

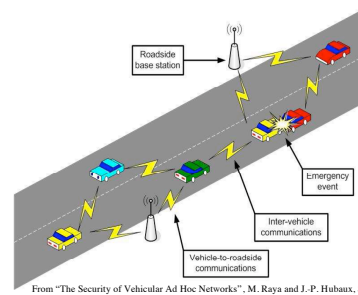
Data Dissemination in Vehicular Ad Hoc Networks

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VANET V2V / V2I Architecture



From "The Security of Vehicular Ad Hoc Networks", M. Raya and J.-P. Hubaux, SASN 2005

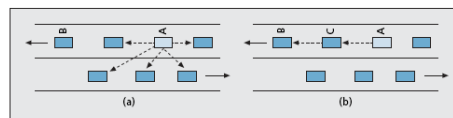
Road-side vehicle communications

- = Directly between vehicle and infrastructure:
 - Sparse, or
 - Ubiquitous (futuristic and expensive)
- Hybrid (inter-vehicle + road-side)

Assumptions

- Central processing unit to run protocols
- Wireless transceiver and GPS receiver
- Sensors to measure various parameters
- Input/output interface for human-vehicle interaction
- Realistically, only a few vehicles will be equipped initially

Single-hop and multi-hop inter-vehicle communications



Diffusion

- = transmitting regular content beacons
- Application collects data from neighboring vehicles, aggregates and stores data
- Current table is transmitted to neighbors at regular intervals, updating their tables
- Nadeem et al 2004
- Wischhof, Ebner, Rohling 2005

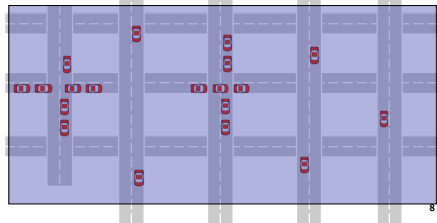
Delivering Road Conditions to Drivers

- **Broadcasting** = data dissemination = warning delivery
 - from one node to all other nodes in the network
- **Geocasting** involves
 - broadcasting of information to all vehicles on a road segment or in a given geographic area,
 - suppressing multiple warnings for the same event,
 - determining boundaries for spreading warnings.

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Problem Statement

- How to reach all vehicles in the selected area, with low message overhead and with high reliability?

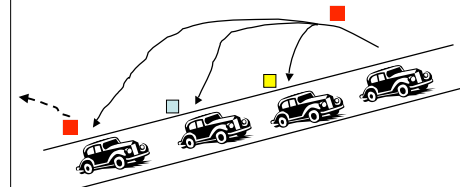


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Inter-vehicle communication: routing or broadcasting?

Sun, Feng, Lai, Yamada, Okada 2000

- Learn neighboring cars on the same highway and direction
- include ID of furthest neighbor in the transmitted message
- furthest neighbor retransmits



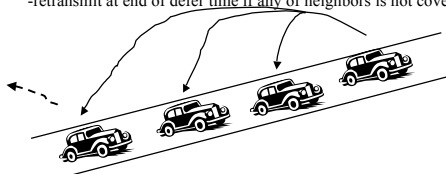
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Inter-vehicle communication with GPS

Sun, Feng, Lai, Yamada, Okada 2000

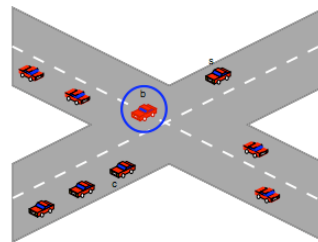
Briesemeister, Schaefers, Hommel 2000

- Include LOCATION with the message
- defer time inversely proportional to distance from vehicle
- discard neighbors covered by any of transmissions
- retransmit at end of defer time if any of neighbors is not covered



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Failure at intersections



S source

C furthest and retransmits

B covered and does not

Cars on other road do not get message

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Opportunistic broadcast

M. Li, W. Lo, K. Zeng, "OppCast: Opportunistic Broadcast of Warning Messages in VANETs with Unreliable Links," IEEE MASS 2009, 534-543.

- 1D broadcasting
- Furthest node from sender retransmit for fast progress
- Node closest to the middle between two senders retransmits for increased reliability
- [SFLYO] does not attempt to deliver to nodes between forwarders

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Probabilistic flooding

- [FM08] Fracchia, Meo, "Analysis and Design of Warning Delivery Service in Inter-vehicular Networks," *IEEE Transactions on Mobile Computing*, 2008.
- Vehicle, after receiving warning message, decides, with probability p , to act as relay and forwards the message.
- few broadcasting cycles, start at regular intervals
 - every D seconds (parameter based).
- The question of which car initiates a broadcast cycle remains unresolved in [FM08].
- The analysis assumes
 - constant density along the safety area and
 - one-dimensional car distribution which allows any car to decide its speed independently.

Drawbacks of existing geocasting

- do not resolve any *temporary disconnection* from the source node. They all assume that vehicles belong to the same connected cluster, except:
- [FM08]: forced additional static flood repeat time parameter with retransmission at sole initiating node in each cycle. It also fails because:
- there is no dynamic mechanism to restart flooding upon discovery of new neighbors (too little),
- Additional flooding may not be necessary (too much).
- Probability p does not adjust quickly to the local network density

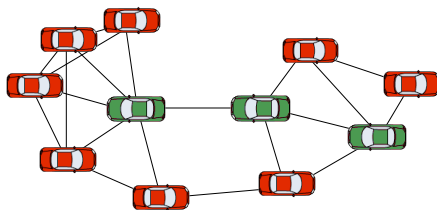
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Highway probabilistic flooding

- Nekovee 2009 (IET Intelligent Transport Systems)
- Front and back counters for received msg copies
- Waiting time includes urgency
- Probabilistic retransmission decision favors large difference in counters and low sum
- Sets another waiting time
- Cluster merging balances counters and reduces retransmission probability
- Problems: one direction traffic only, probabilistic
- Slow merging when one counter is already large

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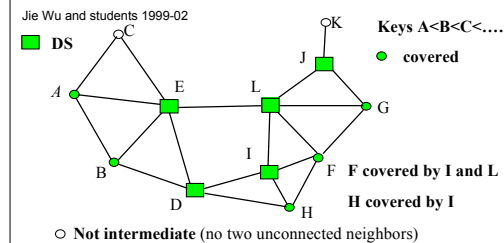
Connected Dominating Sets: CDS



Each node either in *dominating set* or has a neighbor from dominating set

Flooding reduced if only nodes in *connected dominating set* nodes retransmit

Dominating sets by covering



F covered by I, L, ... ← I, L, ... connected and any neighbor of F is neighbor of one of I, L, ... and $\text{key}(F) < \min(\text{key}(I), \text{key}(L), \dots)$

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Parameterless reliable broadcasting

- Ross, Ruiz, Stojmenovic, 2009
- Beacons used by cars to decide whether or not they belong to a connected dominating set (CDS).
- Vehicles in CDS use shorter waiting period before possible retransmissions.
- Identifiers of circulated broadcast messages are added to beacons as *piggybacked acknowledgements*.

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Start forwarder selection

- When node decides that someone should retransmit and starts the process?
- When it receives **new** message (for 1st time)
- *After believing that all neighbors got the message, one neighbors sent beacon without the message ID (or lack of ack in waiting time)*
- **Start**= begin timer and wait until timer expires
- Waiting time depends on number of uncovered neighbors

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Compete to retransmit

- Node that *believes it should be retransmitter*:
- **Compete** = timer expired, I want to transmit
- When waiting timeout expires,
 - *vehicle retransmits if it has at least one neighbor which did not acknowledge circulated message with the last beacon, and*
 - *Medium access resolution in 802.11 style*
 - sets a new waiting period.

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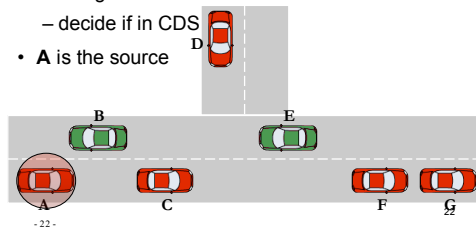
Compatibility with DSRC ?

- Solution requires piggybacking list of received broadcast to periodic beacons,
- not possible or limited with DSRC standard
- Alternative: PBSM
- (Parameterless Broadcasting from Static to Mobile)
- REPEAT
 - Wait for a while, monitor what neighbors are receiving
 - Retransmit if any current neighbor may need message
 - Send regular beacon, neighbors change
- UNTIL message outdated
- Khan, Stojmenovic, Zaguia, 2008 (2-hop variant)

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Detailed AckPBSM example

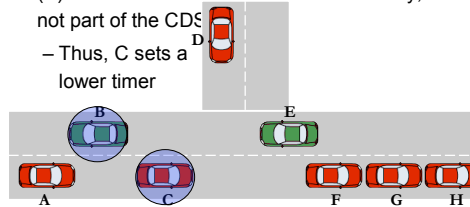
- Vehicles periodically send beacons including their position and recently received ACK messages
 - decide if in CDS
- **A** is the source



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Detailed AckPBSM example

- **B** and **C** receive the message
- **C** is part of the CDS because it has a neighbor (**E**) which is not reachable from **B**. Similarly, **B** is not part of the CDS
 - Thus, C sets a lower timer

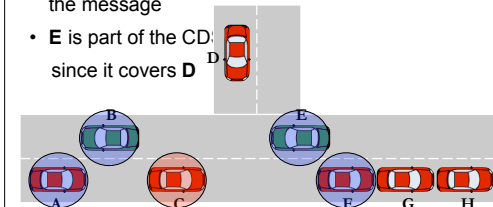


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Detailed AckPBSM example

- **C** transmits, **E** and **F** receive the message
- **B** cancels its retransmission upon reception of the message
- **E** is part of the CDS since it covers **D**

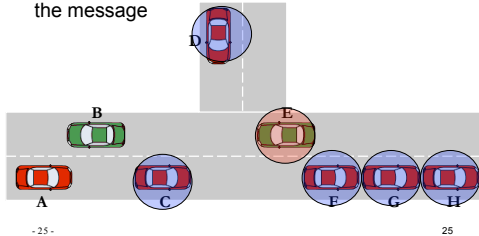


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Detailed AckPBSM example

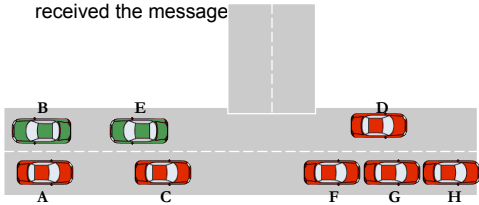
- E transmits, D, F, G and H receive the message
- F cancels its retransmission upon reception of the message



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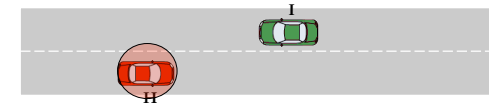
Detailed AckPBSM example

- Let's assume D enters the main road and overtakes
- F, G and H do not need to retransmit, because D is reporting in its beacon that he already received the message



Detailed AckPBSM example

- H now meets new vehicle I
- As I has not reported the reception of the message, H retransmits it
 - Let's assume that the transmission fails
- In the next beacon interchange H realizes and retransmits.



Multi-message broadcasting

- Link duration between cars may limit number of messages/packets exchanged
- ackPBSM has packet length issue to ack all msg
- Network coding NC based on XOR can be applied to transmit combined message
- NC to disseminate k packets of same message: Huang, Wang, Zhang MSN 2009 (no XOR)
- Directional antennas and CDS can be applied to restrict receiving area (or use road ID and movement direction as part of packet) Yang Wu

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