Data Preference Matters: A New Perspective of Safety Data Dissemination in Vehicular Ad Hoc Networks

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Outline

Introduction

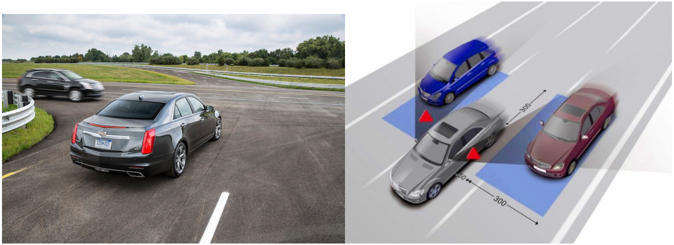
Vehicular Ad Hoc Networks

- Communication infrastructure for Intelligent Transportation Systems (ITS)
- Operate in a dynamic environment

Introduction

Safety Data Dissemination

- Crucial for vehicle safety
- Contain periodic routine data and event-driven emergency data
- More emphasis on QoS, e.g., small delay and high coverage



(a) Collision Avoidance (b) Lane Change

Sources: *www.gm.com* and *www.Mercedes-Benz.com*

Data Preferences

- When collecting safety data, vehicles have preferences on
  - **Closer, Newer and More important data**
- Related works do not consider these preferences
  - Counter-Based Dissemination
  - Farthest-First Dissemination
  - Probabilistic Forwarding

Our Focus

- Quantifying data preferences
- Designing lightweight distributed dissemination protocol
    - Satisfying data preferences of all the vehicles
- Understanding system benefits

Outline

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Data Preferences

- Vehicles show the following preferences when collecting safety data:
  - **Spatial preference**: the closer, the better;
  - **Temporal preference**: the newer, the better;
  - **Type preference**: the more important, the better.
- Quantify these preferences on a per-packet level

$$\text{Packet Value} = \text{Spatial Value} \times \text{Temporal Value} \times \text{Type Value}.$$

- Given a packet p, its **packet-value** for vehicle v:

$$PV_v(p) = S_v(p) \cdot T_v(p) \cdot W_p.$$

Spatial-Value Function

Given a data packet p, its spatial-value

- decreases as p is disseminated away from its origin;
- becomes zeros after p exceeds the **Range of Interest**.

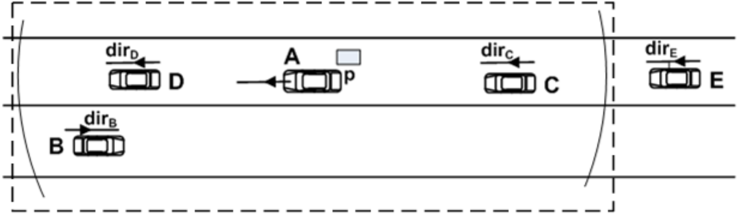


Figure: Region of Interest

Spatial-Value Function

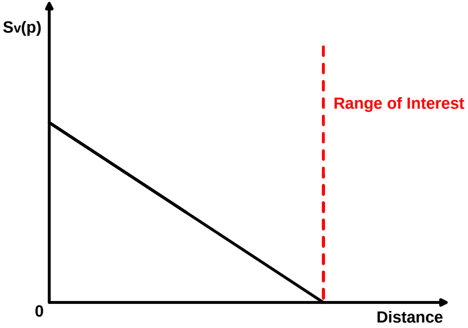


Figure: Spatial-Value vs. Dissemination Distance.

$$S_v(p) = \begin{cases} max(\alpha - \beta d_{pv}, 0), & \text{if vehicle } v \text{ moves towards } (x_p, y_p) \\ 0 & \text{otherwise.} \end{cases}$$

Temporal-Value Function

- Collecting real-time data is crucial for safety applications;
- New packets have much higher temporal-value than old ones;

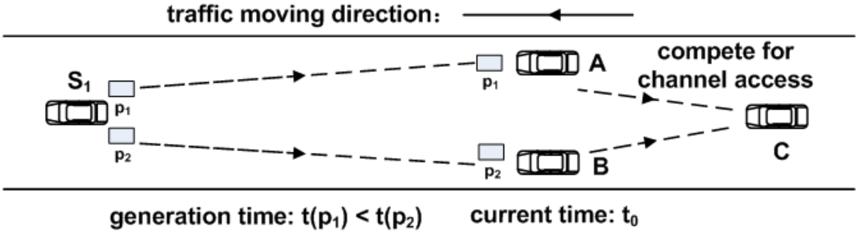
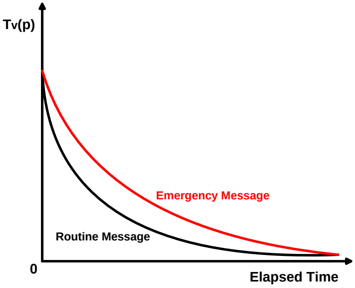


Figure: New data should be disseminated first.

Temporal-Value Function

- Temporal-value decreases as time elapses;
- The decreasing speed becomes slower with time;
- Old packets still have value, e.g., for statistic analysis.



$$T_v(p) = e^{-\mu_{type_p} t_e(p)}.$$

Figure: Temporal-Value vs. Elapsed Time.

Type-Value Function

- Emergency messages are more important than routine messages.

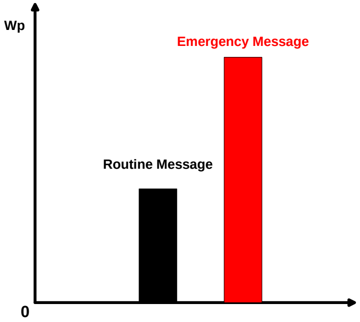


Figure: Type-Value vs. Message Types.

Quantifying Data Preferences

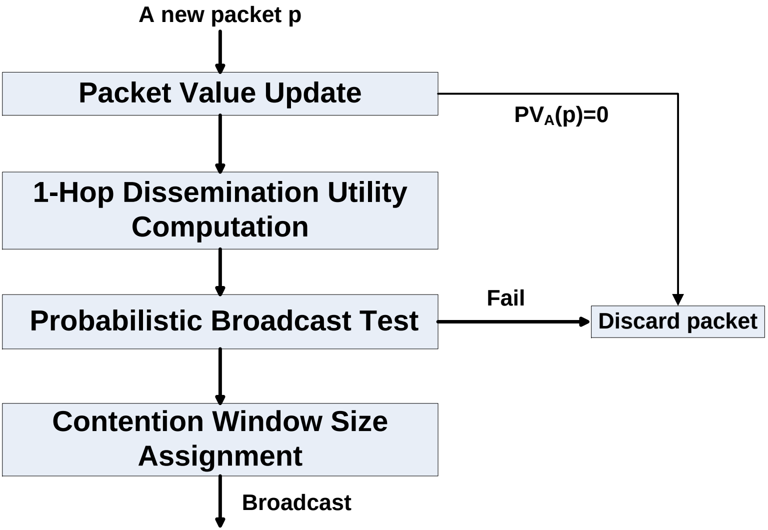
Putting pieces together,

$$PV_v(p) = S_v(p) \cdot T_v(p) \cdot W_p.$$

Packet-value data preference: Given any two packets p_1 and p_2, vehicle v always has a higher data preference to p_1 over p_2 if $PV_v(p_1) > PV_v(p_2)$.

Outline

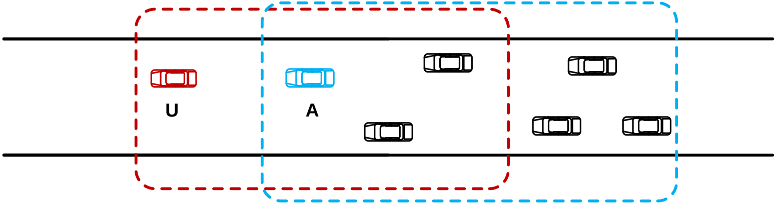
PVCast in A Nutshell



1-Hop Dissemination Utility

Utility = Packet Value × Effective Dissemination Coverage.

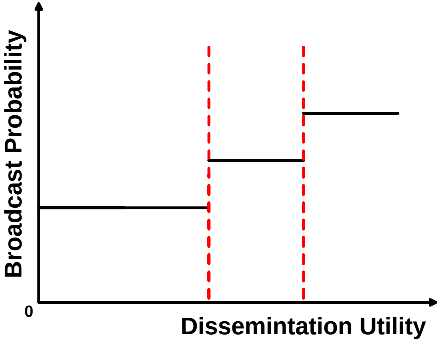
Effective Dissemination Coverage



$$edc_A(p) = 5 - 2 = 3$$

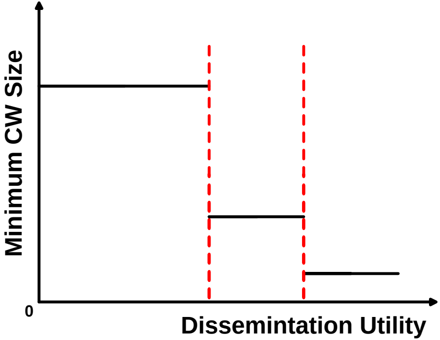
Probabilistic Broadcast Test

- Piecewise function of dissemination utility
- Higher dissemination utility
  → Higher chance for broadcasting



Contention Window Size Assignment

- Piecewise function of dissemination utility
- Higher dissemination utility
  $\rightarrow$ Smaller minimum CW size
  $\rightarrow$ Higher priority to get channel access



Outline

Simulation Settings

- 2000m $\times$ 30m two-way road
- Speed limit: 100kph
- SUMO-generated vehicle trace, $N \in \{20, 40, 60, 80, 100\}$
- Transmission range: 300m
- Range of interest: 1200m
- Routine message: 10/sec
- Emergency message: 1/sec with 0.5 probability in certain segment

Simulation Settings

Comparison

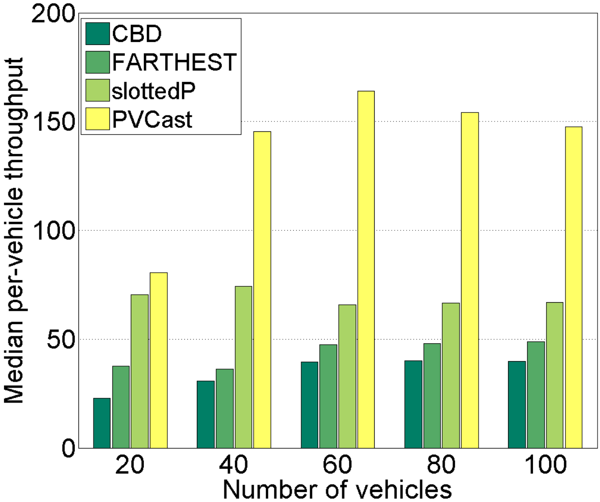
- CBD, FARTHEST, slottedP and PVCast

Metrics

- Per-Vehicle Throughput
- Broadcast Rate
- Broadcast Efficiency
- Per-Packet Delivery Delay
- Per-Packet Vehicle Coverage
- Per-Vehicle Emergency Throughput

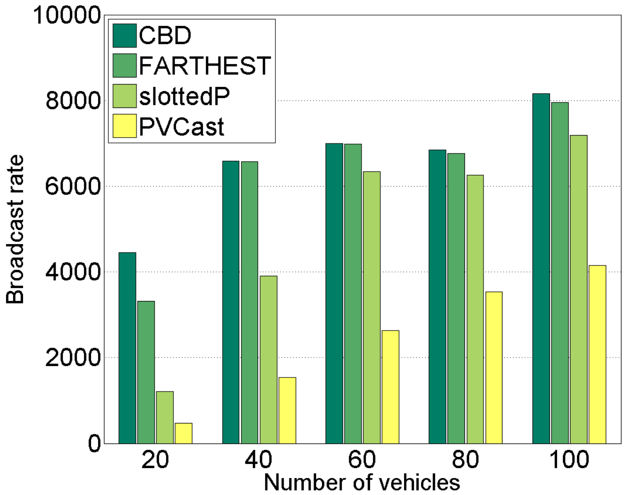
Evaluation Results

Per-Vehicle Throughput (pkt/sec)



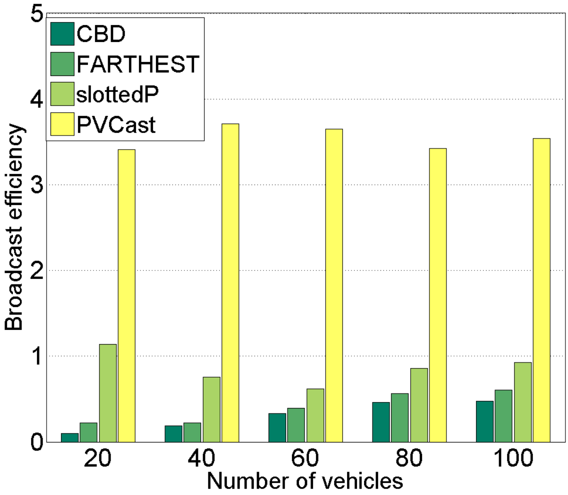
Evaluation Results

Broadcast Rate



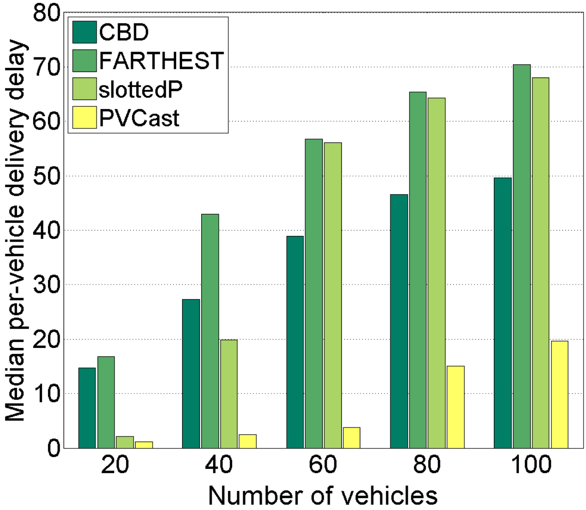
Evaluation Results

Broadcast Efficiency



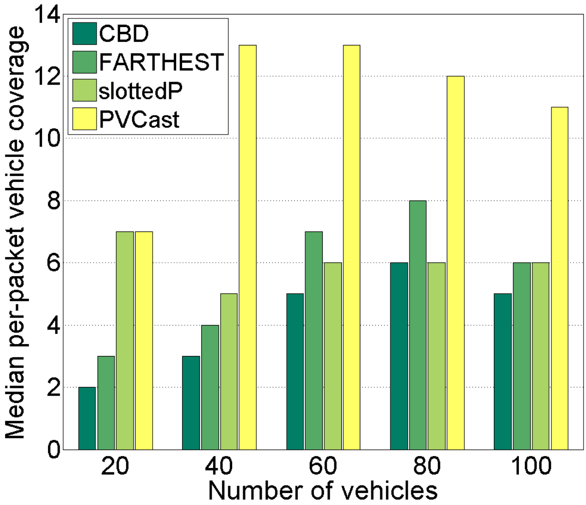
Evaluation Results

Per-Packet Delivery Delay (ms)



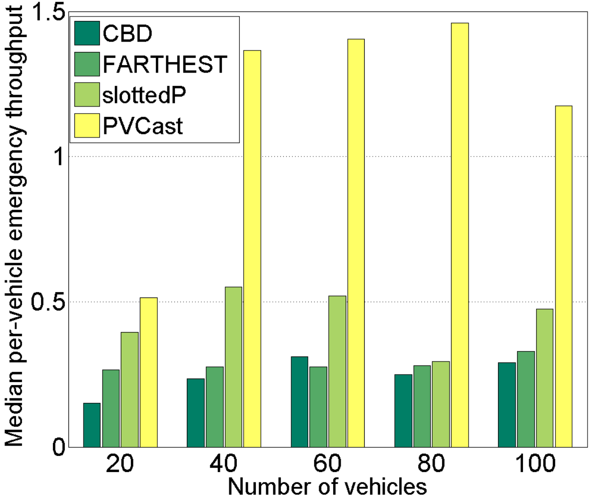
Evaluation Results

Per-Packet Vehicle Coverage



Evaluation Results

Per-Vehicle Emergency Throughput (pkt/sec)



Outline

Conclusion and Future Work

Conclusion

- Quantification of data preferences in VANET
- Integration of data preferences in the design of dissemination protocol
- System benefits in terms of low latency and high coverage

Future Work

- A more comprehensive model of data preference
- Joint adaption of power, data rate and contention window based on packet-value