

Analytical Modeling of MAC Protocol in Dedicated Short Range Communication

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Outline



- Overview of DSRC
- Research Objectives
- Assumptions
- Analytical Model
- Modification in MAC layer
- Numerical Results
- Simulation
- Discussion

Overview of DSRC



Motor vehicle related accidents

■ USA

- 2.49 million injuries in 2007
- 41,059 fatalities

■ Australia

- Death toll is 1,616 in 2007
- Deaths per annum steady since 2003



Overview of DSRC



■ Active safety systems

■ DSRC as the key technology

■ US FCC allocated 75 MHz of spectrum for DSRC at 5.9 GHz

- Vehicle-to-vehicle communications
- Infrastructure-to-vehicle communications

■ DSRC radio technology IEEE 802.11p



Overview of DSRC



Public safety applications

- Emergency warning system
- Lane-changing assistant
- Intersection coordination
- Traffic signal violation warning
- Road condition warning

Types of safety messages

- Routine safety message
- Event safety message



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Overview of DSRC



Link-layer Behaviour

- Single hop
- Uncoordinated
- Broadcast
- Messaging
- Unbounded system
- Dedicated channel



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Research Objectives



- Broadcast performance enhancement
- Disseminate safety messages
 - to all nearby vehicles
 - within time constraint
- Latency (~ 0.4 s) should be less than driver reaction time (0.75 s ~ 1.5 s)
- Best possible Packet Delivery Ratio (PDR) should be achieved



Research Objectives



Hidden terminal problem

- No RTS/CTS mechanism for IEEE 802.11 broadcast
- Potential hidden terminal area is larger

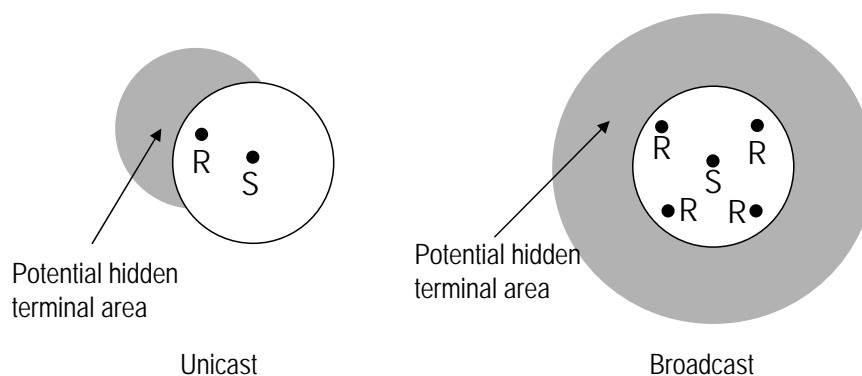


Figure: Comparison of hidden terminal problem



Research Objectives



- Analyse performance of existing protocol
- Propose a feedback mechanism based on
 - Negative acknowledge
 - Retransmission
- Develop an analytical model and compare performance
- Network simulation to verify the results



Assumptions



- Vehicles in the highway are abstracted as one-dimensional ad hoc network
- Poisson distribution for the vehicles
- Transmission and sensing ranges are equal
- Unsaturated network with each vehicle modelled as an M/G/1 queue
- Message lengths are constant
- Perfect channel



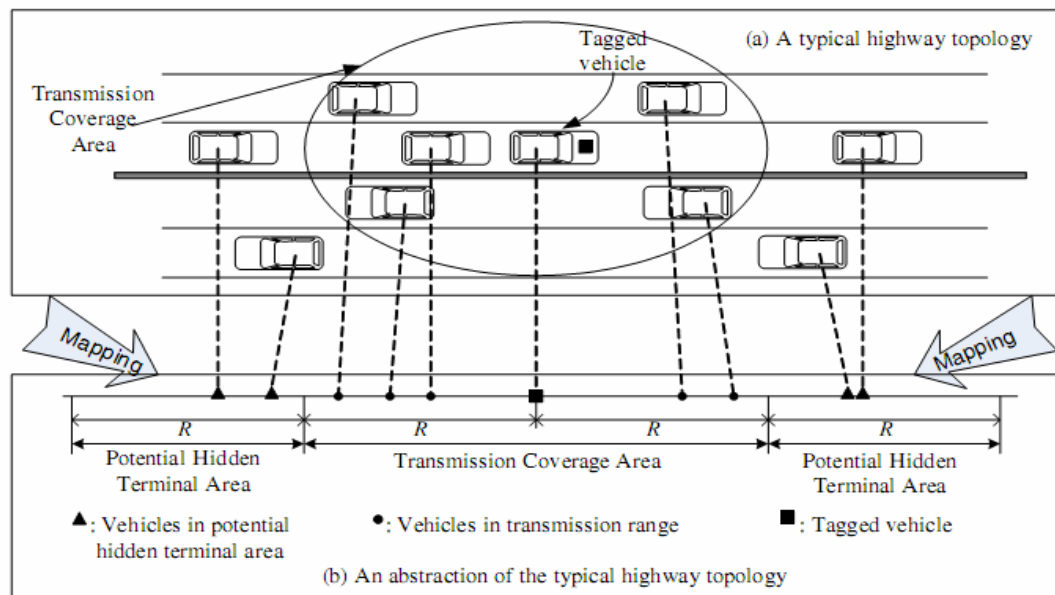


Figure: DSRC highway topology

Ref: Xianbo Chen, H. H. Refai, and Xiao min Ma "A quantitative approach to evaluate DSRC highway inter-vehicle safety communication". Global Telecommunications Conference, 2007.

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Analytical Model



- Based on delay model in saturated network
 - Transmission attempt probability
 - Collision probability
 - Delay as a sum of
 - Queuing delay
 - Backoff delay
 - Transmission Delay



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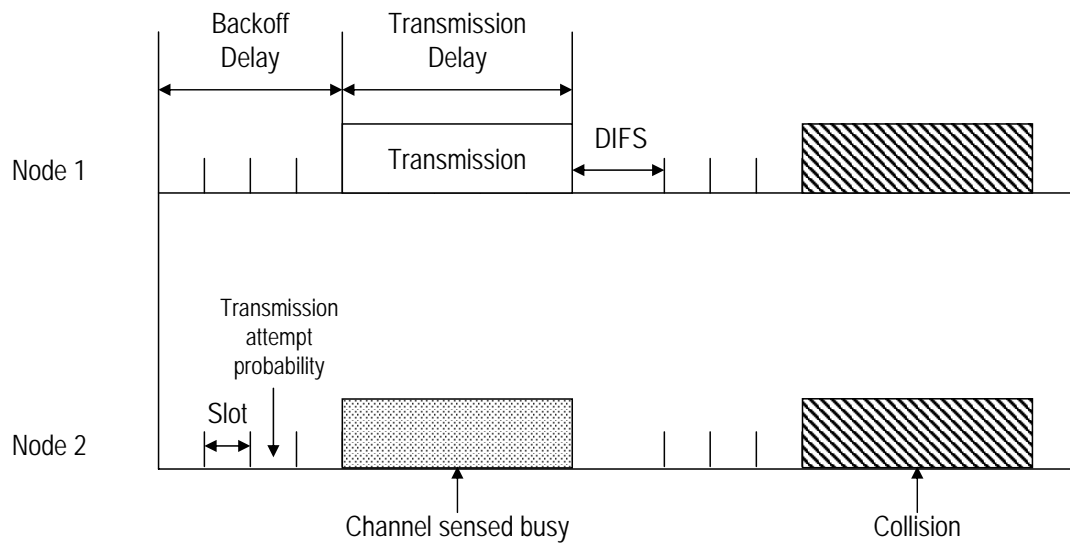


Figure: Backoff mechanism in saturated network



■ Unsaturated network

- A vehicle can have a packet to transmit with probability equal to queue utilization factor, p
- Transmit probability is scaled with p

■ Hidden terminal

- For successful transmission of tagged node
 - No neighbouring node should transmit at the same slot
 - No hidden node should transmit within the vulnerable period
- Collision probability is modified to account for hidden terminal



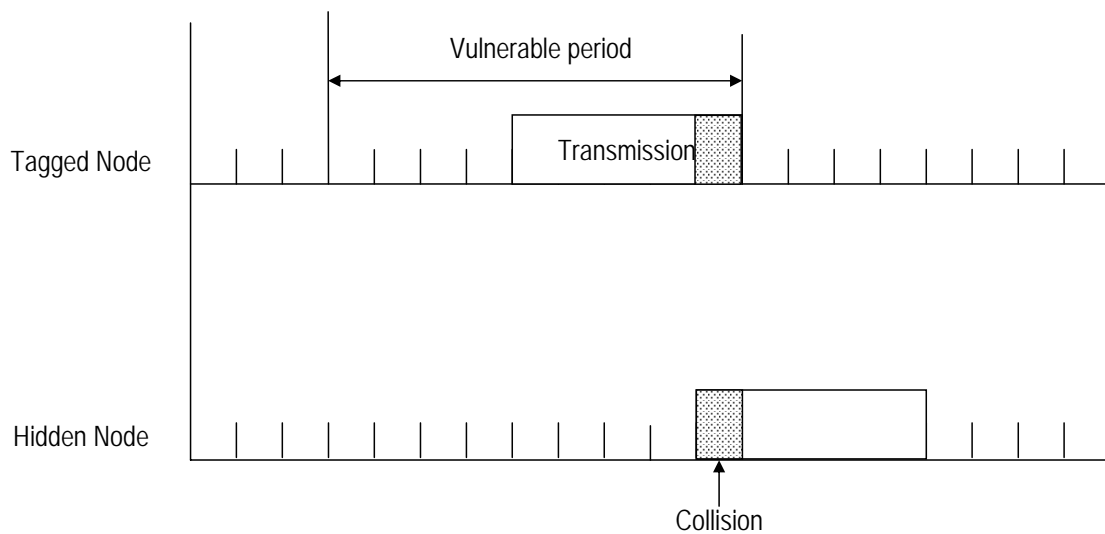


Figure: Collision due to hidden terminal



Modification in MAC Layer



- We introduce NACK for broadcast
- When a node detects collision
 - Waits until both transmissions are complete
 - Sends an anonymous NACK
 - The transmitters retransmit packets
- DIFS is modified to include one packet transmission time and time needed to send NACK
- After DIFS period all the nodes contend



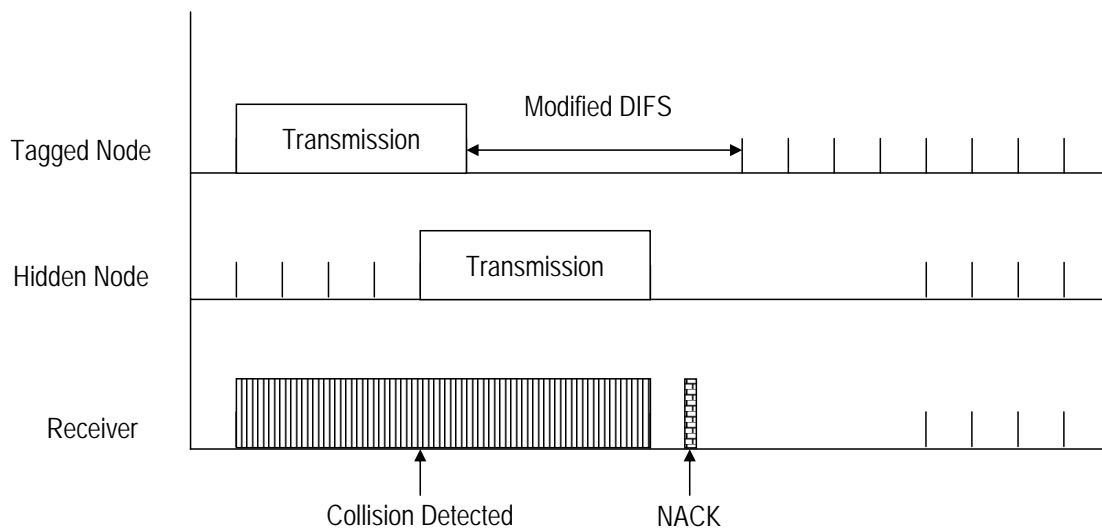


Figure: Sending NACK in Broadcast scenario



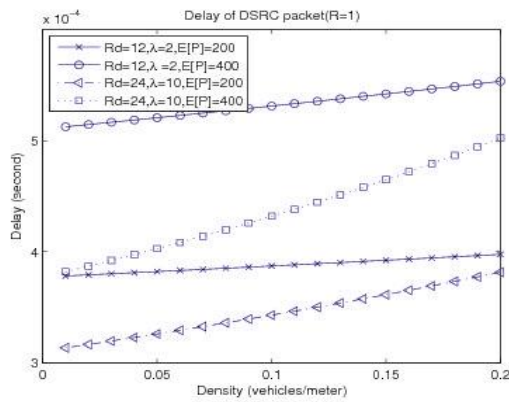
Numerical Results



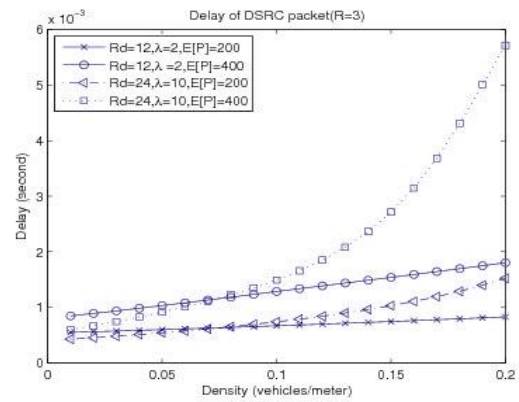
- Numerical studies are performed to analyze
 - Delay
 - Packet Delivery Ratio (PDR)
- Vehicle density is varied
- Parameters
 - Packet arrival rate, λ packets/sec
 - Packet length, $E[p]$ bytes
 - Data rate, R_d Mbps



Numerical Results



No retransmission

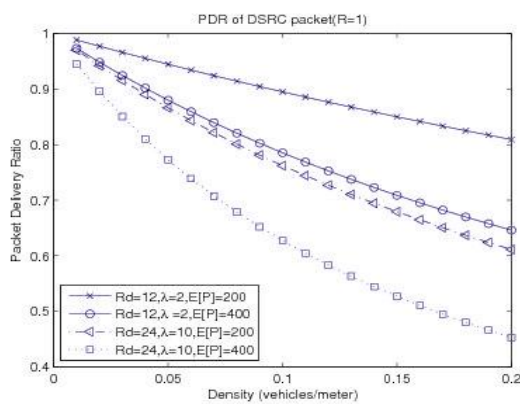


Upto three retransmissions

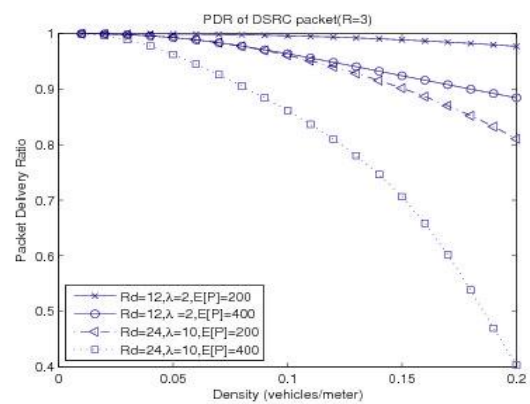
Figure: Delay comparison for simple broadcast and broadcast with retransmission



Numerical Results



No retransmission



Upto three retransmissions

Figure: PDR comparison for simple broadcast and broadcast with retransmission



Simulation



- Network Simulator NS2
- Random linear topology according to Poisson distribution
- Each node broadcasts packet randomly
- Trace file is analysed to calculate delay and PDR
- However, simulation does not quite agree with the numerical results



Discussion



- Corrections in simulation
 - Backoff handler patch
 - Boundary effect
 - Capture effect
 - Intermediate results
 - Compare results for saturated network



Discussion



- Corrections in the model
 - Introduction of queue utilization factor to convert saturated case to unsaturated case
 - Hidden terminals are not synchronized
 - Previous studies also show inaccuracies
- Model based on p-persistent CSMA/CA
 - Difference in the way a packet is rescheduled after sensing the channel busy



Q/A Session

