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A Cross Layer Broadcast Protocol for Multihop Emergency Message Dissemination in Inter-Vehicle Communication

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Abstract—In order to achieve cooperative driving in vehicular ad hoc networks (VANET), broadcast transmission is usually used for disseminating safety-related information among vehicles. Nevertheless, broadcast over multihop wireless networks poses many challenges due to link unreliability, hidden terminal, message redundancy, and broadcast storm, etc., which greatly degrade the network performance. In this paper, we propose a cross layer broadcast protocol (CLBP) for multihop emergency message dissemination in inter-vehicle communication systems. We first design a novel composite relaying metric for relaying node selection, by jointly considering the geographical locations, physical layer channel conditions, moving velocities of vehicles. Based on the designed metric, we then propose a distributed relay selection scheme to guarantee that a unique relay is selected to reliably forward the emergency message in the desired propagation direction. We further apply IEEE802.11e EDCA MAC to guarantee QoS performance of safety related services. Finally, NS-2 simulation results are given to demonstrate that CLBP cannot only minimize the broadcast message redundancy, but also quickly and reliably disseminate emergency messages in a VANET.

Index Terms—Inter-vehicle communication, Cross layer design, Relaying metric, Broadcast protocol

I. INTRODUCTION

Inter-vehicle communication (IVC) [1] enables vehicles to communicate with each other and exchange realtime safety related information such as traffic congestion notification, accident warning, road condition report, etc. As an indispensable component of Intelligent Transportation Systems (ITS) [2], an IVC network usually operates autonomously in an ad-hoc mode without roadside infrastructure support. Advanced protocol design in IVC networks has attached great research attention from academia, industries, and governments.

Taking advantage of the broadcasting nature of wireless channel, broadcast transmission is an efficient approach to advertise information in a wireless network. Nevertheless, effectively broadcasting emergency messages to other vehicles in an IVC system is very challenging especially because of the high mobility and hostile wireless environment in vehicle networks. First, message loss due to packet collisions or poor channel conditions cannot be easily detected because no acknowledgement (ACK) mechanism is applied for broadcast messages in the medium access control (MAC) layer. Since most emergency messages are life critical, and should be delivered to other vehicles as fast and reliable as possible [4], the traditional broadcasting scheme without ACK mechanism is not suitable for emergency message delivery in IVC. Second, without an effective broadcast control in the network layer, multiple redundant messages may be exchanged among nodes, which could cause broadcast storm problem [3] and significantly degrade the network resource utilization.

To address the aforementioned issues, many broadcasting protocols have been proposed in the literature [5]–[8]. Some protocols use network layer broadcast control algorithms to reduce the message redundancy [5]. Other protocols aim to improve the transmission reliability by repeatedly broadcasting messages or selecting the farthest node to relay messages [6]–[8]. However, repeated broadcast cannot completely guarantee the transmission reliability but degrade the resource utilization. The farthest node may suffer from high packet error rate (PER) and is not an ideal relay candidate, especially in high speed vehicle networks. In this paper, we propose a cross layer broadcast protocol (CLBP) for emergency message dissemination in a multihop IVC network, aiming to improve the transmission reliability and minimize the message redundancy in the mean time. Considering the particular characteristics of vehicle networks, we design a novel relaying metric which is composed of geographical locations, physical layer channel conditions, and moving velocities of vehicles. Based on the derived metric, we apply a revised request-to-send/clear-to-send (RTS/CTS) scheme to select an appropriate relaying node distributedly. Furthermore, to support different services with various quality of service (QoS) requirements in an IVC network, we adopt the priority based enhanced distributed coordination access (EDCA) of IEEE 802.11e MAC to support safety services. The emergency messages are served with the highest priority and thus achieve the minimum channel access delay.

The main contributions of this paper are three-fold. First, we design a novel metric for selecting a proper relaying node to forward the emergency message. Second, based on the derived metric, we propose a cross layer protocol to efficiently broadcast emergency messages in IVC. Third, NS-2 simulations are conducted to evaluate the performance of the proposed protocol, in terms of packet error rate (PER) of the emergency message, relay selection delay, and emergency message access delay. Simulation results show that the proposed cross layer approach can quickly and reliably deliver emergency messages while minimizing the broadcast message redundancy.

The remainder of this paper is organized as follows. We briefly review the related work in Sec. II. The proposed CLBP is described in Sec. III. The simulation results are given to demonstrate the efficiency of CLBP in Sec. IV, followed by...
II. RELATED WORK

Broadcast protocols of mobile ad hoc network (MANET) are classified into four categories [5]: simple flooding, probability based methods, area based method, and neighbor knowledge method. However, all these broadcast protocols aim to reduce the number of redundant messages in the network layer, without considering MAC layer issues such as the hidden terminal problem, packet collisions, link reliability, etc. It is well known that broadcast transmission is not reliable due to the lack of acknowledge in the MAC layer, but the delivery of some life critical emergency messages should be guaranteed in an IVC network. Therefore, previous work on broadcast protocol design cannot be directly applied in IVC.

Recently, several protocols have been proposed for emergency message delivery in IVC. In [6], A MAC protocol is presented for emergency message broadcast, and a node rebroadcasts the emergency message for several times to increase the transmission reliability. However, repeatedly rebroadcasting messages not only reduces the resource utilization but also increases the packet collisions in the network. In [7], a black burst based ad hoc multihop broadcast (AMB) protocol is proposed for emergency message dissemination. A neighboring node sends channel jamming signal (black-burst) with the time duration proportional to its distance, and the farthest neighboring node wins and becomes the next relay. Nevertheless, the broadcast node must wait the longest time duration to receive a response from its farthest neighboring node, which results in a long delay for emergency messages. In the position based multihop broadcast protocol (PMBP) [8], the farthest neighboring node waits the shortest time duration to reply the broadcast node and becomes the relaying node. The protocols proposed in [7], [8] choose the farthest neighboring node to forward the emergency message. However, due to the long communication distance, relative velocity, noise, etc., the farthest node usually has a bad channel condition and consequently achieves low transmission rate and suffers from high PER. High PER may cause MAC layer retransmissions and thus a long link delay for emergency messages.

In order to reduce link delay and improve throughput, many channel condition based relaying or routing metrics have been proposed in cooperative relaying schemes and routing protocols. In [9], the expected transmission count (ETX) is proposed to measure the expected number of transmissions a node attempts until a packet is successfully delivered to the next relaying node. The routing scheme based on ETX assures that the selected path achieves the minimum link delay. Similar routing metrics such as expected transmission time (ETT) and weighted cumulative ETT (WCETT) [10] also consider channel conditions and link reliability in the routing metric design. The cooperative MAC (CoopMAC) is proposed in [11], in which each node maintains a table of relays that can improve the link throughput, and selects the relay with a better channel condition and higher data rate. All these schemes select paths or relays based on channel conditions. However, they do not consider the specific characteristics of IVC, i.e., high mobility of vehicles. In this paper, we propose to jointly consider the geographical locations, channel conditions, and relative velocities of vehicles to make a relay decision in vehicle networks.

III. PROPOSED CROSS LAYER BROADCAST PROTOCOL

In the system, vehicles are running on the highway that consists of several lanes. Half of the lanes are used for vehicles driving to one direction, while the other half are used for vehicles to the opposite direction. The value of a vehicle’s velocity is randomly distributed among a discrete set \( V = \{V_i \mid V_{i-1} < V_i, \ i \in (1, P)\} \), and the velocity is directional since vehicles may move to two different directions. Each vehicle is equipped with a half-duplex transceiver and a Globe Positioning System (GPS) by which it can acquire its position information, moving velocity, and moving direction.

We use carrier sense multiple access with collision avoidance (CSMA/CA) based IEEE802.11e MAC for channel access. In order to provide satisfactory delay guarantee for safety related services in IVC, the priority based enhanced distributed channel access (EDCA) is adopted for service differentiation. We include the safety services in the system and divide services into five classes. Different classes of services have different priorities to access the channel based on the access categories (AC) as shown in Table I. The setting of arbitration inter-frame space (AIFS) and contention window (CW) are the same as those specified in IEEE 802.11e [12]:

\[
AIFS[AC] = t_{sifs} + AIFS\_N[AC] \cdot \sigma,
\]

\[
CW[AC] = \min((CW[AC] + 1)PF[AC], \ CW_{max}[AC]),
\]

where \( t_{sifs}, \sigma \) are time durations of a SIFS and a time slot, respectively, AIFS is arbitration inter-frame space number, \( PF \) is the persistence factor which is set to 1.0 for safety services and 2.0 for other services. That is, a node always uses the minimum CW for emergency message delivery while it doubles the CW for other services when a collision occurs. In this way, emergency messages have the highest priority to be served.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>PARAMETERS FOR DIFFERENT SERVICES</th>
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<tbody>
<tr>
<td>AC</td>
<td>CW(_{\text{min}})</td>
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<tr>
<td>0</td>
<td>CW(_{\text{MIN}})</td>
</tr>
<tr>
<td>1</td>
<td>CW(_{\text{MIN}})</td>
</tr>
<tr>
<td>2</td>
<td>(CW(_{\text{MIN}+1})/2-1)</td>
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</tr>
<tr>
<td>4</td>
<td>(CW(_{\text{MIN}+1})/4-1)</td>
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</table>

To provide reliable transmissions of broadcast messages, broadcast request to send (BRTS) and broadcast clear to send (BCTS) frames are exchanged before emergency messages. In addition, in the proposed CLBP, an appropriate relaying node is selected to forward the emergency message in the desired propagation direction, based on a novel relaying metric designed for vehicle networks.
A. BRTS/BCTS handshake

The frame structure of a BRTS is shown in Fig. 1. Compared with the traditional RTS frame, five fields are added into the BRTS frame: \textit{em\_info}, \textit{t\_direction}, \textit{t\_velocity}, \textit{t\_x}, \textit{t\_y}. The field \textit{em\_info} contains the information initiated by the source node, which includes: i) the source node address \textit{init\_addr}, ii) the position information of the source node \textit{init\_x} and \textit{init\_y}, iii) the sequence number of the emergency message \textit{em\_seq}, and iv) the weight factors \(\alpha_1, \alpha_2, \alpha_3\) used for relaying metric calculation and relaying node selection. \textit{t\_direction} is the message propagation direction, \textit{t\_velocity} is moving velocity of the current broadcast node, and \textit{t\_x}, \textit{t\_y} indicate the position of the current broadcast node.

![Figure 1. Format of the BRTS frame.](image)

When a node has an emergency message, it first broadcasts a BRTS frame based on the CSMA/CA mechanism and starts a retransmission timer \(t_{brets} = t_{brts} + t_{difs} + t_{bcts}\), where \(t_{brts}\), \(t_{bcts}\) are time durations for transmitting a BRTS and a BCTS, respectively, \(t_{difs}\) is the time duration of a DIFS. If there is no BCTS response within \(t_{brts}\), the node will contend for channel access to rebroadcast the BRTS immediately until a BCTS is successfully received. The broadcast node sets its \textit{duration} field in the BRTS frame that any node which hears the BRTS but is not eligible for replying a BCTS frame will set its NAV and defers its own transmissions accordingly.

After receiving a BRTS frame, a neighboring node decides whether to reply a BCTS frame based on the direction information or position information in the received BRTS. If \textit{init\_addr} in the received BRTS is same as the address of the current broadcast node, implying that this is the first hop emergency message dissemination, and the node will decide whether to reply a BCTS based on propagation direction \textit{t\_direction}. Otherwise, if its own position is between the original source node and the current broadcast node, it will not reply a BCTS frame since there is no distance gain along the propagation direction for this node to reply. In this case, the node updates its NAV according to the \textit{duration} field in the received BRTS frame. Otherwise, it starts a backoff timer for replying a BCTS frame and senses the channel in the mean time. As shown in Fig. 2, \(A\) is the source node that initiates an emergency message, \(B\) is the current broadcast node. Node \(C\) will not reply a BCTS frame since it locates between \(A\) and \(B\), while \(D\) is eligible for relaying the message and starts a backoff timer upon receiving the BRTS frame. This guarantees that the emergency message will be efficiently forwarded along the desired propagation direction.

Each eligible relaying node which locates at \((x, y)\) and moves at velocity \(v\) will start a timer for replying a BCTS according to the following metrics: i) the distance between itself and the current broadcast node, ii) the received SNR and PER which can be estimated from the received BRTS, and iii) the velocity difference between itself and the current broadcast node. Based on the three metrics, the relay candidate evaluates a composite metric \(F\) used for relay selection, which is given by

\[
F = \alpha_1 \cdot (1 - \frac{\Delta d}{R_t}) + \alpha_2 \cdot \frac{e}{E_{max}} + \alpha_3 \cdot \frac{\Delta v}{2V_p},
\]

where

\[
\Delta d = \sqrt{(x - t_x)^2 + (y - t_y)^2},
\]

and

\[
\Delta v = | \sqrt{v} - t\_velocity |
\]

\(\Delta d\) is the distance, \(\Delta v\) is the value of relative velocity, \(e\) is the PER of the emergency message that is calculated based on the measured SNR, \(R_t\) is the transmission range, \(E_{max}\) is maximum tolerable PER defined in [12], \(V_p\) is the maximum value of velocities, \(\alpha_1, \alpha_2, \alpha_3\) \((\alpha_1 \geq 0, \alpha_2 \geq 0, \alpha_3 \geq 0)\) are weight factors and usually configured by users. For instance, if a user want the messages to be delivered over a fewer number of hops or with a reduced PER, a larger \(\alpha_1\) or \(\alpha_2\) is required accordingly; if the topology is relatively steady, a small \(\alpha_3\) can be used.

The main objective of the proposed CLBP is to deliver the emergency message to other vehicles as fast and reliable as possible. \(\Delta d\) is a metric to determine the number of hops, i.e., the message will be forwarded over a fewer number of hops with a larger \(\Delta d\). In addition, MAC layer delay of the message highly depends on the PER \(e\). A higher PER may result in retransmissions that lead to a longer link delay. Finally, a small relative speed \(\Delta v\) is usually desirable in high speed vehicle networks to guarantee the channel between two moving vehicles is relatively stationary. It has been verified in [13] that if two routing metrics are bounded, their additive composite metric is also bounded. As \(\Delta d \in (0, R_t)\), \(\Delta v \in [0, 2V_p]\), and \(e \in [0, 1]\), the composite metric \(F\) is consequently bounded. The maximum and minimum values of \(F\) are denoted by \(F_{max}\) and \(F_{min}\).

In order to avoid interruptions to BRTS/BCTS handshake by other flows, CLBP requires the selected relaying node reply a
BCTS within DIFS interval. Applying the concept of mini-slot in [14], we further divide a DIFS interval into a number of mini-slots. The value of a mini-slot \( \tau \) and the number of mini-slots \( W_n \) can be be calculated as:

\[
\tau = 2 \cdot \rho + t_{\text{switch}},
\]

\[
W_n = \lfloor t_{\text{difs}}/\tau \rfloor,
\]

where \( \rho \) is the maximum channel propagation delay within the transmission range \( R_n \), and \( t_{\text{switch}} \) is the time duration that a transceiver switches from the receiving mode to the transmitting mode. In order to map the relaying metric \( F \) to a number of mini-slots, we further partition the window between \( F_{\text{min}} \) and \( F_{\text{max}} \) into \( W_n \) segments, and each segment is \( e_i = (F_{\text{max}} - F_{\text{min}})/W_n \). After evaluating the composite metric \( F_i \), an eligible relay candidate sets its timer to \( i \) mini-slots if its \( F_i \) is within \( [F_{\text{min}} + (i-1) \cdot e_i, F_{\text{min}} + i \cdot e_i] \), where \( i \in [1, W_n] \). The relay candidate with the minimum \( F_i \) will reply a BCTS first and thus be selected as the relaying node accordingly. That is, a node with a longer distance, better channel condition, and smaller velocity difference is more preferable for relaying the emergency message.

The BCTS frame also contains fields \( \text{init_addr} \) and \( \text{em_seq} \). If another relay candidate overhears the BCTS frame replying the same BRTS frame before its own backoff timer expires, the node will stop its timer and update its NAV according to the value of \( \text{duration} \) field included in the received BCTS frame. Note that the \( \text{duration} \) fields in a BRTS and BCTS are set to be \( t_{\text{btrs,ms}} = t_{\text{difs}} + t_{\text{bcts}} + t_{\text{ifs}} + t_{\text{act}} + \frac{L}{r_b} + t_{\text{ifs}} + t_{\text{act}} \) and \( t_{\text{bcts,ms}} = t_{\text{btrs,ms}} - t_{\text{difs}} - t_{\text{bcts}} \), where \( t_{\text{act}} \) is the transmission time of an ACK frame. \( L \) is the payload size of the emergency message, and \( r_b \) is the basic rate. \( t_{\text{btrs,ms}} \) is conservative because the receiver waits at most a DIFS to reply a BCTS in CLBP. Whenever a node receives or overhears other BRTS within DIFS interval. Applying the concept of mini-slot in [14], we further divide a DIFS interval into a number of mini-slots. The value of a mini-slot \( \tau \) and the number of mini-slots \( W_n \) can be be calculated as:

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It is possible that multiple relay candidates may choose the same mini-slot to reply a BCTS, which causes collisions. When a collision occurs, the relay candidates that have started their backoff timers but have not replied a BCTS will sense the channel busy, and they will stop their own backoff timers accordingly. If a relay candidate which has replied a BCTS frame receives a rebroadcast BRTS, it will enter the backoff stage again and divide \( e_i \) into \( W_n \) segments, each of which is \( e_1 = e_i/W_n \). That is, the relay candidate will wait \( i \) mini-slots to reply a BCTS again if

\[
F < F_{\text{min}} + \lfloor (F - F_{\text{min}})/e_i \rfloor \cdot e_i + (i - 1) e_i \leq F,
\]

\[
F < F_{\text{min}} + \lfloor (F - F_{\text{min}})/e_i \rfloor \cdot e_i + i e_i.
\]

Therefore, the proposed collision resolution scheme is very efficient for selecting a unique relaying node. The pseudo code of the relay selection process is presented in Algorithm 1.

---

**Algorithm 1 Relay Selection Algorithm**

1. A node \( j \) received a BRTS.
2. \( \text{if } \text{init_addr} = \text{init_addr} \) then
3. \( \text{if } j \) receives the BRTS at the first time then
4. Check \( \text{direction} \).
5. \( \text{if } j \) is in the propagation direction then
7. \( \text{else} \)
8. Set the NAV.
9. \( \text{end if} \)
10. \( \text{else} \)
11. Go to line 27.
12. \( \text{end if} \)
13. \( \text{else} \)
14. \( \text{if } j \) receives the BRTS at the first time then
15. \( \text{if } j \) has distance gain in the propagation direction then
17. \( \text{else} \)
18. Set the NAV.
19. \( \text{end if} \)
20. \( \text{else} \)
21. Go to line 27;
22. \( \text{end if} \)
23. \( \text{end if} \)
24. Compute \( F_{\text{min}}, F_{\text{max}}, e_i \), distance, relative velocity, and PER.
25. Map \( F \) of node \( j \) to mini-slots.
26. Start the backoff timer, and go to line 34.
27. \( \text{if } 0 < t_{\text{retry}} < r_{\text{max}} \) then
28. Compute \( e_{\text{retry}} = e_i/(W_n)^{t_{\text{retry}}} \), map \( F \) of \( j \) to mini-slots.
29. Start the backoff timer, and go to line 34.
30. \( \text{else} \)
31. Randomly select a mini-slot from \( W_n \).
32. Start the backoff timer, and go to line 34.
33. \( \text{end if} \)
34. \( \text{while } \text{the backoff timer } \neq 0 \) do
35. \( \text{if } j \) receives a BCTS replying the same BRTS then
36. Stop the timer and set the NAV.
37. \( \text{break} \).
38. \( \text{end if} \)
39. \( \text{end while} \)
40. \( \text{if } \text{the backoff timer } = 0 \) then
41. Reply a BCTS, and \( t_{\text{retry}}++ \).
42. \( \text{end if} \)
43. \( \text{return} \).

---

**B. Emergency message broadcast**

After a successful BRTS/BCTS handshake, the current broadcast node that successfully receives a BCTS will broadcast the emergency message after a SIFS interval. The selected relay will acknowledge the reception of the emergency message if it receives the message successfully. To avoid message redundancy, each node in the system maintains a list of all received emergency messages. Each entry in the list records the address of the source node as well as the sequence number of the emergency message, and the out-of-date entries will be deleted. A node which receives an emergency message will check the list and drop the message that has already been recorded. Otherwise it will receive the message and update...
the list. After successfully replying an ACK, the selected relay becomes the next relaying node and repeats the aforementioned BRTS/BCTS handshake process.

IV. SIMULATION RESULTS

In this section, we evaluate the performance of the proposed CLBP in terms of the PER, relay selection delay, the emergency message access delay via NS-2 simulations. Due to the space limitation, the analytical study of CLBP is not included in this paper. In the simulations, vehicles are randomly distributed over a two-lane highway with two directions, and a vehicle is selected as the broadcast node. The velocity of a vehicle takes a value among \{20, 25, 30, 35, 40, 45, 50\}. As the default setting, five data flows are set up with the rate of 100 packets/s. Other simulation parameters are listed in TABLE II.

A. PER of the emergency message

We first compare the PER performance of CLBP with that of AMB [7] under various noise power spectral densities \(N_0\) in Fig. 3(a). For a smaller \(N_0\), both CLBP and AMB achieve a low PER. When \(N_0\) increases, the PER of AMB increases while that of CLBP does not change much. In CLBP, the broadcast node jointly considers the distance, channel condition, and the relative velocity to select the next hop relaying node. Under an ideal channel, the farthest relay candidate has the lowest \(F\), and is selected as the relaying node, while under a poor channel, the received SNR at the farthest relay candidate decreases and accordingly the achieved PER increases, in which case a closer relay candidate with a lower PER may be selected with CLBP. As shown in Fig. 3(a), the PER of CLBP decreases slightly when \(N_0\) increases from \(-174.6\) dBw/Hz to \(-173.88\) dBw/Hz. Therefore, CLBP assures the PER performance of the emergency message and thus is more suitable for vehicle networks with variant channel conditions.

B. Relay selection delay

Relay selection delay is defined as the interval from the time the broadcast node attempts to deliver a BRTS frame to the time it successfully receives a BCTS frame. In Fig. 3(b), we compare the relay selection delays of CLBP and AMB.

By applying service differentiation in CLBP, the emergency messages are served with the highest priority when they compete with packets of other data flows. AMB adopts the basic CSMA/CA and achieves a longer access delay compared with CLBP. In addition, the node sending the longest channel jamming signal becomes the relaying node in AMB, while a node waiting the shortest time to reply a BCTS becomes the relaying node in CLBP. As shown in Fig. 3(b), the relay selection delay of CLBP is much smaller than that of AMB. The relay selection delays of CLBP and AMB increase with the increase of node density due to retransmissions caused by collisions.

C. Emergency message access delay

Finally, we study the emergency message access delay under various node densities and background noise levels in Fig. 3(c)-(f). We observe that the emergency message access delays of AMB are higher than those of CLBP, and their differences increase with the node density and background noise level. This can be explained as follows. First, CLBP gives the highest priority for safety services by adjusting AIFSN, PF, CWmin, and CWmax, which results in a smaller access delay, whereas in AMB without service differentiation, emergency messages have to contend with other services with the same priority. Second, in CLBP, the selected relaying node waits the minimum number of mini-slots to reply a BCTS, while in AMB, the selected relaying node sends the longest black burst signal to win the opportunity to reply clear-to-broadcast (CTB). Finally, under a bad channel condition, the broadcast node in CLBP chooses an appropriate node with a reasonable PER performance to relay the emergency message. In AMB, the broadcast node always selects the farthest relay candidate at each hop, which may incur retransmissions due to a low SNR and high PER of the emergency message.

V. CONCLUSIONS

In this paper, we have designed a composite relaying metric to select an appropriate relaying node to forward the emergency message, considering the special characteristics of an IVC network. Based on the metric, we have proposed a cross layer broadcast protocol to efficiently disseminate emergency messages in an IVC system. NS-2 simulations are conducted to study the performance of the proposed CLBP. Simulation results show that CLBP cannot only shorten the emergency message transmission delay, but also deliver emergency messages reliably with less resource consumption. In our future work, we will incorporate more complicated road traffic model in urban environments.

REFERENCES


TABLE II

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
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<td>(t_{sIFS})</td>
<td>10 (\mu s)</td>
<td>PLCP+preamble</td>
<td>192 (\mu s)</td>
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<tr>
<td>(\sigma)</td>
<td>20 (\mu s)</td>
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<td>20byte</td>
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<td>basic rate ((r_b))</td>
<td>1M</td>
<td>BRTS</td>
<td>3byte</td>
</tr>
<tr>
<td>data rate ((r_d))</td>
<td>2M</td>
<td>BCTS</td>
<td>1byte</td>
</tr>
<tr>
<td>(R_t)</td>
<td>250m</td>
<td>L</td>
<td>1024byte</td>
</tr>
<tr>
<td>(V_i)</td>
<td>20m/s</td>
<td>(V_p)</td>
<td>50m/s</td>
</tr>
<tr>
<td>(\rho)</td>
<td>1 (\mu s)</td>
<td>(\tau_{\text{with}})</td>
<td>1 (\mu s)</td>
</tr>
<tr>
<td>(\alpha_1)</td>
<td>1</td>
<td>(\alpha_2)</td>
<td>1</td>
</tr>
<tr>
<td>(\alpha_3)</td>
<td>1</td>
<td>(\tau_{\text{max}})</td>
<td>7</td>
</tr>
</tbody>
</table>

Parameter in simulations
Figure 3. Performance comparisons between AMB and CLBP: (a) PER, (b) relay selection delay, (c)-(f) emergency message access delay.


