VANET Paper Evaluations

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1. The main approaches
2. Methods of analysis
   a) Metrics
   b) Evaluation tools
   c) Analysis and interpretation of resulting simulation or measured data
3. Conclusions
4. What did the author may have missed in the paper, gaps/limitations that could be improved upon and ideas how this could be accomplished? Did all papers use a similar approach? Have they used the same criteria or method of analysis? If not what are the strengths/weakness of each method?

The Broadcast Storm Problem in Mobile Ad Hoc Network, by S-Y. Ni, Y-C Tseng, Y-S. Chen, and J-P Sheu

In a wireless ad hoc network to disseminate information to an area greater than that covered by the transmission range of a node, multi-hop relaying is used. The simplest way to perform multi-hop relaying is by flooding a packet. In this situation, when a node receives a broadcast message for the first time, the node then re-transmits the message. The node then ignores all subsequent broadcast messages it receives from other nodes, which are also rebroadcasting the message. There are three problems associated with flooding. First, there are a number of redundant rebroadcasts because of flooding. An instance of how serious this problem is when a message is to reach *n* hosts, the packet will be sent *n* times. Second contention occurs, there is a high probability that a message will be received by many hosts in a close proximity and when these hosts try to rebroadcast the message. Each host will severely contend with each other for access to the medium. Third, a large number of collisions can occur because of the lack of RTS/CTS and because of the absence of collision detection. The authors of the paper term this problem the "broadcast storm problem".

The authors evaluate the significance of the three problems related to the broadcast storm problem, and show how serious the problem truly is. To begin, a rebroadcast of a message will only provide 0 ~ 61% additional coverage. On the average, a rebroadcast will cover only an area of an additional 41%. The additional coverage dramatically decreases based on the number of times *k* that a message is heard being rebroadcast from other nodes. When $k >= 4$ the additional expect coverage is less than 0.05%. Also, the contention is expected to be higher as the number of nodes *n* increases. The authors show that probability of all *n* nodes experiencing contention increases rapidly to 0.8 when $n >= 6$. The results show that the denser a network is the less chance of a node being able to access the medium without experiencing contention. Last, the number of collisions that occur from broadcasting a message is high for a number of reasons, such as the PCF is not available, the RTS/CTS exchange can not be used, and collision detection is not used in wireless networks.

The Main Approaches

There are two possible solutions to reduce the effects of the "broadcast storm problem", which are to reduce the possibility of rebroadcasts or to differentiate the timing of rebroadcasts. There are five possible schemes proposed by the author to alleviate the broadcast storm problem. First, a probabilistic scheme aims to limit the number of rebroadcasts. When a node receives a broadcast for the first time the message is rebroadcast with a probability *P*. Second, Counter-based broadcast is used to prevent the rebroadcast of a message when the expected additional coverage (EAC) is low. The authors showed when that when k ≥ 4 the additional coverage of a rebroadcast drastically decreases. A counter is used to keep track of the number of times that a message is heard being rebroadcast before a node has a chance to rebroadcast the message. The counter base scheme prohibits the rebroadcast when c ≥ C, with c the being the number of times a broadcast has been heard and C the counter threshold. Third, the distance-based scheme rebroadcasts a message depending on the distance between the sender and receiver. The variable D_{min} is used to record the distance between the sender and receiver of a broadcast. If D_{min} is less than the *D* threshold value, the broadcast is prohibited from being relayed. The distance between the sender and receiver can be calculated in this scheme based on the transmitted and received power. Fourth, location-based scheme allows the coverage area to be calculated with more precision than the previous schemes. A GPS device is used to record the points used in the broadcast. If the additional coverage of a message is greater than a predetermined threshold the message is rebroadcast. One possible solution to calculate the additional coverage area is based on convex polygons. The last scheme is the cluster-based scheme, where the network is partitioned into clusters.

Methods of Analysis

A number of simulations are used to determine the effectiveness of the five proposed broadcast mechanisms.

a) **Metrics:** Three metrics were used to evaluate the protocols: reachability, saved rebroadcast and average latency. Reachability is the number of host that received the broadcast divided by the total number of hosts. Next, saved rebroadcast equals *(r-t)/t* where *r* are the number of hosts that received the broadcast message and *t* are the hosts that actually transmitted the message. Last, average latency is the time from when the broadcast was initiated till the time the last host received the broadcast message.

b) **Evaluation Tools:** The authors developed a simulator written with C++. The parameters used for the simulation are 500m transmission radius, 280 byte packet size, and 1 Mbs transmission speed. The simulations uses 100 mobile hosts and which are randomly placed on a number of different maps. The maps range from a 1 x 1 to a 10 x10 unit map, where each unit is a 500 meters.

c) **Analysis:** The probability simulation shows that a small probability is sufficient to achieve a high reachability, when a map is densely populated. On the other hand, in the case of a sparse map a high probability value is needed to achieve a high level of reachability. Saved rebroadcasts also decrease as P increases, when P is set to one the protocol performs identical to flooding. Next, the counter-based scheme achieves the same level of reachability as the probability-based scheme when the threshold counter *C* is set greater or equal to 3. High density maps exhibited a 27~67% SRB when *C* is set to 3, while the spares maps achieve less savings. The third simulation was the distance-based scheme which achieved better results for reachability, but did not save much in terms of the number of rebroadcasts. The distance simulation also had a higher broadcast latency than the counter-based scheme. Next, the location-based scheme performed the best out of all of the schemes that were simulated. The benefit of using this scheme is it uses exact information to calculate the additional coverage area. Some of the other schemes did not perform well when simulated with sparse maps, but this was not the case with the distance-based scheme. Last, a cluster-based scheme that incorporates the distance-based scheme to send messages between clusters was evaluated. The cluster-based scheme performed better than the distance-based scheme in terms of rebroadcasts and latency. The problem with the cluster-based scheme is the reachability was poor when the maps were sparse. One possibility for why the reachability suffered is because of the hidden terminal problem, when two gateways in different clusters forward a broadcast at the same time to the same neighboring cluster a collision will occur. The simulation were also studied under a number of packet generation rates as the generation rate increased the reachability in the simulations degraded because of a greater number of collisions.

Conclusions

The paper addressed how serious the broadcast storm problem is. The authors introduce five schemes that improve on simple flooding. Some of the schemes presented in the paper performance rely on the topology of the network, with some of the schemes performing poorly in sparse networks. A simple counter-based scheme offers a tremendous improvement over flooding. The authors show that a location-based scheme performs the best under all situations. An area of possible future work is incorporating the schemes given in the paper into a reliable broadcast protocol.

Additional Questions

The paper was one of the first papers to address how serious the problem is with using flooding to broadcast messages in a mobile ad hoc network. One problem is each of the schemes presented in the paper sets the parameters used by the protocols statically. One possible improvement to the presented schemes is changing the parameters dynamically based on the conditions of the network. One additional way that the algorithms may be improved is by dynamically changing the transmit power of the mobile host based on the density of the network. The paper showed that not all of the schemes performed well when the network was sparse. Based on the work done in this paper, many others have used variation of these algorithms for broadcasting in mobile ad hoc networks.

Vehicle-to-Vehicle Safety Messaging in DSRC, by Q. Xu, T. Mak, and R. Sengupta

The paper addresses the feasibility of sending messages in DSRC. Broadcast messages are assumed to be used to for sending safety related information on the control channel of DSRC. The authors address sending broadcast messages in a single-hop scenario.

The Main Approaches

To increase the chance of receiving a message a broadcast messages are repeated k times. Since it there are no guarantees that a message will be received when it is broadcasted, the message is repeated a number of times in the hope that the message will eventually be successfully received. The authors explore the use of six different MAC protocols. The first four protocols use a MAC layer extension, which is placed between the 802.11 MAC and logical link layer. The final two protocols that are evaluated define a new MAC protocol. The first protocol is Asynchronous Fixed Repetition (AFR), k distinct slots are randomly selected among n total slots. Packets are always repeated a fixed number of times k and no carrier sensing is used. Second, Asynchronous p-persistent Repetition (APR) is similar to AFR except the number of repetitions of a message varies. The probability that a message will be transmitted $p=k/n$ where k is a configuration parameter and n is the number of message slot available in the lifetime of the message. Third, Synchronous Fixed Repetition (SFR) is the same as AFR except that the slots used to transmit messages are synchronized to a global clock. Forth, Synchronous p-persistent Repetition (SPR) is the same as SFR, with the synchronization of transmissions to common slots, except it uses p-persistence. Fifth, Asynchronous Fixed Repetition with Carrier Sensing (AFR-CS) generates repetitive packets the same as AFR the difference is this protocol uses carrier sensing. When a node has a packet to send it senses if the channel is busy. If another transmission is currently underway the packet is then dropped. On the other hand, if the medium is free the node broadcasts the packet. Sixth, Asynchronous p-persistent Repetition with Carrier Sensing (APR-CS) is the same as

AFR-CS except message slots are selected in a p-persistent manner.

Methods of analysis

The authors of the paper run a number of simulations to test the six MAC protocols they developed.

a) **Metrics:** The authors use two main metrics to evaluate the proposed protocols. First, Probability of Reception Failure (PRF) measures the probability of a message not be received at a certain distance within the lifetime of the message. Second metric that is evaluated is Channel Busy Time (CBT) which is the $CBT = T_{saftety}/T$, where T_{saftey} is the total amount of time the channel is transmitting safety messages and T is the total time. CBT is measured because the channel will also be used by non-safety applications, so it is important the channel is not saturated with broadcast messages.

b) **Evaluation Tools:** The protocols are simulated using SHIFT and NS-2. SHIFT is used to simulate the traffic used in the simulation. The Friis Free-space and two-ray models are used to determine receive power.

c) **Analysis:** The simulations show that there is an optimum number of repetitions, which depends on message range, traffic density, message size, etc. The simulations showed that the protocols that performed the best are the AFR-CS and SFR. The best protocol was AFR-CS since it does not rely on the global synchronization of nodes. The synchronous protocols out perform the asynchronous equivalents, because the synchronous protocols eliminate the partial overlapping of packets. The fixed repetition protocols also outperformed the p-persistent protocols because there is less fluctuation in the number of packets sent. Finally, the protocols which used carrier sensing outperformed those which did not carrier sensing. An inverse relationship between CBT and PRF was found until the optimum number of repetitions is reached.

Conclusions

The authors conclude it will be feasible to use 802.11a for DSRC, if the protocol designers and applications designers work together. The authors found it is possible to send broadcast messages every 200 ms to 140 points with 250 bytes of data. GPS devices typically are updated at 5 Hz, so sending a message every 200 ms should be acceptable. A broadcast protocol does not need to have a 100% guaranteed rate of reception. An acceptable approximation of vehicular map can be created with a PRF of 1/100.

Additional Questions

One of the problems with this approach is that it is only a single-hop broadcast; it is unlikely that the protocol would support the multi-hop relaying of broadcast messages. If multi-hop relaying was used the CBT would likely rise to an unacceptable level. One weakness is the study doesn't measure the number of collisions that occur from broadcasting a message multiple times. One approach recommended by the authors to improve there protocol is to implement an adaptive control at the MAC layer. Protocols such as the one suggested by the authors could be used to passively construct the topology of the vehicles.

Urban Multi-Hop Broadcast Protocol for Inter-Vehicle Communication Systems, by G. Korkmaz, E. Ekici, F. Ozguner, and U. Ozguber

The Main Approaches

The paper addresses the problem of transmitting multi-hop broadcast messages in areas where shadowing is caused by large buildings. The authors propose the Urban Multi-hop Broadcast (UMB) protocol that selects the furthest node from the transmitter to rebroadcast a message and uses repeaters at intersection to rebroadcast a message to overcome the problem of large buildings obstructing a messages path. The goal of the protocol is to avoid collisions caused by hidden nodes, use the channel efficiently, make broadcast communication reliable, and disseminate messages in all directions at an intersection. The protocol assumes that all vehicles will be equipped with GPS devices and electronic maps. The UMB protocol is a variant of IEEE 802.11.

The first part of the protocol is used to determine the farthest node from the transmitter which will be used to rebroadcast the message. The network is iteratively divided into segments to determine the farthest node from the broadcaster, which is then used to relay the broadcast. The RTS/CTS sequence in 802.11 helps to alleviate the problem caused by hidden nodes. In the case of broadcast messages, if the RTS/CTS sequence is used then a storm around the transmitter would exist. UMB introduces Request to Broadcast (RTB) and Clear to Broadcast (CTB). Only the transmitter and farthest node from the transmitter exchange the RTB/CTB messages. When a node has a broadcast message to send, it transmits a RTB. The protocol then selects the farthest node from transmitter to relay the broadcast. The farthest node is determined by using a black-burst. Each node computes the length of the black-burst based on there distance from the sender. If a node finishes transmitting the black-burst and hears no others sending the burst on the medium, it knows that it is the farthest node, so it sends a CTB to the sender. The sender then transmits the data to the receiver. The receiver of the broadcast that was elected to relay the message sends back an ACK indicating that the message was successfully received. The receiver then continues the process of relaying the broadcast message. The protocol also has number of mechanisms that help to resolve conflicts if two nodes are of equal distance to the sender.

The second part of the protocol involves relaying the message with the use of repeaters at intersections. Each vehicle is equipped with a map and a GPS device. If a vehicle is in range of an intersection it can send an 802.11 unicast packet to the repeater. The repeater will in turn relay the message in all directions except the direction the message was received from. The sender includes directional information in the packet to prevent the repeater from rebroadcasting a message in the same direction. The protocol also addresses the problem of loops by using a cache to determine if a packet has already been seen.

Methods of analysis

To analyze the UMB protocol, the authors developed the Wireless Simulator (WS) which is based on CSIM.

a) **Metrics:** Three metrics were used to evaluate the performance of the protocol. First, success percentage records how many vehicles successfully received a broadcast packet. Second, packet dissemination speed is the distance traveled by the packet divided by the delay. Third, load generated per broadcast packet is the total number of bits transmitted to disseminate the packet to the whole network.
b) **Evaluation Tools:** The UMB protocol is compared with two 802.11 based flooding protocols that attempt to avoid collisions. First, the 802.11-distance protocol assigns the farthest node the smallest wait time, so that the farthest node will rebroadcast a packet first. Second, 802.11-random has each node randomly calculate the amount of time to wait before rebroadcasting a packet. The three MAC protocols are then analyzed using four simulations. The first simulation is conducted with a single intersection over a 1200m x 1200m area. The second simulation is identical to the first except that the density of vehicles in the network is increased. The final two simulations use 2400m x 2400m area with 4 intersections, with one simulation using a sparsely populated network and the other a densely populated network. Also, each scenario is simulated with 100 byte and 2312 byte packets to compare the difference that the

size of the packet makes on the protocol.

c) **Analysis:** The simulations showed that the UMB protocol outperforms the 802.11 variants in both success rate and average packet load. The results were not as clear for packet dissemination speed in some case the 802.11 protocols outperformed UMB while in other cases UMB outperformed the 802.11 flooding protocols.

Conclusions

The UMB protocol performs much better than a flooding protocol. The load on the network from the UMB protocol is lower and success rate of the protocol is much higher.

Additional Questions

The one drawback of the protocol is it requires repeaters. It is unlikely that repeaters will be installed at every intersection. One drawback of the simulation is the only compares the protocol against flooding protocols. The authors should have evaluated the performance of the protocol against other efficient broadcast protocols. Other papers have proposed other distance based broadcast protocols, but the UMB protocol incorporates the RTB/CTB exchange to help eliminate the hidden terminal problem.

A Vehicle-to-Vehicle Communication Protocol for Cooperative Collision Warning, by X. Yang, J. Liu, F. Zaho, and N. Vaidya

The Main Approaches

The paper proposes the Vehicular Collision Warning Communication (VCWC) protocol. The VCWC protocol provides congestion control, service differentiation, and a method for propagating emergency message warnings.

A communication collision warning protocol can be achieved by taking either a passive approach or an active approach. First, in a protocol that uses the passive approach requires each vehicle to frequently broadcast its state information to other neighboring vehicles. Each vehicle then uses the collected state information from the surrounding vehicles to determine if it is in a dangerous situation. The drawback of using a passive protocol is the network is always saturated with safety messages. Second, the active approach only sends messages when an emergency event occurs. For instance, an emergency warning message (EWM) would be sent if a vehicle decelerates abruptly. The VCWC uses the active approach to achieve cooperative collision warning.

A number of problems arise in vehicular communication systems. To begin, the wireless links are unreliable. Next, a vehicle becomes an abnormal vehicle (AV) when an event such as abrupt deceleration occurs. When a vehicle transitions to the AV state it should send EWMs. The surrounding vehicles should receive emergency messages as quickly as possible, so the driver has time to react. Also, a communication protocol must share the channel with other applications. The channel will not be used just to send emergency warnings. Next, when an emergency event occurs surrounding vehicles can also become abnormal vehicles and generate there own emergency message warnings, as result of reacting to the initial emergency situation. The system should support many simultaneous emergency messages. Finally, when an emergency event occurs a chain effect happens, where vehicles behind the initial vehicle that generated a EWM also generate their own EWMs. In this case, the initial vehicle should stop sending EWM if the vehicles behind it are generating their own EWMs. Some of the assumptions made by the authors are each vehicle will have GPS device, a digital map, the communication channel will be used by various types of applications, the transmission range is 300m, and contention will be based on 802.11 MAC.

A number of mechanisms are used by the VCWC protocol to disseminate emergency warning messages. The VCWC protocol focus on three aspects, message differentiation, congestion control policies and emergency warning dissemination.

Message differentiation is used because both time-sensitive and non-time-sensitive messages contend for the channel. The authors distinguish three classes of messages: class 1 emergency warning messages (EWM), class 2 forwarded EWM, and class 3 non-time-sensitive messages. Differentiation between the message classes is achieved by the inter-frame spacing and the size of the contention window. Service differentiation allows high priority messages to access the channel faster.

The focus of the authors work in the paper is providing congestion control for emergency warning messages. In order for the network to remain stable congestion control is applied. When an accident or an emergency arises a large number of emergency messages are generated, to overcome this problem the authors suggests decreasing the rate at which warning messages are generated and state transitions for abnormal vehicles.

A multiplicative rate decrease algorithm is used to limit the number of messages sent by an AV. The emergency warning rate after the k^{th} transmitted EWM is calculated with the formula below. The parameters a and L are fixed parameters, the authors derive there values from the results of their simulations. The parameter λ_0 is the initial transmission rate for emergency messages.

$$f(\lambda_0, k) = max(\lambda_{\min},\ \lambda_0/a^{\text{floor}(k/L)})$$

When an emergency event first occurs, the AV transmits warning messages at the greatest rate. Over time, the timing between consecutive warnings sent by a vehicle is lengthened, based on the assumption that surrounding vehicles have already received the message. The minimum transmission rate should be set so that when a vehicle enters the transmission range of the abnormal vehicle it will have time to react. The time needed to react by approaching vehicles is much longer than the time needed to initially react to the situation. By reducing the rate that emergency warnings are being sent, more warnings can be sent from larger number of vehicles concurrently.

Congestion control is also achieved by state transitions of the abnormal vehicles. There are three states that a vehicle can be in: the initial state, flagger AV and non-flagger AV. A vehicle transitions to the initial AV state when emergency occurs upon the roadway. In the initial AV state the vehicle will begin broadcasting EWMs at the maximum rate and then start decreasing the EWMs with the multiplicative decrease algorithm. A vehicle will transition from the initial AV state to the non-flagger AV state if T_{alert} time has expired and the message is overheard being disseminated by another vehicle directly behind it. T_{alert} is the initial amount of time that a message should be broadcast, so that there is a high probability that the message will be heard by others. In the non-flagger state the vehicle refrains from sending EWMs. The vehicle then keeps a timer *FT* and resets the timer each time it hears an EWM. If the timer expires and no EWMs are heard the vehicle then it transitions to the flagger AV state. In the flagger AV state, the vehicle transmits EWMs at a minimum rate. When a vehicle in the flagger AV state overhears messages from following vehicles it transitions to a non-flagger state.

When an event occurs that triggers the sending of EWMs, the messages must be disseminated to as many vehicles as possible in order to avoid the dangerous situation. Messages are disseminated in two ways. First, the drivers will naturally react to the situation and generate their own EWMs. Second, a forwarding protocol can be used. The paper doesn't recommend the use of any specific forwarding mechanism but determines that there should be a limit to how far messages are transmitted.

Methods of Analysis

1. The primary metric that the authors use to measure the success of the VCWC protocol is EWM delivery delay. During the simulations, the authors vary some of the parameters to their algorithms and determine what affect it has on the EMW delivery delay. The authors are mainly concern with delivery delay because when an accident occurs the quicker that other drivers receive a warning message, the greater the chance they will be able to avoid an accident.
2. The VCWC protocol was analyzed with ns-2 network simulator.
3. The authors perform a number of simulations on the VCWC protocol. The first simulation was used to establish the parameters of the multiplicative rate decrease algorithm. The authors determined the appropriate values to assign to λ_0 and L. The authors conclude that when $L = 5$ and $\lambda_0 = 100$, the network would support more than 50 vehicles sending emergency warnings. Next, the authors compared the performance of the multiplicative decrease algorithm against a constant rate algorithm. In this simulation the authors vary the number of AV from 5 to 50 and the probability of reception set to both 0.9 and 0.5. The simulation showed that the delay greatly increased in the case of constant algorithm, when the number of vehicles approached 25. On the other hand, multiplicative rate algorithm resulted in acceptable delivery rates with 50 abnormal vehicles. A final simulation was run to determine the influence the VCWC protocol has on non-time sensitive traffic. When an emergency first happen the VCWC protocol will generate a lot of traffic in the fist two seconds, after the occurrence of an accident. After two seconds have passed, the amount of traffic generated from AV is significantly reduced.

Conclusions

The multiplicative decrease EWM algorithm allows a larger number of vehicles to simultaneously sending emergency warnings than would otherwise have been possible.

Additional Questions

The VCWC protocol uses an active approach to detect abnormal driving situations. In reality the active approach won't help to prevent all accidents. If a vehicle is gradually decelerating while the vehicle behind it is accelerating and neither of these vehicles reaches a threshold to send an EWM, they could collide with each other and never receive an alert. The active approach would prevent additional accidents from taking place, but may not prevent the original accident. The protocol doesn't address the hidden terminal problem. The VCWC relies on an abnormal vehicle sending warning messages at a high rate to compensate for collisions and the hidden terminal problem. The one drawback of the paper is the authors don't explain how some of the mechanisms they use work. For instance, EWM are given priority by using an out of band black-burst that covers double the transmission range. Also, the authors do not give much detail on the multi-hop relaying strategy they use.

Broadcast Reception Rates and Effects of Priority Access in 802.11-Based Vehicular Ad-Hoc Networks, by M. Torrent-Moreno, D. Jiang, and H. Hartenstein

The paper studies the probability that a broadcast message is received at a certain distance from the sender. Also, the authors investigate the consequence priority access has on the reception rate of a broadcast. Furthermore, the result of deterministic vs. non-deterministic radio propagation models have on reception rate of a broadcast is explored.

The Main Approaches

In all likelihood when VANETs become a reality they will be based on 802.11. The primary media access method of 802.11 is the distributed coordination function (DCF). Priority access is achieved with the use of the Enhanced Distributed Channel Access (EDCA). Two problems exist when using these mechanisms for broadcast messages. First, the contention window (CW) will not be increased with the failed delivery of a message, since acknowledgments are not used for broadcast messages. Second, the RTS/CTS exchange is can not be used, so the hidden terminal problem exists. The authors define 4 classes of traffic, with class 0 the lowest priority and class 3 the highest priority. Priority access is given to a node by shortening the interframe spacing and decreasing the minimum contention window size. The authors of the paper use AIFSD[AC] and CW_{min}[AC] instead of DIFS and CW_{min}, which are typically used by EDCA.

Methods of Analysis

1. **Metrics:** Two simulations were used in the study a static scenario and a dynamic scenario. In both scenarios all vehicles were given an AC = 0 except for one vehicle. Simulations were run with NS-2 to determine the result of giving one vehicle priority access has on the reception rate of a broadcast. The static scenario was used to determine the result that priority access had on the reception rate of a broadcast message. This scenario studies the effect that different interframe spacing and contention window sizes have on the probability of broadcast message being successfully received. Also investigated is the probability of reception when a backoff timer was selected with a value of 0 and the probability of reception when the sending node pauses its backoff timer at 1. Next, the dynamic scenario observed the channel access time and the probability of reception. This scenario used two different radio propagation models the two-ray ground model and the Nakagami model to determine the impact they have on the reception rate.
2. **Evaluation Tools:** NS-2 was used to perform the simulations. Two different transmission ranges were used 100m and 200m. Also, two different sizes of messages were used in the simulation one used packets of 200 bytes and the other used packets of 500 bytes. The network would be highly saturated in the case of vehicles with a 200m transmission range and 500 byte messages.
3. **Analysis:** The static scenario was used to evaluate how message reception is affected by changing parameters of interframe spacing AIFS and contention window size. In this scenario node S broadcasts messages and node R which is located 100m away receives the messages. The results of the simulation showed that shorter interframe spacing dramatically increases the probability of reception. While lowering the size of contention window only slightly increases the probability of reception. The reason that the contention window parameter had a greater affect on the probability of reception is when the network is highly saturated with traffic nodes will frequently have to pause their backoff timers. In this case, a node with a shorter AIFS will decrement its backoff timer before others get a chance to and gain access to the medium. The authors give two cases where a node with a high priority will benefit. First, if a node selects a BT of 0 at the beginning of the backoff process. Second, if the node that has a high priority is paused with its BT = 1, when the backoff is continued it will be the first to gain access to the media. When the sender had an AC = 3, 59.4% of the packets were received. On the other hand, when the senders AC = 0 only 27.7% of the packets were successfully received. In the case of a sender pausing when its BT = 1, when the senders AC = 3 then 71.0% of packets were received compared to only 22.6% when the AC = 0. In the dynamic scenario the probability of reception was measured based on the distance from the sender. A number of simulations were run varying the transmission range and size of the packets. Also, the simulations were run using the two-ray ground model and the Nakagami model. A simulation was run with a 200m

transmit radius and 200 byte packets, in this scenario the node sending packets with a higher priority achieved a 16.3% gain on the average in the reception of broadcast messages over non-prioritized broadcasts. When the packet size was increased to 500 bytes the prioritized messages achieved an even higher probability of reception, compared to the non-prioritized nodes. While the probability of reception decrease for both classes of traffic the probability of reception drastically decreased when the network reached saturation. The same simulations were run using the Nakagami radio propagation model and the results were much worse for both prioritized and non-prioritized traffic. At 50 meter from a node sending a packet with an AC = 3 the probability of reception is approximately 40%. All of the simulation found that when the distance was greater than 66% of the transmission range the probability of reception rapidly dropped as a result of the hidden terminal problem.

Conclusions

Using a non-deterministic model greatly reduces the probability of reception of a broadcast message. A simulation that uses a model such as the Nakagami model is more likely to mirror a vehicular ad hoc network, than a simulation that uses the two-ray ground model. The simulations showed that as the distance from the sender increases a receiver may not receive a message even if it is in the transmission range of the sender. Because of the low probability of reception of broadcast messages both repetition and multi-hop relaying strategies need to be developed.

Additional Questions

One limitation of the study is only one node in the network was given a higher priority. In a network where multiple nodes have a high priority at the same time it is likely that the probability of reception for high priory nodes would be worse than the simulations show. The authors aim was to study the reception rate of broadcast messages and result of giving a node priority access. Because of the hidden terminal problem and lack of acknowledgments for broadcast messages the likelihood of a message being received greatly decreases as the receiver gets father away from the sender. When a receiver is at the edge of the transmission range of the sender it is unlikely that is will receive the message.

List of material to explore later

- two-ray ground model
- Nakagami model
- Out of band black-burst
- 802.11e