microSlotted 1-Persistence Flooding in VANETs

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Traffic Jams...

- pollution
- noise
- waste of time
- unsafe situations

On political agenda

Solutions:
- More roads
- Fewer vehicles
- Increase efficiency
Civil Engineering meets Computer Science

The Congestion Assistant\(^1\)

- Supports drivers in traversing traffic jams

Requires *Over-the-Horizon Awareness*

\(^1\) C.J.G. van Driel, Driver Support in Congestion, PhD. Thesis
V2I - Vehicles communicate with infrastructure

V2V - Vehicles communicate with each other

V2I

- Internet
- Traffic Mgt HQ
- Other services etc.

RSU

GSM
UMTS
GPRS

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Vehicular Ad hoc NETworks

- Vehicles that meet by chance communicate
- Short-lived communication: peers may rapidly move out of range
- “unfriendly” environment: Doppler, fading etc.
- IEEE 802.11-compatible PHY and MAC in development

traffic jam at position \( x \)
Flooding in VANETs

- Send information to all (or large subset) of vehicles, use flooding!
- Use IEEE 802.11-compatible PHY and MAC, so must do this at the Network layer
- Flooding is notoriously inefficient (power, goodput) when used irresponsibly
- May trigger Broadcast Storm

**Blind Flooding**: upon receiving a message, a node repeats the message
Flooding in VANETs
Flooding in VANETs

transmission range

HEY!
Flooding in VANETs

![Diagram showing cars and a tree with speech bubbles saying "HEY!"

T=0

COLLISION!!1

transmission range

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Flooding in VANETs

Hmm.. need a system to do this...
Flooding in VANETs

Found in literature: **Slotted 1-Persistent Flooding**

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\(^1\)Wisitponghan *et al.*, “Broadcast Storm Mitigation Techniques in Vehicular Ad hoc Networks”, 2006
Many flooding strategies (primarily for MANETs) exist. Some are applicable to VANETs (after minor adaptation). Wisitpongphan et al. evaluate four approaches, and we choose the best: Slotted 1-persistent flooding.

- **T=0**
- **T=st**
- **T=2st**
- **T=3st**
- **T=4st**

- **transmission range**
- **distanceToSender**
- **update!**
- **transmit immediately**
Slotted 1-Persistence Flooding

• Slots function as a means to break the synchronisation of rebroadcast:
  – Probability of collision is reduced
• BUT slots also synchronise when multiple vehicles reside in same slot:

Synchronises vehicles *within* slot, high probability of collision with many vehicles.
Intermezzo: 802.11p broadcast

- Special flavour of 802.11 for VANETs: 802.11p
  - Changes predominantly in modulation
    (~half-clocked 802.11a)
- Most communication will be broadcast
- CSMA/CA:
  - node picks $bc$ from CW
  - $bc$ when channel idle for time $\sigma$
  - transmit when $bc==0$
- Contention Window: $(0, \cdots, 15) \rightarrow 16$ possible $bc$s
Typical Dutch Traffic Jam

160 vehicles/lane/km, 4 lanes
transmission range 250m, 5 slots
→ so we have 32 vehicles in one slot!

- 32 Vehicles choose from CW of size 16...
- Probability of collision increases as number of vehicles in slot increases, called Timeslot Boundary Synchronisation Problem

\[ \text{References} \]

\[ \text{J.J. Blum and A. Eskandarian, “Avoiding timeslot boundary synchronization for multihop message broadcast in vehicular networks”, VTC 2009.} \]
microSlotted 1-Persistence Flooding

- Breaks synchronisation within slot
- Add small delay depending on distance:

\[ T_{msij} = \left\lfloor N_{ms} \left( 1 - \left\lfloor \frac{\min((D_{ij} \mod S), S)}{S} \right\rfloor \right) \right\rfloor \text{DIFS} \]

Full analysis in \(^3\). Next sheets show some highlights.

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Simulation (OMNeT++ with Mobility Framework)
10km highway, mobility by IDM
802.11(p) PHY/MAC, communication range $\sim 250\text{m}$
100% communicating vehicles
No gaps larger than R
Delay, number of hops, medium utilisation lower with microSlots
Reachability higher with microSlots

- Propagation with MicroSlots
- Propagation without MicroSlots
Slotted VS microSlotted cont’d

![Graph showing slot utilization with and without microslots](image-url)
Fewer collisions: rebroadcast in later slots not needed
First rebroadcast succeeds: low delay
Spend less time doing more
Conclusion

- Especially under high vehicle densities flooding is challenging: → need a good broadcast suppression technique
- Slotted 1-Persistence Flooding found to scale poorly with vehicle density
- Proposed microSlotted scheme outperforms Slotted scheme
- Using V2V communications, 10km can be bridged in 50–200ms
—EMERGENCY USE ONLY—
Flooding in VANETs

Differs from flooding in MANETs:

- Node movement is restricted to geographically defined grid
  - Abstracts to a line or mesh
- Speeds can be very high, moments of contact short
- Nodes generally have abundant power
- Size of equipment is less limited
- Modern vehicles have GPS locators (comes in handy)
The Simulator

- OMNeT++ is Open Source (C++)
- VERY modular
- Mobility Framework provides base classes for own Mobility Model
- MFw provides IEEE 802.11b reference implementation
The Mobility Model

- Nodes move in a straight line: a one-lane highway
- Node mobility is governed by the Intelligent Driver Model:
  - Speed is adjusted based on distance and relative speed of vehicle in front
  - Evaluated 10 times per second
- Problem: requires knowledge of vehicle in front
- Solution: provide hack in simulator

ChannelControl Module maintains list of interferers (based on position). ChannelControl has full global knowledge, so it can provide $d$ and $\Delta v$ to vehicle in front:

```c
double getHeadway(int id, Coord* ownPos, double* peerSpd);
```
Intelligent Driver Model\textsuperscript{4}

\[
\frac{dv}{dt} = a^{(\alpha)} \left[ 1 - \left( \frac{v_\alpha}{v_0^{(\alpha)}} \right)^\delta - \left( \frac{s^*(v_\alpha, \Delta v_\alpha)}{s_\alpha} \right)^2 \right]
\]  \hspace{1cm} (1)

\[
s^*(v, \Delta v) = s_0^{(\alpha)} + s_1^{(\alpha)} \sqrt{\frac{v}{v_0^{(\alpha)}}} + T^{\alpha} v + \frac{v \Delta v}{2 \sqrt{a^{(\alpha)} b^{(\alpha)}}}
\]  \hspace{1cm} (2)

Or: change in speed is dictated by distance to the vehicle in front and speed of both vehicles.

\textsuperscript{4}Treiber et al., 2000
Set-up:

- Transmission range $\approx 250m$
- Interference range $\approx 500m$
- 100 floods per run, 50 runs per density
- different densities: $\rho \in [10, 15, 20, 30, 40, 50, 60, 80, 100, 125, 150, 200]$
- Nodes move on one-way one-lane “highway”
- Placed with uniformly distributed spacing
- Guarantees fully-connected network
- Reduced speed zone: 4-6km (mobility only)
Slotted vs. microSlotted:

Hop count: less hops are needed for microSlotted scheme

Delay: microSlotted has shorter delays
Slot utilisation: microSlotted uses slot 0 more often (optimal)

End-to-end propagation: microSlotted allows greater reachability
Medium utilisation is high for slotted scheme

- Culprit: Slotted generates lots of collisions
- As a result, utilisation of slots 1, 2, 3 and 4 is high
- Ultimately, floods stop if slot 4 collides
- All these collisions cause high medium utilisation
- What does come through, suffers delay
- → microSlots used in TrafficFilter system
Influence of Mobility: static vs. IDM with jam between 4 and 6km

Hop count: results differ little

Delay: mobility has little influence
Slot utilisation: node distribution is different, this explains differences

end-to-end propagation: density $\geq 30$ has no gap, hence end-to-end propagation is high.
Flood traces: position of reception of a unique flood ID

\[ \leftarrow \rho = 10 \]
\[ \rho = 15 \rightarrow \]

\[ \leftarrow \rho = 20 \]
\[ \rho = 30 \rightarrow \]
Different timescales: to comm. mob. seems static

IDM generates different distribution of nodes: gaps exist

At high density vehicles hardly move → resembles static

Gaps in network fundamental problem (out of scope)
Speed / Position information is vital for correct operation of Congestion Assistant.

- A solution using V2V communication has been proposed, communicates highly compressed and relevant information in a very efficient way.
- Based on simulations, this solution looks promising.
- Correct functioning depends on thresholds and traffic dynamics. The two must match for optimal performance.
- Resulting TrafficMap useful as input for the Congestion Assistant (still a bit work in progress).
General Conclusions

- VANETs have the potential for very high node densities; collisions easily occur when flooding.
- Fundamental problem: crossing gaps in network
  - Some proposals are to use opposite lane as carrier
  - For this application, no vehicles means no jam, so no problem!
  - BUT... there might be a jam a km ahead, want to see that coming too!
- Future work: How to cope with complex road networks?
(a,b) Dahui et al., Hysteresis phenomena of the intelligent driver model for traffic flow, 2007

(c,d) Own IDM implementation
Shiny time-position-speed plot of the IDM at work: