Exploiting Opportunities in V2V Transmissions with RSU-Assisted Backward Delivery

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Outline

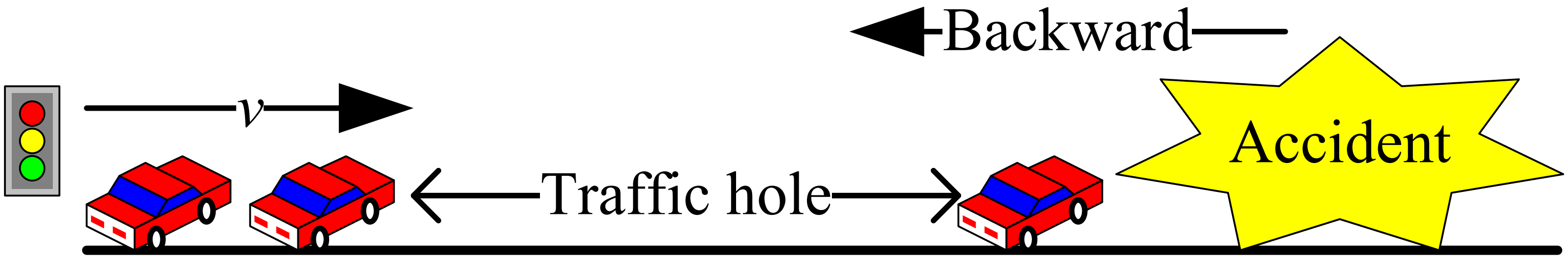
- ***Motivation***
- Problem statement
- RSU-Assisted Backward Delivery
- Simulation results
- Conclusion

Motivation

- The vehicle-to-vehicle (V2V) data transmissions in VANETs have been applied in many areas including the Internet of Vehicles, mobile data offloading, and mobile crowdsensing.
- Timely and lossless multi-hop data delivery among vehicles is essential for VANETs, and various routing protocols have been proposed for infrastructure-less vehicle-to-vehicle (V2V) communications.
- Due to intermittent connectivity in VANETs, the type of movement-assisted routing protocols adopts the carry-and-forward mechanism by considering the delay-tolerant network (DTN).

Backward delivery

- The V2V-based data delivery that is the opposite of the moving directions of vehicles, termed as backward delivery against the traffic flow, is blocked by the existing problem of a traffic hole.



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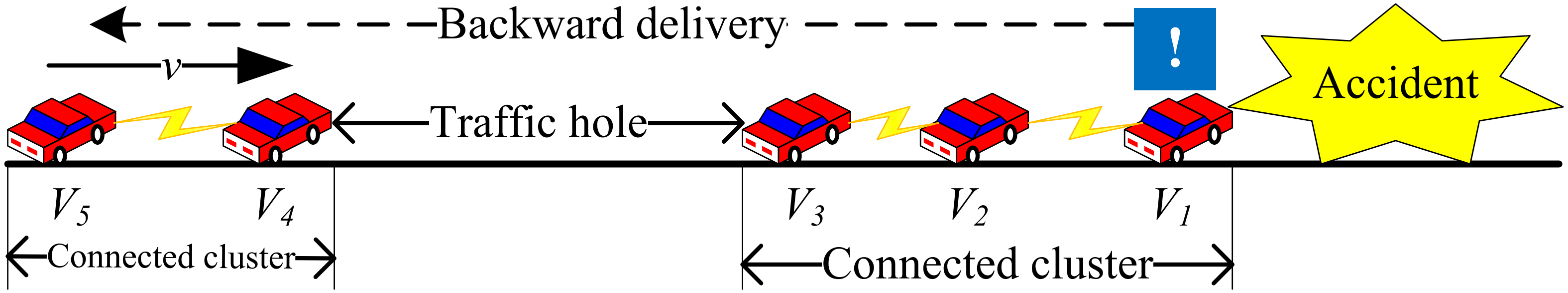
Backward Delivery

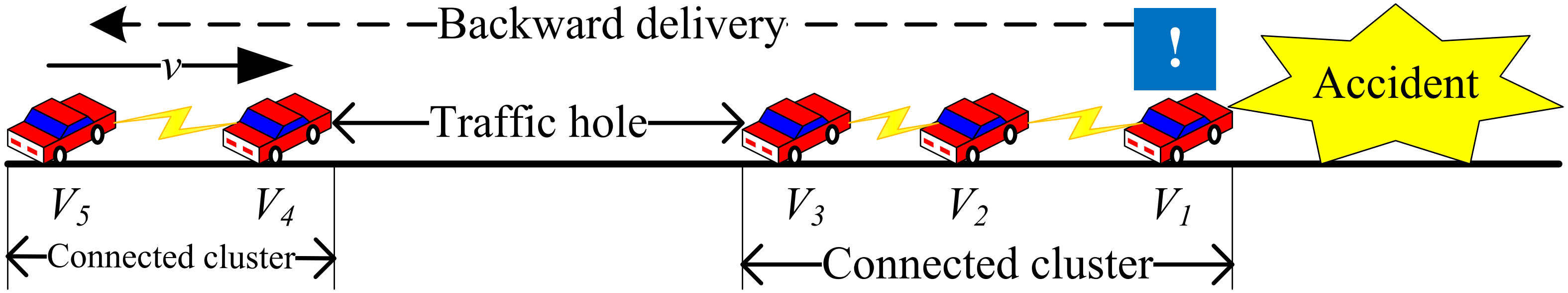
- In sensing applications, vehicles need to obtain the conditions about the roads that lie ahead of them.

- The total data delivery delay is calculated from the interval time between when the first vehicle V_1 generates the alert message and when V_5 receives the message, which is denoted by $\sigma_{1\rightarrow 5}$.



Traffic Hole Problem

- Data delivery with V2V communications in VANETs is based on the vehicles on the roads, but the distribution of the vehicles could be affected by their mobilities or by external means, such as traffic lights.
- A gap with a distance larger than the communication range of the vehicles could appear along the traffic flow; this is considered a traffic hole.
- It could block the data delivery along the traffic flow.



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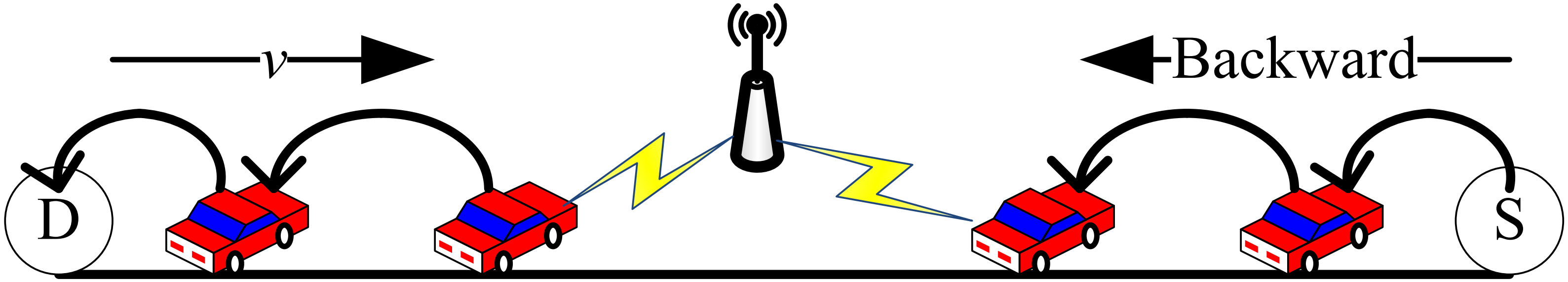
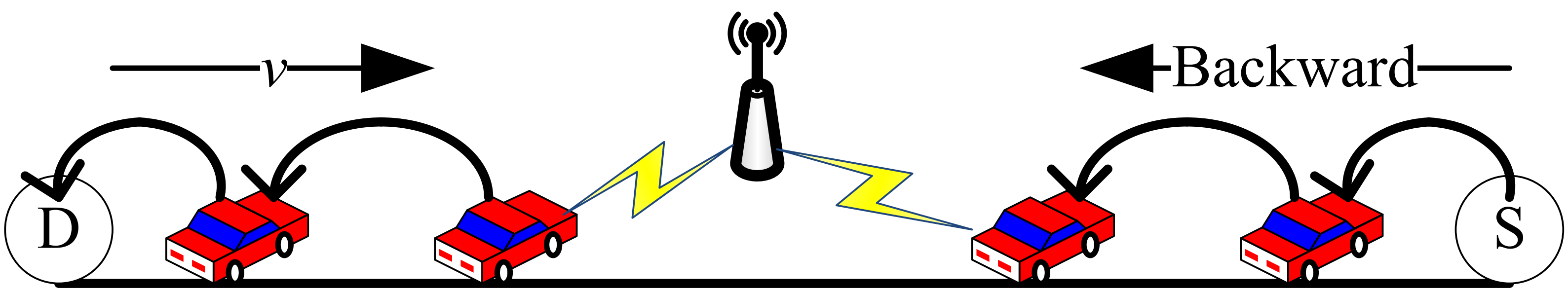
RSU-Assisted Backward Delivery

- We can utilize some static road-side units (RSUs) to help forwarding the packets to reduce the data delivery delay.
- An RSU can be a wireless access point, a parked vehicle, vehicles waiting at an intersection, or the static node.
- The RSU only acts as a relay, so it incurs a lower cost than a traditional access point.



Upload link

- We assume that the quality of the upload-link from the vehicle to an RSU is unreliable. The probabilities of upload-links between the i^{th} vehicle and the road-side unit are denoted by P_i, which are independent and identically distributed (i.i.d.).
- Due to the powerful communication capability of the RSU, we assume that the download-link from the RSU to the vehicle is reliable and that its PDR is equal to 1.



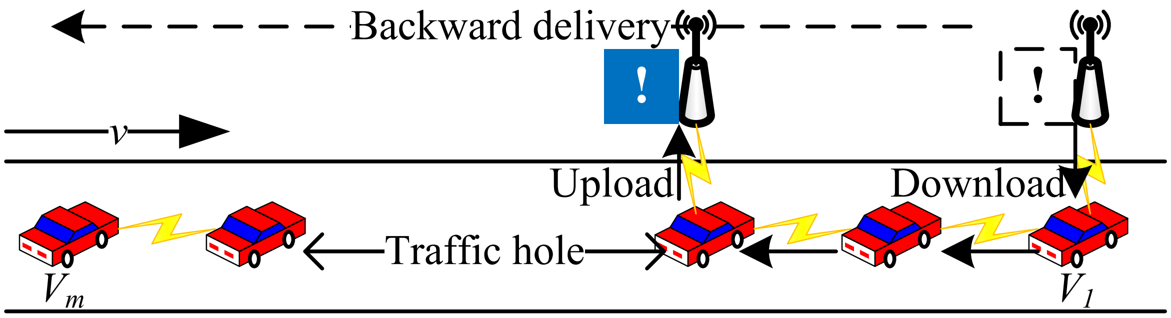
Single-copy scheme of RABD

Step 1 (Intra-cluster forwarding): the data packet is forwarded to the specified vehicle in the connected cluster, such as the j^{th} vehicle;

Step 2 (Uploading): the j^{th} vehicle tries to upload the data packet to the RSU with an unreliable upload-link. If the vehicle fails to upload the data packet, it will carry the packet until the next upload-link to the next downstream RSU;

Step 3 (Downloading): the RSU sends the data packet to the first vehicle in the next connected-cluster;

Step 4 (Receiving): repeat step 1 until the target vehicle receives the data packet.



Conditional Expected Delay

- Let $E[\sigma_n \mid K_1 = k_1]$ denote the expected data delivery delay from the first vehicle in the first connected cluster to the last vehicle in the nth connected cluster, when the number of the vehicles in the first connected cluster (K1) is equal to k1.

$$E[\sigma_n \mid K_1 = 1] = \frac{d}{v}[(n-1)(\beta+\gamma-1) + \frac{q}{p}w]$$

$$E[\sigma_n \mid K_1 = 0] = 0,$$

$$E[\sigma_n \mid K_1 = k_1]$$
$$= \frac{d}{v}[\frac{p+1}{p}k_1 - \frac{1}{p} + \frac{q}{p}w + (n-1)(\beta+\gamma) - n]$$
$$+\frac{1}{p}E[\sigma_n \mid K_1 = k_1 - 1] \ (k_1 \geq 1)$$

Expected Delay

- We assume that the number of vehicles in a connected cluster follows a geometric distribution.
- The expected data delivery delay can be calculated as follows:

$$E[\sigma_n] = \frac{\lambda}{1-\lambda} u(1-\lambda),$$

where

$$u(z) = \frac{f_1 z - \phi(z)}{1 - \frac{z}{p}},$$

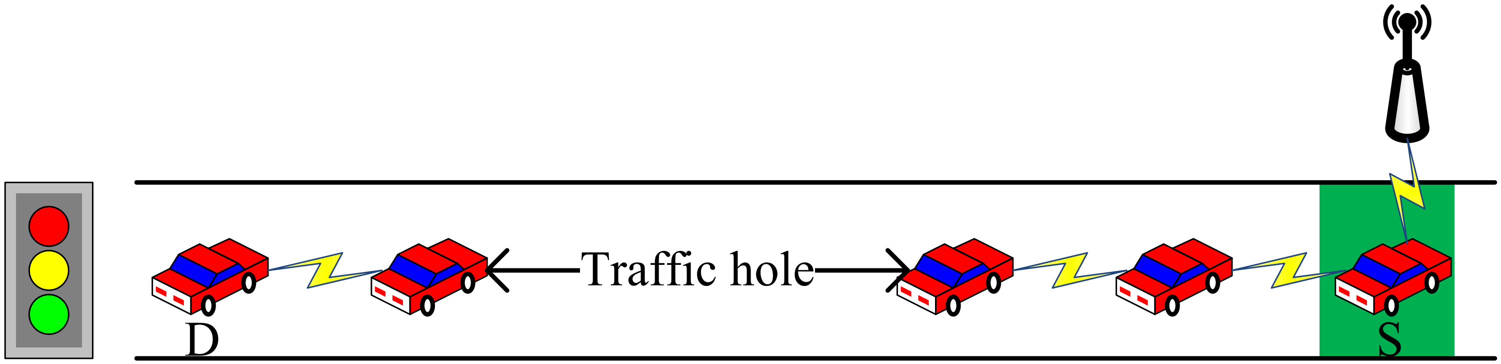
and

$$\phi(z) = \sum_{k=2}^{\infty} (ak+b) z^k$$
$$= a \cdot z\left(\frac{1}{(1-z)^2} - 1\right) + b \cdot \left(\frac{1}{1-z} - 1 - z\right)$$

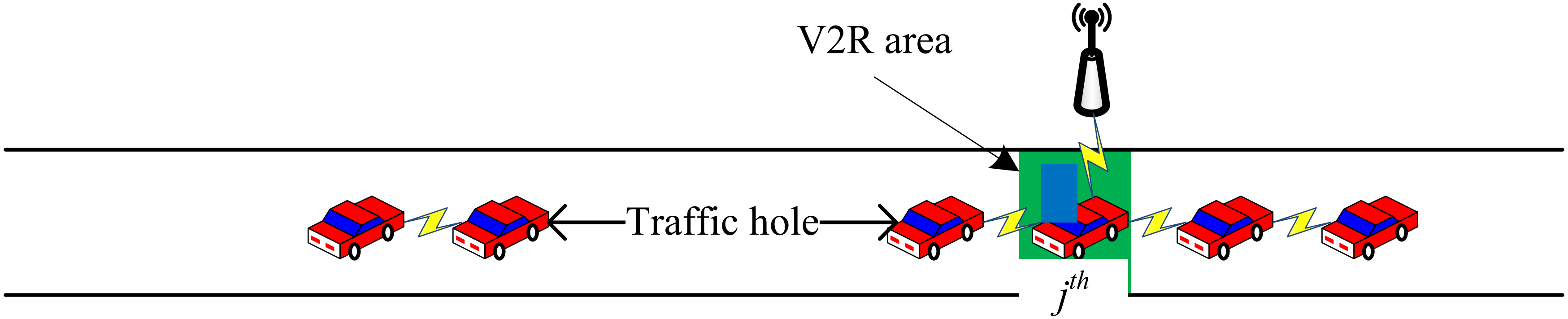
Extensional Schemes of RABD

- Two-copies scheme of RABD:
  - Two ways for backward delivery: V2R backward delivery and V2V backward delivery.
  - Each method of backward delivery only has one copy of the data packet.
- Multiple-copies scheme of RABD:
  - Two ways for backward delivery: V2R backward delivery and V2V backward delivery.
  - During backward delivery, all the contacted vehicles and RSUs will have a copy of each data packet.

Comparisons

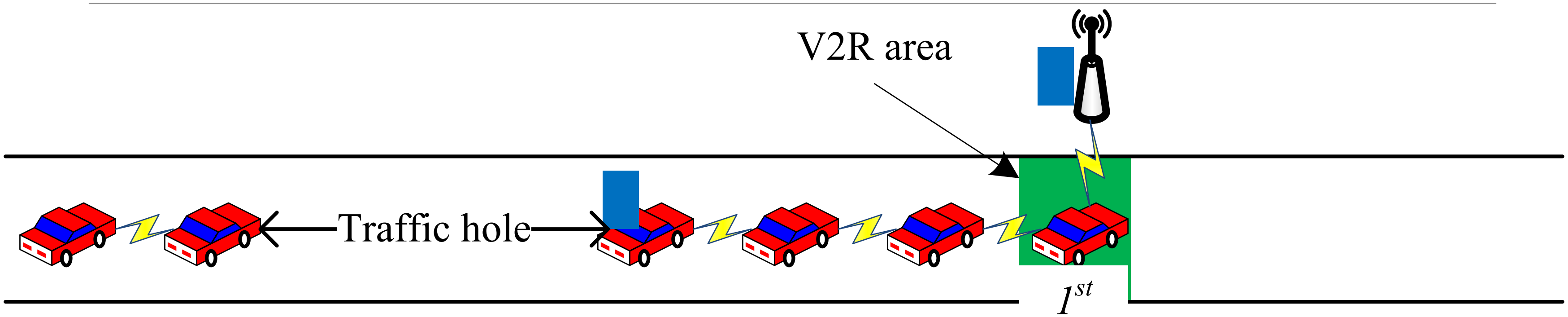


(a) Backward delivery under traffic hole

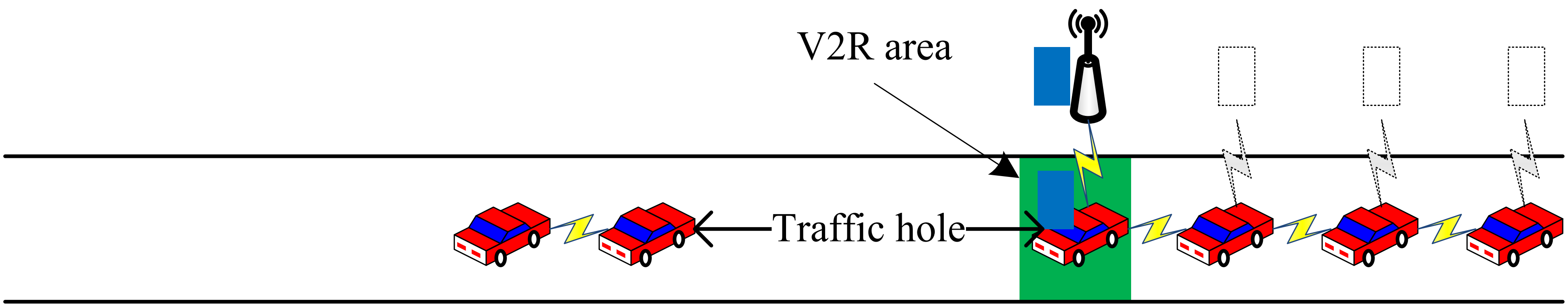


(b) Single-copy scheme of RABD

Comparisons



(c) Two-copy scheme of RABD



(d) Multiple-copy scheme of RABD

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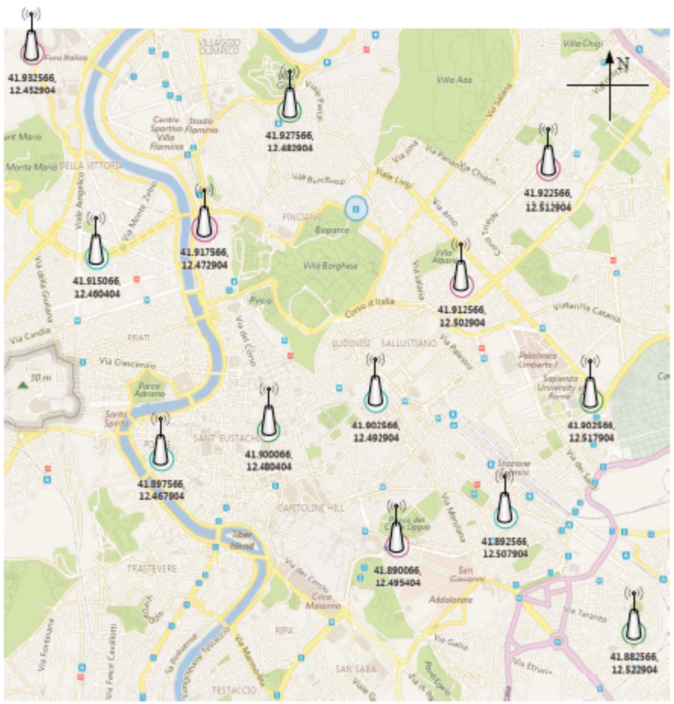
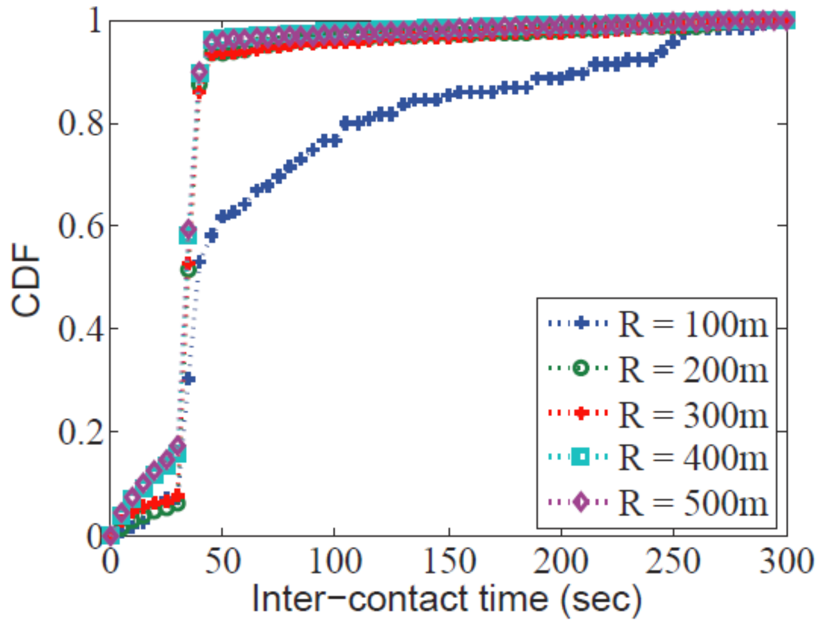
Inter-contact time with RSUs

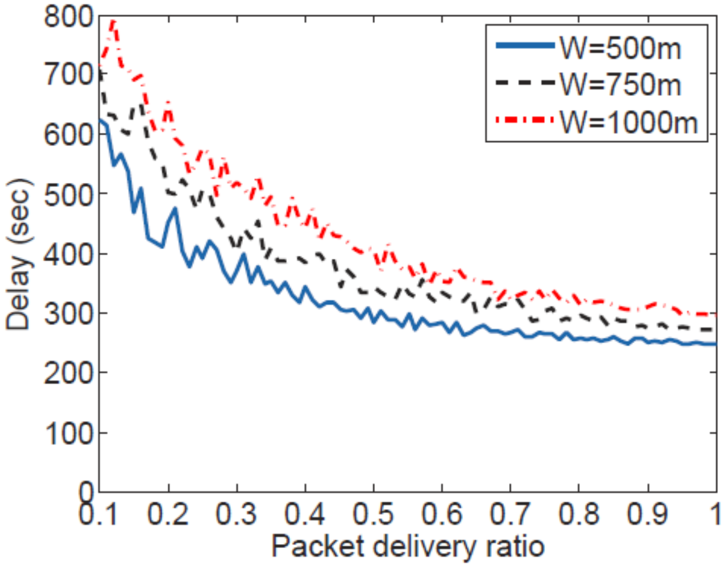


(a) Map of Roma

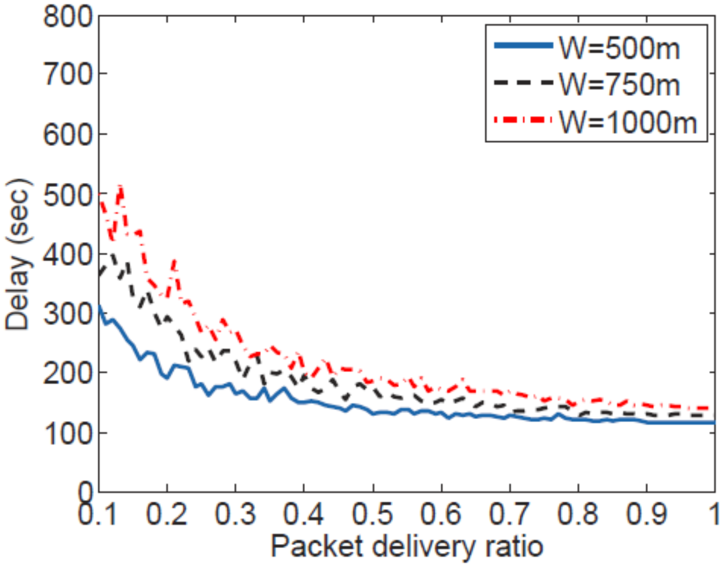


(b) CDF of ICT

Impact of PDR on data delivery delay with the single-copy scheme

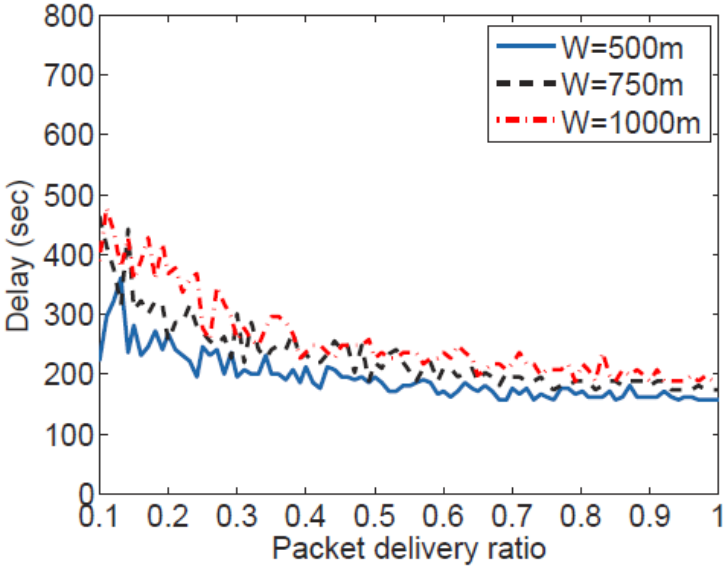


(a) $v = 10$ m/s

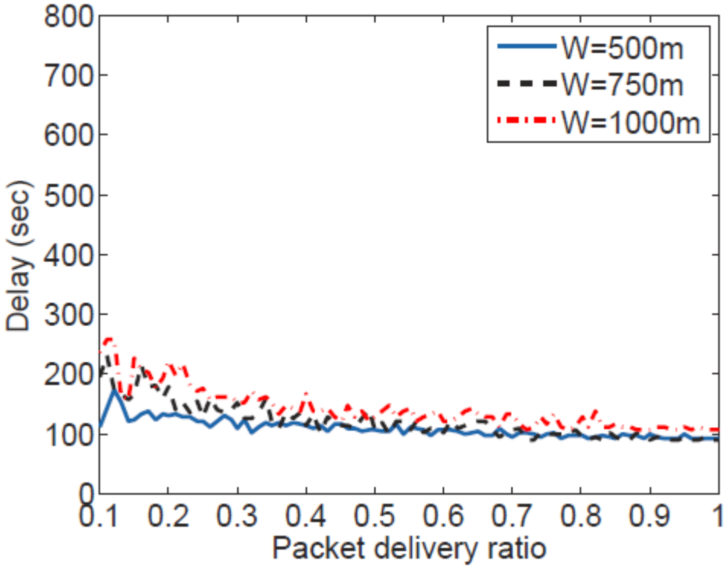


(b) $v = 20$ m/s

Impact of PDR on data delivery delay with the two-copies scheme

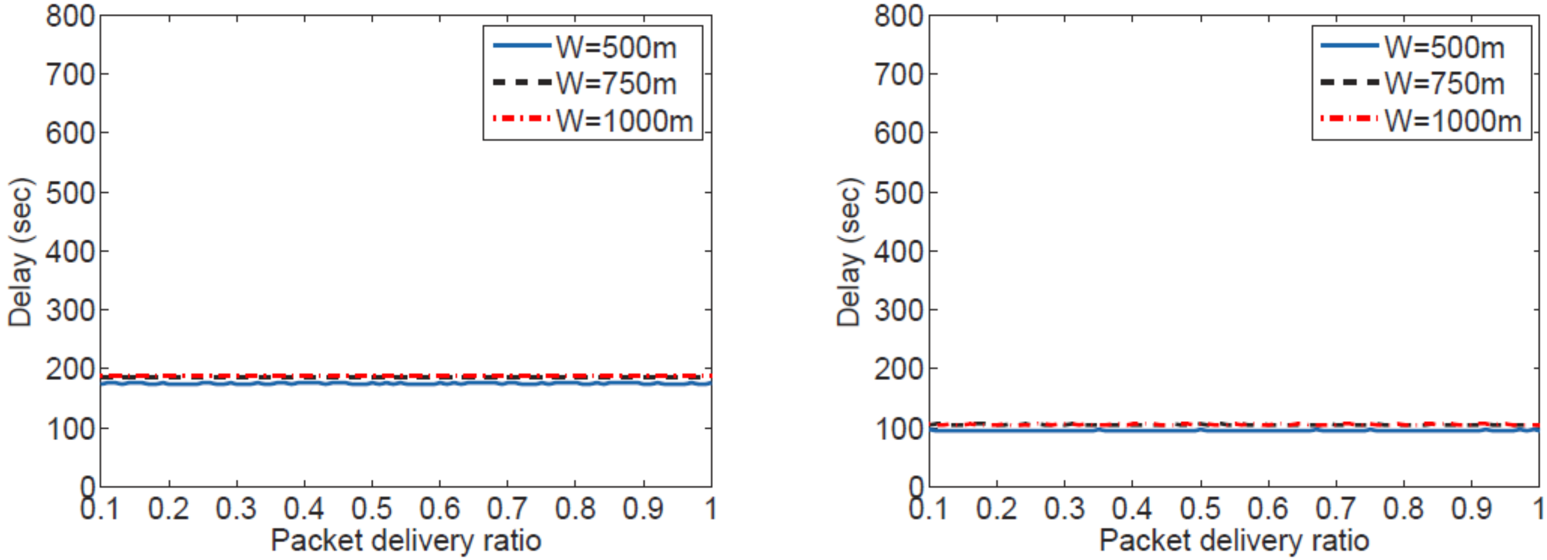


(a) $v = 10$ m/s



(b) $v = 20$ m/s

Impact of PDR on data delivery delay with the multiple-copies scheme



(a) $v = 10$ m/s (b) $v = 20$ m/s

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Conclusion

- Backward delivery with the traffic hole problem

- RSU-Assisted Backward Delivery

- Future work

Thank you!

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