NEIGHBOUR COVERAGE-BASED REBROADCAST PROTOCOL FOR VANET

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Abstract

In Vehicular Ad-hoc Networks (VANETs), fast and reliable dissemination of safety messages is a key step toward improving the overall road safety. In a highly dynamic VANET environment, safety message dissemination in a multi-hop manner is a challenging and complex problem that has gained significant attention recently. Many protocols and schemes have been proposed to efficiently share safety messages among vehicles. However, most existing techniques do not perform well under real-world traffic conditions, or perform adequately only under very limited scenarios and traffic conditions. This paper proposes a highly efficient and reliable multi-hop broadcasting protocol, Intelligent Forwarding Protocol (IFP), that exploits handshake-less communication, ACK Decoupling and an efficient collision resolution mechanism. In this paper, IFP has been extensively and evaluated to establish its robustness and superiority over existing schemes. A key contribution of this paper is to present an in-depth analysis and optimization of IFP using theoretical modelling, thorough simulations, and extensive real-world experimentation. With IFP, the message propagation delay is significantly reduced and packet delivery ratio is drastically improved.

Key Words: Intelligent Forwarding Protocol, Vehicular Ad-hoc Networks

1. Introduction

Vehicular ad hoc networks (VANETs) enable communication between vehicles or between a vehicle and infrastructure. The idea of having inter-vehicle communications connected to a wired network has been investigated since the 1980s. On a VANET, we can achieve traditional safety applications such as collision, icy road and red light warnings, as well as non-safety applications such as traffic information dissemination, reservation query, camera picture feed etc. Recently, there has been an emerging trend of utilizing mobile communication for environmental issues. It is possible to obtain significant information from VANETs to improve the uses of gas or other resources.

When there are not sufficient roadside units (RSUs) or direct communications between distant vehicles are preferred, it usually takes more than one step of vehicle-to-vehicle (V2V) communications to send information from a specified source to destination. The transmission range of a radio device is normally 150-250m for V2V, which is much smaller than the dimension of the considered area. Researchers have studied such multi-hop communications extensively not only because VANET applications have a large market potential, but also they are scientifically interesting.

Although, several research works have attempted to solve this complex multi-hop broadcasting problem in VANETs, they show a severe performance degradation under real-world traffic conditions in terms of message propagation speed, network throughput, message reliability etc. due to numerous factors such as inaccurate assumptions, protocol inefficiencies, and a highly dynamic vehicular environment. Here, we briefly discuss some of the major limitations of these multi-hop protocols. Most existing multi-hop broadcasting protocols use vehicles geographical information only (such as distance from the sender) in the forwarder selection process. However, such protocols are often not very reliable or accurate as they do not consider terrain interference, signal characteristics, GPS errors, etc. while selecting the next forwarder. Additionally, many traditional broadcasting algorithms use handshaking mechanisms (RTB/CTB) before broadcasting the safety message, and require Acknowledgments (ACKs) after every message transmission. While, the handshaking procedure does improve the message reliability, this sequential process introduces overheads and thus reduces the message dissemination speed. Contrarily, while achieving high propagation speeds, some broadcasting protocols tend to ignore the message reliability and guaranteed message delivery to all nodes in the target region

2. Objectives of the Work

- Experimentation and performance gain of IFP, a fast and reliable multi-hop broadcasting protocol for VANETs
- IFP fills that gap by forwarder selection mechanism, handshake-less communication, ACK Decoupling, and improved collision resolution
- Introduce a neighbor coverage-based probabilistic rebroadcast (NCPR) protocol for VANETs
- Proposed approach combines the advantages of the neighbor coverage knowledge and the probabilistic mechanism, which can significantly decrease the number of retransmissions

3.Intelligent Forwarding Protocol

In this project, describe the motivation and key design principles of the proposed Intelligent Forwarding Protocol (IFP). The few main contributions of IFP, are to reduce the channel access time by removing the handshaking mechanisms (i.e. RTB/CTB) preceding the safety message transmission, to minimize the message propagation delay by either eliminating the ACK-ing process or at least decoupling the message propagation process from ACKs to the sender, and to quickly recover from collisions using a novel collision resolution mechanism.

3.1 Motivation

Speed and reliability are the most important requirements for any forwarding protocol. They are especially essential considering the highly dynamic nature of the VANET environment. However, ensuring rapid propagation of safety messages in a reliable manner is one of the biggest challenges in VANETs due to vehicle movements, limited wireless resources, lossy characteristics of wireless communication, and so on. To address this complex problem, we propose IFP, a fast and reliable broadcasting protocol that exhibits high performance gain in terms of speed and reliability as compared to existing schemes. Below, we highlight the major improvements and contributions of IFP.

As opposed to stochastic-based protocols, IFP reduces the network load by removing unnecessary rebroadcasts from multiple forwarder candidates. These unnecessary rebroadcasts increase the collision probability, especially under high vehicular density, which in turn reduces the overall reliability of the safety message dissemination process. IFP also improves the one-hop message progress (average distance covered during each hop) by ensuring furthest forwarder candidates win the contention to rebroadcast.

3.2Protocol Design

IFP removes the handshake process (exchange of RTB/CTB packets) prior to the message broadcast. The original sender (safety message initiator) simply accesses the medium using the standard 802.11 CSMA/CA technique and broadcasts the safety message. Upon message reception, each node i in the vicinity of the sender (i.e. within its transmission range) calculates its corresponding SNR value (SNRi) and its Euclidean distance (Di) from the sender using the GPS coordinates. Each of these nodes then uses these values to compute its own maximum contention window size (CWmax) according to equation. In below equation, k is a scaling factor to contain CWmax values within a suitable range (the contention window range is typically [0, 1023] but it could be optimized under different traffic conditions, as discussed later in the paper), Dmax (or R) is the maximum transmission range of the sender (typically 300 meters), SNRthresh is the minimum SNR threshold value (in dB) allowed for reliable transmission in VANETs, α is the exponential scaling factor to accommodate the effect of SNRi while determining CWmax, and CWbase is the contention window base value that can be optimized based on the traffic density. The equation ensures shorter CWmax (which in turn ensures shorter waiting times before forwarding) to those forwarding nodes that are furthest from the sender within the transmission range (Dmax).

$$CW_{max} = k\frac{D_{max}}{D_i} CW_{base}^{\left(\frac{SNR_i - SNR_{thresh}}{\alpha}\right)}$$

Each node then chooses a random time slot CWchosen within the range [0, CWmax] and waits for that period of time. The node with the smallest CWchosen value wins the contention and is chosen as the forwarder, hence, rebroadcasting the safety message. All the remaining nodes, after receiving this rebroadcast message from the forwarder, drop out of the rebroadcasting race. Note that in IFP, nodes further away from the sender are more likely to be chosen as forwarders, thus improving the one-hop message progress. Additionally, the unique approach of selecting forwarders based on nodes' GPS coordinates and SNR values, helps counter the effects of terrain interference, signal characteristics, GPS errors, malicious nodes injecting false GPS values, and other limitations that exist in traditional schemes.

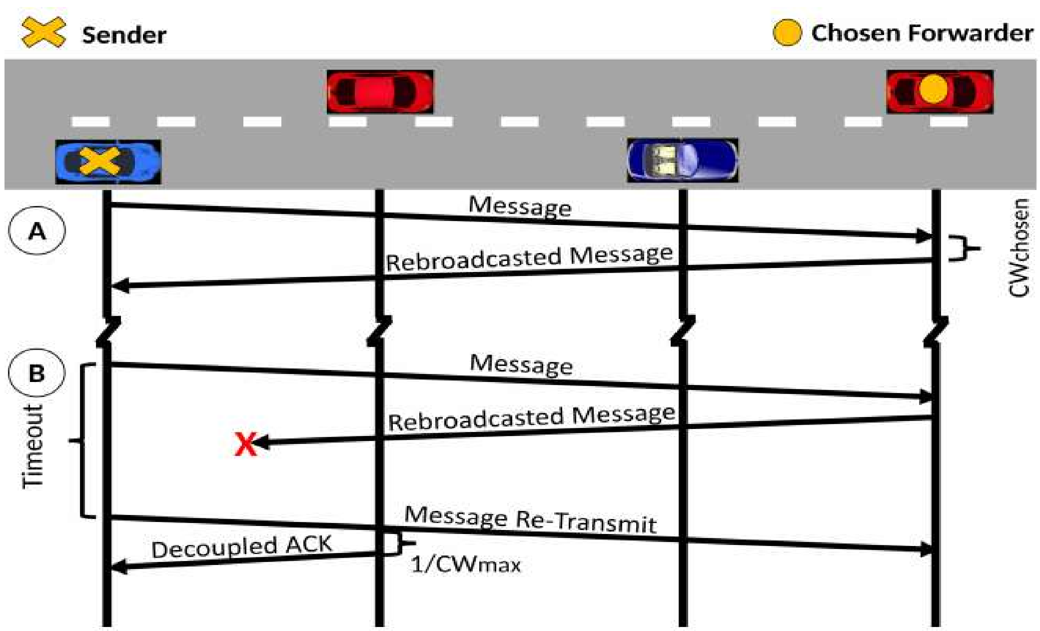

Fig. 1 Sequence of packets being transmitted under: (A) normal rebroadcast scenario, (B) ACK Decoupling and Recovery Process.

Due to the proposed forwarder selection mechanism in IFP and the omni-directional nature of message broadcasts, the sender is almost always able to overhear the rebroadcast message from the forwarder, thus eliminating the need for a costly ACK-ing process. As a result, the safety message can progress without having to wait for the successful reception of an ACK, as opposed to the traditional multi-hop protocols such as UMB [7], SB [8], etc. Eliminating the ACK dependency yields a significant delay improvement in IFP. However, under certain rare circumstances where the sender is unable to overhear the rebroadcast message due to the backward communication channel being lossy or the forwarder node moving out of the vicinity of the sender, IFP proposes the following ACK Decoupling and Recovery mechanism: If the previous sender (source) does not receive the rebroadcasted message from the forwarder within a predefined time-out period, it will once again broadcast the safety message. Upon getting the same message twice from the source, a node in the vicinity of both the source and the forwarder will send an explicit ACK to the source to cancel any further re-transmissions. However, this ACKing process is totally independent and decoupled from the message propagation progress, and thus, will not contribute toward the message propagation delay at all.

Although the ACK-ing process does slightly increase the collision probability in the vicinity of the sender, these collisions are drastically reduced in IFP by choosing the node closest to the sender for sending ACK as well as by limiting the power with which the ACK is transmitted. In this way, a node closest to the sender and with a strong SNRi is prioritized to send an ACK back to the sender. Nevertheless, the best way to completely eliminate the need for ACKs is to select SNRthresh with an extra power budget, so that the sender is always able to overhear the broadcasted messages from the forwarder, and the entire need for the ACK decoupling procedure is removed. Note that the additional power budget in SNRthresh will only slightly reduce the distance between the sender and the chosen forwarder, since the receiving power in typical mobile environments is inversely proportional to the 4th power of distance.

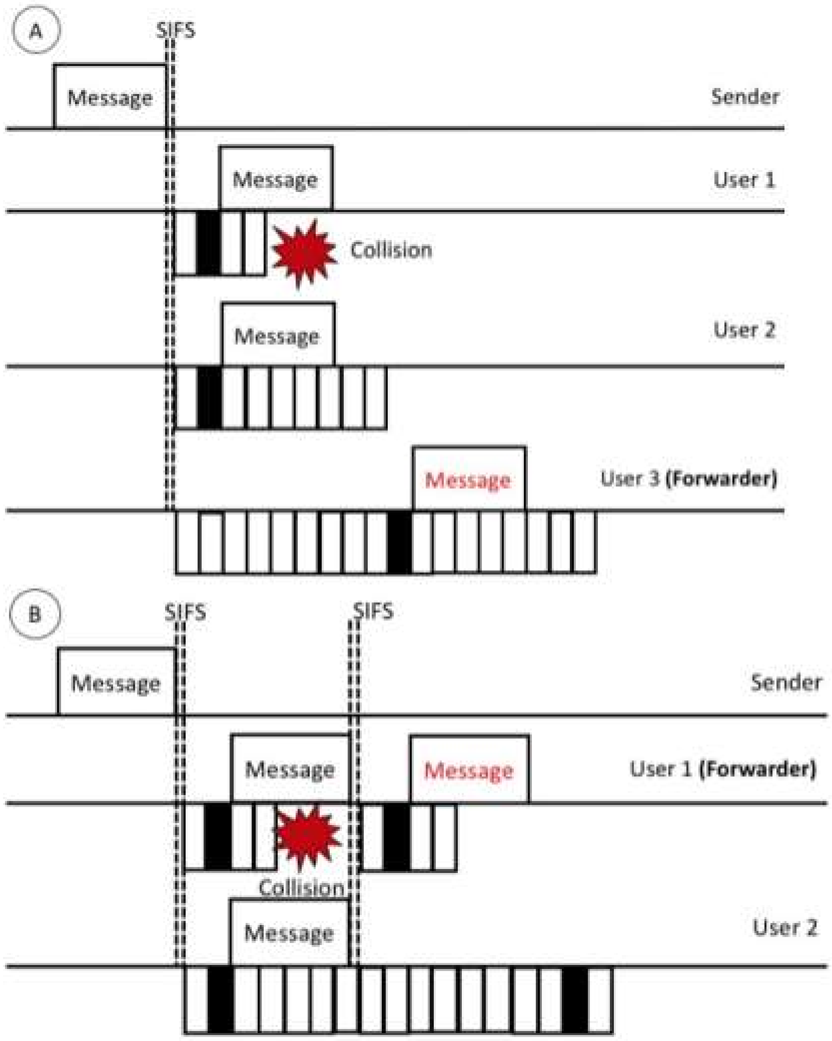

Fig. 2: Collision Resolution Mechanism

In a typical VANET environment, even with a large number of message broadcasts (usually 10/sec/node), only a few safety messages actually collide, as safety messages are quite small in size and are randomly distributed over time. Once a collision does occur in IFP, it can simply be resolved by the quicker of the following two mechanisms: 1) by selecting the next node (other than the two nodes involved in collision) that wins the contention to be the forwarder, as shown in (Figure 2:A), or 2) by repeating the contention resolution procedure between the colliding nodes until the message gets successfully rebroadcast, as depicted in (Figure 2:B). Note that in this second mechanism, the nodes use the same CWmax as computed before, but with a new random time slot (CWchosen) to rebroadcast the safety message. Figure 2:A shows the first mechanism described above. If two (or more) nodes are involved in a message collision, any other contending node (i.e. forwarding candidate) within the transmission range of the sender may forward the safety message instead. Figure 2:B depicts the second mechanism when a collision occurs between two (or more nodes). The nodes involved in collision once again back off for a new random time slot CWchosen to rebroadcast the message and repeat the cycle until the collision has been resolved. Out of the above two mechanisms, the one through which the forwarder is selected the earliest is used to resolve collisions in IFP. To the best of our knowledge, this novel mechanism in IFP to resolve collisions in a VANET environment by selecting the quicker of the two aforementioned mechanisms, has been proposed for the first time. The improved collision resolution mechanism results in a significant reduction in the overall message propagation delay. Lastly, if the sender does not receive a message back within the time-out period due to unavailability of nodes in the transmission range, the entire forwarding mechanism is repeated over again after the time-out period until the sender is able to successfully receive (or overhear) a rebroadcast from a forwarding node or until the safety message remains valid.

3.3. Neighbor coverage-based probabilistic rebroadcast protocol

Here calculate the rebroadcast delay and rebroadcast probability of the proposed protocol. We use the upstream coverage ratio of an RREQ packet received from the previous node to calculate the rebroadcast delay, and use the additional coverage ratio of the RREQ packet and the connectivity factor to calculate the rebroadcast probability in our protocol, which requires that each node needs its 1-hop neighborhood information.

3.4 Neighbor knowledge and rebroadcast probability

The node which has a larger rebroadcast delay may listen to RREQ packets from the nodes which have lower one. For example, if node ‘ni’ receives a duplicate RREQ packet from its neighbor nj, it knows that how many its neighbors have been covered by the RREQ packet from nj. Thus, node ni could further adjust its UCN set according to the neighbor list in the RREQ packet from n. We do not need to adjust the rebroadcast delay because the rebroadcast delay is used to determine the order of disseminating neighbor coverage knowledge to the nodes which receive the same RREQ packet from the upstream node. Thus, it is determined by the neighbors of upstream nodes and its own

Combining the additional coverage ratio and connectivity factor, we obtain the rebroadcast probability. Rebroadcast probability is defined with the following reason. Although the parameter Ra reflects how many next-hop nodes should receive and process the RREQ packet, it does not consider the relationship of the local node density and the overall network connectivity. The parameter Fc is inversely proportional to the local node density. That means if the local node density is low, the parameter Fc increases the rebroadcast probability, and then increases the reliability of the NCPR in the sparse area. If the local node density is high, the parameter Fc could further decrease the rebroadcast probability, and then further increases the efficiency of NCPR in the dense area. Thus, the parameter Fc adds density adaptation to the rebroadcast probability

4. Performance Analysis

To evaluate the efficiency and effectiveness of IFP as compared to the traditional schemes, we conducted simulations using the latest version of C#.net. Some of the default ns3 modules were modified to depict realistic parameters and scenarios. Additionally, new modules and features were implemented to capture accurate IFP behaviour such as packet forwarding, collision resolution, etc. The parameters chosen in the simulation environment were practical with minimal assumptions to achieve accurate and realistic results. Table 1 depicts the parameters and models used in the simulation. It can be noted that the models and parameters chosen for the simulation environment accurately characterize a typical VANET environment, , two-ray ground path loss model, and mobility model etc. The nodes are placed randomly on a 4 km long road strip. A maximum of 30 nodes can be accommodated in the simulation environment at any given time due to constraints in computational resources.

4.1. End-End Delay

First, we measured each protocol's end-to-end delay, which is the time taken to disseminate the safety message throughout the entire target region. Figure-3 shows end-to-end delay results of the three protocols as node intensity increases. For each protocol, we vary the control parameters according to recommended optimal values.

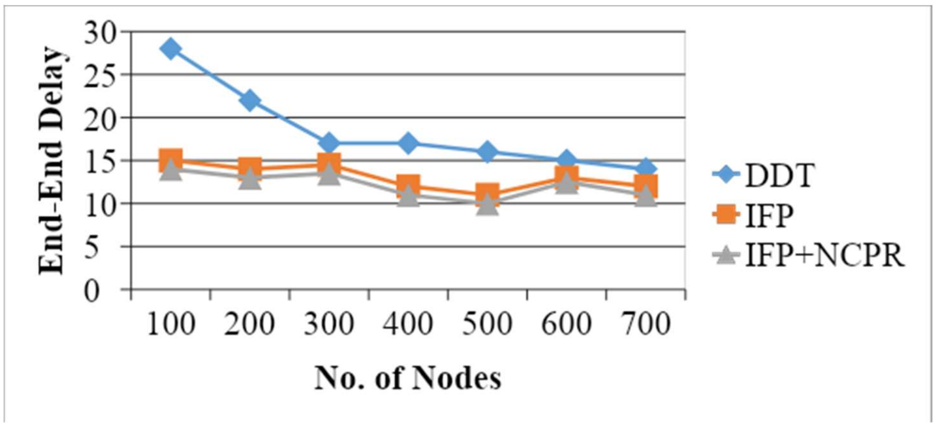

Fig.3.End-End Delay

4.2 Packet Delivery Ratio (PDR)

Next, to determine the message reliability (guaranteed message delivery to each node in the target region), we measured each protocol's PDR, which is the ratio of number of vehicles that receive the safety message to the total number of expected receivers. Since reliability is an important criterion for safety message dissemination, it is worthwhile to study the PDR achieved by each protocol.

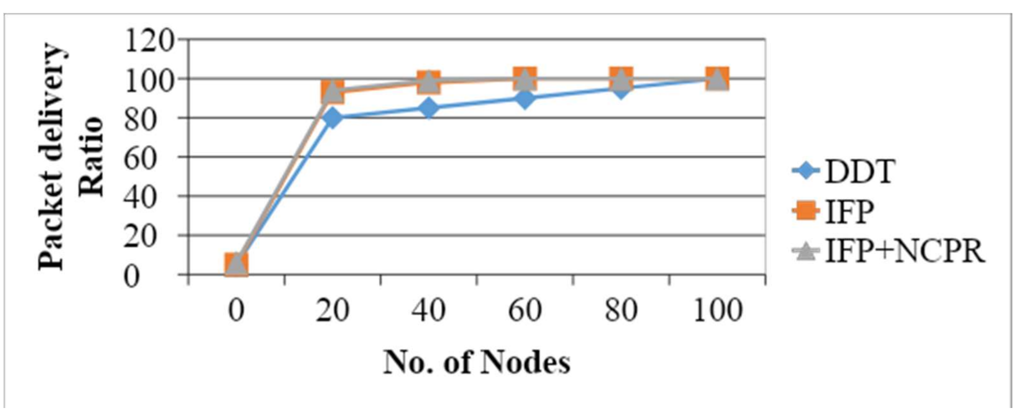

Fig.4.End-End Delay

5. CONCLUSION

This project proposed an in-depth and thorough study regarding the design, analysis, optimization, real-world experimentation and performance gain of Intelligent Forwarding Protocol, a fast and reliable multi-hop broadcasting protocol for VANETs. In this paper, we identified the shortcomings of the existing multi-hop schemes and how IFP fills that gap by exploiting an innovative and a highly efficient forwarder selection mechanism, handshake-less communication, ACK Decoupling, and an improved collision resolution mechanism. Here also proposed a new scheme to dynamically calculate the rebroadcast delay, which is used to determine the forwarding order and more effectively exploit the neighbor coverage knowledge. Simulation results show that the proposed protocol generates less rebroadcast traffic than the flooding and some other optimized scheme in literatures. A key contribution of this research is that the real-world experimentation and field-trials were conducted using the IEEE 802.11 p devices to evaluate the performance of IFP under real traffic conditions. The results validate the performance gain achieved by IFP in such conditions

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