Impact of Vehicles as Obstacles in Vehicular Ad Hoc Networks

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Joint work with:
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Outline

Vehicular Ad Hoc Networks (VANET)

- Network with two kind of nodes

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  - Roadside Units.

Vehicular Communications

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  - Data from Autoridade Nacional de Segurança Rodoviária: In 2007, traffic related accidents killed 854 people and injured 43202. And in 2008, there were 772 fatalities e 40745 injuries.

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Vehicular Communications: Potential Applications

- Safety
  - Road Work Ahead

Vehicular Communications: Potential Applications

- Safety
  - Weather Conditions

Vehicular Communications: Potential Applications

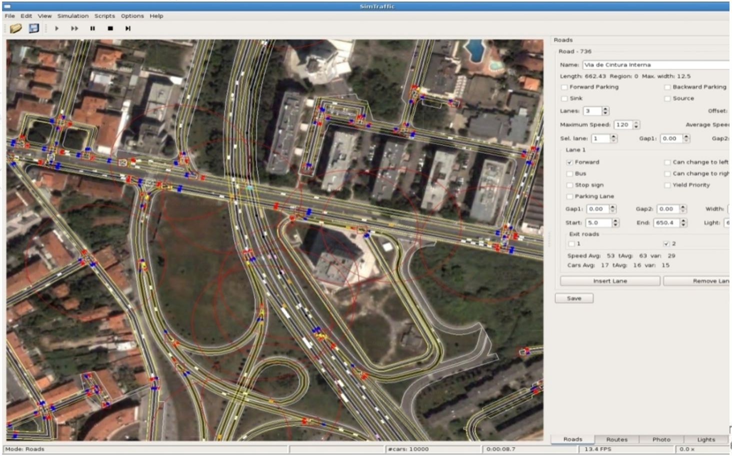
- Mobility
  - Traffic Information

Vehicular Communications: Potential Applications

- Mobility
  - Dynamic Route Guidance

VANET Simulation

- Provides feedback from extremely complex scenarios
- Enable insights, identify critical problems, and test solutions.



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VANET Simulation

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- Realistic propagation models (e.g., ray tracing): computationally expensive
- Mobile obstacles increase the complexity even further.
- Simplified stochastic radio models (Shadowing): rely on the statistical properties of the chosen environment and do not account for the specific obstacles in the region of interest
- Do not provide satisfying accuracy for typical VANET scenarios.

Desired VANET Propagation Model

- Realistic
  - Modeling both static and dynamic obstacles
    - Static: buildings, trees, overpasses, hills, parked vehicles,...
    - **Mobile: other vehicles on the road**
- As topology/location independent as possible
- Computationally manageable
  - Propagation model is only one of several simulated models in VANETs (mobility, MAC, routing, application,...)
  - Modeling vehicles is only one part of propagation modeling
  - Has to execute within certain time, otherwise is not useful

Model for evaluating the impact of vehicles

- Impact on line of sight (LOS)
- Impact on signal propagation
- Time complexity of the model

Problem Setup

- Spatial characteristics of vehicular networks that are of interest:
  - Exact position of each vehicle and the inter-vehicle spacing
  - Vehicle dimensions (height, width, length)
  - Speed distribution of vehicles
  - To obtain these data, we used stereoscopic aerial photography
  - Data from A28 and A3 collected by FCUP group.
  - 404 vehicles on a 12 km highway strip and 55 vehicles over 7.5 km respectively.

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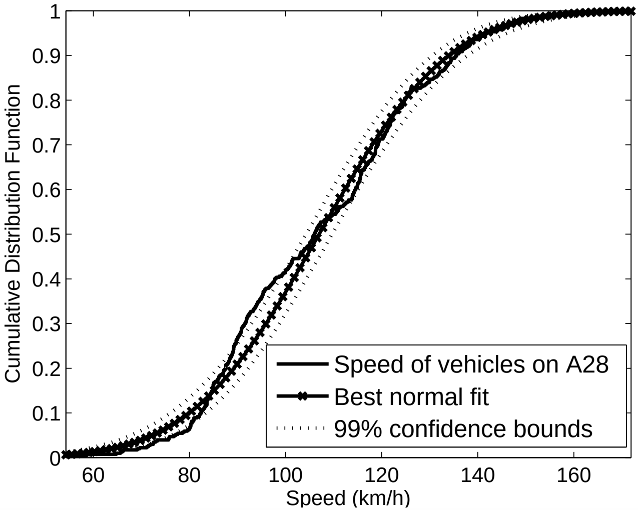
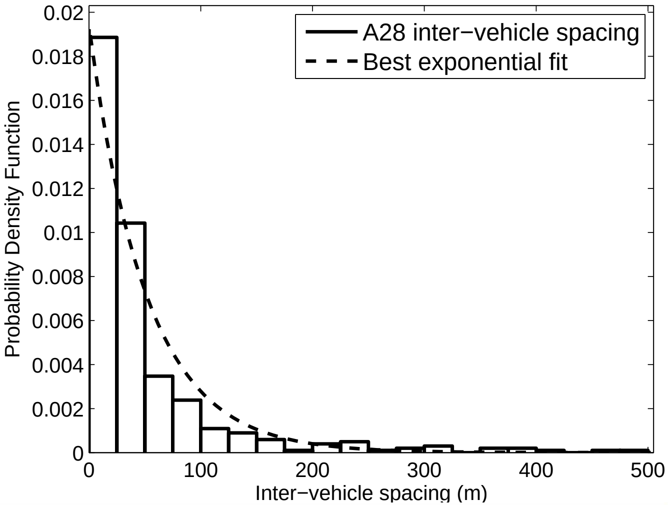
  - Automotive Association of Portugal
  - 18 brands comprising 92% of vehicles
  - Both H & W normally distributed

Speed Distribution A28

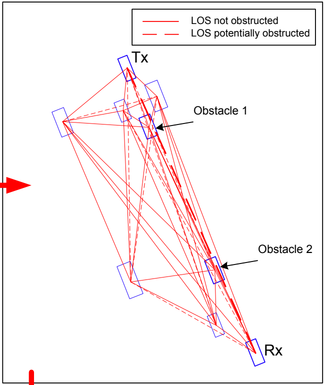


Inter-vehicle spacing A28

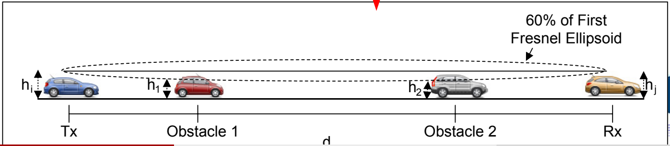


How do we evaluate probability of LOS?

(a) Stereoscopic aerial photography



(b) Abstracted model showing possible connections



How do we evaluate probability of LOS?

- Per-link probability of LOS $\longrightarrow$ Average probability of LOS for a given vehicle $\longrightarrow$ Macroscopic probability of LOS behavior.

Effect on Received Signal Power

- Obstructing vehicles are approximated as knife-edge obstacles;
- Additional attenuation due to multiple knife-edge obstacle calculation.

Computational Complexity

- The described model can be regarded as a special case of geometric intersection problem
- Well know problem in computational geometry.
- Red-Blue intersection problem:
  - Given a set of red line segments r and blue line segments b in the plane, report all K intersections of red with blue segments
  - Time complexity of the algorithm: $O(N^{4/3} \log N + K)$
  - $N = r + b$
  - Additional time for multiple knife-edge: $O(K)$
  - Overall $O(N^{4/3} \log N + K)$

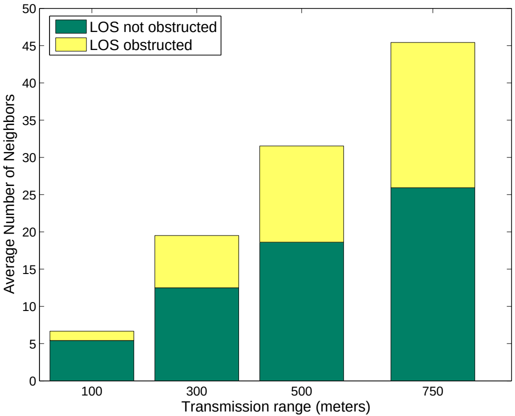
Results: Probability of LOS

- Macroscopic probability of LOS.
- A28: 32.3 vehicles/km, A3: 7.3 vehicles/km.

	Transmission Range (m)		
Highway	100	250	500
A3	0.8445	0.6839	0.6597
A28	0.8213	0.6605	0.6149

Results: Obstructed Neighbors

- Neighbors with unobstructed and obstructed LOS
- Half of the neighbors will not have LOS due to vehicles only at 500 m of observed range.



Stationarity of Poisson Process

- Stationarity of the generating Poisson process
- Important for characterizing the moving network (i.e., over time)
- Important for determining the refresh rate for vehicles-as-obstacles model

Time offset	$\Delta P(LOS)_i$ (%) $< 5\%$	5-10%	10-20%	$>$20%
1ms	100%	0%	0%	0%
10ms	99%	1%	0%	0%
100ms	82%	15%	3%	0%
1s	35%	33%	22%	10%
2s	31%	25%	29%	15%

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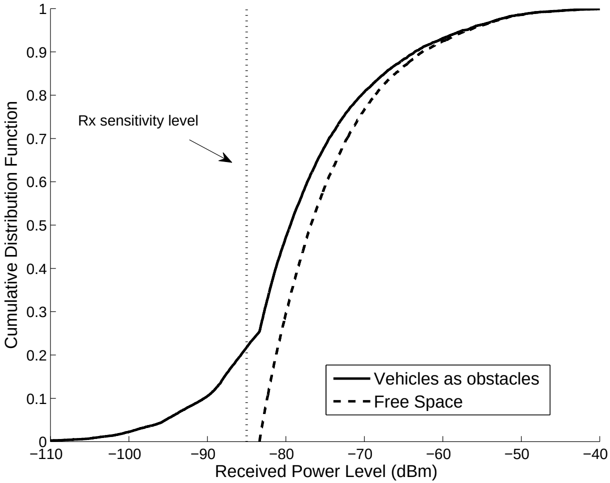
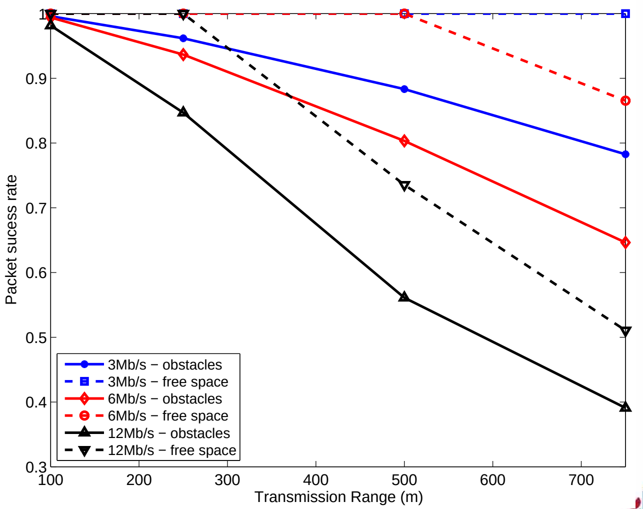
Results: Received Signal Power

$P_T = 20$ dBm, $G_T = G_R = 1$ dBi, Tx Range $= 750$ m.



Results: Packet Reception



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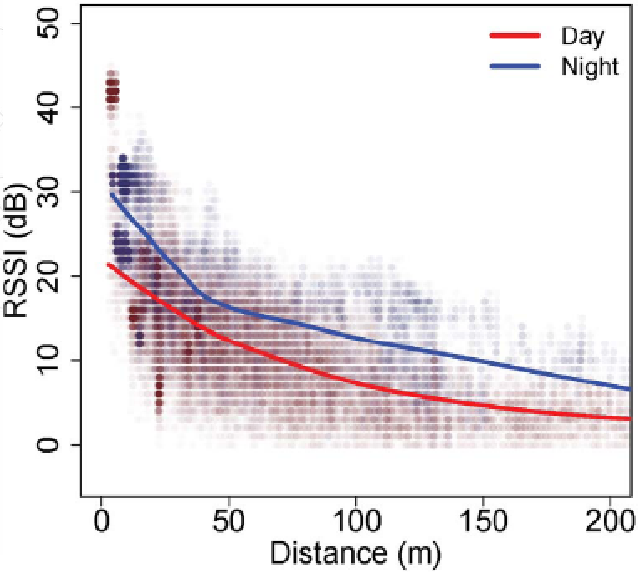

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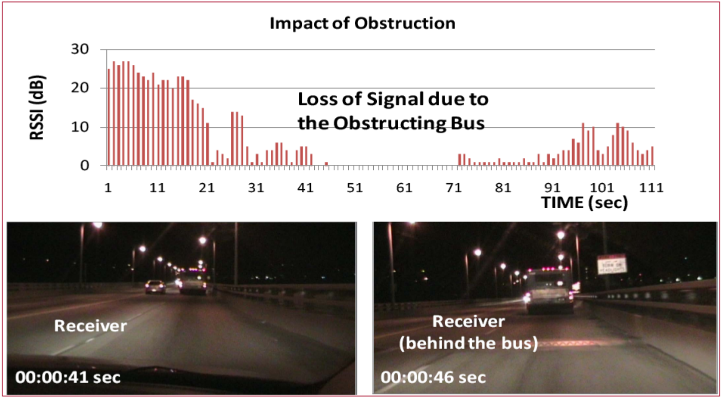

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- Credibility of simulation results
  - 5 dB attenuation and 20% packet loss on average are far from negligible!
  - If vehicles are not accounted for, optimistic results are obtained
  - In reality, routing protocols will behave worse, network reachability will be reduced, delay will be incorrect.

Thank You!

- Questions?
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