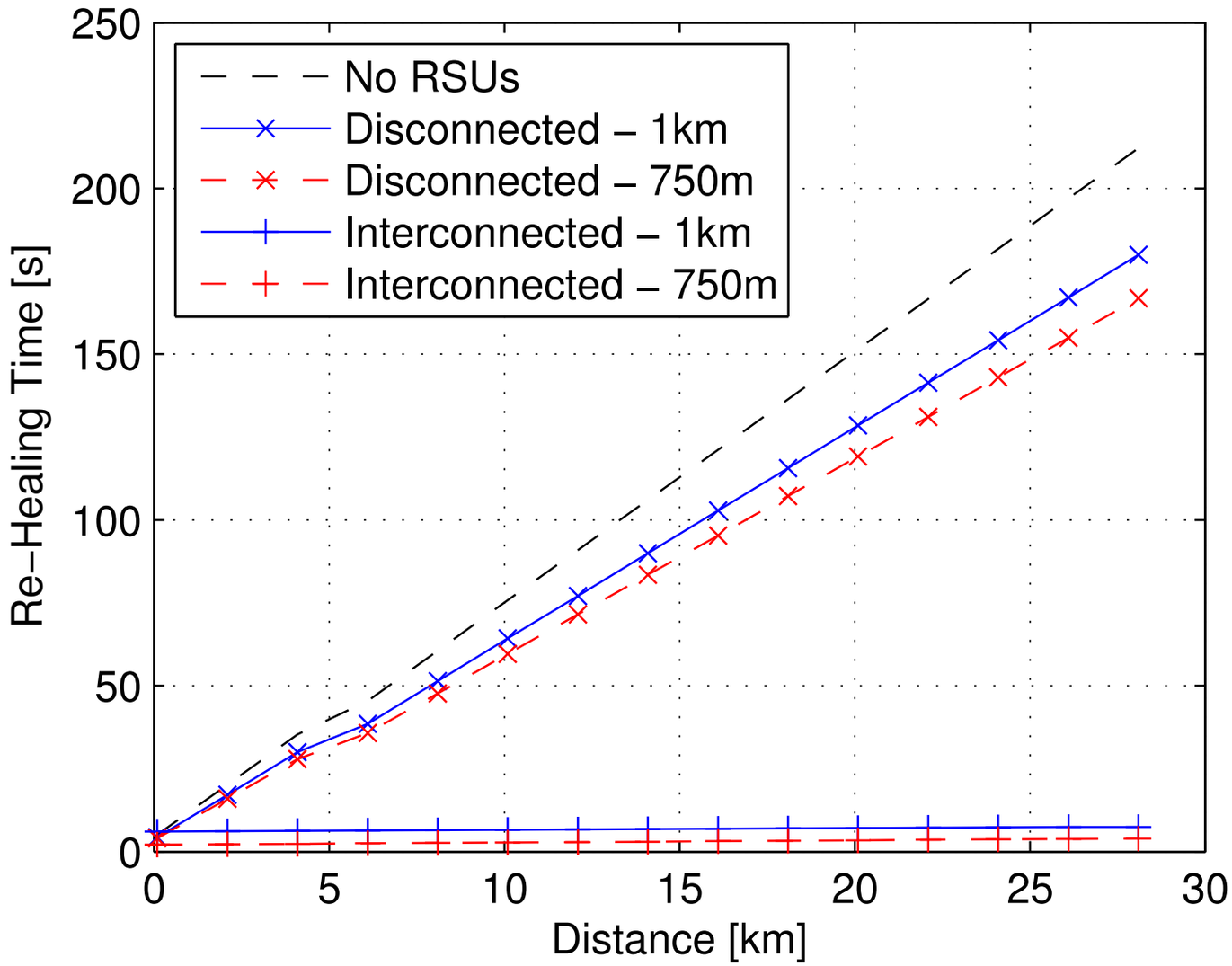
Clustered vehicle



- Clusters larger than the gap between RSUs are always connected
- If cluster is smaller:
  - Cluster could be in range of an RSU — no delay
  - Custer could be disconnected — spatial delay

Multi-gap re-healing time

accumulated re-healing time
vs. distance to destination



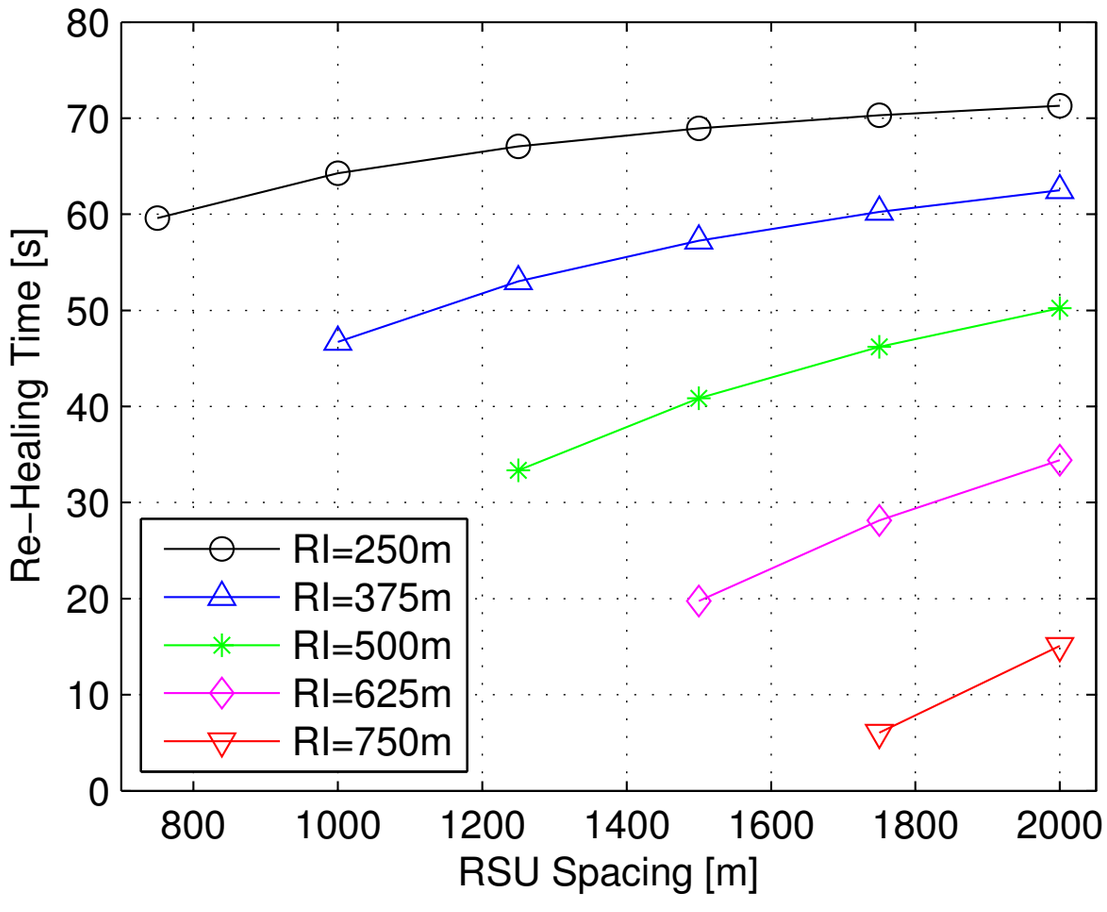
minor gains with disconnected RSUs

huge decrease w/ connected RSUs

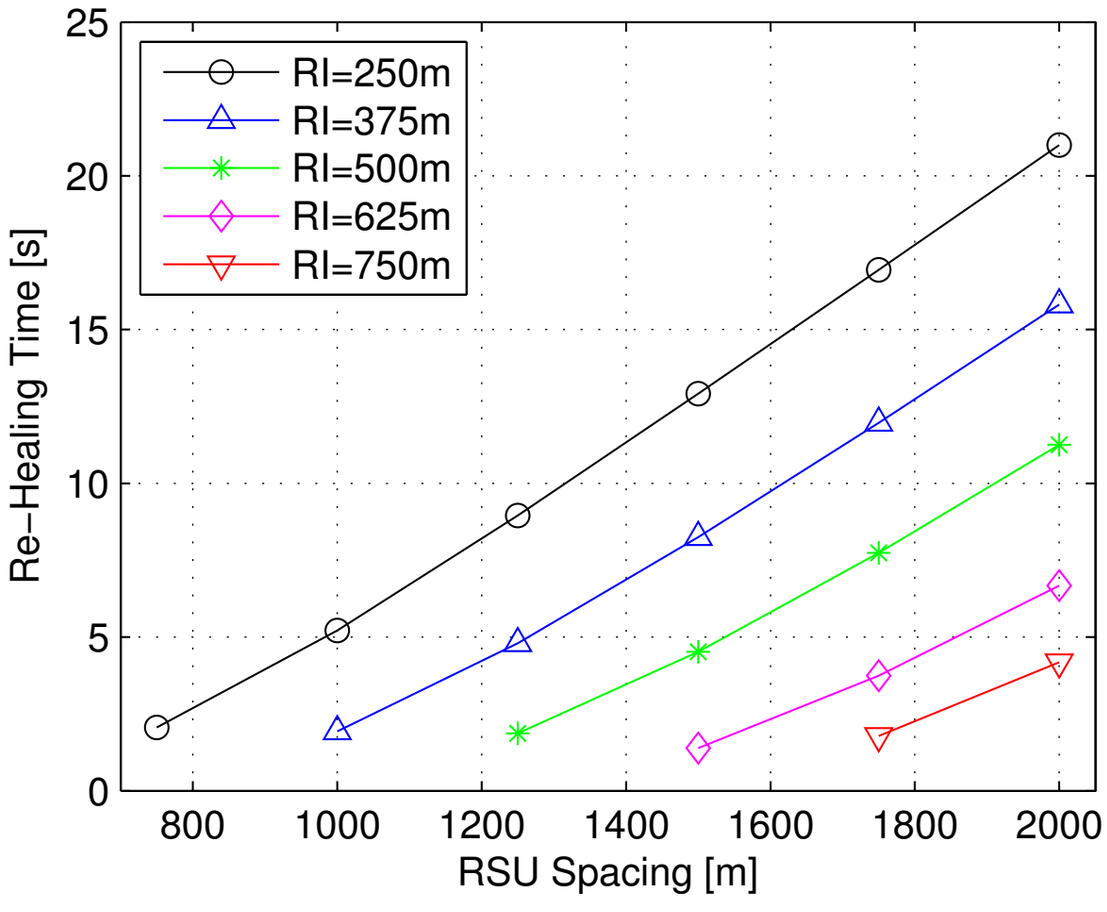
RSU density & radio range

10km accumulated re-healing time

Disconnected RSUs



Connected RSUs



Final Notes

- Disconnected RSUs are a poor choice
  - Even high density deployments of disconnected RSUs (1per750m) yield very poor gains for the cost of deployment
- Connected RSUs bring much lower delay, and are the ideal choice
  - Only way to support delay-sensitive applications
  - Further hardware and infrastructure is required to connect RSUs
- Improving the RSU's radio range yields more gains than deploying more RSUs

Thank you

Andre B. Reis — abreis@cmu.edu
Susana Sargento — susana@ua.pt
Ozan K. Tonguz — tonguz@ece.cmu.edu