Project Proposal

Increasing Broadcast Reliability in Vehicular Ad Hoc Networks
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Motivation

Broadcast messages will play a large role in Vehicular Ad Hoc Networks (VANET). A large portion of the messages sent in a vehicular network will be broadcast messages. Broadcast messages may play a larger role than the use of unicast messages in VANETs. Some of the uses for broadcast messages are: sending emergency warning messages, transmitting state information to other vehicles, broadcasting aggregate data, address resolution, and determining routes. The FCC in the United States reserved 75 MHz of bandwidth in the range 5.850 to 5.925 GHz to be used for vehicle-to-vehicle and vehicle-to-roadside communication. The 5.9 GHz spectrum was termed Dedicated Short Range Communication (DSRC) and is to be based on a variant of 802.11a. The transmission range of the vehicles in DSRC is expected to be approximately 300m.

There are a number of problems with ensuring the reliable delivery of data for broadcast messages. The IEEE 802.11 protocols use an optional RTS/CTS handshake followed by an acknowledgment to guarantee the delivery of a unicast packet. Broadcast messages, on the other hand, cannot use the RTS/CTS exchange because it would flood the network with traffic. For instance, if all receivers transmitted a CTS in response to a RTS then many collisions would occur at the prospective transmitter of the broadcast message. As a result of not using the RTS/CTS exchange, the network exhibits the problem known as “the hidden terminal problem” [1]. The hidden terminal problem occurs when there are two nodes that are outside the transmission range of each other but will each transmit to a node that is shared between them, if both nodes were to transmit at the same time a collision would occur at this shared node. The hidden terminal problem is the main cause of collisions in a wireless network.

Broadcast messages that require a transmit distance greater than the transmission range of the node broadcasting the message must use multi-hop relaying. The easiest way to implement multi-hop relaying is to use flooding in which a node, receiving a broadcast for the first time, rebroadcasts the message. Flooding results in the problem known as “the broadcast storm problem” [3], which is characterized by a large number of redundant broadcasts, nodes in the network contending with each other for access to the medium, and the likelihood of a large number of collisions occurring. Another problem associated with broadcast messages is it isn't practical to receive an acknowledgment from each node. The lack of an acknowledgment makes it difficult to guarantee the delivery of a broadcast message. If acknowledgments were used, a broadcast storm problem would occur around the receiver of the ACKs.

When emergency warning messages are broadcast, they should be given a higher access priority than common data messages. The vehicular network should support the ability to prioritize messages. The IEEE 802.11e MAC layer extension provides the Enhanced Distributed Coordination Function (EDCF). The priority scheme is provided by EDCF as a result of differentiating the inter-frame spacing and the initial window size. One problem with using EDCF for broadcast messages is that the size of the contention window will never grow for broadcast messages since the transmission will either succeed or fail with sender having no knowledge of the result.

Due to the reasons previously mentioned, there are a number of challenges to the implementation of a reliable broadcast in vehicular ad hoc networks.

Related Work

A number of authors have addressed the problem of sending broadcast messages in MANETs and VANETs. In [3] the authors address the broadcast storm problem in MANETs, and they propose five multi-hop relaying strategies: a probabilistic-based scheme, a counter-based scheme, a distance-based scheme, a location-based-scheme, and a cluster-based scheme. The authors found that a location-based scheme performed the best because the scheme eliminated the most redundant broadcast and performed well in both sparse and dense networks. In [4] the authors show that the probability of reception of a broadcast message decreases as the the distance from the sender increases. The primary reason that the reception rate decreases is because of the hidden terminal problem. The authors implement a priority access mechanism which improves the reception rate of broadcast messages, but still fails to achieve reliability anywhere near 100%. In all likelihood, it may be unrealistic to expect every node in an 802.11 based network to successfully receive a broadcast because of the hidden terminal problem. The authors in [7] propose a single-hop broadcast protocol that increases the probability of a message's reception by sending the message multiple times. The problem with this scheme is it will not scale well when used for multi-hop relaying. In [2] the authors propose using a number of iterations of sending black-bursts to select the node to relay a broadcast message. The authors of [8] propose the VCWC protocol to transmit emergency warning messages (EWM), which is based on a state machine and a multiplicative rate decrease algorithm. When an accident first occurs the vehicle starts transmitting EMWs at the maximum rate and over time decreases the rate at which EMWs are sent. Both [7] and [8] aim at increasing the probability of reception by broadcasting a message multiple times,which increases the load on the network. Other solutions aim at assigning time slots to nodes for them to transmit during, these solution are likely inapplicable to VANETs because it requires the synchronization of nodes which is hard to achieve because of the high mobility of nodes. Also, many of the algorithms that need to maintain sets or clusters may not perform well in VANETs because of the high mobility and the large amount of overhead that is necessary to maintain the sets. Probably the best approach to achieving a high reliability of broadcast messages in a VANET based on 802.11 is to use a repetition strategy based on feedback from the network.

Project

Problem Statement

In a vehicular ad hoc network it is important that broadcast messages are received with a high probability. Broadcast messages such as emergency warnings should be received by all vehicles in the proximity of the endangered vehicle with the smallest delay possible. The goal of the project is to implement a broadcast protocol that improves the reliability of receiving broadcast messages for a vehicular ad hoc network.

Scenarios

VANETs are highly dynamic, the topology of the network can change quickly, but the vehicles in the network usually follow a predictable pattern. The simulations should come as close as possible to modeling a real world vehicular environment. The simulations should support vehicles on the road moving at various speeds, as they would on a real highway. The simulations should also consider both densely and sparsely populated networks. On a road with light traffic it is common for the network to become partitioned, so that a portion of the network is not reachable. Some algorithms that perform well in densely populated networks perform poorly in sparse networks and vice versa. The simulations should use a mobility model that closely approximates vehicles on a highway.

The primary use of broadcasting in vehicular ad hoc networks is for accident avoidance. A broadcast protocol should operate efficiently under a number of different conditions. The simulations should account for a number of driving conditions that are likely to occur. To begin, the simulations should model a highway where no accident has occurred. In this scenario, the vehicles in a network will move at a constant rate and vehicle will periodically exchange their state with the other vehicles. Also, the simulations should account for situations in which an accident occurs on the highway, which triggers the broadcast of emergency message warnings to other vehicles. When an accident occurs the vehicles on the road decrease their speed and the network will become more congested with traffic as more nodes are in the same communication range.

The VANET should account for three types of traffic: periodic broadcasts, emergency warnings and private application messages. First, the periodic broadcasts will be transmitted approximately every 100ms by each vehicle. The periodic broadcast are used to exchange the state of a vehicle to the surrounding vehicles (i.e. location, direction, velocity, etc.), so that the vehicles can passively detect dangerous road conditions. Second, emergency warnings are exchanged only when a dangerous condition arises. Emergency warnings are used to actively warn other vehicle of an abnormal condition such as an accident on the highway. When an accident takes place warning messages should be disseminated as quickly as possible to all surrounding vehicles. Last, VANETs will be used to send private unicast messages, which will be sent either vehicle-to-vehicle or vehicle-to-roadside. Unicast messages will be used for these value added services such as electronic toll collection. It is essential that broadcast messages do not consume all of the available bandwidth in the VANET, so that private application messages can be exchanged.

DSRC will be based on 802.11a so the simulations should use parameters that will mirror the values that are likely to be used when VANETs are deployed.

Methodology

In order to improve the performance of the broadcast protocol some feedback from the network will be used. The amount of overhead used to obtain the feedback from the network should be minimized. Ideally, a passive approach should be used where each node monitors the network to detect collisions and congestions. The benefit of using a passive approach is that no additional overhead is required. Nodes can receive feedback from the network by monitoring the loss rate of packets. Each node in the network assigns a sequence number for each packet sent. The nodes would maintain a cache of recently overheard broadcast messages. The cache would contain a tuple to uniquely each broadcast message based on (address, port, sequence_number). A Node would then able to detect lost messages based on gaps in the sequence numbers. For instance, if node B is receiving periodic broadcasts from node A and if node B has received broadcast messages with the sequence numbers 1, 2, 3, 6, 7 than messages 4 and 5 were lost. Gaps in the sequence numbers of a broadcast are due to either collisions or congestion.

Nodes can use the information obtained from monitoring the received broadcasts to adjust the parameters used to broadcast a message. The first possible improvement is using the obtained feedback to adjust the contention window of a node. Another area where the feedback may be beneficial is for adjusting the transmit power of a node. The transmit power of a vehicle can be adjusted based on the number of nodes broadcasting during an interval, which will give an idea of whether the network is densely or sparsely populated. In the case of a densely populated network the transmission range of the vehicle will be reduced to limit contention.

The methodology that will be used to evaluate the broadcast protocol is a network simulator. NS-2 will be used to evaluate the protocol. Also, some modification may need to be made to the NS-2 to conduct the simulations, such as modifying the mobility model or modifying packet headers.

Evaluation Metrics

A number of metrics will be used to evaluate the protocol. First, percentage of vehicles that received the broadcast (PVRB) will measure how effectively the protocol is at reaching all of the intended recipients of a broadcast. If the protocol achieves 100% PVRB then all of the vehicles will have successfully received the broadcast, although it may be unrealistic that all nodes will receive a broadcast because of the hidden terminal problem. Next, a broadcast protocol should use the bandwidth efficiently, because the the channel will be used for other types of messages along with the broadcast messages. The percentage of the bandwidth that is consumed by broadcast messages should be evaluated. A protocol that use less bandwidth is preferable. Finally, the latency should be measured which is the time elapsed from the start of the broadcast till the final host receives the broadcast.

The simulations should be evaluated based on using feedback and no feedback. The broadcast protocol should perform better with the use of feedback.

References

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