Vehicle to Vehicle Emergency Message Communication through WiBro Network

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Abstract

In this paper, we proposed a new method to guarantee the successful V2V (Vehicle to Vehicle) emergency message communication with utilizing the commercialized WiBro wireless network. Differently from the well-known standards of V2V communication such as DSRC and WAVE which are basically Ad-hoc based approaches, our method is on WiBro, also known as the Potable Internet, which is an infrastructured wireless network. In order to adopt V2V emergency application to WiBro feasibly, the connectionless broadcasting scheme is suggested in this paper in which the modification of UL subframe structure and FUDE backoff algorithm are introduced. The delayed time of dissemination the emergency message covering a desired area is considered as a performance measure. From the simulation studies on the given scenario, the results show the proposed scheme reaches to the reasonable low delay characteristics in V2V emergency communication.

1. Introduction

Recently, as a real application of MANET (mobile ad hoc networks), VANET (Vehicular Ad hoc Networks) gains much attention from network researchers and is regarded as the important one of the next generation network technologies.

VANET is proposed to provide vehicle drivers with safe driving to their destination. For this purpose, in a real time or a given time, VANET should guarantee forwarding emergency events such as car crash on the road to the following cars to avoid the additional car accidents[1-2]. At the same time, VANET is used to monitor the real time traffic information and to distribute the information to each driver to spread out the traffic flow. The traffic on the road may be, thereby, maintained relatively free. Therefore, the most important requirement of VANET is to meet the real time condition to deliver the information. Moreover, the extension to the Internet through VANET should be considered.

Over the VANET, wireless communications are assumed to be autonomously possible from a vehicle to a vehicle (V2V) or from a vehicle to an infrastructure such as the base station on the road (V2I). The direct communication between cars, in other word, The V2V communication is considered more important than V2I communication to avoid chain-reaction car collision.

Realizing V2V communication based on MANET is, however, a challenging work because VANET is characterized by so high mobility of each mobile node (or vehicle), which introduces fast change of network topology and the network density. These lead to frequent disconnection of wireless link, high loss rate of data delivery, and low throughput due to unstable wireless channel.

In this paper, we briefly review the standards of V2V communication such as DSRC and WAVE. Then, we propose an implementing V2V communication utilizing WiBro[3-6], the commercialized networks infrastructure renowned as the mobile Internet.

We assume that a car experiencing a collision starts to access to a BS to get a channel allocation as in the conventional WiBro system. After the car obtains CID (Channel ID), the car broadcasts the emergency message to all neighboring cars. This process should satisfy the emergency message delivery requirement that the emergency message should be broadcasted within 500ms over the area with the 1 km radios. In order to realize this process, we propose a minor modification to the original system, broadcasting without connection scheme. We have evaluated the performance of our proposal by repeating a few simulations.

2. V2V communications review

Services in Telematics ensuring the safety of vehicles, monitoring the traffic status, and controlling traffic flow have been already extensively researched in EU and US. However, only a few services are commercialized and very simple in monitoring the traffic status utilizing the BSs on the road.

In order to stimulate services in Telematics, a few
of projects are executed. In US, VII (Vehicle Infrastructure Integration) driven by DOT (Department of Transportation) and VSCC (Vehicle Safety Communication Consortium) by the major car making companies are representative. VII are focusing on the nationwide infrastructure providing car safety service and traffic information. The major car companies such as BMW, DCX, Ford, Honda, and Nissan and telecommunication company such as Telcordia are involved in this project. This project mainly considers public car services and general commercial services based on WAVE using 5.9 GHz.

VSCC is developing V2V communication for car safety ensuring services. This project studies the communication requirements to reduce car collisions and to improve the communication capacity. Also, this project extensively evaluates the WAVE standard to deploy this standard into real industry.

In EU, eSafety forum starts since 2005 with a slogan, i2020, ‘Intelligent Car Initiative’ [7] to provide smarter, cleaner, and more intelligent mobility. Also, each country in EU is executing its own project. For example, NoW (Network on Wheels) project in Germanis doing researches on V2V communications. European car companies formed the private consortium, C2CC_CC (Car to Car Communication Consortium) to developing applications using V2V and V2I communications.

EU is making ADHOC MAC [8] as their own VANET network standard through Car TALK2000 project. ADHOC MAC is using TDMA based on RR-ALOHA [14]. Due to the advantage of TDMA, ADHOC MAC shows the stable performance even under the congested network or higher network density. However, the high mobility of VANET makes it difficult for ADHOC MAC to synchronize TDMA schedule and to exclusively allocate TDMA slot, which leads to the performance degradation of VANET.

IEEE is also making its own VANET standard, called as WAVE (wireless access in vehicular environment). WAVE is mainly made up of IEEE 802.11p [9] defining PHY and MAC layer and IEEE 1609 [10] defining from application layer to a part of MAC layer. Since EU also follows the similar specifications, WAVE is strongly likely to be the dominant standard of VANET. Because the IEEE 802.11p is the one of the random access family, it is expected to work well at low density of VANET. However, at the high density of VANET, the data transmission collisions may highly happen, which leads to lower performance.

3. V2V Communication Scenario through WiBro Networks

3.1 V2V Communication in Conventional WiBro Systems

Transmission of emergency message between vehicles requires a different frame structure from the conventional wireless communication systems. While the uplink/downlink data frame structure in the conventional wireless network is designed from a long-term average perspective of data transmission, the frame structure used in V2V emergency communication embeds a function to overcome outages due to heavy congestion from lots of trials of access during a short time after an accident occurred. In this paper, taking into accounts of this feature, a simple method for transmitting emergency message between vehicles through WiBro network is suggested, which leads to modify the frame structure. Figure 1 shows the effect of the emergency report trials to the channel after car accident when the conventional WiBro is operating normally.

As shown in Figure 1, three users who newly arrive at up to DL subframe of Frame(i) try to access to ranging channels of UL subframe at Frame(i) with users who have eligible backoff numbers from the previous frames. If resource assignment for an initial ranging is appropriate, new arrival user will seize the high probability of success for trials of ranging. At Frame(i+1), because lots of vehicles try to access to a channel right after an accident occurs, the probability of success for initial ranging at that frame decrease significantly. In addition, high backoff CW will be selected due to the successive collisions, so that delay will rapidly increase.

The followings are the summary of transmission scenario for emergency report between vehicles (or V2V communication) through the conventional WiBro systems.

- Resource assignment for an initial ranging channel: $N_{\text{null}}$ (the number of sub-channels for the initial and handover rangings), $N_{\text{code}}$ (the number of CDMA codes for the initial handover rangings). Assumed that one transmission duration is assigned to a frame

![Figure 1. The effect of the emergency report trials to the channel after car accident when the conventional WiBro is operating normally.](image-url)
for the ranging resource in time axis. The total number of assigned resources is $N_{\text{sub}} \times N_{\text{code}}$.

- **Assumption of collision condition in the initial ranging:** When the number of users who use the same code in the same sub-channel of the initial ranging resources in a frame is more than 1, it is considered that a collision occurs. We assume that the BS (base station) is able to successfully perceive the collision.

- Since a BS is assumed to be able to always perceive the collision, the collision resolution procedure employed in initial ranging is ignored.

- After a collision occurs, backoff is carried out according to BEB algorithm. (The minimum contention window is assumed as $CW_{\text{min}} = 2^i$, and the maximum contention window is $CW_{\text{max}} = 2^i$).

- The offset of backoff is defined as the basic resource element assigned in the initial ranging.

- The normal users trying to access the WiBro network for the general services can be assumed as background load which issues $T_{\text{user}}$ attempts of the initial ranging in a frame.

- Vehicles that have a WiBro device and witness an accident attempt the initial ranging through WiBro network. Then, the vehicle who obtain the resource in an UL subframe assigned by a BS through the initial ranging transmits emergency message to the BS in order to warn the neighboring vehicles within a certain interested area.

- The total number of frames needed by the first vehicle who has succeeded to transmit emergency message among vehicles that witness the accident is calculated when the background load is given. Performance is evaluated according to the number of vehicles that simultaneously witness the accident and the background load.

- One frame duration is 5ms, and it can be flexible according to the system specification of WiBro.

### 3.2 The proposed connectionless broadcasting scheme in WiBro for V2V communication

In a connectionless broadcasting scheme, the BS does not identify the terminal who has sent an emergency message but simply detect whether the emergency access to the channel occurs or not. When it happens, the BS quickly gets and broadcasts the information such as the position and time of an accident to the vehicles to prevent possible successive accidents. Emergency message dissemination scenario to prevent successive accidents in the connectionless broadcasting scheme suggested in this paper implies the communication between a BS and vehicles explicitly (or from vehicle to vehicle implicitly) without assignment of CID and SA.

To guarantee this scenario more efficiently, it is assumed that the conventional WiBro system can provide following modifications and options in this scenario.

- Define a CDMA code for urgent transmission (or a specific purpose) usage.

- BS has ability to modify the structure of UL subframe (temporarily change the multichannel structure into the structure of the single random access channel which is similar to DCF mode in 802.11), after receiving emergency indication. This modification is suggested to diminish the high collision rate at the time when an accident happens. Figures 1 and 2 show the effect of the burst access trials and the suggested modification of UL subframe, respectively.

- Define RTS/CTS message which will be used in modified UL subframe structure.

- Define BEB algorithm parameters (such as contention window size, offset, and timing information) for resolving the collision problem of RTS transmission.

- Modify the structure of FCH (Forward Channel) including field assignment for broadcasting an emergency message.

- Define MMPDU for sharing emergency messages between the BSs.

- It is necessary to define all parameters and modify the structure for accommodating requirements in suggested algorithm. Details such as frame structure, message structure, and timing relation between messages etc. will be dealt with later.

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**Figure 2.** Modification of UL subframe structure into the single channel DCF structure after perceiving emergency access by the BS.

The following is the procedural descriptions of the transmission for V2V communication through WiBro in the suggested connectionless broadcasting scheme.

- Avoid the competition with Background user (conventional users in WiBro) by using CDMA code $C_u$ for emergency transmission. (Additional overhead for the detection of code $C_u$ can be
required as the BS has to check it in each frame whether \( C_w \) is used or not.)

- When an accident happens, most of WiBro vehicles running by the accident attempt the initial ranging with \( C_w \), so that the BS recognizes the usage of \( C_w \) successfully. We assume that the BS can recognize the usage of \( C_w \) even though many users attempt to access with the same \( C_w \) at the same time. It is reasonable assumption under the condition that the time synchronization at the receiver side of a BS is accomplished in advance.

- The BS who has detected the usage of \( C_w \) in the previous frame changes the normal operation mode to the emergency message handling mode and broadcasts the information to users through FCH DL channel. In the emergency message handling mode the UL subframe structure is modified into the single channel DCF structure as shown in Figure 2.

- Since we foresee heavy collisions amidst emergency access trials, we apply the RTS/CTS scheme in order to mitigate collision effect. A RTS message is defined to be transmitted in a slot of a modified UL subframe, and the number of slots in a UL subframe is defined as \( N_{RTS} \). Slots can be considered as offsets for CW (Contention Window) in CRC (Collision Resolution Control) algorithm.

- Adaption of the backoff algorithm for transmitting RTS is carried out on a frame basis. Additionally, a novel Fast Up-Down Backoff (FUDB) algorithm is suggested so as to increase the probability of success for RTS transmission.

- The facts and assumptions for the proposed Fast Up-Down Backoff (FUDB) algorithm:
  - \( CW \) is updated through FCH in a frame basis. (That is, the value of \( CW \) announced from downlink of the BS is valid within that frame.)
  - The terminals which select offset value less than \( N_{RTS} \) among their \( CW \) size can obtain the opportunity of transmitting RTS at current frame, while other terminals eliminate the selected value and renew a backoff procedure in the next frame.
  - \( CW \) window size is assumed that the minimum \( CW \) is \( CW_{min} = 2^4 \) and the maximum \( CW \) is \( CW_{max} = 2^{16} \), and it increases as multiples of \( \beta \) or decreases as multiples of \( \gamma \) every frame.
  - Fast Up: When no terminal gets grant from the BS because of the collision once RTS transmissions are issued at this UL subframe, the next \( CW \) size increases to the \( \beta \) times 'UP' for the next frame.
  - Fast Down: When no terminal tries to RTS transmission at the UL subframe, the next \( CW \) size decreases to the \( \gamma \) times 'DOWN' for the next frame.
  - The proposed FUDB algorithm adapts a \( CW \) size for the number of active trials of emergency message transmission.

- Validity of the FUDB algorithm: As the purpose of our method is to get a successful terminal among terminals which attempt to access to the BS for emergency message, the FUDB induces any terminal to quickly succeed within \( N_{RTS} \) of a frame by adapting a \( CW \) size according to the number of terminals which attempt.

### 4. Performance Evaluation

We used the following simulation parameter to measure the performance of our proposal. Fig. 3 shows the delay time of broadcasting the warning message in the original WiBro system when a car crash happens and the following cars recognizing the car accident broadcast the event to others. At this scenario, the another cars trying to access the same BS of the broadcasting cars will acts as a kind of interruption to transmit the broadcast. X-axis means the number of cars interrupting the broadcast and y-axis means the time to broadcast. The unit of the y-axis is ms. As the graph shows, the number of interrupting cars more increases and the access trials also more increases, the broadcasting time of the warning message takes longer time.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number of subchannel used in the initial handover ranging (( N_{sub} ))</td>
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</tr>
<tr>
<td>The number of CDMA code used in the initial handover ranging (( N_{code} ))</td>
<td>4</td>
</tr>
<tr>
<td>The number of access trials of background users per frame (( T_{user} ))</td>
<td>variable</td>
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<tr>
<td>The duration of one frame (( T_{frame} ))</td>
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</tr>
<tr>
<td>The maximum contention window (( CW_{max} ))</td>
<td>( 2^4 )</td>
</tr>
<tr>
<td>The increasing parameter for contention window in AUDB (( \beta ))</td>
<td>4</td>
</tr>
<tr>
<td>The decreasing parameter for contention window in AUDB (( \gamma ))</td>
<td>1/2</td>
</tr>
</tbody>
</table>

Table 1. Simulation parameters

Figure 4 shows the comparison broadcast time between our proposal and the original WiBro system. The number following each graph name of the original WiBro system means the number of background cars. X-axis means the number of cars transmitting the emergency message and y-axis means the delayed time for the broadcast completion, whose unit is ms. In the original system, as the number of cars transmitting
the emergency message, the delayed time to the broadcast completion became longer. At this time, the effects of background cars becomes different depending on the number of background cars. When the number is large, the effect is not marginal but the number becomes small, the adverse effect becomes ignorable.

From Figure 3 and Figure 4, we lead to a conclusion that the broadcast time of emergency message is delayed in the original WiBro system because it does not differentiate the access trial of usual cars with that of emergency cars. However, our proposal, connectionless broadcast method is not affected by background cars and the broadcast time is increased by the number of cars trying to broadcast emergency message. But the increasing rate is slower than that of the original system, which can be considered more robust in terms of the number of cars. This performance evaluation shows our proposal is more efficient to the original WiBro system in the view of emergency message delivery.

5. Conclusions

In this paper, we proposed a new method to guarantee the successful V2V emergency message communication with utilizing WiBro system. Differently from the well-known standards of V2V communication such as DSRC and WAVE which are basically Ad-hoc based approaches, our method is on WiBro which is an infrastructured wireless network. In order to adopt V2V emergency application to WiBro feasibly, the connectionless broadcasting scheme is suggested in this paper. The delayed time of dissemination the emergency message covering a desired area is considered as a performance measure. From the simulation results, we concluded that our proposal is sufficient to support V2V emergency message delivery.

References