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MULTICAST COMMUNICATION USING VEHICLE TRAJECTORY DATA

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Abstract

Road network and security conditions are transferred to all nodes in the VANET. Data broadcast operations are carried out with forwarder nodes. Waiting time information is used in the forwarder node selection process. Data broadcast operations are carried out using Robust and Fast Forwarding (ROFF) protocol. Waiting time and priority factors are considered in the forwarder node selection process. Vehicle location and gap between vehicles are shown in the Empty Space Distribution (ESD) bitmap. Forwarding priority is identified with the support of the ESD bitmap information. Data broadcast and multicast operations are handled with the integration of the Robust and Fast Forwarding (ROFF) and Trajectory based Multicast (TMC) protocols. Forwarding capacity and Message Forwarding Metrics are estimated to identify the forwarder nodes. Data security and replica node concepts are adapted to improve the system. Network communication status is predicted with reference to the trajectory details.

1. Introduction

The concept of leveraging wireless communication in vehicles has fascinated researchers since the 1980s. In the last few years, we have witnessed a large increase in research and development in this area. Several factors have led to this development, including the wide adoption of IEEE 802.11 technologies; the embrace of vehicle manufactures of information technology to address the safety, environmental, and comfort issues of their vehicles; and the commitment of large national and regional governments to allocate wireless spectrum for vehicular wireless communication. Although cellular networks enable convenient voice communication and simple infotainment services to drivers and passengers, they are not well-suited for certain direct vehicle-to-vehicle or vehicle-to-infrastructure communications. Vehicular ad hoc networks (VANETs), which offer direct communication between vehicles and to and from roadside units (RSUs), can send and receive hazard warnings or information on the current traffic situation with minimal latency.

With the availability since the late 1990s of low-cost, global-positioning system (GPS) receivers and wireless local area network (WLAN) transceivers, research in the field of inter-vehicular communication gained considerable momentum. The major goals of these activities are to increase road safety and transportation efficiency, as well as to reduce the impact of transportation on the environment. These three classes of applications of VANET technology are not completely orthogonal: for example, reducing the number of accidents can in turn reduce the number of traffic jams, which could reduce the level of environmental impact. Due to the importance of these goals for both the individual and the nation, various projects are underway, or recently were completed and several consortia were set up to explore the potential of VANETs. These consortia projects involve several constituencies, including the automotive industry, the road operators, tolling agencies, and other service providers. These projects are funded substantially by national governments. National governments also contribute licensed spectrum, generally in the 5.8/5.9-GHz band and at least in Japan, the 700-MHz band.

The term VANET was originally adopted to reflect the *ad hoc* nature of these highly dynamic networks. Because the term *ad hoc network* was associated widely with unicast routing-related research, there is currently a debate among the pioneers of this field about redefining the acronym VANET to deemphasize ad hoc networking. Because this discussion has not yet reached consensus, we will continue to refer to vehicle-to-vehicle and vehicle-to-roadside communication based on wireless local area networking technology as a VANET.

2. Related Work

Naive flooding is a simple approach for multihop MAC-layer broadcast. It results in serious redundancy, contention, and collision due to a large number of nodes trying to resend the packet to their neighbors at the same time. In the literature, this effect is termed as the broadcast storm problem. Many broadcast schemes for message dissemination in VANETs have been proposed in the literature [2], [9]. The impact of the broadcast storm problem has been studied in the context of VANET scenarios, and suppression techniques have been devised by combining probabilistic and time-delay-based methods. Although these methods guarantee 100% reachability, they are unable to completely eliminate broadcast redundancy. Role-based multicast is proposed with the objective to maximize reachability in a sparsely connected network by employing the store-carry-forward mechanism. Most of state-of-art VANET broadcast schemes [7], [8] follow the distance-based approach, in which the farthest node is chosen as the forwarder. In such schemes, each node needs to be aware of its own position only. In addition to this, the farthest node offers maximum additional coverage as a result of which number of hops is reduced, which, in turn, reduces the end-to-end delay. Consequently, this approach has been favored over no distance-based methods.

Some researchers designed cluster-based solutions to achieve fast dissemination of the emergency message [6]. One of them presents an interesting concept of a virtual backbone consisting of a chain of forwarders selected based on relative mobility. It is crucial to determine the appropriate refresh interval for efficient use of the backbone. An efficient 802.11-based protocol called urban multihop broadcast (UMB) is proposed. UMB selects the furthest possible node as the forwarder. To accomplish this, the area inside the transmission range is divided into a certain number of segments of equal width. The nodes in all segments choose black-burst lengths proportional to the distance of their segment from the source with the furthest segment having the longest black-burst duration. On completion of black burst, the node senses the channel. If black burst is still present, the node exits the contention phase as not being part of the furthest segment. The node replies to the source, which then transmits the broadcast packet. If a relay node cannot be found in the collision resolution phase, then a random phase occurs to select one of the candidates as the relay node. Smart broadcast (SB) is another distance-based protocol that uses the same segment-based approach. It differs from UMB a way that each segment is assigned a fixed-size contention window. On receiving request from the source, nodes randomly choose a back-off time from the window allocated to their segment.

UMB and SB have been two of robust protocols designed so far for VANETs. In UMB, the relay node waits for the longest time period before rebroadcast. The latency is further exaggerated if the protocol enters the collision resolution phase in high node densities. Even if the hop count is minimized because of high message progress, the total delay for message dissemination in the desired area becomes large due to longer rebroadcast delay. SB shows a good endeavor to reduce the latency. Simultaneously, it keeps the message progress nearly the same as that of UMB. It is unable to sustain the same performance level in all possible node densities. In the case of high node density, there is high probability that the relay node exists in the outermost segment, reducing the waiting time incurred in a forwarding phase. In contrast to this, low node density results in higher waiting time by not finding potential relay nodes near the border. Due to the inherent nature of backoff time assignment, SB experiences a large performance gap between high and low node densities.

Unlike UMB and SB the proposed scheme addresses the latency issue by introducing a different segment based approach. We attempt to make the latency constant, regardless of node density and scenarios. We use a binary partition-based approach to iteratively partition the area inside the transmission range to produce a farthest narrow segment. Then, a node in that segment is chosen at random as the forwarding node. The method involves a fixed number of iterations. Each iteration has black-burst emission for one time slot duration. Black burst is used to select a potential segment and eliminate the nonpotential segment from further consideration. Because of a constant number of time slots, the relay node experiences the same delay, irrespective of its distance from the source, except for a small variable delay due to random contention in the final resultant segment. Since the required number of iterations an be kept as possible protocol achieves significant improvement in terms of broadcast latency.

3. Routing Protocols in VANET

The characteristic of highly dynamic topology makes the design of efficient routing protocols for VANET is challenging. The routing protocol of VANET can be classified into two categories such as Topology based routing protocols & Position based routing protocols. Topology based routing protocols use link's information within the network to send the data packets from source to destination. Topology based routing approach can be further categorized into proactive and reactive routing. Proactive routing protocols are mostly based on shortest path algorithms. They keep information of all connected nodes in form of tables because these protocols are table based. Furthermore, these tables are also shared with their neighbors. Whenever any change occurs in network topology, every node updates its routing table. No Route Discovery is required and low latency for real time applications are the pros of proactive routing protocols. Unused paths occupy a significant part of the available bandwidth.

FSR is a proactive or table driven routing protocol where the information of every node collects from the neighboring nodes. Then calculate the routing table. It is based on the link state routing & an improvement of Global State Routing. FSR reduces significantly the consumed bandwidth as it exchanges partial routing update information with neighbors only. Reduce routing overhead and changing in the routing table will not occur even if there is any link failure because it doesn't trigger any control message for link failure. Very poor performance in small ad hoc networks and less knowledge about distant nodes are the cons of fisheye state routing. The increase in network size the storage complexity and the processing overhead of routing table also increase. Insufficient information for route establishing are the cons of fisheye state routing. Reactive routing protocol is called on demand routing because it starts route discovery when a node needs to communicate with another node thus it reduces network traffic. To update routing table not require periodic flooding the network. Flooding requires when it is demanded and beaconless so it saves the bandwidth are the pros the reacting routing protocol. The reacting routing protocol for route finding latency is high. Excessive flooding of the network causes disruption of nodes communication.

Ad Hoc On Demand Distance Vector routing protocol is a reactive routing protocol which establish a route when a node requires to send data packets. It has the ability of unicast & multicast routing. It uses a destination sequence number which makes it different from other on demand routing protocols. An up-to-date path to the destination because of using destination sequence number is pros of AODV routing protocols. It reduces excessive memory requirements and the route redundancy. AODV responses to the link failure in the network. It can be applied to large scale adhoc network are pros of AODV routing protocols. More time is needed for connection setup & initial communication to establish a route compared to other approaches. If intermediate nodes contain old entries it can lead inconsistency in the route. For a single route reply packet if there has multiple route reply packets this will lead to heavy control overhead. Because of periodic beaconing it consumes extra bandwidth.

The Dynamic Source Routing (DSR) protocol presented in which utilize source routing & maintain active routes. It has two phases route discovery & route maintenance. To obtain route between nodes, it has small overload on the network. It uses caching which reduce load on the network for future route discovery. No periodical update is required in DSR. If there are too many nodes in the network the route information within the header will lead to byte overhead. Unnecessary flooding burden the network is the cons of DSR protocol. In high mobility pattern it performs worse. Unable to repair broken links locally is the cons of DSR protocol. Temporally Ordered Routing Protocol is based on the link reversal algorithm that creates a direct acyclic graph towards the destination where source node acts as a root of the tree. In TORA packet is broadcasted by sending node, by receiving the packet neighbor nodes rebroadcast the packet based on the DAG if it is the sending node's downward link. It creates DAG (Direct acyclic graph) when necessary. Reduce network overhead because all intermediate nodes don't need to rebroadcast the message. Perform well in dense network for pros of TORA protocol. It is not used because DSR & AODV perform well than TORA. It is not scalable are cons of TPRA protocol.

4. Data Dissemination using Forwarder Nodes

A lot of safety applications over vehicular ad-hoc networks (VANET) rely on emergency message dissemination (EMD) through multi-hop broadcast. In EMD, a certain vehicle issues an emergency message when a dangerous situation such as vehicle collision has been detected. Since the emergency message includes time-sensitive life-critical information, it should be disseminated to all vehicles in the target region as quickly and reliably as possible. The target region is a road segment that is up to several kilometers long in the opposite direction of the source. Since the one-hop communication range of a source cannot cover the target region fully, multi-hop broadcasting should be used to disseminate the emergency message [1].

Many broadcast schemes have been proposed to meet the requirements on the timeliness and reliability of EMD. The reliability can be improved by retransmitting the original copy of the emergency message or removing interference from hidden nodes [3]. Retransmissions and control messages exchanged for the interference avoidance increase the latency of the message dissemination. Apart from reliability issues, for fast message dissemination, the vehicle farthest from a forwarder in the message dissemination direction should be designated as a next forwarder. Since the farthest vehicle can fail to successfully receive the message due to an inherently lossy wireless channel, the

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explicit designation of the farthest vehicle as the next forwarder may cause the multi-hop forwarding to be suspended. In most forwarding mechanisms [4], vehicles which have received the broadcast message and are farther away from the previous forwarder contend to become a new forwarder in a distributed manner. Eventually, the forwarder candidate (Farthest Forwarder Candidate (FFC)) farthest from a forwarder is opportunistically selected. In particular, since retransmissions can help to increase the reliability of dissemination, each of contentions for transmission should be completed as quickly as possible in order to minimize the latency of the overall dissemination process. Note that achieving conflicting both goals simultaneously is a challenging issue [5].

The common idea behind existing forwarding mechanisms is to differentiate each waiting time (WT) of forwarder candidates. The waiting time ranges from 0 to the predefined upper bound (PUB). A forwarder candidate selects a point in the time range and uses it as the waiting time. In particular, in order to maximize the hop progress of the message each forwarder candidate uses its waiting time that is inversely proportional to the distance from itself to the previous forwarder. The farthest forwarder candidate uses the shortest waiting time and then forwards the message first. The other forwarder candidates detect the transmission from the newly selected forwarder and suppress their scheduled transmissions.

We reveal two problems of existing fast forwarding schemes in this paper. First, existing schemes tacitly assume the perfect suppression of redundant transmissions, which means that all forwarder candidates can successfully receive the message from FFC within their waiting times. Due to the short difference between waiting times of forwarder candidates, some forwarder candidates may start their transmissions before detecting the transmission from FFC and such redundant transmissions can collide with the transmission from FFC. The waiting time difference between two forwarder candidates is affected by PUB and the difference between distances from the previous forwarder to the forwarder candidates. The distance difference depends on the spatial vehicle distribution. In addition, under a given distribution of vehicles, a smaller PUB allows the next forwarder to be selected earlier, but results in a higher probability of collisions caused by the short waiting time difference. Existing schemes simply regard PUB as a system parameter without considering the relationship between the selected PUB and collision probability (CP) under dynamically changing vehicle distributions. Second, the vehicle distribution is not uniform and continuously changing due to dynamic VANET traffic conditions. Various scales of empty space with no vehicle can be present between vehicles. In existing schemes, waiting times of forwarder candidates are only affected by the locations of forwarder candidates without considering such an empty space. Therefore, given two vehicles separated by a large empty space, one closer to the previous forwarder should delay its forwarding necessarily for a long time even though there exists no vehicles farther than itself when it becomes FFC.

In this paper, we therefore propose a RObust and Fast Forwarding scheme (ROFF) as a solution to collision and latency-related problems mentioned above. Given two adjacent forwarder candidates A and B where A is farther from the previous forwarder than B, A’s forwarding priority will be always higher than B’s one, regardless of the size of the empty space between A and B. ROFF allows forwarder candidates to use waiting times which are inversely proportional to the forwarding priority in order to avoid unnecessary delay caused by the large empty space. In addition, ROFF finds out the minimum difference between waiting times of two adjacent vehicles required for the successful suppression. minDiff is affected by the latency in MAC and PHY layers. Based on minDiff, ROFF

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sophisticatedly adjusts the waiting times of forwarder candidates for guaranteeing that the waiting time difference between any two vehicles is larger than minDiff. Our main contributions are twofold. First, we highlight and analyze the collision and latency problems which existing forwarding schemes overlooked. Second, we propose a practical solution called ROFF in order to tackle the above-mentioned problems we indicated.

5. Issues on Data Dissemination Schemes

Multi hop broadcasting schemes are used to disseminate safety messages. Forwarder node manages the data transmission process in multi-hop broadcasting protocols. Forwarder node selection process is carried out with reference to the waiting time details. RObust and Fast Forwarding (ROFF) protocol solves the unnecessary delay and collusion issues in data dissemination process. A forwarder candidate is allowed to use the waiting time is inversely proportional to its forwarding priority. Empty Space Distribution (ESD) bitmap describes the distribution of empty spaces between vehicles. A forwarder candidate acquires its forwarding priority using the concept of ESD bitmap. Collisions are avoided by control the waiting time differences than the predefined lower bound. The following issues are identified from the current VANET data transmission methods. They are multicast data delivery is not supported, data security is not provided, forwarder node selection is not optimized and sparse vehicular network conditions are not managed.

6. Multicast Communication using Vehicle Trajectory Data

The Robust and Fast Forwarding (ROFF) protocol is integrated with Trajectory based Multicast (TMC) protocol for data dissemination process. Message Forwarding Metric is applied to select the forwarder node with capability factors. Data dissemination process is improved with security features. Network connectivity information is managed with vehicle trajectory information.

The VANET data transmission scheme is adapted to handle multicast and broadcast operations. Replicas are deployed to improve the data transmission process. Data transmission process is improved with security features. The system is divided into four major modules. They are ESD Bitmap Construction, Forwarder Node Selection, Trajectory Analysis and Multicast Data Transmission.

6.1. ESD Bitmap Construction

Vehicles identify the topology of neighbors by collecting periodic beacons of neighbor vehicles. Neighborhood topology is referred as local view. Each vehicle manages a neighbor table (NBT) for monitoring its local view. Update and delete operations on Neighbor Table is carried out to maintain the freshness of the local view. Space between the vehicles is represented in the Empty Space Distribution (ESD) bitmap. The ESD bitmap is constructed through two phases. A forwarder measures its distances towards each of all the PFCs using the Potential Forwarder Candidate (PFC) topology. The ESD bitmap is constructed with the distance information of the vehicles.

6.2. Forwarder Node Selection

RObust and Fast Forwarding (ROFF) protocol is used to select forwarder nodes. Each vehicle within Naive Forwarding Area (NFA) is called as a Potential Forwarder Candidate (PFC). Waiting time and collusion factors are considered in the forwarder node selection process. A PFC can be assigned as a forwarder candidate when it is allowed to participate in the new forwarder selection process. Forwarding priority is used to assign the waiting time limits for the forwarder nodes. Forwarding priority is estimated using the Empty Space Distribution (ESD) bitmaps and the location of the previous forwarder. Each forwarder candidate is assigned with different waiting time limits. The waiting time is used to initiate the data forwarding process

6.3. Trajectory Analysis

Trajectory of vehicles is identified using Global Positioning Services (GPS) enabled navigation systems. Trajectory based Multicast (TMC) exploits vehicle trajectories for efficient multicast in vehicular networks. Message forwarding metric is estimated to identify the capability of a vehicle to forward a message to destination nodes. TMC scheme uses the distributed approach for the message communication process.

6.4. Multicast Data Transmission

Message dissemination and group coordination operations are carried out under the multicast transmission. Network disconnection, sparse communication and mobility uncertainty factors are handled in the data transmission process. Trajectory information is used to make the message forwarding decisions. Message forwarding metric is also used to predict the entry of intermediate vehicle.

7. Conclusion

Vehicular Ad hoc networks (VANET) are constructed to manage communication between vehicles. Robust and Fast Forwarding (ROFF) protocol is used to handle data dissemination process. Trajectory based MultiCast (TMC) protocol is applied for multicast data delivery process. The system integrates the ROFF and TMC protocols with security features. The system supports faster and reliable data delivery scheme with security. The vehicular ad-hoc network communication system controls the collision and latency in data dissemination process. Data transmission is handled without the central information management authority. Multicast and broadcast operations are integrated in the VANET data communication process.

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