BL-CAST: Beacon-Less Broadcast Protocol for Vehicular Ad Hoc Networks

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Abstract

With the extension of wireless technology, vehicular ad hoc networks provide important services for the dissemination of general data and emergency warnings. However, since, the vehicle topology frequently changes from a dense to a sparse network depending on the speed of the moving vehicles and the time of day, vehicular ad hoc networks require a protocol that can facilitate the efficient and reliable dissemination of emergency messages in a highly mobile environment under dense or intermittent vehicular connectivity. Therefore, this paper proposes a new vehicular broadcast protocol, called BL-CAST, that can operate effectively in both dense and sparse network scenarios. As a low overhead multi-hop broadcast protocol, BL-CAST does not rely on the periodic exchange of beacons for updating location information. Instead, the location information of a vehicle is included in a broadcast message to identify the last rebroadcasting vehicle in an intermittently connected network. Simulation results show that BL-CAST outperforms the DV-CAST protocol in terms of the end-to-end delay, message delivery ratio and network overhead.

Keywords: Beacon, Broadcast protocol, VANET, Store-carry-forward

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1. Introduction

Vehicular Ad hoc NETworks (VANETs) are a hot topic for research,due to the significant number of applications are expected to be developed to improve transportation safety and mobility on the road. Such VANET applications include the dissemination of traffic condition updates, accident warnings, and free parking spot advertisements. While most of these applications rely on the delivery of broadcast messages to vehicles inside a certain region of interest (ROI), unrestricted message broadcasting can lead to frequent contention and collisions among neighbor vehicles. This problem is known as a broadcast storm [1]. In addition, features such as a high vehicle mobility, limited transmission range, and intermittent connectivity can prevent vehicles from communicating with each other, resulting in network-partitioning. Thus, to increase the message delivery probability in VANETs, several store-carry-forward (SCF) mechanisms have already been proposed [2][3].

However, this paper focuses on the broadcasting of emergency messages for safety applications in the case of VANETs. When designing a broadcast protocol for VANETs, two major problems must first be considered: the broadcast storm problem and network-partitioning problem. Both problems are well known in the research community, especially the broadcast storm problem. Thus, many algorithms have already been developed to cope with the broadcast storm problem, yet very few can also handle the network-partitioning problem. Accordingly, since a good routing protocol must be able to deal with both problems effectively and simultaneously, this study presents a distributed broadcast protocol that can mitigate the broadcast storm problem, while maintaining network connectivity in partitioned networks.

The proposed beacon-less broadcast (BL-CAST) protocol for VANETs uses slotted 1-persistence scheme [1] and store-carry-forward mechanism to solve the broadcast storm and disconnected network problems, respectively. Plus, local topology information (acquired via received duplicated messages from one-hop neighbors) is used as the main criterion to find the last vehicle in a cluster to carry a message in an intermittent network.

The remainder of this paper is organized as follows. Section II describes related work. Section III presents a design overview of BL-CAST, and the detailed implementation is explained in Sections IV and V. Section VI describes the simulation environment and compares the performances of BL-CAST and DV-CAST. Finally, Section VII provides some conclusions.

2. Related Work

Various studies have already investigated effect of beacon collisions and developed schemes to avoid such collisions. In [4], congestion-controlled-coordinator-based MAC (CCC-MAC) is a time-slot-based medium access protocol that reduces the congestion of beacons and emergency messages. It utilizes a time-slot-scheduling mechanism to mitigate channel congestion by reducing the transmission time of beacons using multiple data rates. Adaptive Traffic Beacon (ATB) [5] is a new message dissemination protocol that uses adaptive beaconing based on two key metrics: message utility and channel quality. The adaptive beaconing produces much broader dissemination of messages (in terms of the penetration rate) than flooding-based approaches, albeit at a slower rate. In [6], extensive simulations are used to analyze the loss rate of single-hop periodic safety beacons. As a result, greater beacon interval and smaller beacon size and transmission range are shown to be more effective in reducing the beacon loss ratio. In [7], V-DESYNC desynchronizes vehicles to broadcast beacons at different times based on timing information. V-DESYNC is specifically designed to avoid the beacon collisions and tolerate the highly dynamic behavior of vehicular networks. In [8], the effect of the beacon message overhead is examined in different multi-hop wireless broadcasting protocols. As a result, the higher beacon rates in topological methods are found to consume 5 to 10 times more bandwidth. Therefore, since sending constant beacons can increase the beacon overhead and affect the protocol performance, beacon-less broadcasting protocols would seem to be more desirable.

The ideal solution to alleviate a broadcast storm in a VANET is for the rebroadcasting to be performed by the vehicle furthest from the broadcaster and various broadcast storm mitigating schemes have already been proposed in [9][10][11][12][13][14][15][16]. These protocols use contention to automatically select the forwarder(s) in a distributed fashion. All the one-hop receivers of an emergency message enter a contention phase after receiving the message. Following a waiting time, calculated using the distance from the broadcaster, the message is rebroadcasted. Statistically, the vehicle farthest from the broadcaster has a higher chance of rebroadcasting the message first. All other vehicles, after overhearing this rebroadcast, then cancel their pending rebroadcasting process. In [17], the dynamics of multi-hop message dissemination are analyzed, and it is shown that the multi-hop message dissemination reliability decreases as the distance from the emergency message initiator increases and as the vehicle density increases. In [18], a position based multi-hop broadcast protocol (PMBP) is proposed for emergency message dissemination in inter-vehicle communications. In this case, a cross-layer approach that considers both the MAC and Network layers is used to select the vehicle for forwarding an emergency message according to its distance from the source vehicle in the message propagation direction. In [19], a cross layer broadcast protocol (CLBP) is proposed for multi-hop emergency message dissemination in inter-vehicle communication systems. Here, a novel composite relaying metric for relaying node selection is designed based on considering the geographical location, channel conditions and vehicles velocities. Using the designed metric, a unique relay is selected for reliable forwarding of the emergency message in the desired propagation direction. In [20], application-level control of the message transmission phase is suggested rather than 802.11p MAC, when frequency adaptation is not allowed due to the application requirement. However, none of the above-mentioned protocols considers the network disconnection problem.

A few studies have addressed broadcasting issues in intermittently connected VANETs. For example, in [21], when a vehicle is disconnected from vehicles travelling in the same direction, a vehicle travelling in opposite direction is selected to forward the message. A simple and robust dissemination protocol (SRD) is proposed in [22], where an optimized slotted 1-persistence scheme is used to reduce the number of rebroadcasting vehicles in the same slot. Meanwhile, the Distributed Vehicular Broadcast protocol (DV-CAST) [23] uses a combination of broadcast suppression and a store-carry-forward mechanism to overcome the broadcast storm problem and carry a message in an intermittently connected network, respectively.

Therefore, to enhance the DV-CAST scheme [23], this paper proposes a beacon-less broadcast (BL-CAST) scheme for VANETs. In the case of DV-CAST, vehicles periodically announce their position by sending hello messages (beacons). After receiving a message, a vehicle determines (using a neighbor table) whether or not it is the last vehicle in a cluster. For this purpose, DV-CAST maintains three separate neighbor tables that contain the list of neighbors who are leading, following, or moving in the opposite direction, respectively. If a vehicle is not the last vehicle, it applies broadcast suppression using the slotted 1-persistence scheme [1]. However, if it is the last vehicle in the cluster and it is also not connected to any vehicle moving in the opposite direction, it must hold onto the broadcast message until it can forward the message to a vehicle moving in the opposite or same direction. Unlike DV-CAST, BL-CAST does not rely on beacons, but rather includes the position information of a vehicle in its broadcast message to avoid the overhead of beacons. As a result, BL-CAST does not need to maintain neighbor tables to keep the location information of one-hop neighbor vehicles. In the case of an intermittent network, BL-CAST utilizes the vehicle position information to select the last vehicle in the cluster to carry and continuously broadcast the message until it can deliver the message to an approaching vehicle. Since a broadcast message is only generated when a vehicle receives an emergency message, the overhead generated by the broadcast messages is usually less than that generated by beacons, as in most application scenarios the interval between beacons is much shorter than that between emergency messages.

Nearly all existing broadcasting schemes, including DV-CAST, rely on the periodic exchange of beacons to advertise the vehicle positions. Plus, each vehicle needs to maintain the position information of its one-hop neighbors in a neighbor table that can be old when a broadcast message arrives, resulting in incorrect estimations of the vehicle location relative to the broadcaster. Furthermore, while the local topology information of a vehicle acquired via beacon messages helps to improve the protocol performance, obtaining such information also increases the overhead. These periodic exchanges of beacons also waste bandwidth and can cause collisions with broadcast messages. Therefore, this large bandwidth consumption highlights the importance of designing protocols that are insensitive to rapidly changing topological information in highly mobile applications such as VANETs. Thus, to the best of our knowledge, no previous study has dealt with both the disconnected network problem and broadcast storm problem in a highway VANET scenario without relying on periodic beacons.

3. Overview of BL-CAST

This section presents an overview of BL-CAST, which is an enhancement of the DV-CAST protocol. BL-CAST reduces the overhead of the DV-CAST protocol by utilizing the following two key features:

- No reliance on beacons: Using the Global Positioning System (GPS), BL-CAST includes the position information of a vehicle in a broadcast message, thereby alleviating the need for the periodic exchange of beacons.
- Periodic message broadcasting: In an intermittently connected network, the last vehicle in the cluster uses a SCF mechanism by periodically broadcasting the emergency message.

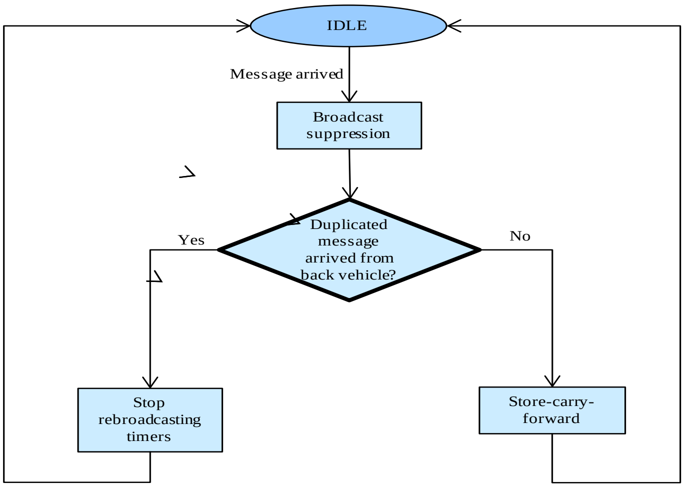

Fig. 1. Basic concept of BL-CAST protocol

While the performance of DV-CAST depends on periodic beacons, BL-CAST does not rely on the periodic exchange of beacons and hence is not affected by the period used to broadcast such beacons. Also, the network overhead by beacons can be avoided in BL-CAST. BL-CAST assumes that each vehicle can obtain its current location information using a GPS system. Each vehicle also maintains a message list to keep track of all the received messages. Since a message may not be beneficial to all vehicles, an emergency message is only broadcasted within a limited region, called the region of interest (ROI), which is usually several kilometers. When an emergency event occurs, an emergency message is generated and broadcasted by a source vehicle. All vehicles located within its transmission range receive this message. If there are no vehicles within its transmission range, the last vehicle in the cluster starts a relay mode using a store-carry-forward mechanism. An event lifetime is also defined to stop the dissemination process.

Fig. 1 shows the basic concept of the BL-CAST protocol. When an emergency message arrives, each vehicle applies a broadcast suppression mechanism, which helps to reduce the number of vehicles that transmit the broadcast message. When a vehicle receives a broadcast message, each message includes the position information of the one-hop neighbor vehicle, which assists the receiving vehicle in estimating its local topology. For BL-CAST, the local topology is important information for determining how a broadcast message should be handled. More specifically, each vehicle checks the received broadcast messages to determine whether there is any vehicle in the broadcast direction. When a vehicle receives a duplicated message from a back vehicle (i.e. farther away from the source than its position), it cancels its rebroadcast. However, if no duplicated message is received from a back vehicle, the vehicle then starts a store-carry-forward mechanism in an intermittently connected network.

4. Key Components of BL-CAST

Fig. 2 shows a flow chart for BL-CAST that consists of two major components: broadcast suppression and a store-carry-forward mechanism. This study focuses on a highway scenario with traffic traveling in both directions. A typical scenario is considered where a source vehicle broadcasts a warning message to approaching vehicles. Generally, such a message will only be beneficial to vehicles following the source vehicle i.e., moving toward the source.

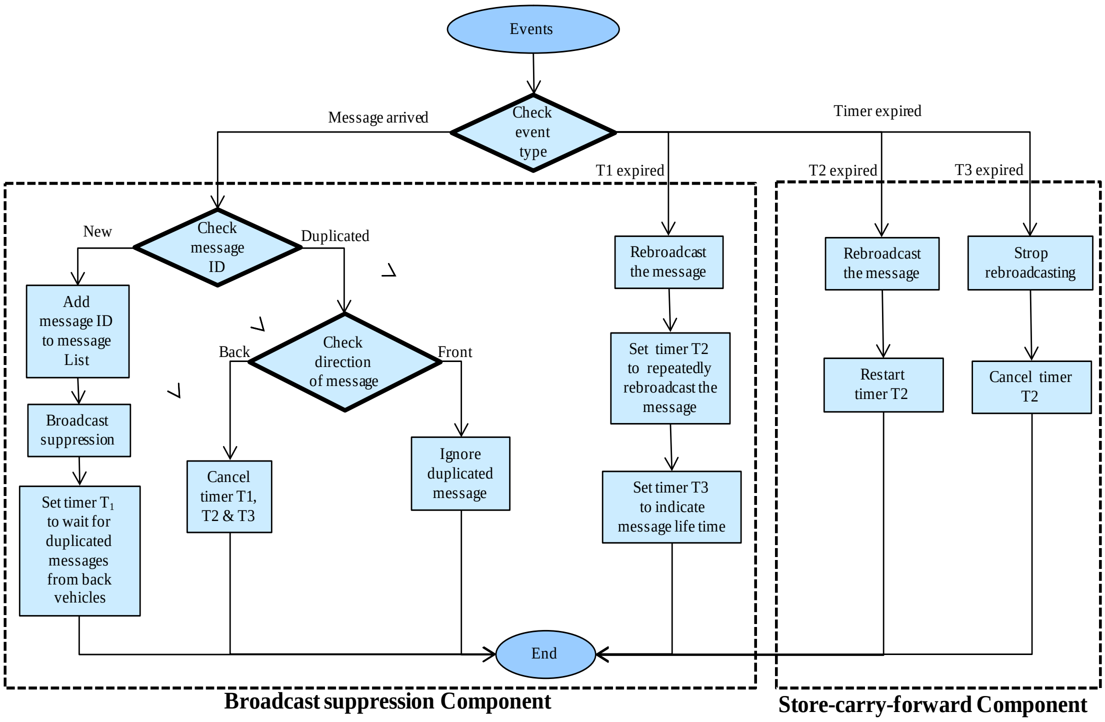

Fig. 2. Flow chart of BL-CAST protocol

Thus, the goal of BL-CAST is to disseminate the broadcast message to certain range of following vehicles within the limited ROI.

4.1 Broadcast Suppression

The broadcast suppression mechanism is applied when a vehicle receives a message. The format of the broadcast message, as shown in **Fig. 3**, includes the sender ID, message ID,and GPS coordinates of the sender. Upon receiving a message from a sender, each vehicle checks the ID of the received message to determine whether the message is new or a duplicated. If the message is new, it is added to the message list and the vehicle then rebroadcasts the message. However, similar to DV-CAST, the messages are not rebroadcasted simultaneously by all the receiving vehicles; rather, for broadcast suppression, each vehicle rebroadcasts the message at an assigned time slot T using a slotted 1-persistence scheme [1] as shown in **Fig. 4**. In this example, the transmission range is spatially divided into five equal slots, where a shorter waiting time is assigned to the vehicles located in the farther slots. Upon receiving a message, vehicles in slot 0 i.e. vehicle A and vehicle B rebroadcast the message at slot time T=0 with probability 1. After receiving a duplicated message, all the vehicles in remaining slots cancel their rebroadcasting timers. As a result, this slotted scheme reduces the number of vehicles rebroadcasting the message at the same time, thereby reducing the collisions caused by the simultaneous rebroadcast of messages. After rebroadcasting the message, the vehicle starts timer T1 to wait for messages from one-hop back vehicles.

Source ID	Received message ID	Source GPS position

Fig. 3. The broadcast message format

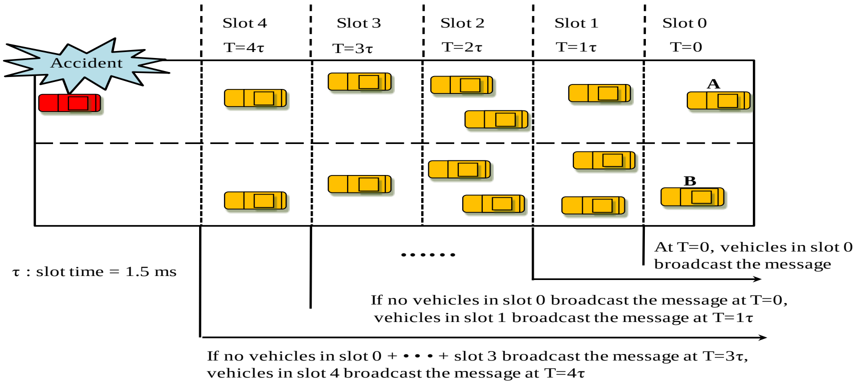

Fig. 4. Broadcast suppression mechanism using slotted transmissions

Upon receiving a duplicated message from a neighbor, the vehicle then compares its position with the neighbor position indicated in the received duplicated message and determines whether the neighbor is a front vehicle (i.e. closer to the source than its position) or a back vehicle (i.e. farther away from the source than its position). If the vehicle receives a duplicated message from a back vehicle, it cancels all its timers and the message rebroadcasting process is canceled, as the back vehicles will have already been informed of the event. However, if the vehicle receives a duplicated message from a front vehicle, it ignores this message and waits for duplicated messages from back vehicles until timer T1 expires. Since the last vehicle in the initial transmission range will not receive any duplicated message from back vehicles, it will be the only rebroadcasting vehicle when timer T1 expires. As shown in **Fig. 2**, when timer T1 expires, the vehicle rebroadcasts the message, and also starts two new timers, T2 and T3.

4.2 Store-Carry-Forward

In the case of an intermittently connected VANET, BL-CAST uses a store-carry-forward mechanism. If a vehicle receives no duplicated messages from back vehicles before the expiration of rebroadcasting timer T2, this vehicle is then the last in the cluster. In this case, the vehicle applies a store-carry-forward mechanism, which means that when timer T2 expires, the vehicle rebroadcasts the message and starts timer T2 again, as shown in **Fig. 2**. When timer T2 expires, the message is then rebroadcasted and this message rebroadcasting process is repeated until a duplicated message arrives from a back vehicle or vehicle travelling in the opposite direction, the predefined message-life timer T3 expires, or the vehicle leaves the ROI. If a duplicated message arrives from a back vehicle before the expiration of timer T3, timers T2 and T3 are cancelled to stop the rebroadcasting process and the vehicle becomes idle. However, if no duplicated message is received before the expiration of timer T3, it is then assumed that the message is no longer beneficial to approaching back vehicles due to the extended delay in the message forwarding. In this case, the vehicle stops the message rebroadcasting by cancelling timer T2 and becomes idle.

5. Network Scenarios

5.1 Well-Connected Network

A vehicle is said to be in a well-connected network if it receives a duplicated message from at least one neighbor in the message-forwarding direction. As shown in **Fig. 2**, upon receiving a

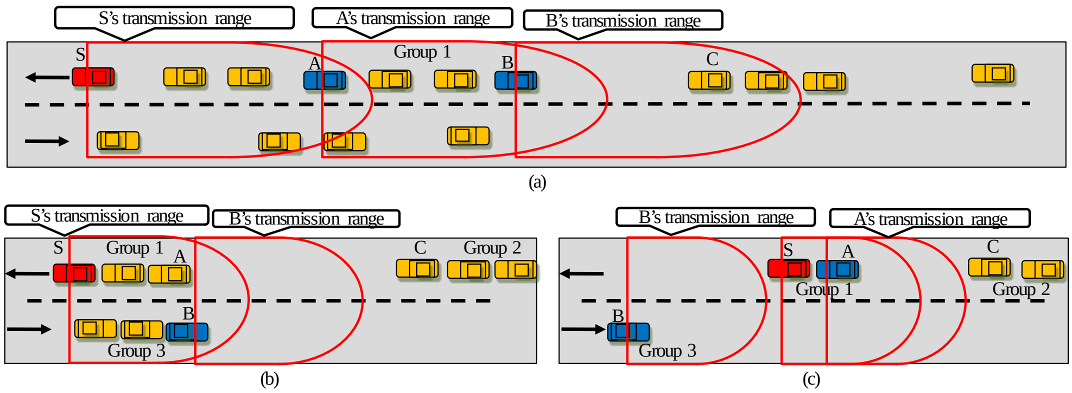

Fig. 5. Three different scenarios: (a) well-connected network, (b) sparsely-connected network, and (c) totally disconnected network

broadcast message, a vehicle in a well-connected network applies the broadcast suppression mechanism. For example, if there are vehicles in each slot, these vehicles use the relative distance information calculated using the information in the received message header to determine the necessary back-off time T before rebroadcasting a message. During this back-off period, if a vehicle does not overhear any duplicated message, it then rebroadcasts the message when its back-off time expires. However, if a duplicated message is overheard from a back vehicle, the pending rebroadcast is cancelled and the vehicle returns to an idle state.

Fig. 5(a) shows an example of a well-connected network. Upon receiving a broadcast message from the source vehicle S, it is assumed that the last vehicle to receive this broadcast is vehicle A in Group 1. Next, all the vehicles apply the broadcast suppression algorithm (shown in Fig. 4) as regards rebroadcasting the message. In this scenario, since A is the last vehicle in the transmission range of the source S, it has a shorter back-off time T to rebroadcast the message. When the back-off time expires, vehicle A rebroadcasts a message and starts its timer T1. All the vehicles in front of vehicle A then receive a duplicated message from vehicle A and cancel their rebroadcasting timer T1.

In **Fig. 5(a)**, it is assumed that all the back vehicles receive the broadcast from vehicle A until the last vehicle B. Since B is the last vehicle in the transmission range of vehicle A, vehicle B rebroadcasts the message when its back-off time expires. Upon receiving a duplicated message from vehicle B, vehicle A cancels its timer T1 and becomes idle. The same process is then repeated for each vehicle in a well-connected network.

5.2 Sparsely-Connected Network

A vehicle is in a sparsely connected network if it is the last vehicle in a cluster and there is at least one neighbor travelling in the opposite direction, as in the case of vehicles A and B in **Fig. 5(b)**.

In this scenario, it is assumed that vehicles A and B receive the broadcast from source vehicle S at the same time. If both vehicles are in slot 0, they both rebroadcast the message and start timer T1. Upon receiving a duplicated message from the back vehicle B, vehicle A stops its timer T1 and returns to an idle state. Since vehicle B is the last vehicle in the transmission range of source vehicle S, it will not receive any duplicated message from back vehicles and will be the only rebroadcasting vehicle when its timer T1 expires. Thus, vehicle B rebroadcasts the message repeatedly until it detects a new neighbor vehicle travelling in the opposite direction or the message lifetime expires. After continuous rebroadcasting, when vehicle C in Group 2 moves into the transmission range of vehicle B, it receives a broadcast message from vehicle B. When vehicle B receives a duplicated message from vehicle C, vehicle B then stops the rebroadcasting of the message and returns to an idle state. However, if the gap between the vehicles in Group 1 and Group 2 is significant, vehicle B will likely be timed out and drops the message before it reaches the vehicles in Group 2.

5.3 Totally-Disconnected Network

A vehicle is said to be in a totally disconnected network if it has no neighbor in the message forwarding direction or opposite direction. **Fig. 5(c)** shows an example of a totally disconnected network, where the disconnected vehicle, vehicle A, holds a broadcast message using the store-carry-forward mechanism until it connects with a vehicle moving in the same or opposite direction, yet carries the message no longer than the message-life time T3.

In **Fig. 5(c)**, vehicle A is disconnected from the vehicles in Groups 2 and 3. In this scenario, vehicle A continuously rebroadcasts the message, while waiting for a duplicated message from either a vehicle moving in the opposite direction or a vehicle in Group 2. Once vehicle B in Group 3 or vehicle C in Group 2 moves into the transmission range of vehicle A, it receives a broadcast message from vehicle A. After receiving a duplicated message from either vehicle C (moving in the same direction as vehicle A) or vehicle B (moving in the opposite direction to vehicle A), vehicle A stops rebroadcasting the message and returns to an idle state.

6. Performance Evaluation

This section compares the performance of BL-CAST with that of DV-CAST using simulations of various traffic conditions.

6.1 Simulation Environment

The protocol was implemented using an ns-2 (version 2.35) simulator and tested based on a highway mobility scenario. The mobility traces were generated using the Graph Walk mobility model in VanetMobiSim [24]. The network topology was a four-lane straight highway. The ROI was set at 10 km from the source vehicle. It was also assumed that the source vehicle periodically broadcast an emergency message to approaching vehicles. Each vehicle moved along the highway at a random speed chosen between a minimum vehicle speed (V_{min}) of 80 km/hr and maximum vehicle speed (V_{max}) of 130 km/hr. The Distributed Coordination Function (DCF) of IEEE 802.11p was used as the Medium Access Control (MAC) protocol. The transmission range of each vehicle was assumed to be 500 meters, and 8 different vehicle densities were considered. Shadowing was used as the propagation model with a path loss exponent of 2dB and shadowing deviation of 4dB. The 95% confidence interval was computed for the mean values.The three rebroadcasting timers T1, T2, and T3 defined in BL-CAST were set at 2.5 ms, 1 sec, and 10 min, respectively. The interval between beacon messages in DV-CAST was set at 1 second. One thousand messages were generated to collect results for each vehicle density. The simulation duration was set at 10,000 seconds. The results presented for each vehicle density are averaged over 10 simulation runs, and the simulation parameters are summarized in Table 1.

Table 1. Simulation parameters

Parameter	Value
Simulation scenario	highway
Simulation Area	15Km x 4 lanes
Region of interest	I0 Km
MAC protocol	IEEE 802.11p
Transmission range	500 m
Propagation model	Shadowing
Path loss exponent	2dB
Shadowing deviation	4dB
Vehicle density	5,10,15.....40 vehicles/km
Vehicle velocity	80~130 Km/h
Timer 1	2.5 ms
Timer 2	1 second
Timer 3	10 minutes
Confidence interval [%]	95
Broadcast messages	1,000
Simulation duration	10,000 sec

6.2 Performance Metrics

To investigate the performance of the proposed BL-CAST protocol, the following metrics were used:

- End-to-end delay: refers to the average end-to-end time it takes for a message to reach the maximum penetration distance.
- Message delivery ratio: refer to the percentage of vehicles that successfully received the message within the target ROI. Whenever a message was broadcasted, the number of vehicles that successfully received the message was measured. The message delivery ratio was calculated as the number of vehicles that received the message successfully over the total number of vehicles in the ROI.
- Network overhead: refers to the average number of duplicated messages and beacons sent by each vehicle during a single broadcast.

6.3 End-to-end Delay

Fig. 6 compares the end-to-end delay for DV-CAST and BL-CAST according to the vehicle density. Both protocols showed that the end-to-end delay decreased as the vehicle density increased. However, the differences in the end-to-end delay between the two protocols were higher with a heavy vehicle density than with a light vehicle density. This was because DV-CAST experienced more beacon collisions as the vehicle density increased, in contrast to BL-CAST.

In the case of a light vehicle density, more vehicles are disconnected from back vehicles in the ROI. Therefore, the end-to-delay increased as a vehicle in the SCF mode had to carry a message for a long time until it met with the next suitable forwarder. Conversely, in the case of a heavy vehicle density, more vehicles are connected with each other, so the delay in the SCF mode was decreased. However, the end-to-end delay was around 25% lower with BL-CAST on average when compared with DV-CAST. This was because DV-CAST requires all vehicles to excahnge beacons periodically, which leads to frequent contention and collisions among

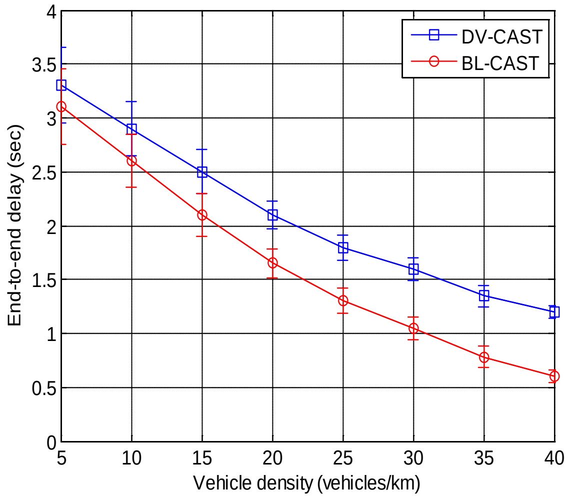

Fig. 6. Comparison of end-to-end delay.

neighboring vehicles. In such cases, the vehicles must wait for a busy channel to become idle. However, BL-CAST does not rely on the periodic exchange of beacons.

6.4 Message Delivery Ratio

For the highway scenario considered in this study, a message was assumed to be successfully delivered if it reached all the vehicles approaching the source vehicle in the ROI. Thus, as the vehicle density increased, the delivery ratio also increased.

Fig. 7 shows the message delivery ratio according to the vehicle density, where the message delivery ratio for BL-CAST increased from 76 percent to 97 percent when the vehicle density increased from 20 vehicles/km to 35 vehicles/km. Plus, at 40 vehicles/km, the BL-CAST message delivery ratio increased to 100 percent. Conversely, as the vehicle density decreased, the message delivery ratio also decreased, yet generally remained higher than 40% for both protocols. This was because disconnected vehicles used the store-carry-forward mechanism

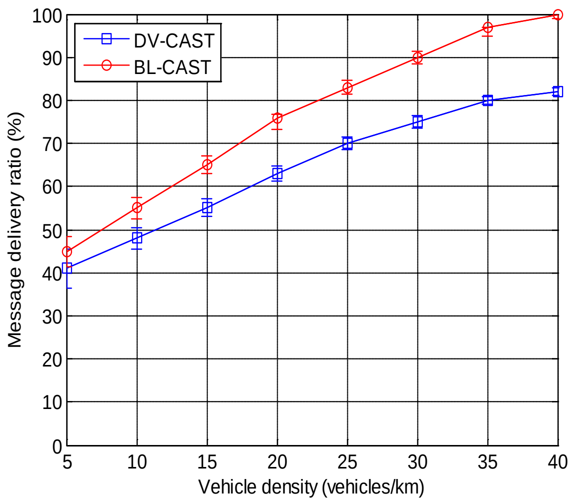

Fig. 7. Comparison of message delivery ratio

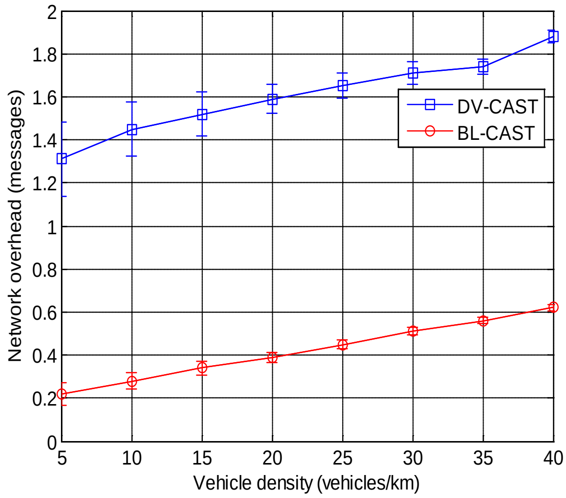

Fig. 8. Comparison of network overhead

and carried a message until it was delivered to a more suitable approaching vehicle. However, in the case of a low vehicle density, some vehicles did not receive the broadcast message, as the disconnected relay vehicle was either timed out before encountering a new approaching vehicle or there was no other vehicle within its transmission range at the time of the broadcast.

Both protocols showed that the message delivery ratio increased as the vehicle density increased. However, the differences in the message delivery ratio between the two protocols were higher with a heavy vehicle density than with a light vehicle density, as DV-CAST experienced more beacon collisions as the vehicle density increased, in contrast to BL-CAST. Therefore, on average, BL-CAST achieved an 18% higher message delivery ratio than DV-CAST.

6.5 Network Overhead

Fig. 8 compares the average network overhead for BL-CAST and DV-CAST according to the vehicle density. The DV-CAST overhead increased with a higher vehicle density, as more beacons were exchanged to maintain network connectivity. Meanwhile, for BL-CAST, as the overhead was due to the continuous transmission of a broadcast message by the last vehicle in an intermittently connected VANET, this overhead was much lower than the DV-CAST overhead caused by the periodic exchange of beacons by all vehicles. As a result, the average network overhead for BL-CAST was about 75% lower than that for DV-CAST.

7. Conclusion

This paper proposed a new beacon-less broadcast protocol for safety applications in VANETs. The proposed BL-CAST protocol is fully distributed and relies on the local information provided by one-hop neighbors via broadcast messages. Simulation results confirmed that BL-CAST outperforms the DV-CAST protocol under various vehicle densities in terms of the end-to-end delay, message delivery ratio, and network overhead. Future studies will compare BL-CAST with other reliable dissemination protocols designed for both highways and urban areas.

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