Chapter 3: Multicast Protocols on VANETs

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Goals of this chapter

- Introduce some existing multicast protocols in VANETs.

Outline

- 3-1: Distributed Robust Geocast: A Multicast Protocol for Inter-Vehicle Communication
- 3-2 : A multicast protocol in ad hoc networks: Inter-vehicles geocast

3-1: Distributed Robust Geocast Multicast Routing for Inter-Vehicle Communication

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Section Outline

- Abstract
- Introduction
- Related Work
- Forwarding Algorithm
- Overcoming Network Fragmentation
- Angle as a Proxy for Coverage Ratio
- Evaluation
- Future Work

Abstract

- Inter-vehicle communication is expected to significantly improve transportation safety and mobility on road.
- Several applications of inter-vehicle communication have been identified, notably **safety** and **warning applications**, traffic control applications and driver assistance applications.
- A majority of these applications require multicast to a group of vehicles satisfying a **geographic criterion**.
- To reap the benefits of inter-vehicle communication in a short time with minimal investment, use of vehicular ad hoc networks (VANETs) is envisioned.
- It has been shown that VANETs, with very high node mobility, benefit from the use of location information for routing.

Cont.

- The multicast of a message, using geographic routing, to nodes satisfying a **geographical criterion** is called *geocast*.
- Numerous protocols for geocast have been proposed in literature for general mobile ad hoc networks as well as VANETs.
- It has been shown that *explicit route setup* approaches perform poorly with VANETs due to **limited route lifetime** and **frequent network fragmentation**.
- The *broadcast based* approaches have considerable redundancy and add significantly to the overhead of the protocol.

Cont.

- In this work, we propose a completely distributed and robust geocast protocol that is resilient to frequent topology changes and network fragmentation.
- We use a **distance-based backoff** algorithm to reduce the number of hops and introduce a novel mechanism to reduce redundant broadcasts.
- We also propose several approaches to overcome **network fragmentation** and to keep a message alive in the geocast region, ensuring that a node entering the region even after the spread of the message receives it.

Cont.

- The performance of the proposed protocol is evaluated for various scenarios and compared with simple flooding and a protocol based on explicit route setup.

Introduction

- In recent times, the term *Vehicular Ad Hoc Networks* (VANETs) is frequently used in place of MANETs in the context of IVC, highlighting its distinct characteristics such as: high node speeds, constrained mobility, availability of resources such as location information (GPS) and abundant energy.

Applications of IVC include:

- ***Safety Applications**:* Collision warning system, Emergency vehicle notification
- ***Traffic Control Applications**:* Traffic monitoring, Traffic control, Route planning
- ***Driver Assistance**:* Platoon formation and maintenance, Merging assistance
- ***Miscellaneous**:* Localized advertisements, Instant messaging, Interactive gaming

To serve the applications identified above, an IVC system should satisfy the following criteria:

- ***Reliability:*** the system should be reliable enough to serve the safety applications.
- ***Low Delay:*** safety applications can be intolerant to end-to-end delays.
- ***High Throughput:*** traffic control, driver assistance and some other applications can generate considerable packet traffic requiring high throughput.
- ***Scalability:*** the system should be able to scale for thousands of nodes and several square miles.
- ***Robust Architecture:*** the system should be robust enough to withstand high node mobility, frequent topology changes and temporary network fragmentation.

Cont.

- ***Infrastructure Independence:*** the systems should not rely on an external infrastructure for its operation.

Contribution

- This work proposes **Distributed Robust Geocast** (DRG), a **geocast** protocol designed for VANETs which is completely distributed, without control overhead and state information and is resilient to frequent topology changes.
  - We use a distance-based backoff for directed and restricted flooding.
  - We do not require neighbor information for forwarding decision and neither do we assume a one-dimensional road.
  - We use a state-less forwarding algorithm which efficiently spreads the message through the target region and ensures delivery to all the relevant nodes.
- The algorithm can overcome a **temporary network partitioning** or temporary lack of qualified relay nodes and has a mechanism to prevent loops.

Cont.

- We also show a completely distributed method for keeping a message alive in the target region thereby ensuring that a node entering the region even after the spread of message receives the message.
- We evaluate the performance of DRG and compare it with pure flooding and with **ROVER**, an on-demand protocol based on AODV and modified for VANET.
- We also modify STRAW, the vehicular traffic simulator, to include **lane-changing model** proposed in
  - A. Kesting, M. Treiber, and D. Helbing, “Game-theoretic approach to lane-changing in microscopic traffic models," *Submitted to Transp. Res. B.*, 2006.
- We carry out an exhaustive performance evaluation of the protocols for safety and traffic monitoring applications, on highways and city streets, for various node densities, transmission ranges, and target region area.

Related Work

- Williams and Camp [27] present a comparison of **broadcasting** techniques for **MANETs**. They classify the broadcasting techniques as simple flooding, probability based methods, area based methods and neighbor knowledge methods.
  - [26] S.-Y. Ni, Y.-C. Tseng, Y.-S. Chen, and J. Sheu, “The broadcast storm problem in a mobile ad hoc network," in *Proc. of the Fifth Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom'99)*, pp. 151-162, 1999. (Google Cited Number: 1049)
  - [27] B. Williams and T. Camp, “Comparision of broadcasting techniques for mobile ad hoc networks," in *Proc. of the ACM International Symposium on Mobile Ad Hoc Network-\ing and Computing (MOBIHOC'02)*, pp. 194-205, 2002.

Cont.

- ***Probability based methods*** assign some probability to a node to rebroadcast. Since in dense networks multiple nodes have similar transmission coverage, by not having some node rebroadcast network resources can be saved without adversely affecting delivery effectiveness. While assigning low probability for rebroadcast reduces redundant transmissions, it also reduces the reliability of packet delivery for a given node density.
- ***Area based methods*** allow a node to rebroadcast only if the rebroadcast will reach sufficient additional coverage area. These schemes are the distance-based and location-based schemes of Ni et al. and they are discussed earlier in greater detail.

Cont.

- ***Neighbor knowledge methods*** maintain state on their neighborhood, through hello packets, which is used in the decision to rebroadcast. These methods may keep state on 1-hop or 2-hop neighbors. While some of the methods specify through data or control packet on which nodes are supposed to rebroadcast the packet, other methods allow a node to make re-broadcast decision locally. These ethods trade-off the overhead of larger data packets for the overhead of smaller control packets. This trade-off is profitable only if there is significant dfference between the size of control and data packets.
- It is shown through simulations that in a static network probability based and area based techniques of broadcasting, such as location based scheme of [26], are less effective in reducing redundant broadcasts compared to neighbor knowledge based methods.

Geocast for MANETs

[28] Y.-B. Ko and N. H. Vaidya, "Geocasting in mobile ad hoc networks: Location-based multicast algorithms," in *Proc. of WMCSA*, (New Orleans), 1999.

[11] Y.-B. Ko and N. H. Vaidya, "Location-aided routing (LAR) in mobile ad hoc networks," in *Mobile Computing and Networking*, pp. 66-75, 1998.

- Ko and Vaidya outline two schemes for **location-based multicast** to a geographical region called multicast region.
  - A forwarding zone is defined to include the multicast region as well as other areas around it such that delivery of packet to the multicast region is improved.
  - The membership to the forwarding zone is defined using one of the two proposed algorithms.

Cont.

- Both these schemes are based on restricted flooding and does not require topology information.
- However, they do not include any mechanism for overcoming empty forwarding zone or network partitioning.
- The algorithms proposed here are similar to the algorithms proposed in [11] for unicast routing.

- Ko and Vaidya propose another geocasting protocol, called **GeoTORA**, which combines a unicast routing protocol, **TORA** [30], with flooding. The packet is delivered to one of the nodes in the geocast region using a route created by a slightly modified TORA, and then flooded within the geocast region.
- GeoTORA is shown to be better than flooding and location-based multicast [28] in terms of overhead, although the end-to-end delay caused by route creation has not been evaluated.

Geocast for VANETs

- Bachir and Benslimane [18] propose a geocast for inter vehicle communication based on [17, 16].
- This approach **does not require maintenance of neighbor tables**, and instead of detection of new neighbors, it uses **periodic broadcasts to overcome network fragmentation**.
- The re-broadcast period is calculated based on the maximum vehicle speed such that a node upon entering the current **relay's reception area** should be able to get at least one broadcast before it crosses safe braking distance from the relay.
- It might be noted that this is necessary only in the case when the current relay is the origin of a safety message, and that a much larger delay can be tolerated when the current relay is far from the incident location.

Cont.

- Though we also use periodic broadcasts to overcome network fragmentation, we recognize two different reasons for broadcasts and accordingly introduce use of two different re-broadcast periods.
- The algorithm proposed in this work is designed for a one-dimensional highway scenario and does not adapt well to a two-dimensional city street scenario.

Summary

- Some approaches require frequent update of neighbor table for vehicular routing that increasing network overhead
- Flooding is an expensive technique for routing, that restricted flooding may be a better alternative to explicitly setup routes for high mobility as in VANETs.

Distributed Robust Geocasting Protocol

- We first identify some of the **desired characteristics** of a geocast protocol for VANETs.
- Then we define our **design space** and outline the **assumptions** about the underlying system on which our protocol is based.
- We then present the core algorithms of our protocol.

Desired Characteristics of Geocast Protocols for VANET

- ***Reliability**:* the routing protocol should reliably deliver the packet to the *expected recipients*, i.e., all the nodes that satisfy the specified geographic criteria, called the *zone of relevance.*
- ***Low Delay**:* the packet should be delivered to the expected recipients within the quality of service (QoS) specifications of the relevant application. For safety applications, an explicit route setup approach may result in unacceptable delays.

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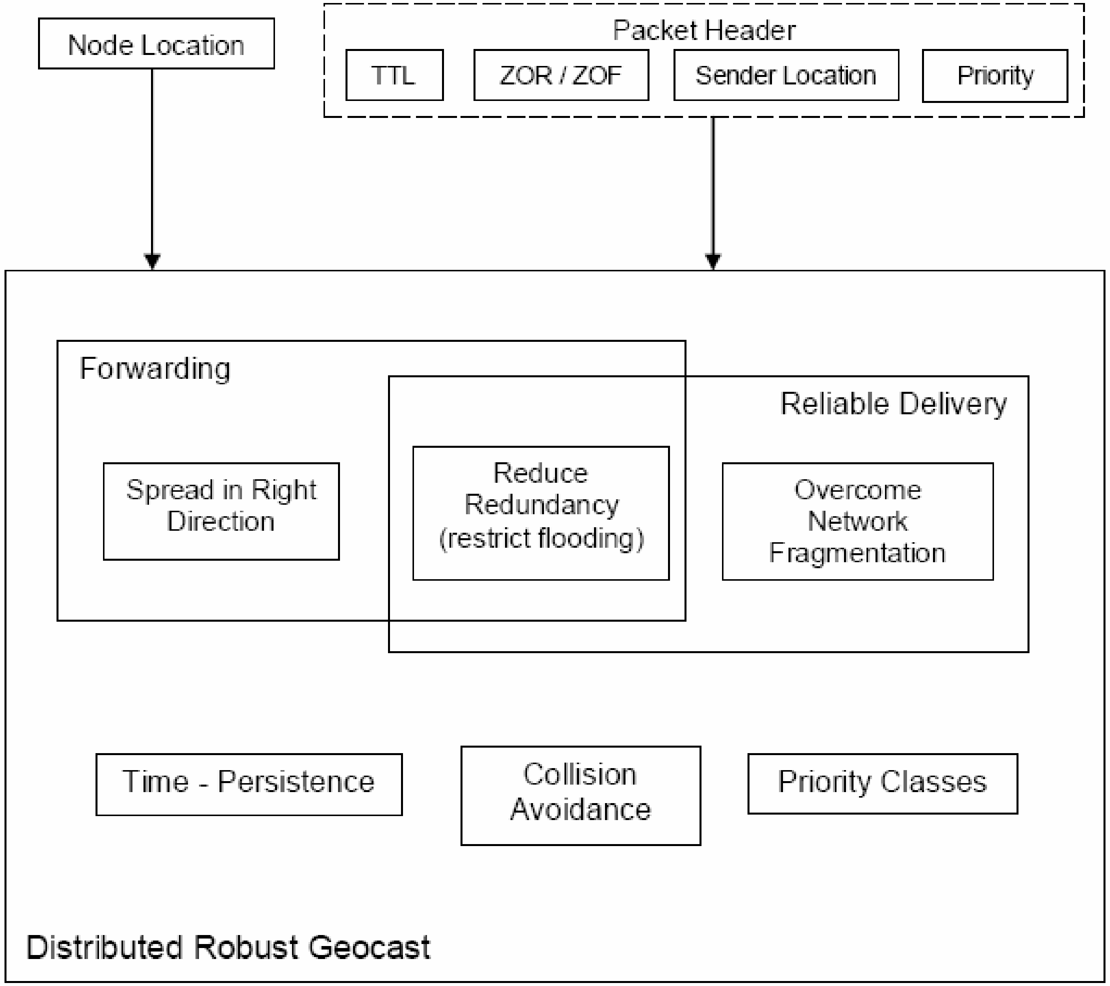
- ***High Throughput:*** the protocol should minimize blocking of the shared wireless medium by reducing the amount of transmissions. Frequent transmissions of control packets, as in explicit route setup approaches or maintenance of neighbor tables such as [12, 16, 34], should be avoided as should be unrestricted flooding of entire network.
- ***Robust Architecture:*** the protocol should be robust enough to work in a highly mobile environment with frequent topology changes. The explicit route setup approaches may fail in this environment, as pointed out in [22]. The protocol should have a mechanism to overcome temporary fragmentation of the network frequently occurring in a VANET.

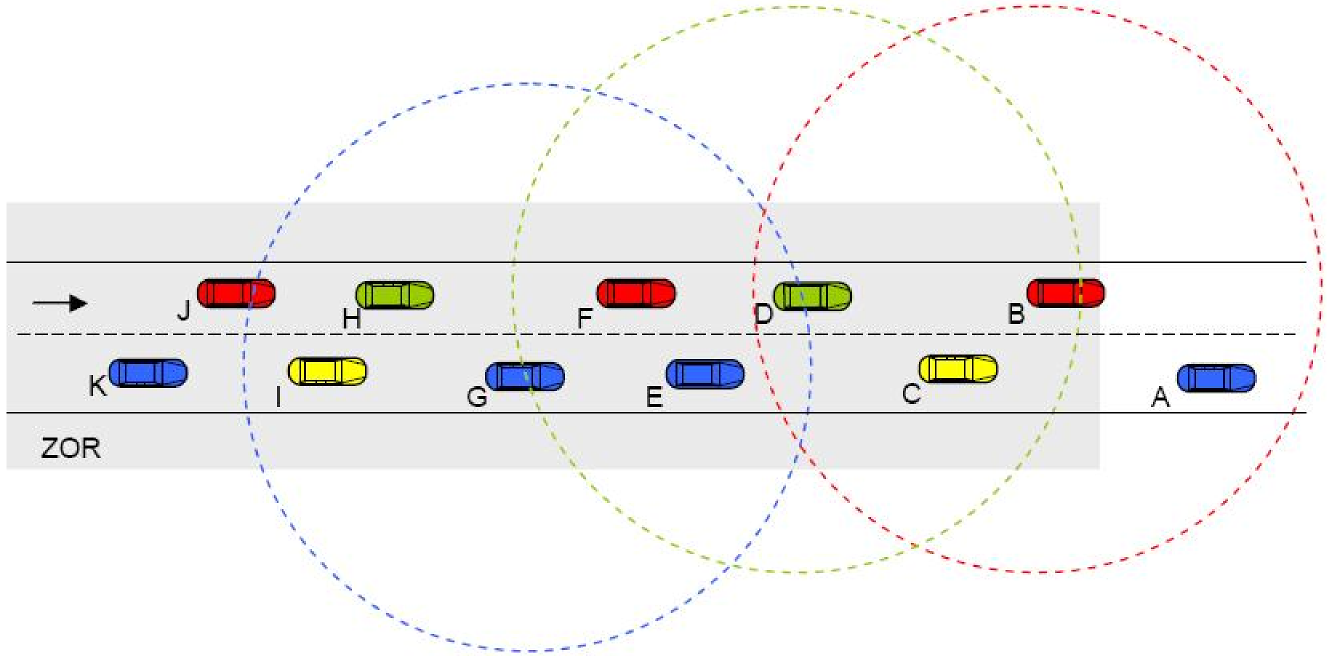
Architecture

- This work proposes to use a restricted, directed flooding approach for the design of our geocast protocol.



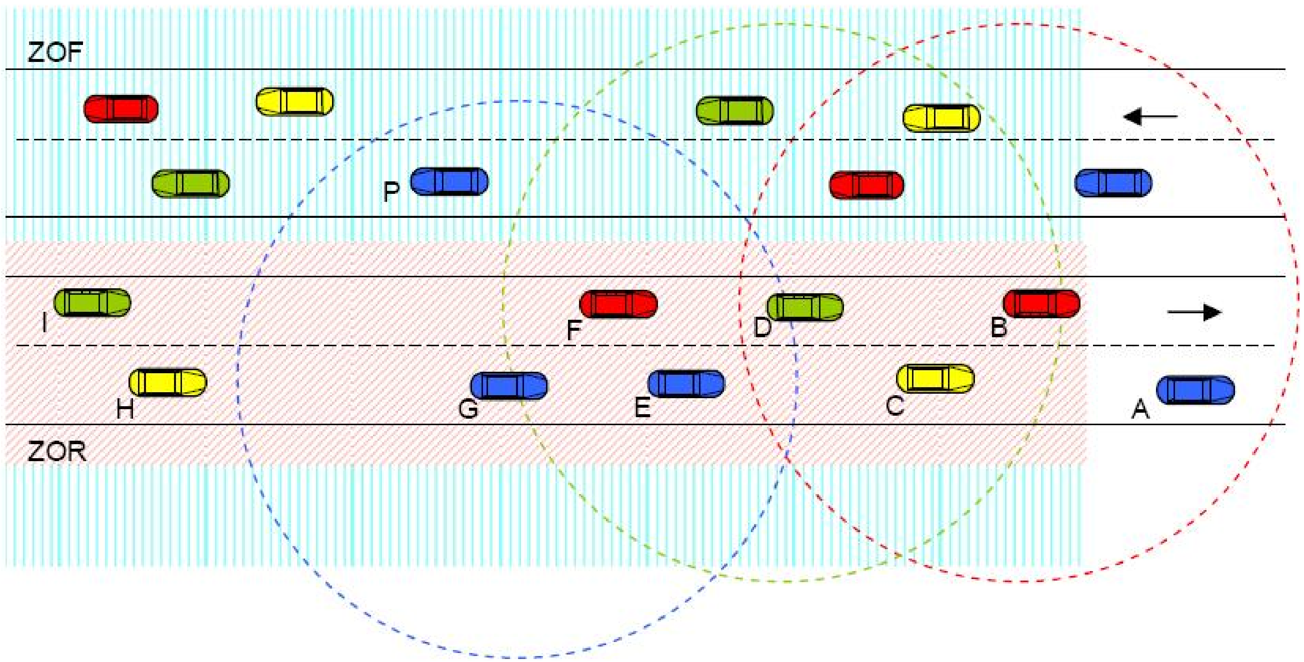
Cont.

- The ***zone of relevance (ZOR)*** is defined as the set of geographic criteria that a node must satisfy in order for the geocast message to be relevant to that node. This is similar to the “geocast region" or “multicast region", except that additional criteria, e.g., the direction of node movement, can be used to select among the nodes that are within a geographic area.



Cont.

- The ***zone of forwarding (ZOF)*** is defined as the set of geographic criteria that a node must satisfy in order to forward a geocast message. This is similar to the “forwarding region", except that additional criteria, e.g., the direction of node movement, can be used to select among the nodes that are within a geographic area.



The geocast protocol has two main functions:

- *Forwarding* the message through zone of forwarding towards zone of relevance, and through zone of relevance such that the message travels towards the edges of zone of relevance, i.e., *spreading* the message in right directions.
- *Delivering* the message reliably to all the nodes within the zone of relevance.
- These functions must be performed with the least amount of *redundancy*, by restricting flooding.

Cont.

- The information contained in geocast packet header regarding the sender location and the zone of relevance or zone of forwarding is used in conjunction with the node's current position to restrict flooding and reduce redundancy.
- A forwarding algorithm to restrict flooding with backoff based on a node's distance from the last transmitter.
- All of these algorithms are developed so that a node does not need to know its one-hop neighbors or to build multi-hop routes.

Design Space

Forwarding Algorithm

- On receiving a message, each node schedules a transmission of the message after a distance-based backoff time.

$$BO_d(R_D, d) = MaxBO_d \cdot S_d \left| \frac{R_D - d}{R_D} \right|$$

BO_d : backoff time depending on the distance from the previous transmitter

S_d : is the distance sensitivity factor used to fine tune the backoff time

$MaxBO_d$: maximum backoff time

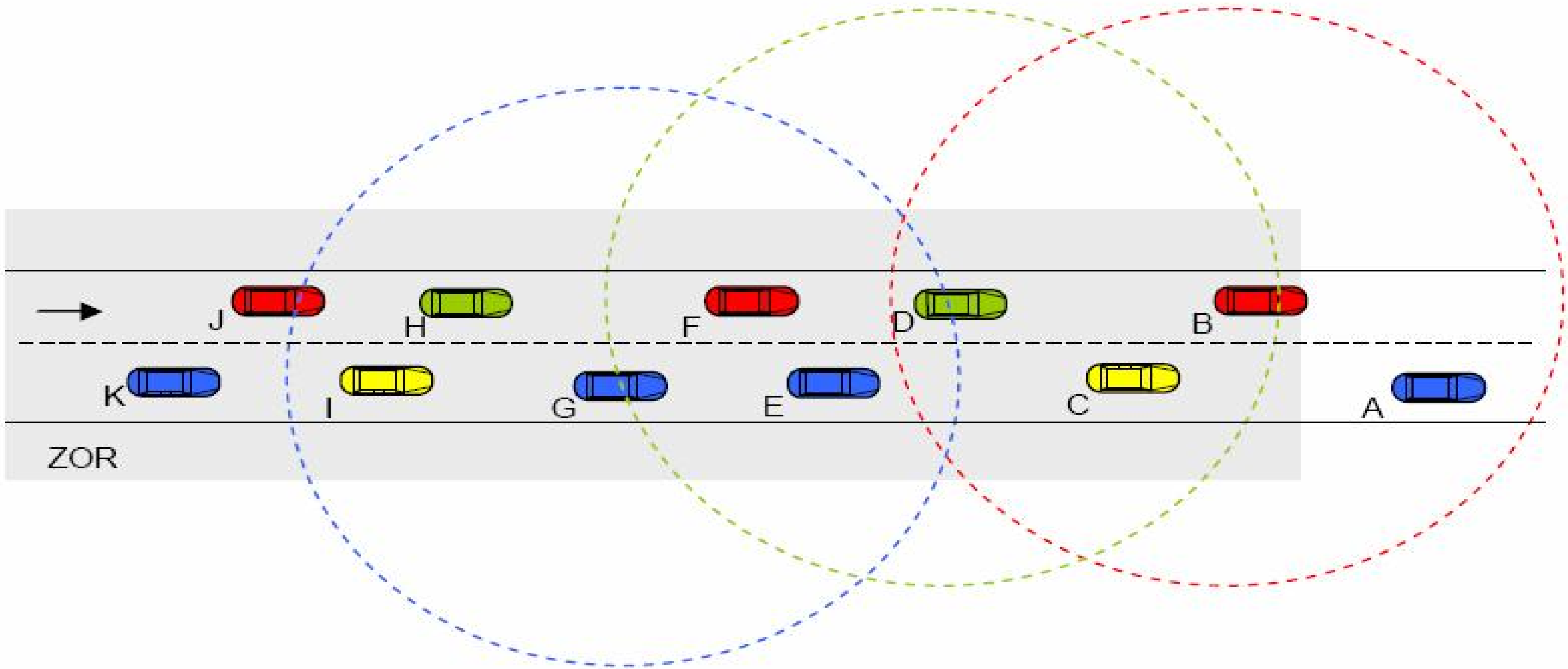
R_{tx} : nominal transmission range

d ： the distance between receiver and transmitter

- $MaxBO_d$ ≧ 2 (max (transmission time + propagation time + processing time))

Fig. 3.2

- A straight road scenario with distance-based backoff



Example

- Assume that node **B generates a message to be delivered to vehicles 2 km behind it.**
- The shaded region on the road shows the zone of relevance.
- The dotted circles with a radius of nominal transmission range *Rtx*, is an approximation of the edge of the *coverage area* of respective nodes.
- The transmission from B is received by nodes A, C and D. Since **node A is not in the zone of relevance**, the message is ignored. Among nodes C and D, since node D has the most forward progress it should relay the message.
- With the backoff time proposed in (3.1), the node closest to the edge of coverage area (i.e., node D) indeed transmits the message first.

Cont.

- Node C cancels its scheduled transmission on receiving a transmission from node D.
- The message spreads towards the destination in this fashion when node **G wins the contention** and becomes the relay as the node at the edge of coverage area.
- Now, if due to uncertainties inherent in wireless communication the node at the edge of the coverage area does not receive a packet, the node with next most progress will win the contention and become the relay.
- In Fig. 3.2, **if node J does not receive the message from G**, then **node I** will turnout to have the lowest backoff and will relay the message.

Collision Warning Application

- In this application, if a vehicle is either involved in or detects a collision or breakdown, it sends a warning message to vehicles behind it.
- A suitable zone of relevance (ZOR) is determined by the application.

Overcoming Network Fragmentation

- VANET is prone to frequent network fragmentation, even though it may be temporary.
- Hence, the geocast protocol must have a mechanism to overcome network fragmentation in order to have a robust performance in an environment of sparse vehicle distribution.
- We identify three approaches to overcome network fragmentation:
  - periodic retransmissions
  - new neighbor approach
  - the vehicle as message ferry

New Neighbor Approach

- Each node maintains a list of neighboring nodes, and another list of senders for each geocast message.
- Whenever a node receives a geocast message, it notes the sender's identity against the sender list.
- If there are neighbors in the neighbor list that are not present in the sender list, the node sends the message to those neighbors.

Periodic Retransmissions

- The last node on the edge of network fragmentation **periodically retransmits the message**.
- we propose a modification to this periodic retransmission mechanism by introducing a **long backoff (*LongBO$_d$*)** time after a certain number of retransmissions, denoted ***maximum retransmissions* (*MaxReTx*).**
- The selection of value for *LongBOd* is a trade-off between redundant transmissions and end-to-end delays.

$$MaxLongBO_d = \frac{R_{tx}}{V_{max}},$$

$MaxLongBO_d$: maximum value of long backoff

R_{tx} : nominal transmission range

V_{max} : maximum velocity of the vehicles

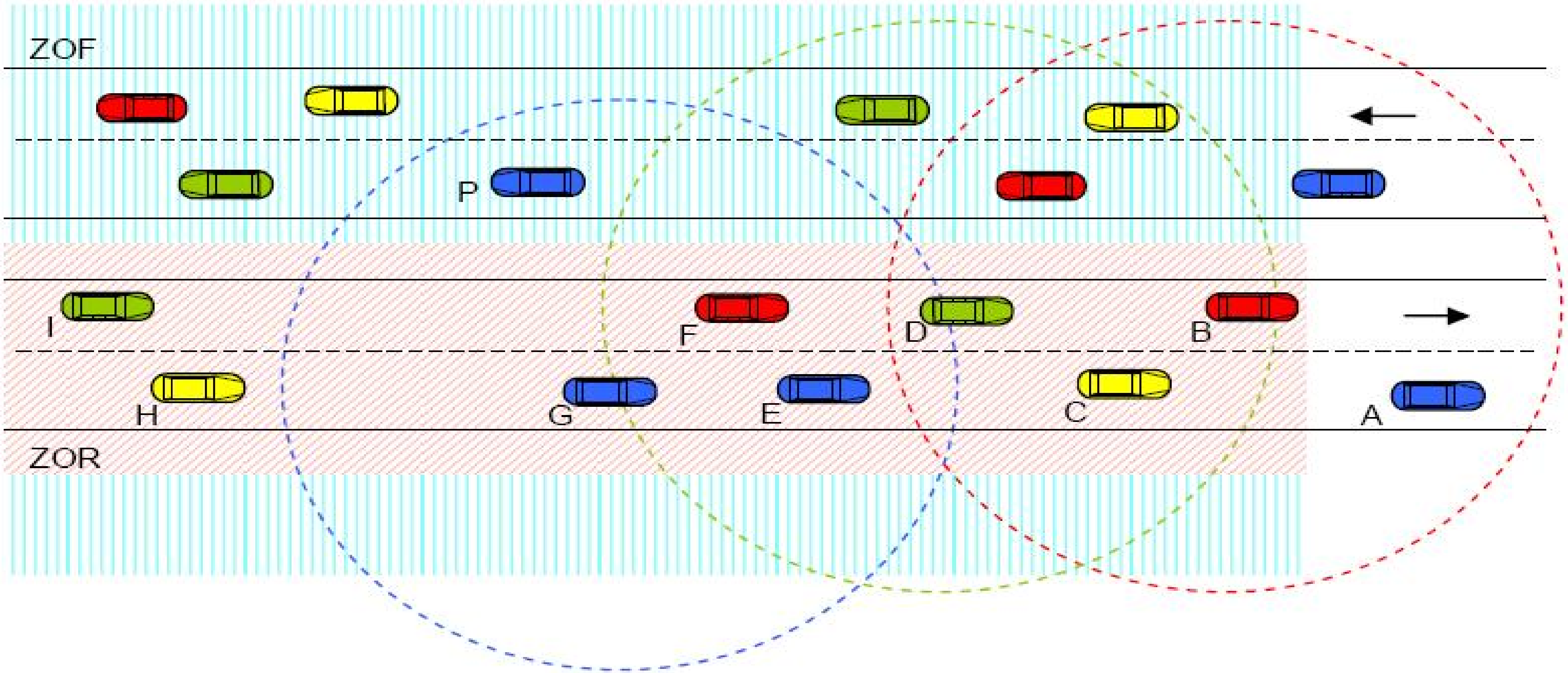
Vehicle as Message Ferry

- VANET can be used to overcome network fragmentation by using vehicles moving in the opposite direction to bridge the gap in the network.
- By using vehicle as a **message ferry**, even a fairly long term or permanent fragmentation in network of vehicles moving in the same direction can be **bridged**.
- This approach requires the use of one of the two approaches outlined earlier for actual delivery of the message to the next network fragment.

Fig. 3.3 A temporarily fragmented vehicular network

ZOF：zone of forwarding

ZOR：zone of relevance



Cont.

- It suffers from most of the disadvantages the earlier approaches had.
  - If it is used with new neighbor approach, faster updates of neighbor list and sender list is required.
  - If used with periodic retransmissions, it may cause some redundant retransmissions when network is not fragmented.
- Since we use the concept of a zone of relevance and zone of forwarding instead of geocast region and forwarding region, the vehicles moving in opposite direction can be easily used as **message ferry** by changing the geographic criteria of zone of forwarding.

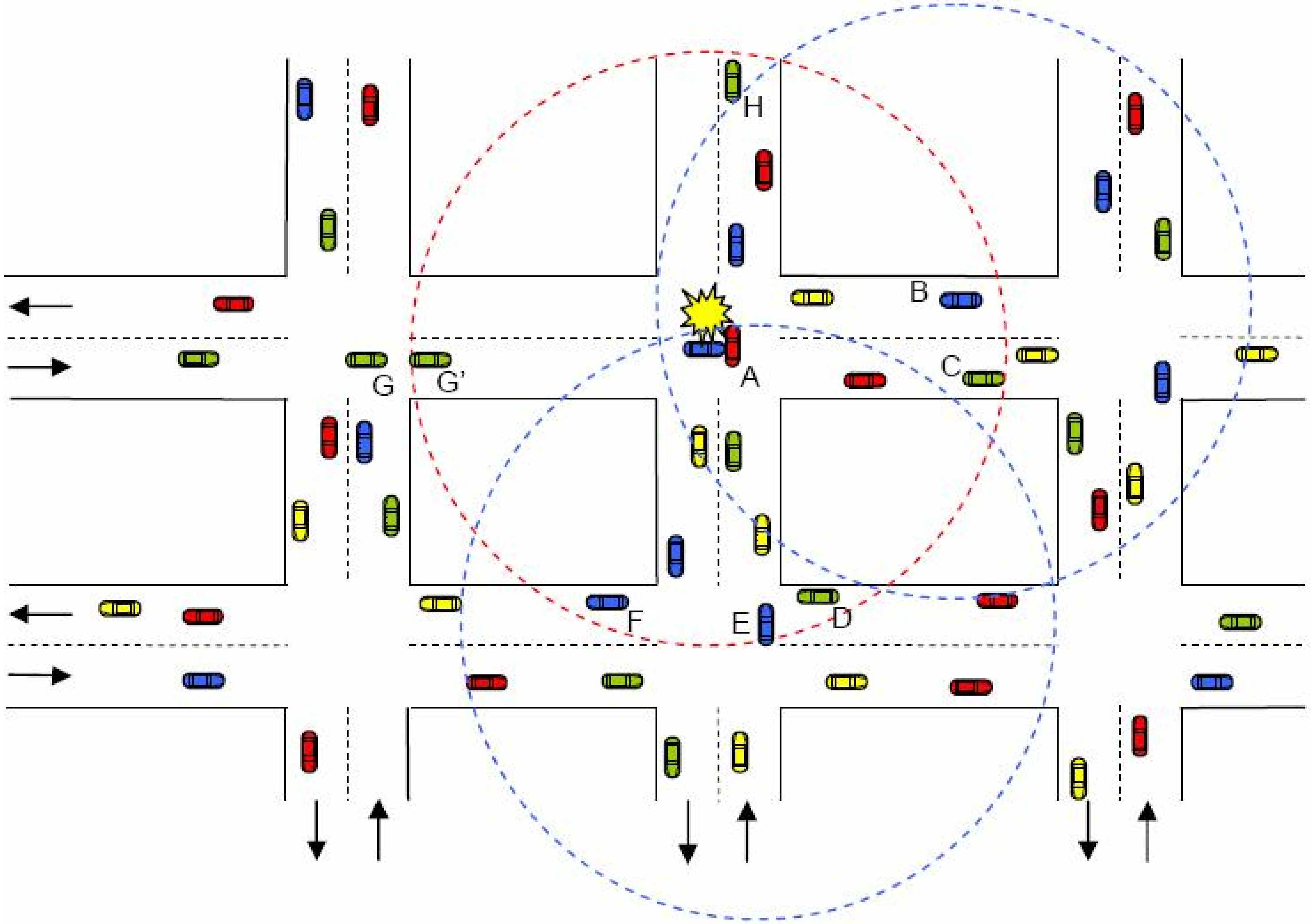
Spreading and Implicit Acknowledgement

- A node receiving a geocast message may retransmit the message with the objectives of spreading or delivering the message.
- The distance-based backoff algorithm proposed is designed for spreading and delivering of the message in one-dimensional zone of relevance.

Spreading and Implicit Acknowledgement

- **Consider a two-dimensional scenario** shown in Fig. 3.4, set on a city street network.
- **Node A** generates a geocast message to warn about the crash, with a zone of relevance and zone of forwarding restricted to the vehicles moving towards A and covering the entire region shown in the figure.
- If node A treats the transmission from node E and/or node B as an implicit acknowledgement, it may fail to ensure the spread of the message in all directions since the network is fragmented towards left where node G is just outside coverage area of A.
- However, **if node A continues to retransmit, G eventually comes within the coverage area** and the fragmentation can be overcome. Thus, we need a criterion for implicit acknowledgement that will make the forwarding algorithm robust to temporary network fragmentation, but that, at the same time, will reduce redundant transmissions.

Figure 3.4: A two-dimensional city street scenario



Cont.

- In a two dimensional scenario, the distance-based backoff prefers the nodes towards the edge of the "transmission range" to take on the role of a relay.
- To spread the message throughout the **two-dimensional zone of relevance** the relay nodes should be selected such that they are best positioned to cover substantially new regions of the zone of relevance.
- A node should continue to retransmit a message until it receives an implicit acknowledgement from other relay nodes such that the message has a high probability of spreading as well as delivering.
- At the same time, the number of retransmissions should be minimized to reduce contention with other transmissions.

Cont.

- If the current node receives the same message from relays that cover a major portion of its own coverage area, there is a high probability that other nodes in the coverage area would have received the message from either the current node or one of the relays.
- The ratio of the area of overlap of coverage area or coverage disk of two nodes with respect to their average coverage area is called *coverage ratio*.
- If the relays have a small **angular distance** among themselves with respect to the current node, the probability of spreading the message is low.

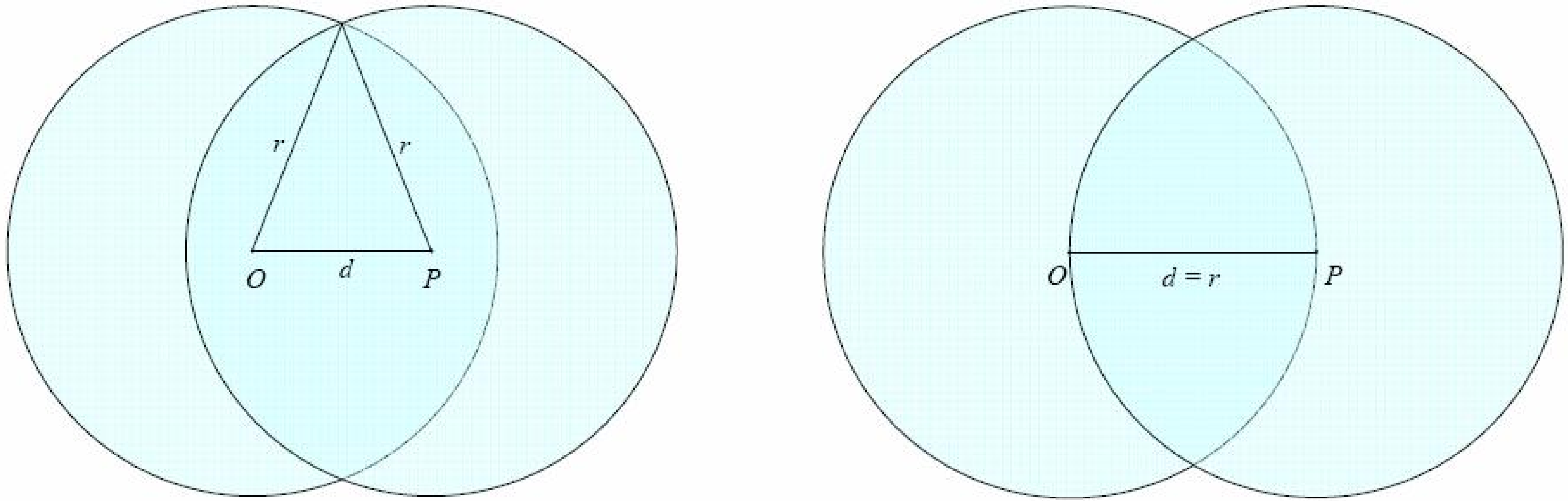
Cont.

- Hence, the angular distance and the coverage ratio of the relays should be greater than certain thresholds to ensure spreading and flooding of the message.
- Let us call these thresholds the ***angular threshold*** and the ***coverage ratio threshold*** respectively.

Area of Overlap of Coverage Disks of Two Nodes

- All the nodes within a certain distance from the transmitter receive all the packets and all the nodes with more than that distance from transmitter do not receive any packets.
- We will show later that the results we obtain with this assumption can be used even when the assumption is not true.

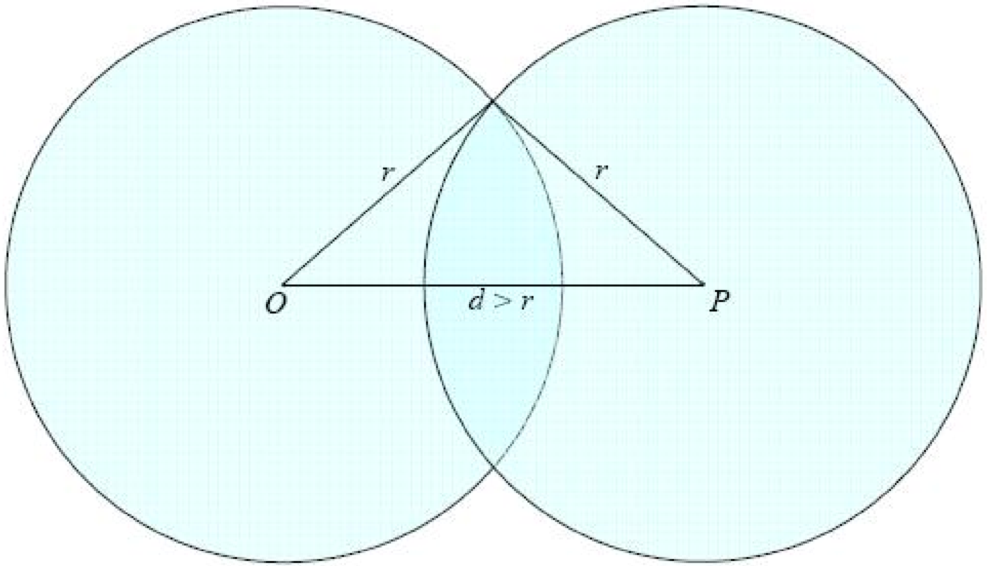
Figure 3.5: Various cases of overlap of Transmission Ranges of two Nodes



(a) Two nodes at a distance less than transmission range

(b) Two nodes at a distance equal to transmission range

Figure 3.5: Various cases of overlap of Transmission Ranges of two Nodes



(c) Two nodes at a distance greater than transmission range

Cont.

- We are interested in finding the area of overlap of coverage disks of two nodes when $d \leq r$, i.e., when they are within each other's transmission range.
- We can see that this area is minimum when *d* = *r*, and maximum (equal to the area of the disk) when *d* = 0.
- The minimum area of overlap of two node's coverage disk when they are within each other's transmission range is found using equation (A.20) substituting *d* by *r*.

$$A_{intersection} = 2r^2 \arccos\left(\frac{1}{2}\right) - \frac{\sqrt{3}}{2}r^2 = \frac{2\pi r^2}{3} - \frac{\sqrt{3}}{2}r^2$$

The area of coverage disk is,

$$A_{disk} = \pi r^2$$

Cont.

- The area of overlap of coverage disk, as a fraction of coverage area is given as,

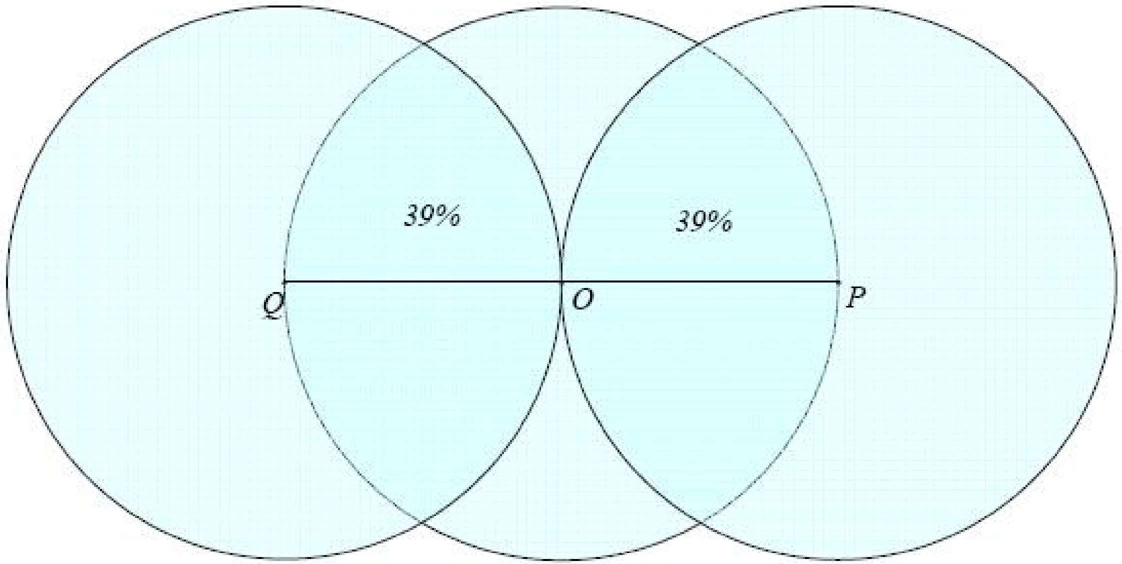
$$P_{overlap} = \frac{A_{intersection}}{A_{disk}}$$
$$= \frac{2}{3} - \frac{\sqrt{3}}{2\pi}$$
$$\approx 0.391$$

Cont.

- From above equation, we know that the *Q* and *P* cover approximately 78% of node *O*'s coverage area. If the coverage ratio threshold is higher than 78%, node *O* will continue to retransmit the message without any gain in spreading or flooding of the message. Thus, the upper bound on coverage ratio threshold $CR_{threshold}$ is:

$$CR_{threshold} \leq 0.78.$$

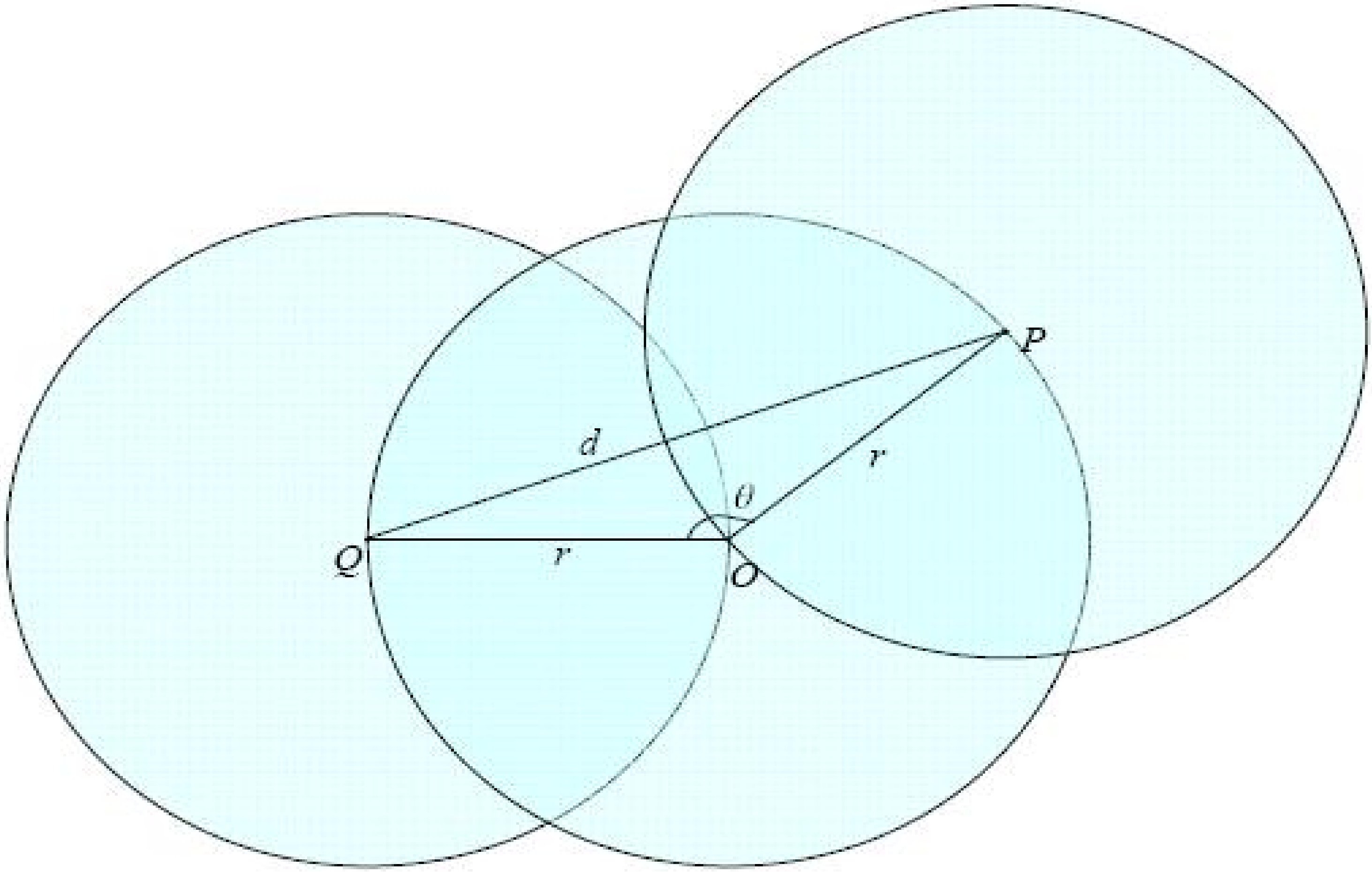
Figure 3.6: Two nodes on the edge of center node's transmission range



Cont.

- The success of the $CR_{threshold}$ criterion depends on a very accurate estimate of actual transmission range.
- We propose to use angle based criterion instead by mapping a minimum coverage ratio to an angle, e.g., coverage ratio of 78% is mapped to 180^o.
- Nodes *P* and *Q* make an angle θ at the center node *O*.
- Let our desired $CR_{threshold}$ be *x*.
- What should be the minimum value of θ for the minimum coverage ratio to be more than the threshold *x*. We need to find an angle θ such that the area of intersection of disks *P* and *Q* should not be more than (0.78 - *x*), i.e.,

Figure 3.8: Two nodes on the edge of center node's transmission range, forming an angle μ at the center node



$$d = 2r\sin\left(\frac{\theta}{2}\right)$$

$$\theta = 2\arcsin\left(\frac{d}{2r}\right)$$

Cont.

$$A_{P\cap Q} \leq (0.78 - x)A_{disk}, \tag{6}$$

$$A_{P\cap Q} = 2r^2 \arccos\left(\frac{d}{2r}\right) - \frac{d}{2}\sqrt{4r^2 - d^2}, \tag{7}$$

where d is the distance between nodes P and Q.

Without loss of generality, we can assume the disks to be unit circles, or the transmission range r to be 1. Thus, equation (6) becomes,

$$2\arccos\left(\frac{d}{2}\right) - \frac{d}{2}\sqrt{4 - d^2} \leq (0.78 - x)\pi, \tag{8}$$

where $0 < d \leq 2$.

From the Fig. 1 (b), the relation between distance d and angle θ is:

$$\theta = 2\arcsin\left(\frac{d}{2r}\right). \tag{9}$$

- Thus, from equations (8) and (9) we can find a value of θ_{min} such that the minimum coverage ratio is above the $CR_{threshold}$.
- Thus, when a node receives a message from **at least two other nodes** that make an angle $\theta \geq \theta_{min}$, the message should be considered to be acknowledged and spreading in desired direction and all retransmissions of that message should be canceled since a retransmission will not significantly add to the coverage.

Performance Evaluation

- The simulation models used for network and vehicle traffic simulation are discussed in the section on simulation environment.
- The values of some of the parameters of DRG are selected for a typical scenario.
- Then the performance is evaluated for a **collision warning application** on both highway and city scenarios.
- The performance for traffic monitoring is evaluated next in city scenario.
- The protocols used for comparison of performance of DRG are discussed first along with the metrics used for measuring performance.

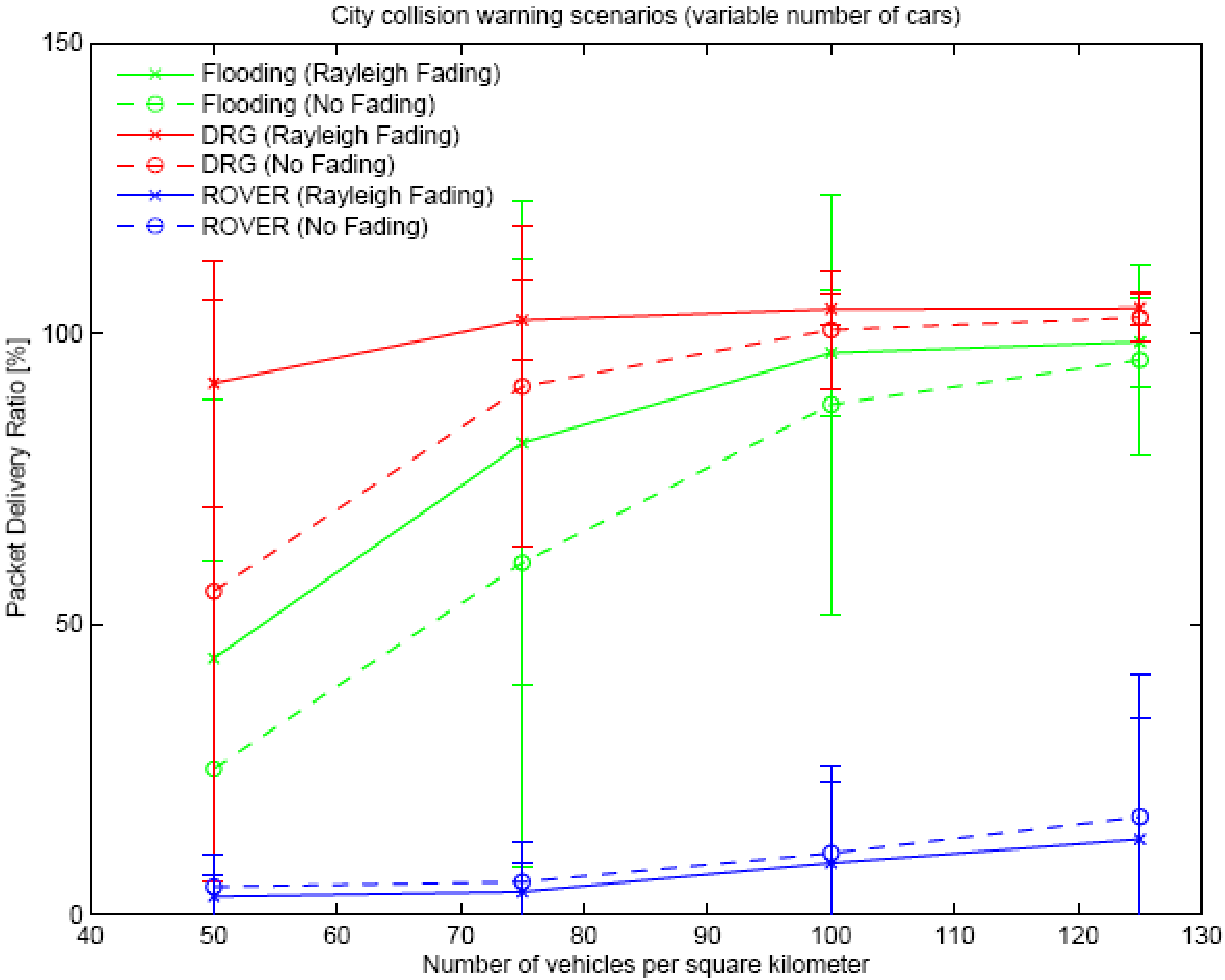
Performance Metrics

- ***Packet Delivery Ratio (PDR)*** is the ratio of the number of nodes receiving the packet and the number of nodes that were supposed to receive the packet.
- ***End-to-End Delay*** is the time delay between the time a geocast message is sent by an application at the source node to the time the application running on receiver node receives the message.
- ***Overhead*** is the ratio of the number of network layer bytes transmitted to the number of bytes sent by the application layer for a unique message. The overhead provides a measure of efficiency of the routing protocol in reducing redundant transmissions for restricted flooding based protocol.

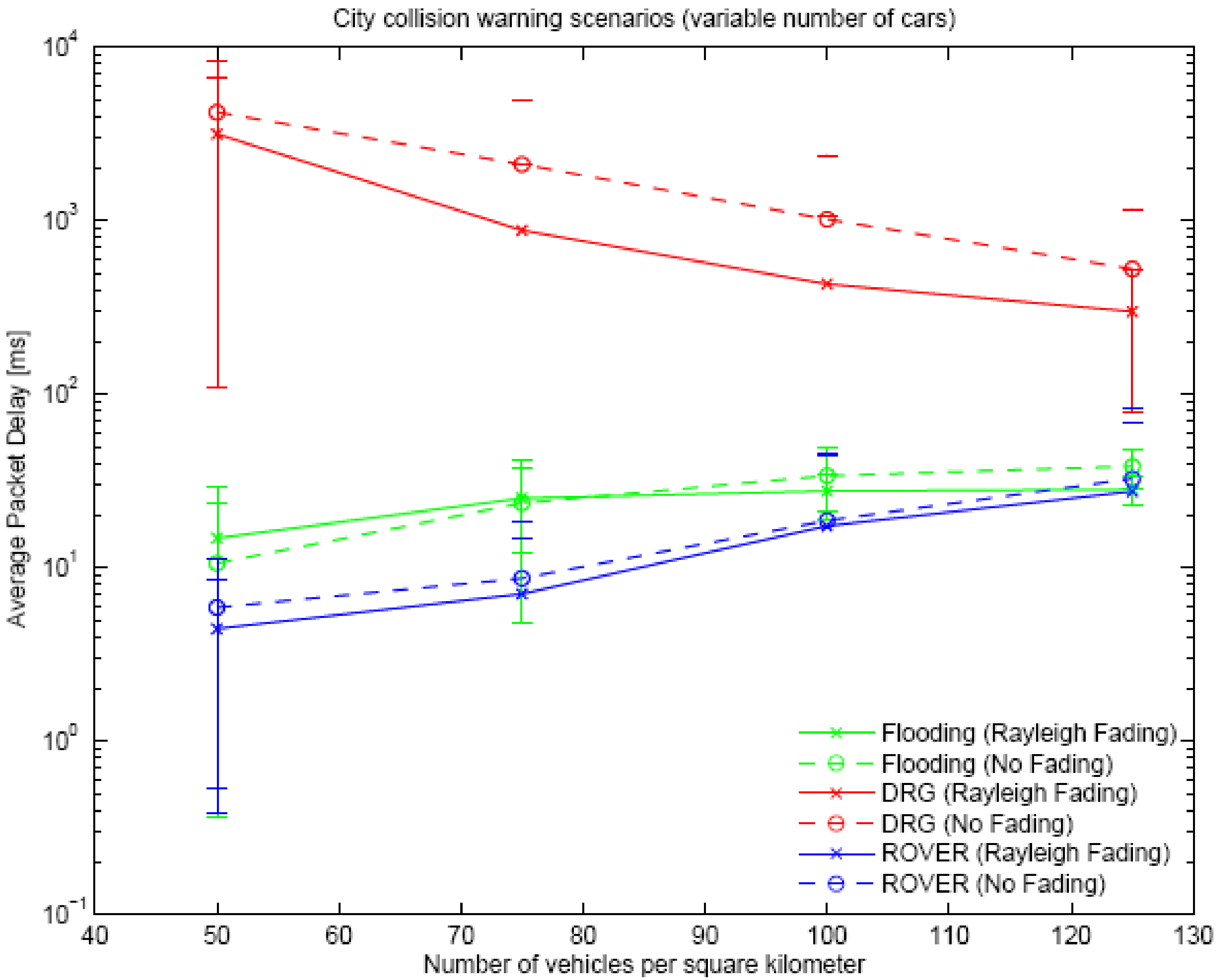
Flooding and ROVER

- We use simple **flooding** as the most simple algorithm to compare performance of our algorithm.
  - In a simple flooding each node on receiving a new message rebroadcasts it once.
  - In our implementation of flooding for geocast, we use zone of relevance to restrict the flooding to the relevant nodes.
- A more complex protocol, robust vehicular routing (**ROVER**) [38], is used as a representative of the explicit route setup approach for performance comparison.
  - The data packets are unicast, potentially increasing efficiency and reliability.
  - The objective of ROVER is to build a multicast tree from the source vehicle to all the vehicles within the zone of relevance.

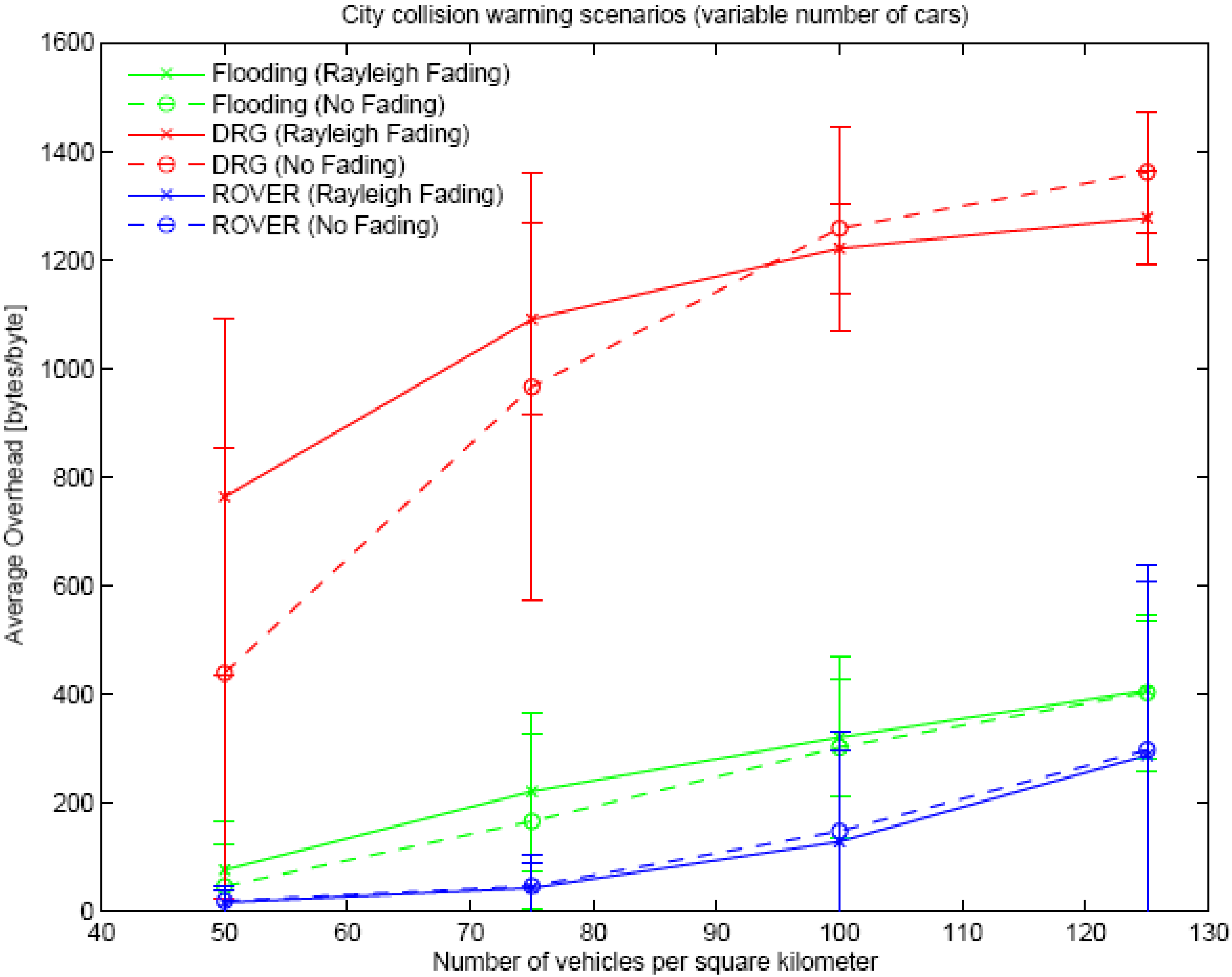
Packet Delivery Ratio (PDR) vs. density



Average Packet Delay vs. density



Overhead vs. density



Conclusion

- This work proposed a completely **d**istributed and **r**obust **g**eocast protocol, DRG, that relies on a **distance**-based backoff algorithm and a novel **angle** based algorithm to determine implicit acknowledgement.
- This work proposes several modifications to make the protocol robust and more efficient. In contrast to other distributed geocast protocols designed for highway collision warning applications, this work presents algorithms that work in both **one-dimensional** and **two-dimensional** network topology.

Future Work

- The underlying physical model needs to be modified to more accurately represent the radio propagation in a city environment.
- In a city scenario, if a node can somehow know that it is at an intersection, then it should retransmit the geocast message. This will ensure that the message spreads in all the direction.
- In the city scenario, the optimum threshold of the angle criterion needs to by found.

3-2: A multicast protocol in ad hoc networks: Inter-vehicles geocast

Abdelmalik Bachir and Ahderrahim Benslimane

IEEE Vehicular Technology Conference, 2003.

Section Outline

- Introduction
- Related Work
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- Simulation
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Introduction

- The Intelligent Transportation Systems (ITS) cause a significant passion since the appearance of new Inter-Vehicles communication mechanisms based on mobile networks.
- The wireless ad hoc network, completely distributed and not depending on infrastructures, allow the fast and cheap development of such mechanisms.

Introduction

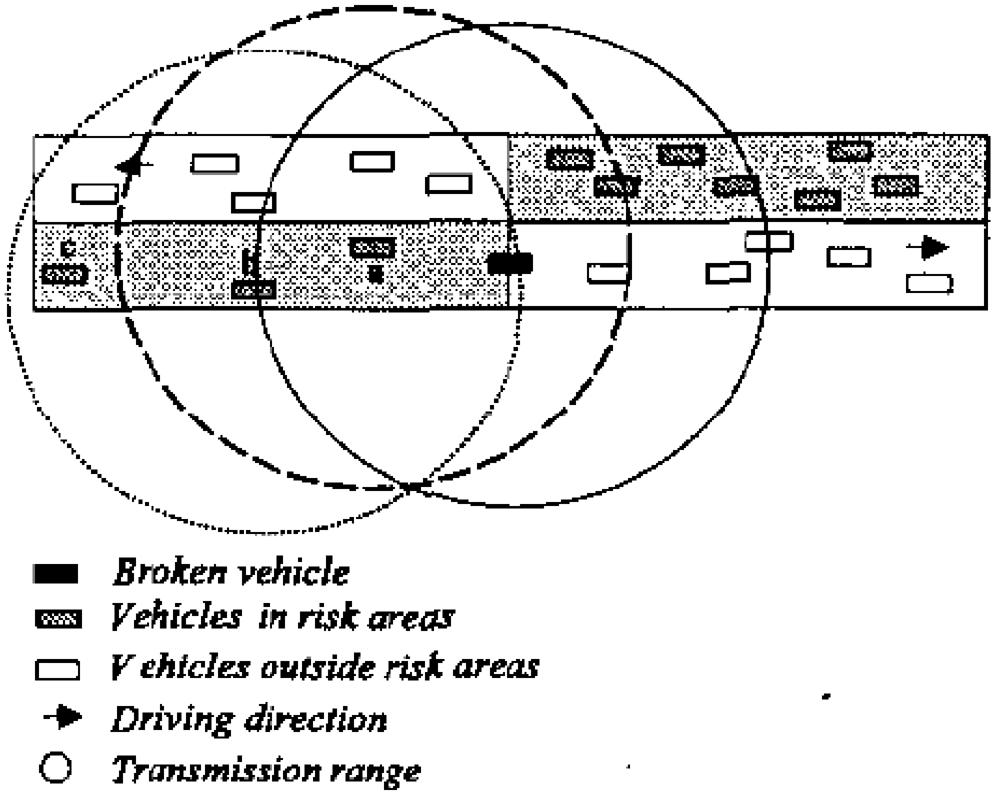
- This article concerns multicast in wireless ad-hoc networks applied to ITS**.**
- This work develops a new Protocol, called **IVG** (Inter-Vehicles Geocast)
  - which consists in informing all the vehicles of a highway about any danger such as an accident or any other obstacle.
- In this case, risk areas are determined according to the driving direction and the positioning of the vehicles.
- These vehicles define a restricted broadcast group, so-called, **multicast group**.

Related Work

- **REM** (Role Based Multicast) consider that the vehicle having to make the repeat broadcast must be ensured of the existence of a neighbor within its transmission range.
- The maintenance of this list generates a significant overload in the network that can delay the transmission of the alarm message and causes collisions in dens networks.
- **DDT** (Distance Defer Time) inserts defer time slots for each message rebroadcasting. A vehicle executing DDT determines if its alarm message rebroadcast can be dropped or not after the defer time is expired.
- It can`t overcome the fragmentation that could exist in the ad hoc network composed temporally of vehicles in highways.

Effective Broadcast with IVG

- Relay selection



Effective Broadcast with IVG

- The defer time of node receiving a message from another node (s) is inversely proportional to the distance separating them that is to favorite the farthest node to wait less time and to rebroadcast faster.

$$defertime(x) = Maxdefertime * \frac{R^e - D_{sx}^e}{R^e}$$

- R is the transmission range
- D_{SX} is the distance between the node (s) and (x)
- $\varepsilon = 2$

General Algorithm

- **when** a node (x) receives a broadcasted alarm message m

  if m is not relevant

  then it is deleted

  else node (x) sets its timer according defer time algorithm

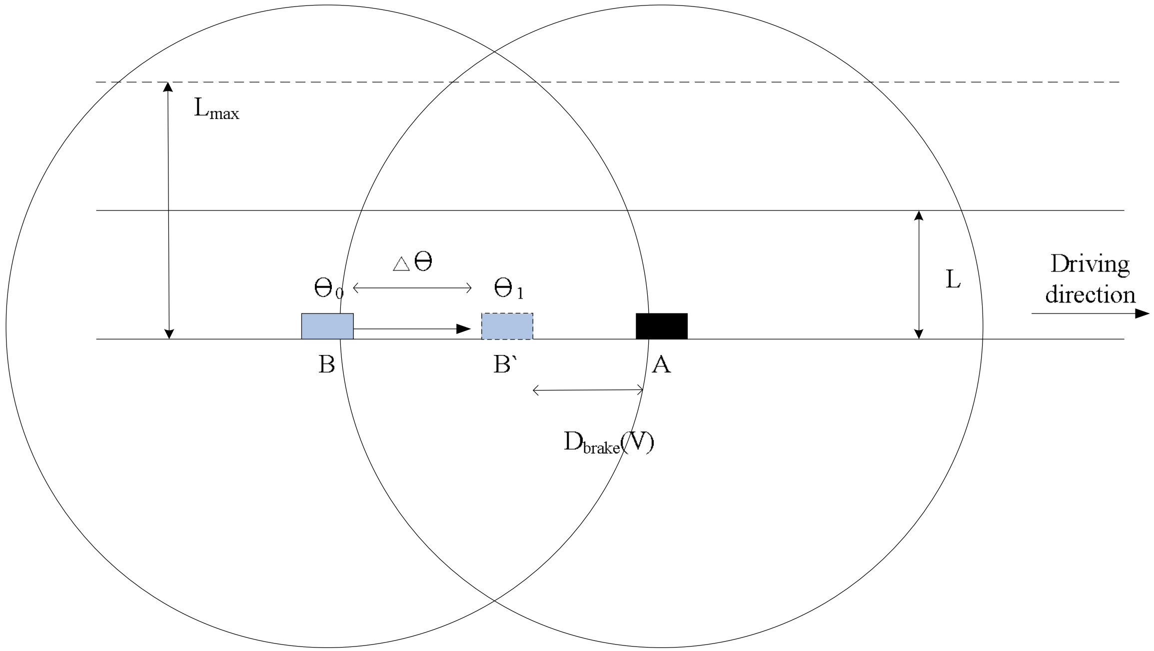
  when the timer expires it broadcasts the message if it still relevant

  fi

end

IVG

- Relay has to overcome any fragmentation in the network by rebroadcasting periodically the alarm message.



- Δq 兩次廣播間走的距離
- D_{brake}(V) 車速V時煞車所需要的距離

IVG

$$\Delta q_{\max} = q_1 - q_0 = \frac{R - D_{brake}(v)}{V}$$

$$D_{brake}(v) = V * \Delta t_{reaction} + \frac{V^2}{2 * b_{\max}}$$

$$t = \frac{v}{a}$$

$$S = \frac{1}{2} a t^2$$

- $\Delta t_{reaction}$ is the reaction time of driver =1
- b_{max} is the maximum deceleration = 4.4 m/s^2

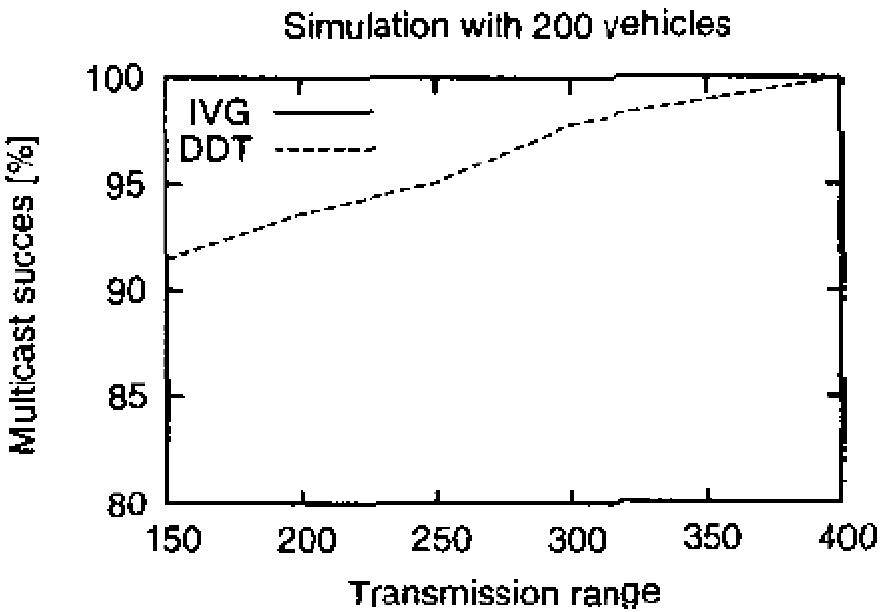
$$L_{\max} = \frac{\sqrt{3}}{2} R$$

Simulation

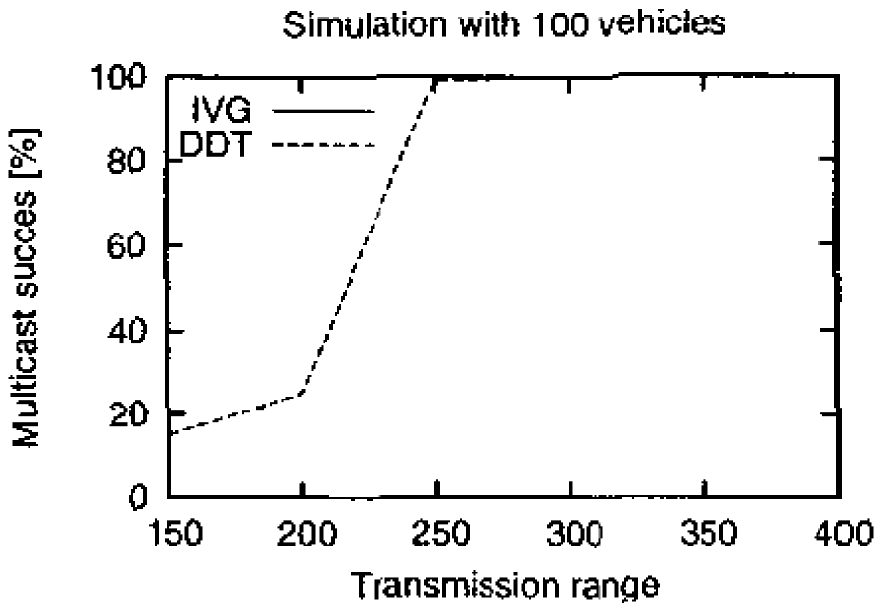
- Simulation parameter

MAC layer	IEEE 802.11
Packet size	64 bytes
MaxDeferTime	4ms
Transmission range	150m ~ 400m
Average speed	110 ± 15 km/h

Simulation



Simulation with 200 vehicles
IVG
DDT
Multicast succes [%]
100
95
90
85
80
150
200
250
300
350
400
Transmission range



Simulation with 100 vehicles
IVG
DDT
Multicast succes [%]
100
80
60
40
20
0
150
200
250
300
350
400
Transmission range

Conclusion

- With the use of GPS. IVG allows to efficiently restraint the alarm message dissemination to relevant areas.
- These areas define the members of the multicast group geographically.