From Communication to Traffic Self-Organization in VANETs

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WASNLAB Wireless Ad-hoc and Sensor Network Laboratory

Outline

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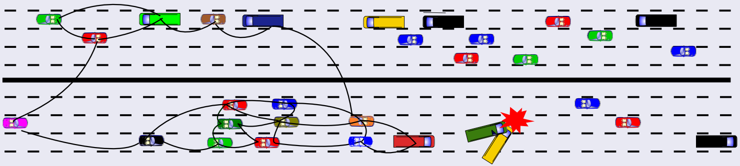
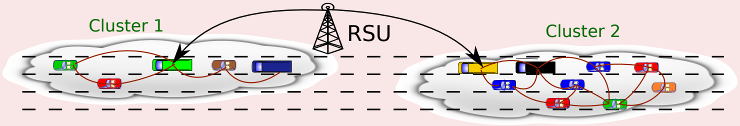
VANETs: The Big Picture

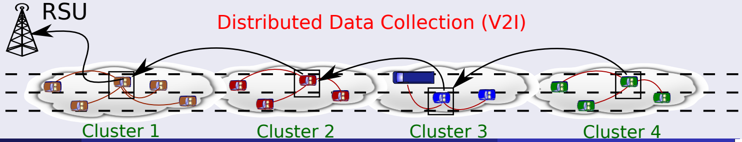
Event-driven Communications (V2V)



Data dissemination (I2V)



Distributed Data Collection (V2I)



Broadcast Protocols in VANETs

Topology information dissemination

- Periodic **one-hop** *broadcast* transmissions
- Unicast forwarding protocol need topology information
- Weak QoS requirements

Event-driven information dissemination

- Event-driven **multihop** *broadcast* transmissions
- Most of the information is intrinsically *broadcast* (i.e., accidents)
- Large area to be covered in **short time** and **reliably**
- No time to establish unicast communications
- Broadcast storm problem!!

Silencing Irresponsible Forwarding: the starting point

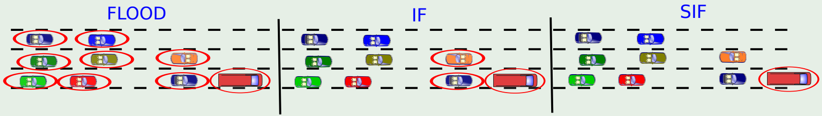
Our proposal

- Nodes decide to retransmit in a probabilistic way
- A node with a scheduled transmission interrupts the backoff when it hears a retransmission from a better placed node (silencing)
- Intuition: the best relay is the farthest one reachable from the transmitter
- Location-dependent retransmission probability:

The Retransmission Probability

$$P_{\mathrm{re-tx}} = \exp\left\{-\frac{\rho_{\mathrm{s}}(z-d)}{c}\right\}$$

where ρ_{s} is the vehicle spatial density, z is the transmission range, d is the distance between transmitter and receiver, and c is a *shaping* parameter



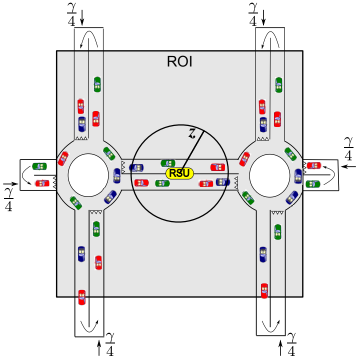
Impact of Mobility on Broadcast Dissemination (1)

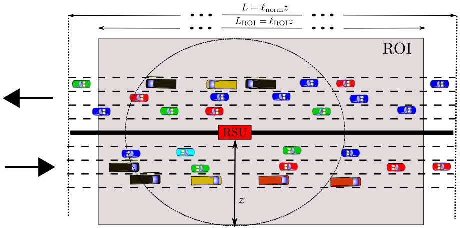
Urban scenarios

- Roads with traffic lights and roundabouts
- SUMO simulator with Krauss model
- $v^{\max} = 20$ m/s

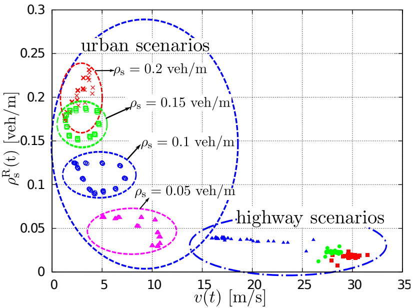
Highway scenario

- Multi-lane roads
- VanetMobiSim simulator
- Intelligent Driver Model (IDM)
- $v^{\min} = 30$ m/s, $v^{\max} = 50$ m/s

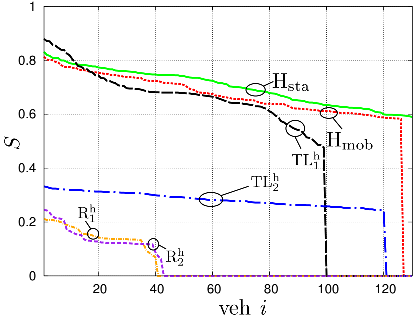




Impact of Mobility on Broadcast Dissemination (2)

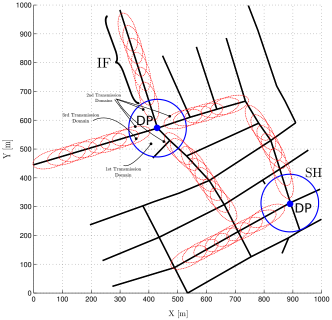


Mobility



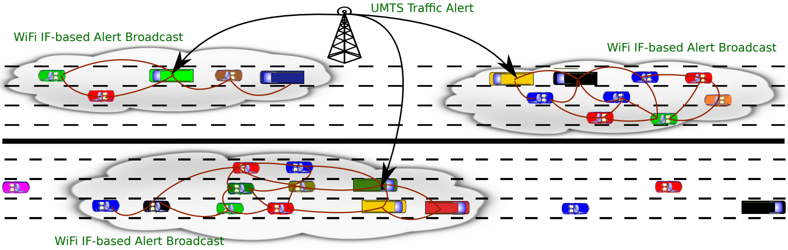
Throughput (communication)

Exploiting “Hot” Traffic Intersections



Idea: extend the coverage of dissemination points (DPs) positioned at “hot” intersections (high traffic, great connectivity)

Cross-Network Effective Traffic Alert Dissemination (X-NETAD, Eureka Label E! 6252)



Idea: rapid diffusion of UMTS-based traffic information through local WiFi networking

From Communication to Traffic Self-organization

- Communication/networking applications: assume a given *traffic model* (e.g., SUMO: car-following models)
- No interest in traffic control
- Traffic accumulation (e.g., jams): very good for connectivity
- Traffic control goal: improve drivers' safety
- Can we *embed* traffic control information in ever increasing vehicular communications?
- Ultimate goal: hidden (to drivers) self-organizing traffic mechanism

Outline

Traffic Self-Organization

- Several (mostly highly theoretical) models, inspired by empirical data:
  - microscopic follow-the-leader;
  - cellular automata-based;
  - continuous Markov chain-based (statistical mechanics);
  - macroscopic;
  - gas-kinetic.
- Several “universal” properties emerge (e.g., transition to congested traffic at bottlenecks and ramps)
- What about traffic *control*?

A Pragmatic Per-road Approach

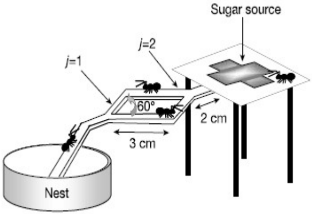
- Define the following "danger" function of a vehicle:

$$f_{\text{danger}}(d, v) = \begin{cases} \dfrac{d_{\text{break}}(v) - d}{d} & 0 < d < d_{\text{break}}(v) \\ 0 & d > d_{\text{break}}(v) \end{cases}$$

  where d is the distance to the preceding vehicle, $d_{\text{break}}(v) \propto v^2$ is the breaking distance
- If all vehicles are moving at the same speed and given an overall space, then minimizing the overall danger function ($\sum_i f^{(i)}_{\text{danger}}$) leads to the intuitive solution that all vehicles should be equally spaced.
- What happens in an urban scenario with intersections, pedestrian crossings, etc., i.e., in a multi-road scenario?
- Other objectives (minimize transit times, e.g., eletrical cars)

Taking Inspiration from Ants

- Foraging ants: form attractive (fastest) trails to food sources through *pheronome*-based mechanisms (reinforcement of pheronome density)
  - *cohesive* forces
- What happens in the presence of bottlenecks?



A. Dussutour, V. Fourcassi, D. Helbing, J.-L. Deneubourg, "Optimal traffic organization in ants under crowded conditions," *Nature* **428**, 70-73 (4 March 2004). doi:10.1038/nature02345.

From Ants to Vehicle Traffic Control

- Ants balance *cohesive* and *dispersive* forces
  - cohesion: pheronome-based
  - dispersive: pushing
- Self-organization can be described through a nonlinear modelling approach (based on inhibitory interactions)
- Mimic this behaviour in realm of traffic control
  - What is an information pheromone?
  - What is the equivalent of pushing?
- Practical perspective: given that we can identify proper messages (e.g., with inertial information) to be disseminated, what is the communication overhead?
- Design goal: self-organize at the minimum communication cost

Outline

1. Our Activities: Communications in VANETs
2. Traffic Self-Organization: Learning from Ants
3. Conclusions

Conclusions

- Where do we come from: vehicular communications
- Self-organization: several existing approaches
- Where we would like to go: embed information "pheromones" in information dissemination packets
- Traffic self-organization at minimum communication cost

THANK YOU
FOR YOUR ATTENTION

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