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Broadcasting messages in V2V communication for safety applications

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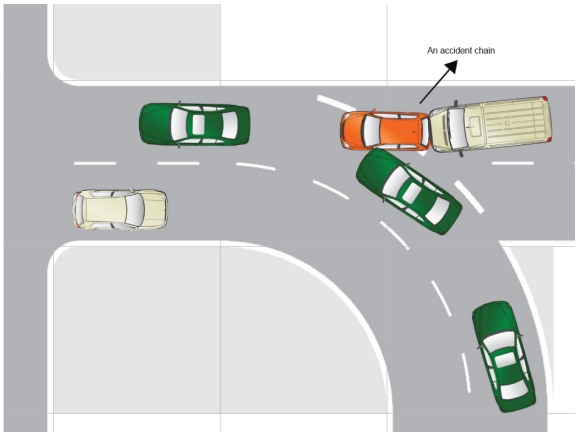
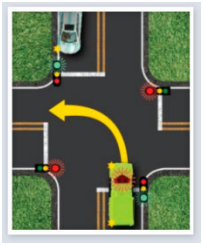
Motivations



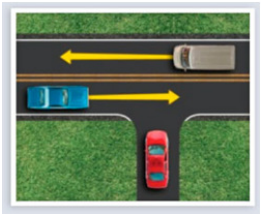
An example of an accident chain.

Safety applications can improve road safety by informing drivers about the dangers ahead.

Safety Applications

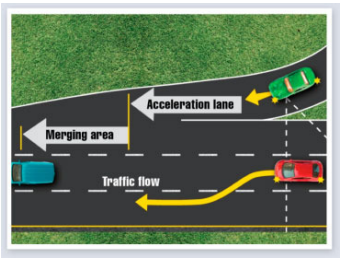


Entering intersection warning.



Entering the roadway.

Obstacle discovery.



Lane change warning.

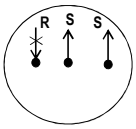
The standard and requirements

- Standard:
  - Using the Dedicated Short-Range Communication (DSRC) standard (or IEEE 802.11p) to broadcast messages.
- Safety application requirements: Standard (2010), Hassan (2011):
  - Reliability: > 90% of nodes in the targeted area should receive the information.
  - Delay: < 100 ms.

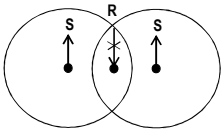
Problems

- The standard IEEE 802.11p using one-hop broadcast **cannot** satisfy the reliability requirement.
- Due to:

Direct collisions



Hidden collisions



- Research aims:

Improve broadcast performance in vehicular networks by analyzing, designing and developing different techniques for V2V safety applications.

Outline

- Research questions.
- Literature review.
- Analytical modeling.
- Model validation.

Research questions

1. Broadcast protocol

- How to effectively broadcast messages in V2V safety applications ?

2. Performance analysis

- How to evaluate the network performance of broadcast protocols in V2V safety applications?

3. Optimal design

- How much the network performance of V2V safety applications can be improved by using optimal designs?

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Our approach:

- Studying the network performance of one-hop and multi-hop protocol via simulation.
- Proposing a scheme that can improve the performance of the 802.11p protocol.

Research questions

1. Broadcast protocol	2. Performance analysis	3. Optimal design
• How to effectively broadcast messages in V2V safety applications ?	• How to evaluate the network performance of broadcast protocols in V2V safety applications?	• How much the network performance of V2V safety applications can be improved by using optimal designs?

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• How to effectively broadcast messages in V2V safety applications ?	• How to evaluate the network performance of broadcast protocols in V2V safety applications?	• How much the network performance of V2V safety applications can be improved by using optimal designs?

Our approach:

Developing an analytical model to evaluate the network performance.

Research questions

1. Broadcast protocol

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Research questions

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- How much the network performance of V2V safety applications can be improved by using optimal designs?

Our approach:

Suggesting the optimal broadcast protocol, the optimal values of parameters, based on the network context such as vehicle densities, beacon rates.

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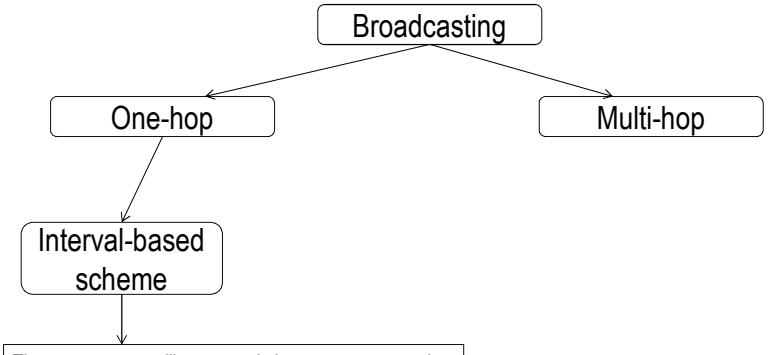
Literature review

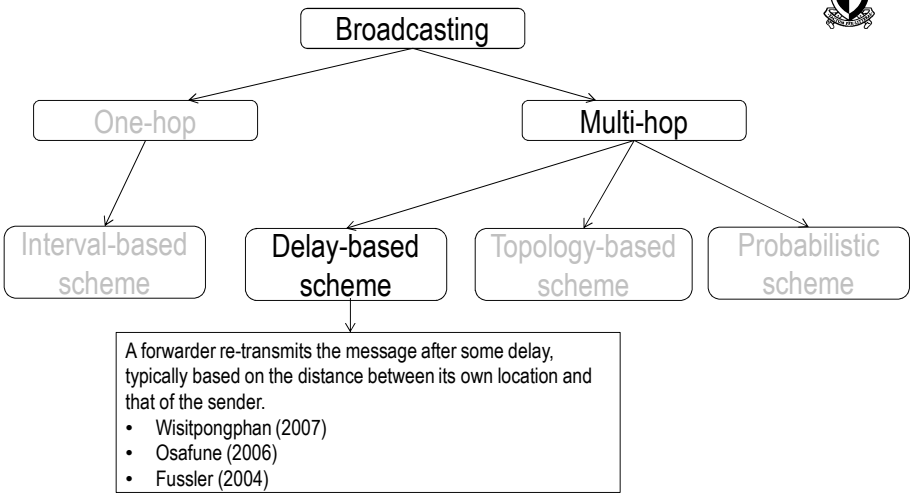
- The literature is summarized in the following two areas:
  - Broadcast protocols.
  - Performance analysis.

Literature review: broadcast protocols



The same source will re-transmit the message several time based on a time interval.
- Hassan (2011)
- Zhong (2008)
- Nadeem (2004)

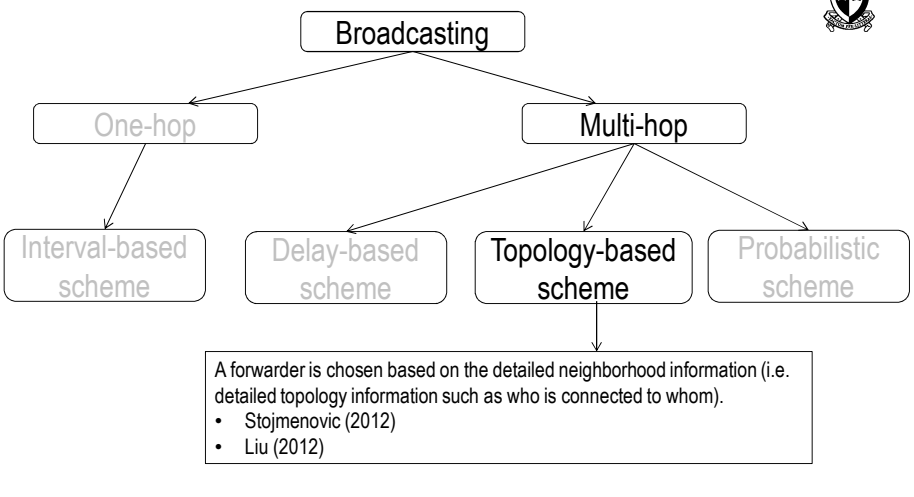
Literature review: broadcast protocols



A forwarder re-transmits the message after some delay, typically based on the distance between its own location and that of the sender.

- Wisitpongphan (2007)
- Osafune (2006)
- Fussler (2004)

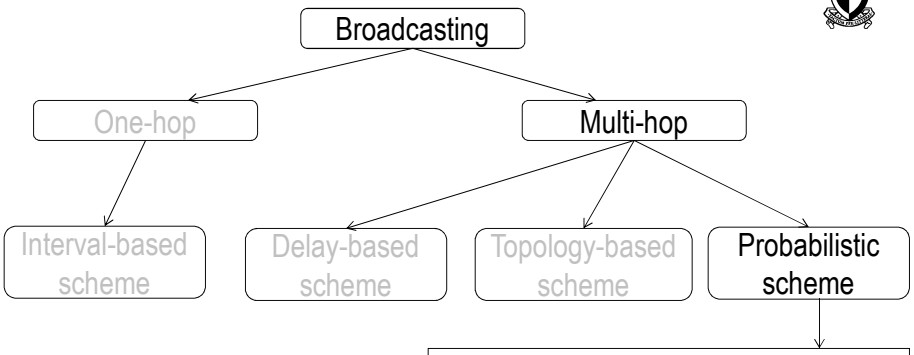
Literature review: broadcast protocols



A forwarder is chosen based on the detailed neighborhood information (i.e. detailed topology information such as who is connected to whom).

- Stojmenovic (2012)
- Liu (2012)

Literature review: broadcast protocols



Every node has a probability to retransmit the message. The probability either depends on the distance to the sender, or is predetermined.

- Slavik (2010)
- Panichpapiboon (2008)
- Wisitponghan (2007)

Literature review: Performance Analysis

No.	Model	Single-hop	Multi-hop	Hidden Analysis	Unsaturated
1	Ma (2007)	✓	-	-	-
2	Fracchia (2008)	✓	✓	-	✓
3	Vinel (2008)	✓	-	-	✓
4	Rao (2008)	✓	-	-	✓
5	Hassan (2011)	✓	-	✓	✓
6	Hafeez (2013)	✓	-	✓	✓
7	Yin (2013)	✓	-	✓	✓
8	Chen (2007)	✓	-	✓	✓
9	Yao (2013)	✓	-	✓	✓
10	Fallah (2011)	✓	-	✓	✓
11	Khabazian (2011)	✓	✓	✓	✓
	Proposed model	✓	✓	✓	✓

where nodes may or may not have messages to send.

Table 1: Comparison of existing analytical models for broadcast protocols in the literature.

Literature review: Performance Analysis

No.	Model	Single-hop	Multi-hop	Hidden Analysis	Unsaturated
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Drawbacks:

Ignoring the detailed operation of the 802.11p MAC protocol (i.e., the backoff process).
--> A problematic observation: all nodes within the transmission range of the sender will have the same collision probability independent from the distance between their positions and the sender (Hafeez, 2013).

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Literature review: Performance Analysis

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	Proposed model	✓	✓	✓	✓

Our model:

Considers:
- The backoff process.

Provides:
- Insight into the spatial distribution of forwarders.

Table 1: Comparison of existing analytical models for broadcast protocols in the literature.

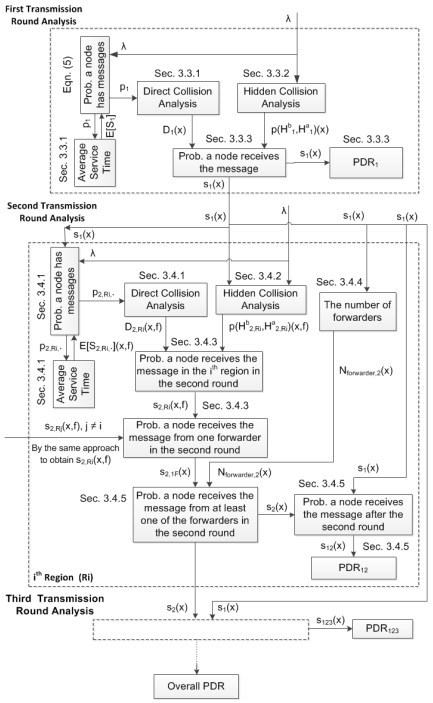
Analytical model

- Develop a comprehensive analytical model to evaluate the performance of the generic forwarding scheme, considering:
  - The backoff process
  - The impact of hidden terminals
  - Node densities
  - The spatial distribution of forwarders in an unsaturated network.

Challenges

- Challenges in modelling multi-hop protocols:
  - Hidden terminals analysis.
  - Many potential forwarders and receivers: each forwarder-receiver pair has its own set of hidden nodes.
  - Network load changes over space and time.

Analytical model



Results

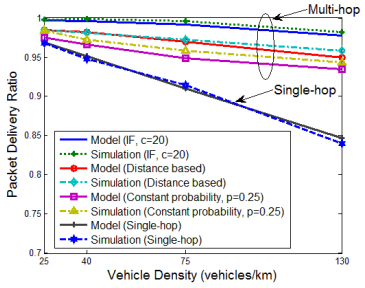


Fig. 1: Packet delivery ratio.

The percentage of nodes in the transmission range of the source that receives the safety message.

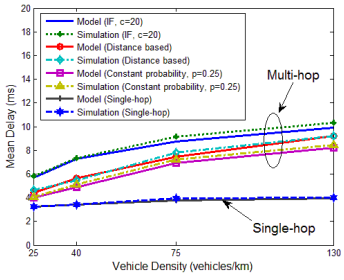


Fig. 2: The mean delay.

The average delay after which an arbitrary node receives the message

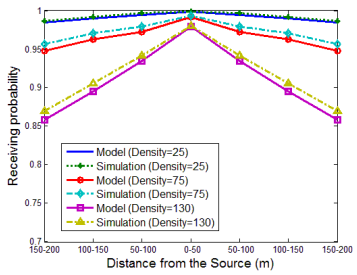


Fig. 3: The probability that a node receives the message as a function of the distance from the source.

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Optimal design

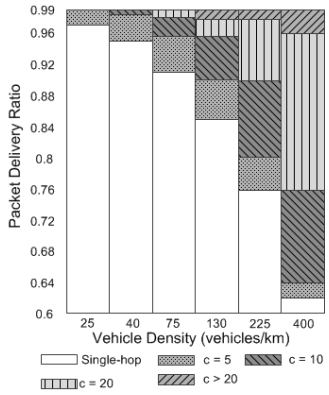

Fig. 4: The most effective broadcast protocol and the optimal values of coefficient *c*, at different network densities, given different thresholds for PDR.

Summary

- Propose an analytical model for a generic probabilistic forwarding scheme.
- Single-hop broadcasting protocol cannot satisfy the requirements of safety applications.
- Improve network performance of V2V broadcasting protocols by:
  - Retransmissions,
  - Optimal designs.

Thank you.

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