Leveraging Parked Cars as Urban Self-Organizing Road-Side Units

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- Road-Side Units (RSUs) are very useful to a vehicular network
  - Central points of coordination
  - Improve connectivity
  - Content distribution
  - Controlled broadcasting

- Road-Side Units are a costly proposition
  - RSUs are predicted to cost $15,000 each to deploy, plus another $2,400 per year for maintenance

Cars as Road Side Units

- Find ways to improve message broadcasts, without Road Side Units
  - Have cars self-organize and take the roles of RSUs
  - Store and carry messages to other cars when needed

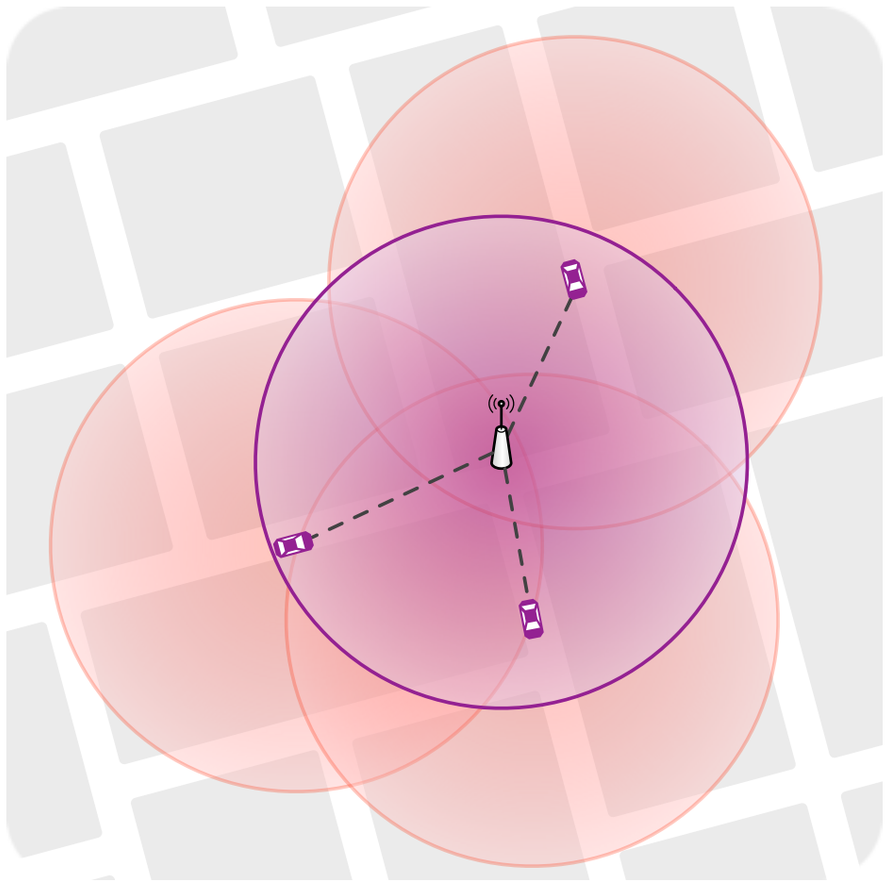
- Use parked vehicles as Road-Side Units
  - They already have the hardware (WiFi and DSRC radios)
  - When a vehicle parks, keep the on-board radios running

- Issues: *organisation*, *car battery life*

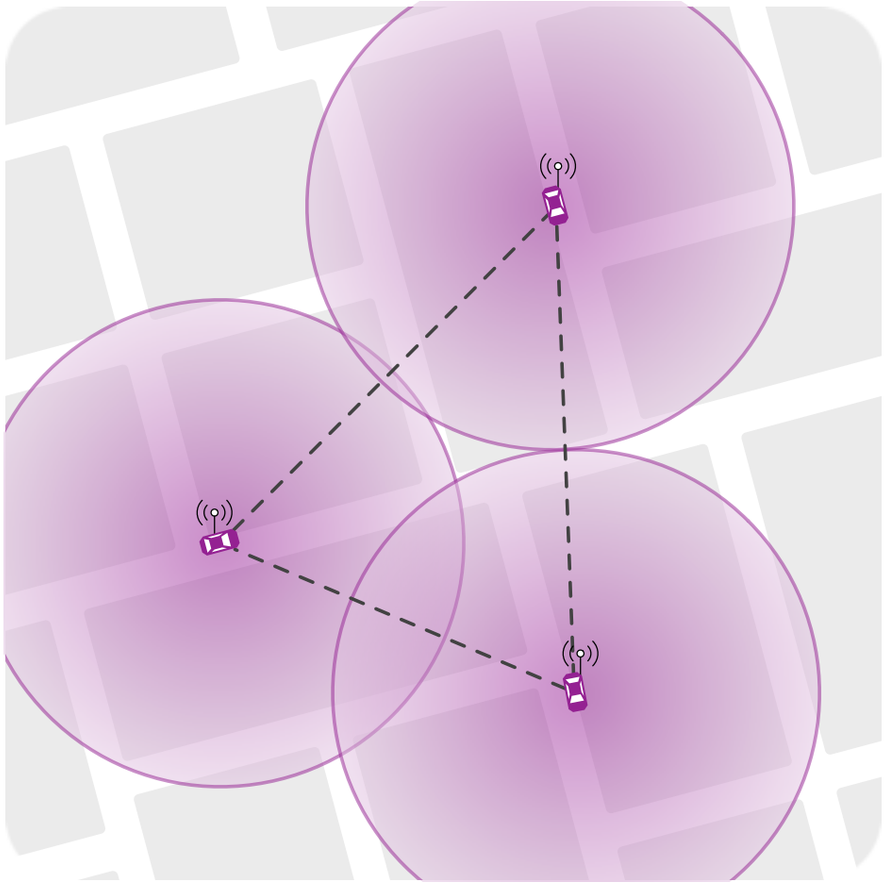
Methods of operation

As relays: extending a nearby Road-Side Unit

Standalone: using onboard cellular radio for upload



Road-side unit relays



Standalone

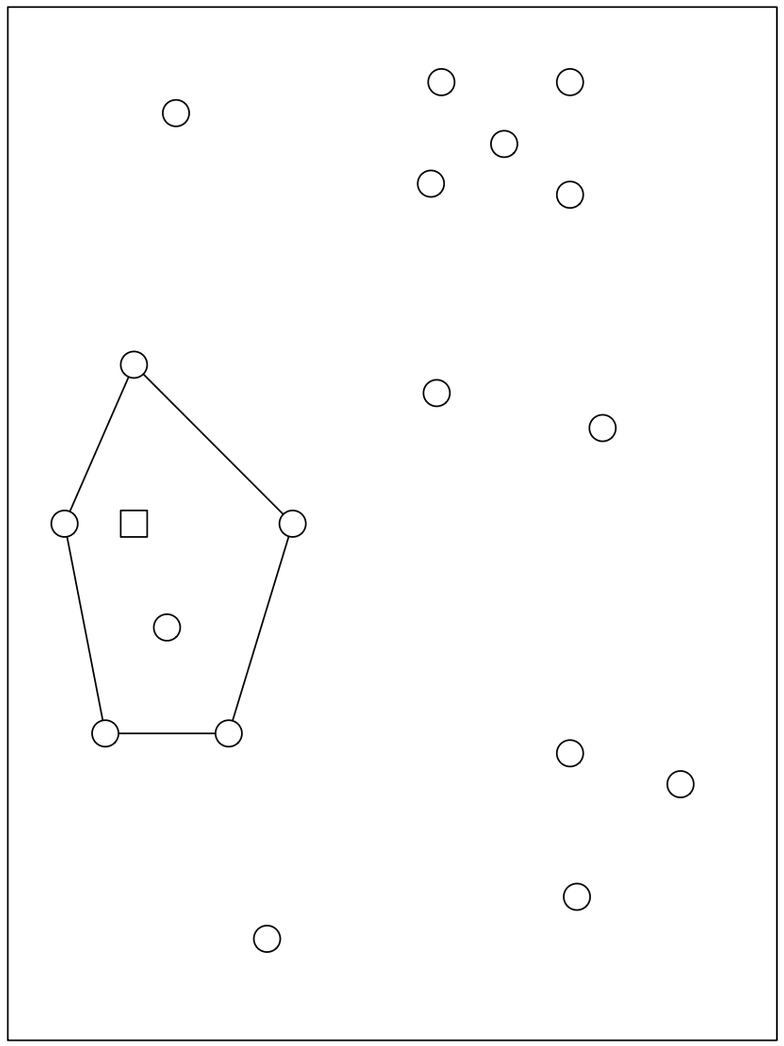
Two scenarios:

- Sparse urban network
  Few cars with radios, or limited uplinks for connecting RSUs
  - Determine which kinds of gains are possible when broadcasting safety messages

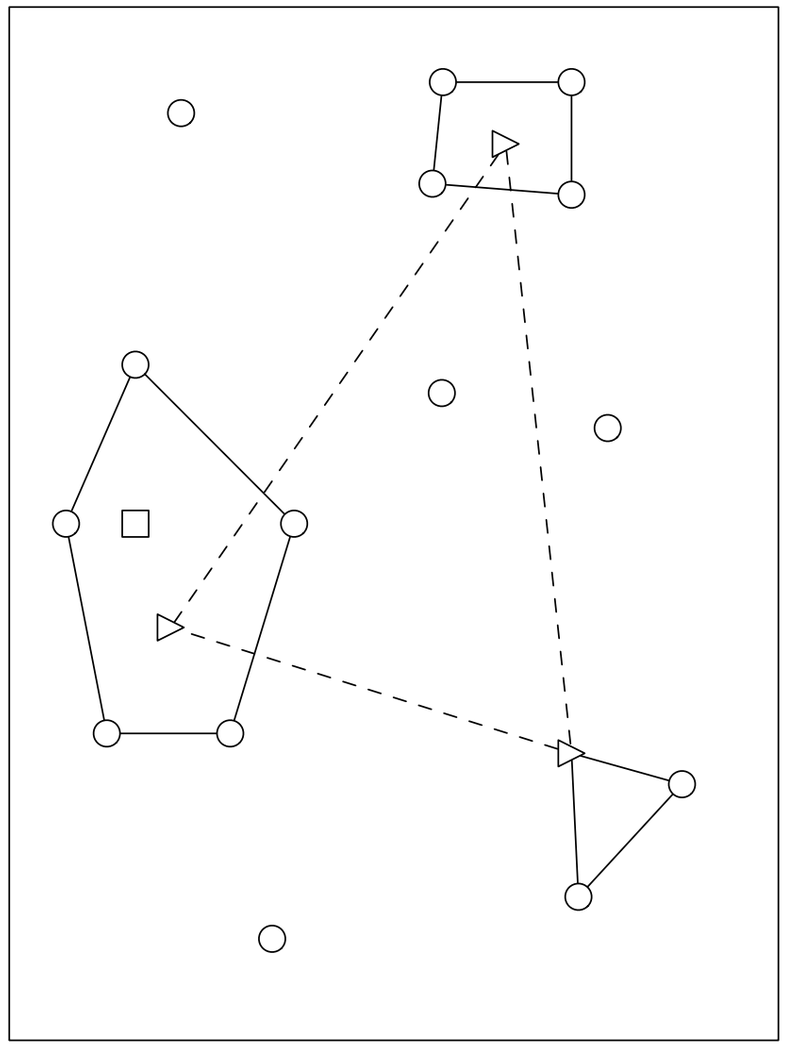
- Dense urban network

Example: UV-CAST with RSUs

UV-CAST
no RSUs

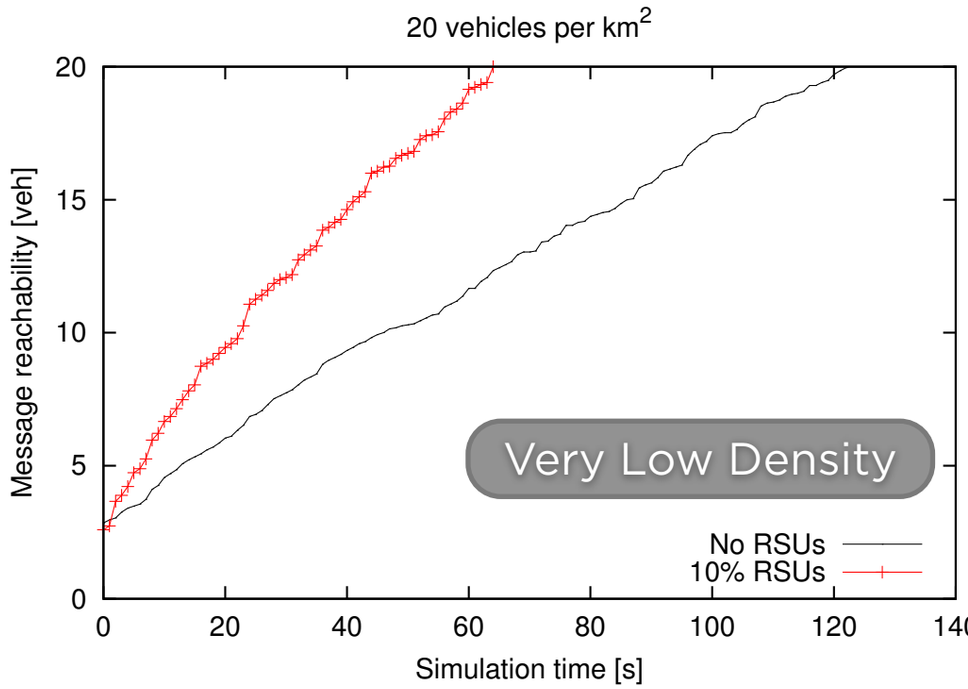


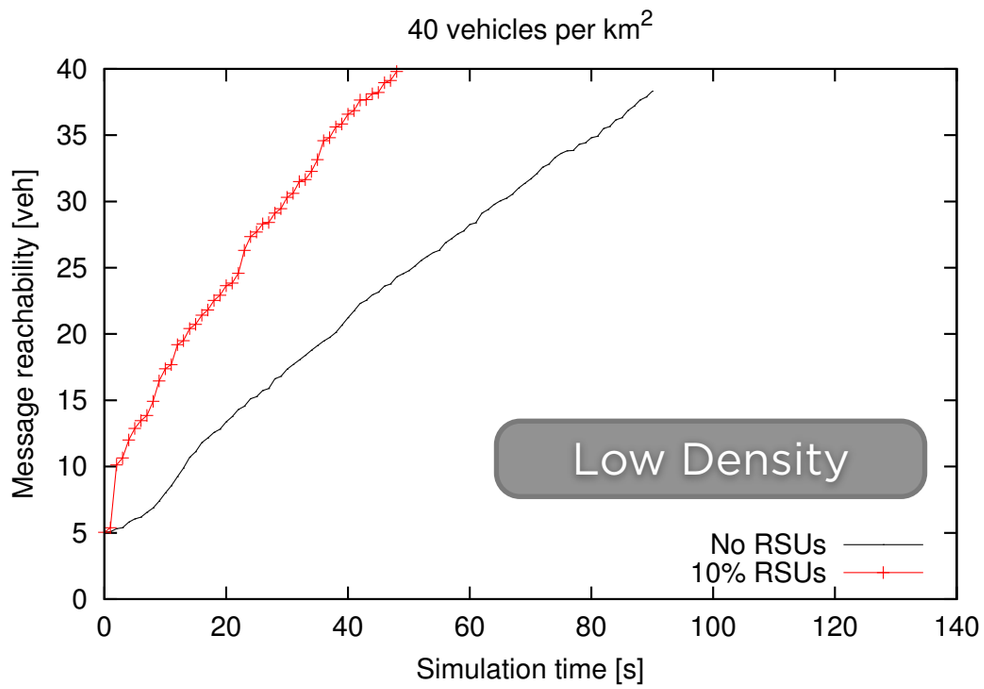
UV-CAST w/
connected RSUs



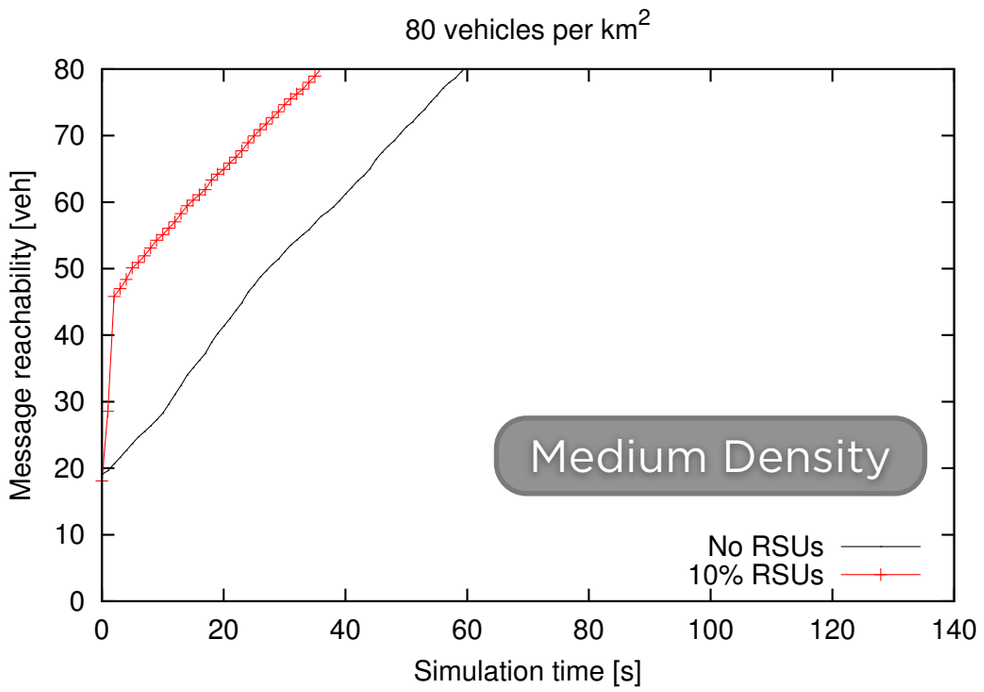
Multiple points of origin

Message Reachability





- Metric: time for a message to reach all cars
- Small number of parked cars active (1 in 10)
- 40-50% improvement in reachability time



Two scenarios:

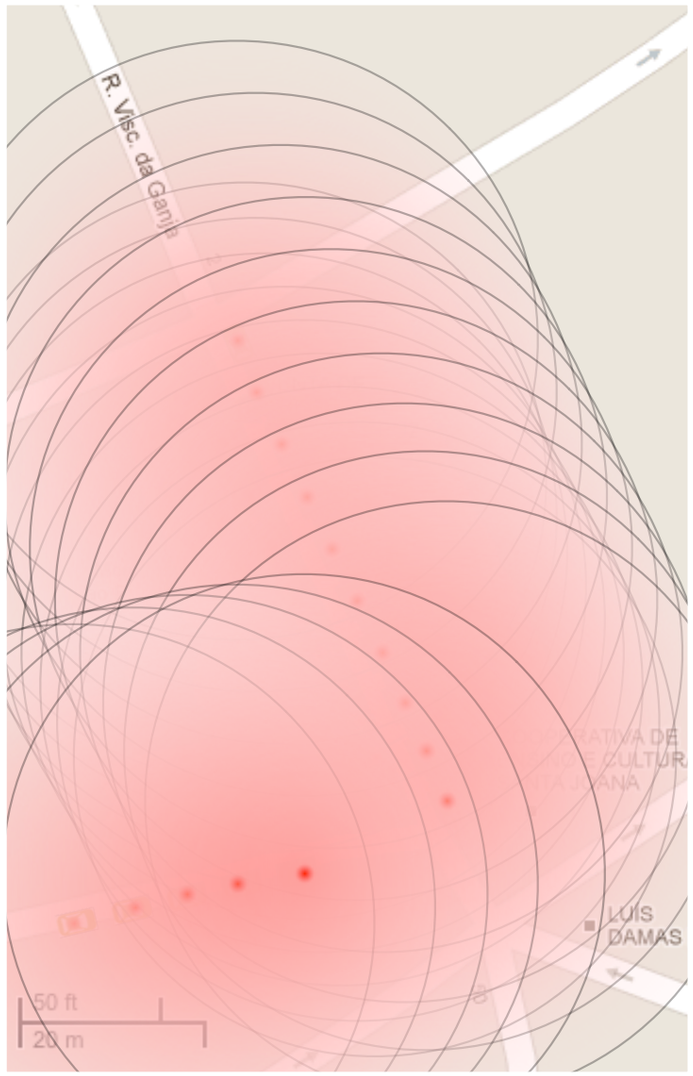
- Sparse urban network
  Few cars with radios, or limited uplinks for connecting RSUs
  - Determine which kinds of gains are possible when broadcasting safety messages

- Dense urban network
  Very high number of cars parked and on the road
  - Decide which parked cars should become RSUs

Election problem

Not all parked cars should become RSUs

Need a way to select which cars to use



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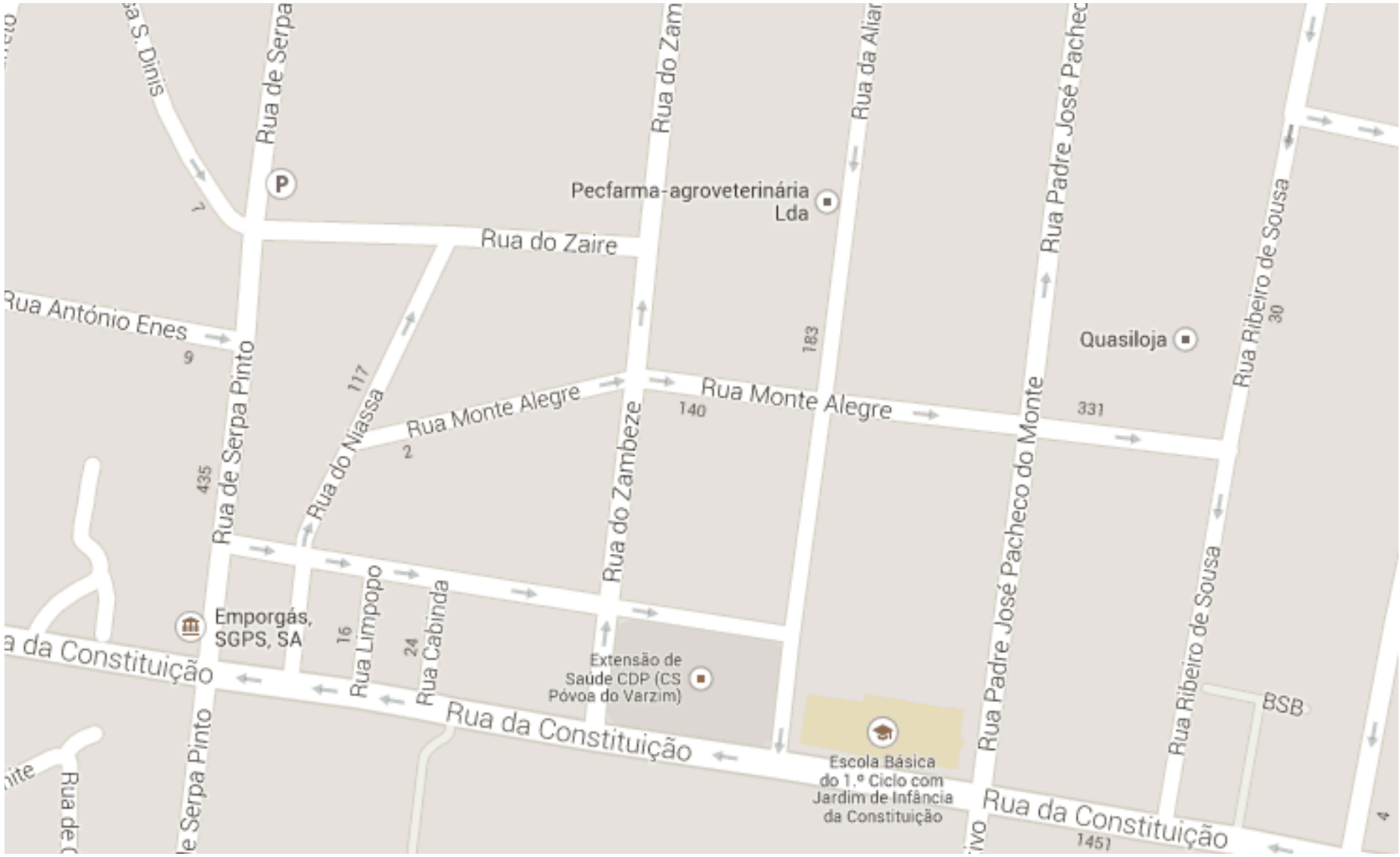
Electing parked cars

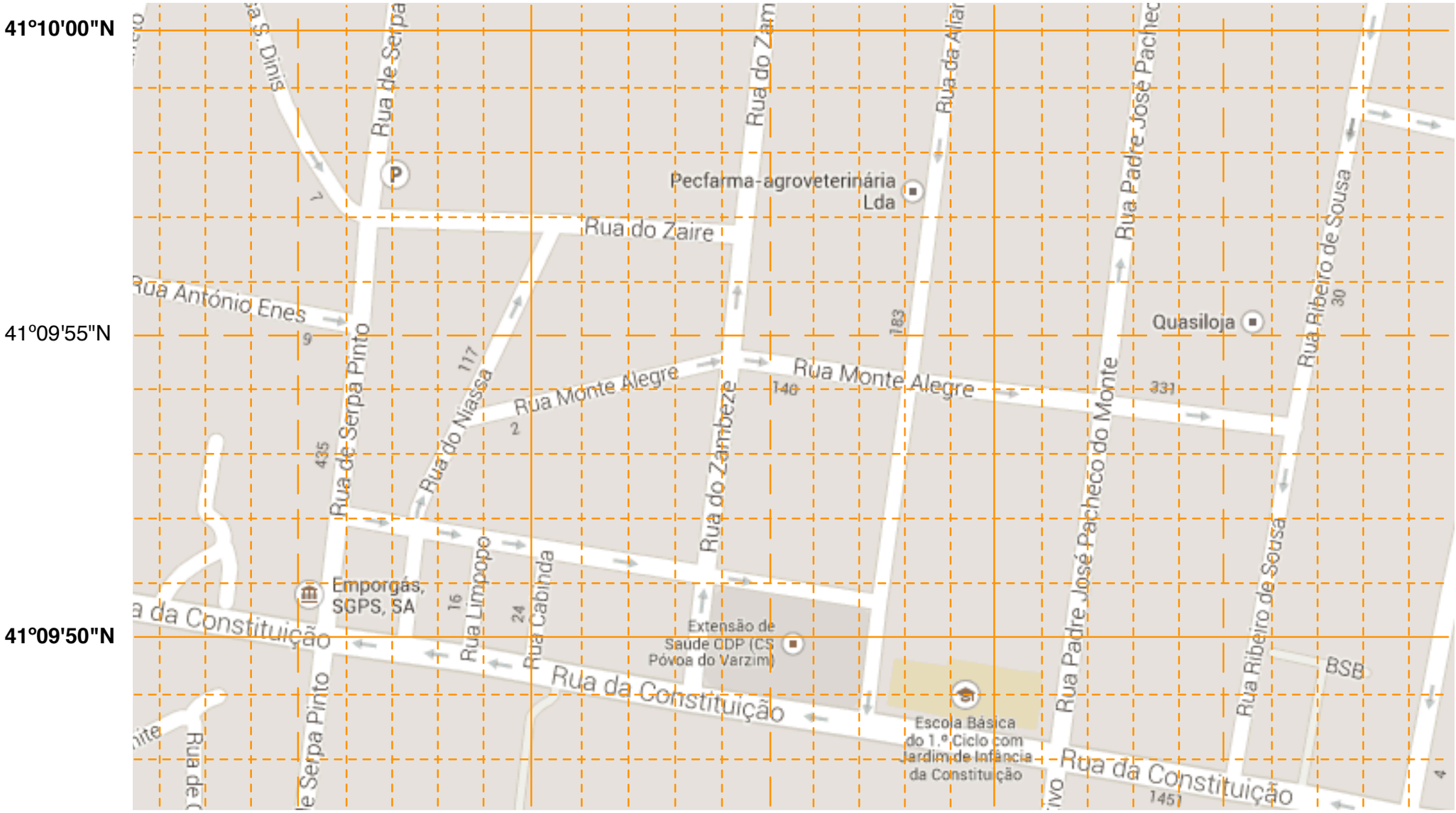
- Need a way to track the coverage area of each parked car
  - Divide the city into cells
  - Parked cars listen to beacons from other cars and build their own coverage map
    - No need to pre-distribute road maps
    - Adapts to any new roads and conditions
- Self-organize: parked cars decide to become RSUs with information from their neighbors
  - Ideally, only 1-hop information

Cell maps in real cities



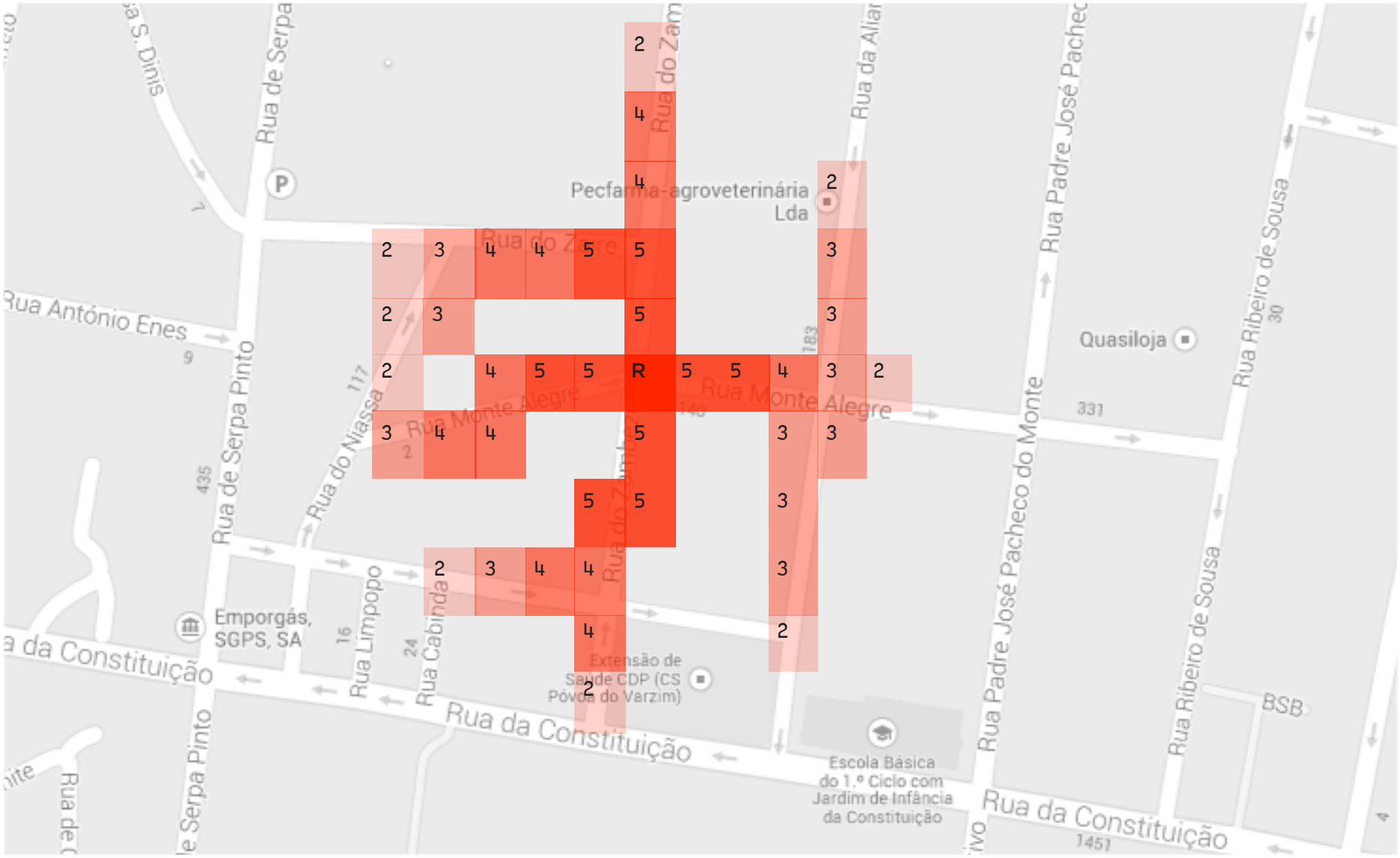
Cell maps in real cities

Align cells to GPS coordinates



Cell maps in real cities

Cars discover their reach by listening to beacons



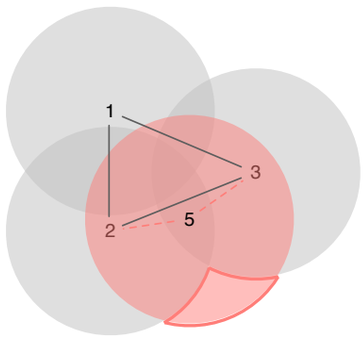
Usefulness criteria

- Parked cars exchange their coverage maps
  - They can build a local map of coverage with this data
- With the local map and its own coverage,
  a car decides if it is being useful to the network

$$d_{score} = \kappa \cdot d_{new} + \lambda \cdot d_{boost} - \mu \cdot d_{sat} - d_{bat}$$

0 ➤ 5 Points for covering new cells

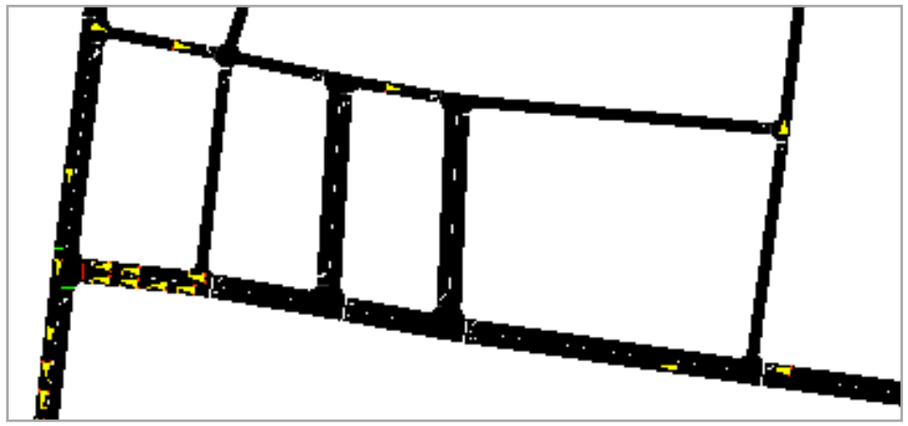
2 ➤ 4 Points for boosting signal quality in already-covered cells



Penalties for saturating the network (unnecessary coverage)

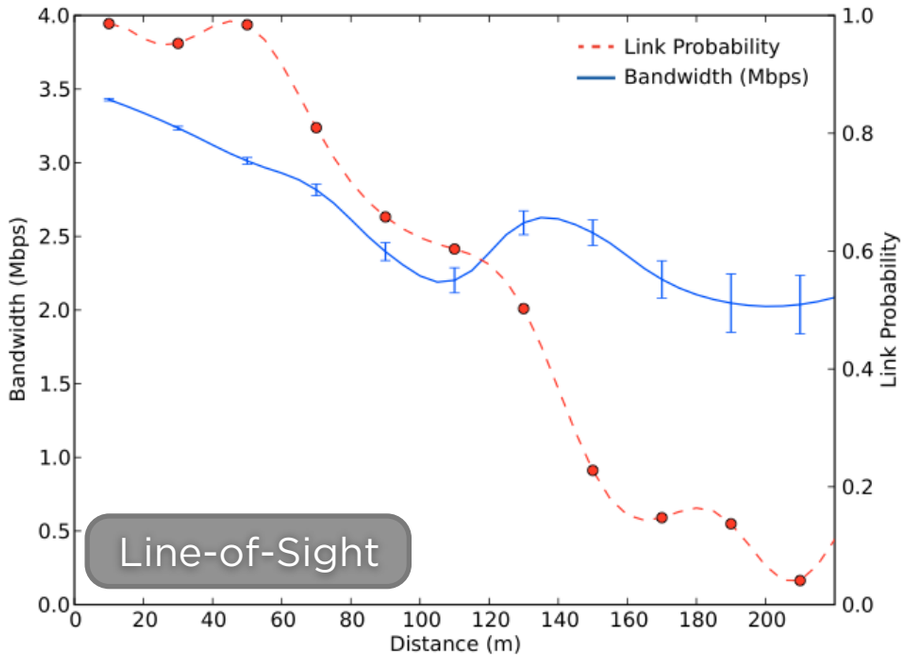
Comprehensive Simulation Platform

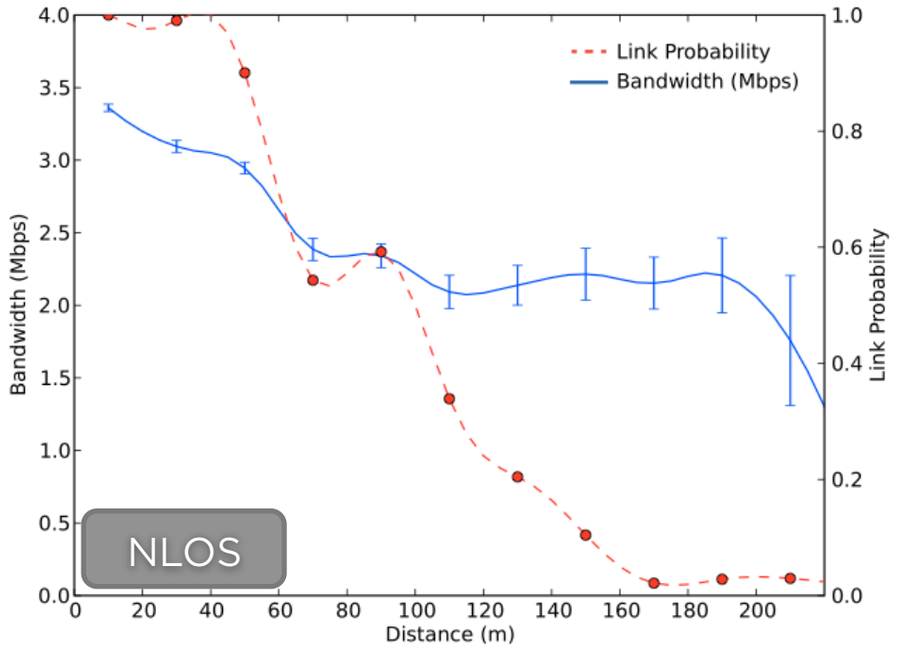
Realistic vehicle mobility
Real urban street layout



Real maps of urban buildings
to determine obstructions

Bandwidth and Link Probability
from real measurements in the same city



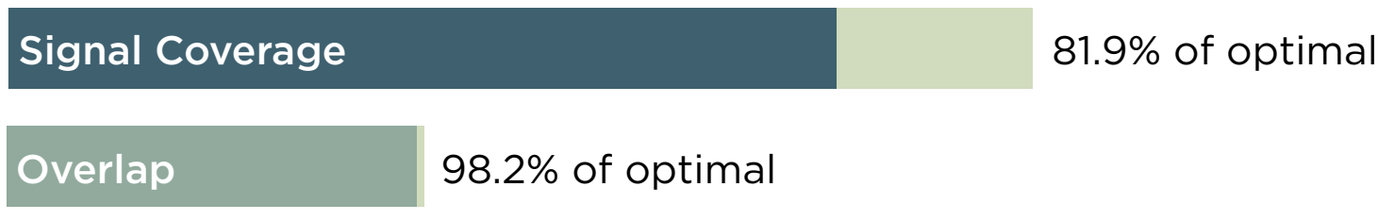


Example scenario

24 parked cars
1/4 sq. km

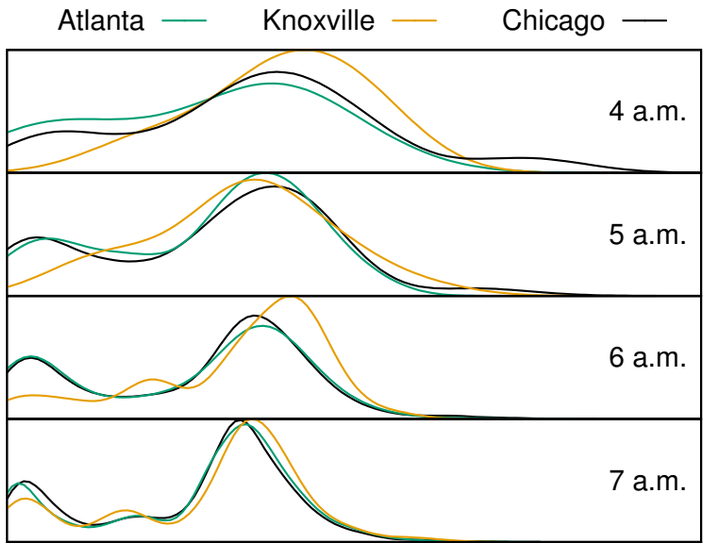
Optimal Solution
~16 million tries

Algorithm
1-hop information

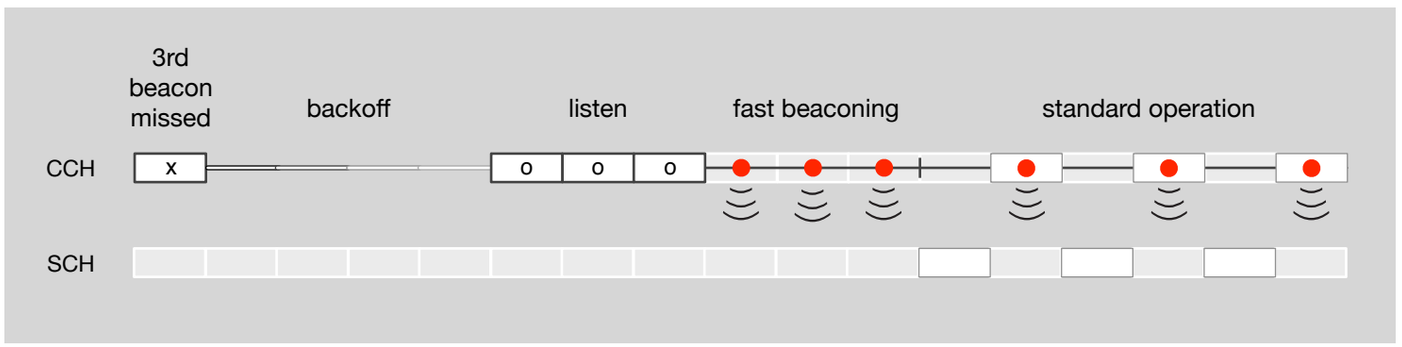


Future work

- Study parking trends in major cities, down to individual behaviour



- Deal with active RSUs that leave the network



- Algorithm to rotate roles between parked cars
  Keep the car battery in check

Thank you