Development of Vehicular Communication (WAVE) System for Safety Applications

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Abstract—**These years, there has been much research and development activity in safety service for ITS (Intelligent Transports System) globally because fatal accidents have been increasing rapidly according to spread of vehicles. In order to decrease traffic accident, cooperation between vehicle and infrastructure (C2I: Car to Infrastructure) and between cars (C2C: Car to Car) attracts much attention.**

In this paper, we introduce WAVE (Wireless Access in Vehicular Environment) technology that is under standardization for C2I and C2C communication as IEEE802.11p and IEEE P1609. Then we present developing WAVE device with dual 11p wireless device. With dual device, WAVE system is expected to provide stable operation, reliable communication and higher performance. For the purpose of validity of WAVE system, we have developed typical safety application systems of crossroad collision avoidance scenario and front-tail collision avoidance scenario, and show evaluation plan.

Keywords—**ITS, C2I/C2C, Safety application, WAVE**

Area of interest —In-Vehicle, Inter-Vehicle and infrastructure to Vehicle Communications

I. Introduction

There have been much research and development activities in safety services for ITS (Intelligent Transports System) all over the world around last five years because fatal accidents have been increasing in proportion to rapid spread of vehicles and have been causing huge economic loss.

And more than two thirds of the number of accidents is due to non-respect of traffic regulation or carelessness of drivers to their traffic environments etc. Hence vehicle's safety mechanism by its own is not enough to decrease dramatically the number of traffic accidents. For that purpose, cooperation between car and infrastructure (C2I) and between cars (C2C) is expected to be one of the most effective ways.

The sharing of traffic situation by warning and hazarding via C2I/C2C causes driver to realize the dangerous situation with ease and clarity on the spot within low latency to avoid accidents.

The standardization of C2C and C2I communication technology has been done in U.S, Europe and Japan, these years.

In U.S and Europe, WAVE (Wireless Access in Vehicular Environment) technology using frequency of 5.8GHz/5.9GHz, which supports both C2I and C2C communication, is under standardization aiming at the finalization in April 2009. It consists in IEEE802.11p[1] (hereafter we call it as 11p) for PHY/MAC layer and IEEE P1609[2][3][4][5] (hereafter we call them as P1609) for higher layers. IEEE802.11p is referred to IEEE 802.11a, and modifies it mainly in the light of frequency, bandwidth and MAC protocol.

On the other hand, in Japan, based on unique technology (ARIB STD-T75) which is used for ETC (Electric Toll Collection) system for highway, standardization of C2C communication commenced using frequency of 5.8GHz or 700 MHz. Communication for C2I would be different from one for C2C because STD-T75 as C2I cannot apply to C2C in nature.

Considered on those activities, WAVE would be substantially global standard certainly.

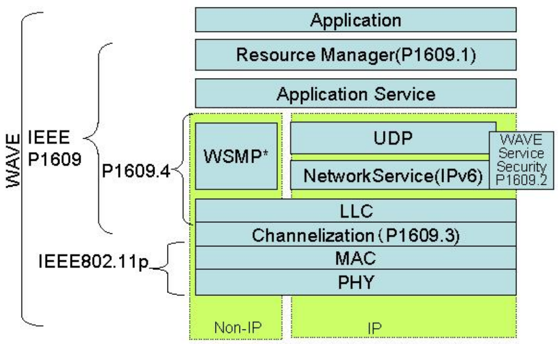
We focus on WAVE and have been developing WAVE device applied to safety services. Then the feasibility test will be done for realization of safety application.

In this paper, we introduce WAVE technology in the next section and point out technical issues of current WAVE draft. We propose our WAVE system in section III, and potential safety applications using WAVE and their evaluation plan are shown in section IV. Future work is shown as conclusion in section V.

II. WAve Technology

A. WAVE Architecture

WAVE components are illustrated in Fig.2.1. Unique architectural components are mainly resource manager of upper layer, WSMP(WAVE Short Message Protocol) of network layer ,and channelization function and IEEE802.11p of lower layer. WAVE system supports both IP and non-IP based applications. Non-IP based applications are supported through the WSMP defined in P1609.3. WSMP allows applications to directly control physical characteristics, e.g., channel number and transmitter power etc., which is utilized for high priority safety message (emergency message). Channelization is an enhancement to the IEEEStd 802.11 MAC and interacts with the IEEE802.2LLC and 11p. This function coordinates the channel intervals (CCH interval and SCH interval hereafter explained) according to the channel synchronization operation of MAC layer.



*WSMP: WAVE Short Message Protocol

Fig.2.1 WAVE Architecture

In a WAVE system, there are two types of devices: Road Side Units (RSUs) and On Board Units(OBUs). An RSU is a WAVE device theat operates at a fixed position. An OBU is a mobile or portable WAVE device that supports information exchange with RSUs and other OBUs. WAVE devices shall accommodate a Control channel and multiple service channels. Upon startup, a device monitors the Control Channel (CCH) until a WAVE service advertisement is received that announces a service which utilizes a Service Channel(SCH), or the device chooses to utilize the Service Channel based on WAVE announcement frames it transmits.

Talble.2.1 shows the CCH and multiple SCHs. CCH is fixed with channel number of 178. Number of 172 is devoted to C2C applications.

Table.2.1 WAVE channel allocation

Channel No.	Usage	Frequency (MHz)
172	C2C communication	5855-5865
174	Service channel	5865-5875
175	Optional channel	5865-5885
176	Service channel	5875-5885
178	Control channel	5885-5895
180	Service channel	5895-5905
181	Optional channel	5905-5925
182	Service channel	5905-5915
184	Public safety with high power	5915-5925

All devices shall monitor the CCH during common time interval(CCH interval) during which all high priority WSMP messages shall be transmitted. Fig.2.2 illustrates the Sync interval, CCH interval and SCH interval for single-channel WAVE device. For WAVE devices being synchronized each other, CCH and SCH intervals are uniquely defined with respect to an absolute external time reference, Universal Coordinated Time(UTC), which is commonly provided by GPS systems.

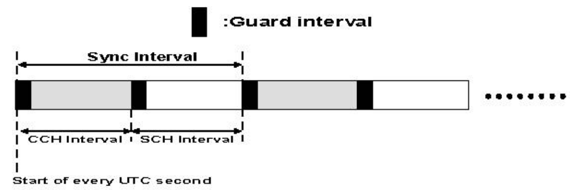


Fig.2.2 Sync interval, CCH interval and SCH interval for single-channel device

B. *IEEE802.11p*

11p is a core technology of WAVE. WAVE includes a number of new classes of applications that pertain to roadway safety (such as collision avoidance) and emergency services (such as services by ambulance, police and rescue vehicles). These applications impact WAVE in a number of ways. Some critical applications require that the total time form first signal detection to completion of data exchange must be completed within the order of 100 millisecond. Table 2.3 is 11p draft specification compared with IEEE802.11a. 11p aims at shorter connection latency and higher reliability than 11a. Main differences are frequency, bandwidth, usage of channel and

Table 2.3 11p specification

Name	IEEE802.11p	IEEE802.11a (USA)
Frequency	5.85-5.925GHz	5.15-5.35GHz 5.725-5.835GHz ISM
Capacity	Max 27Mbps	Max 54Mbps
Modulation	OFDM	OFDM
Bandwidth	10MHz	20MHz
Number of Channel	7 (CCH×1, SCH×6)	12
Service zone	10-300m	5-50m
Transmission power	28.8dBm	28.8dBm
Velocity	45m/s (~160km/h)	6m/s (~20km/h)

CCH: Control Channel SCH: Service CHannel

degree of mobility (velocity). The bandwidth is half of 11a with twice guard bandwidth. 11p adds capability to simplify the MAC operation (such as partial removal or summary of several management frames of IEEE802.11a MAC protocol) and associated management in order to support fast access.

C. *Issues of current WAVE draft*

There are yet some technical issues for current WAVE draft to be discussed, especially one at lower layer.

(1) Single-channel WAVE system

Shown at sub-section A in this section, with use of single-channel WAVE device, it might have problems.

a) There would be time loss by switching between CCH and SCH on one device.

b) The high priority messages, which are generated during SCH interval, are not always received to other WAVE device on SCH correctly because of probable collision with other normal application data even if QoS control on SCH.

(2) WSMP specification

WSMP supports both unicast and broadcast, even forwarding function. However it does not describe on device identification, unicat/forwarding protocol to communicate each other.

(3) Support of C2C communication

The draft does provide mostly the C2I communication but C2C communication. There are two cases for C2C system: C2C via RSU and pure C2C without RSU. Utilization of CCH and SCH for C2C communication has to be defined.

III. Developed WAVE System

In developed WAVE system, we have dealt with the issues of single-channel WAVE system in this paper.

A. Developed WAVE device

Fig.3.1 shows structure our WAVE device. Main characteristics of the device is to equip dual 11p wireless device for CCH and SCH respectively, while standard draft is based on single-channel 11p device. Two those device could be independently managed. 11p control function plays a role of management of dual 11p device and control usage of CCH interval and SCH interval. According to the draft, WAVE announcement through CCH informs OBU in the vicinity of usage of SCH and WSMP messages.

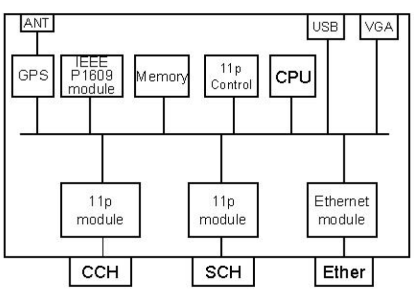


Fig. 3.1 WAVE device

Due to the dual device, there is no need of switch between CCH and SCH during sync interval. Therefore no time loss by switching and no data loss during switching can be realized. Moreover, there is no need for priority control on SCH to other normal application. Every device monitors on CCH all the time by 11p module for CCH as shown in Fig. 3.2.

As a result, it can be expected more reliable communication, stable operation and higher throughput performance. And it is easy to make priority control between CCH and SCH.

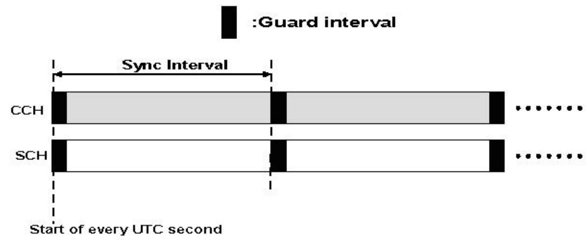


Fig.3.2 Sync interval, CCH and SCH for dual-channel device

B. Software for WAVE device

Fig.3.3 shows the software structure for developed WAVE device. In this first version of device, minimal functions for WAVE system are implemented. That's say, 11p, P1609.3 and 4. Channelization function (P1609.4) coordinates CCH and SCH as non-IP data (WSM) and IP data. At present, safety application (see next section), video (Camera) application and network topology application are prepared. Network topology application includes collection of link connection status among WAVE device and display of connection status and its position.

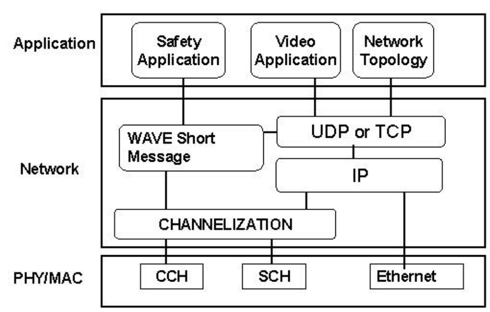


Fig.3.3 Software structure of WAVE device

IV. Safety Application System

In this section, we pick up two kinds of interested safety applications for the purpose of evaluating WAVE system for practical usage in near future. The one is a crossroad collision avoidance which is known as front-lateral collision avoidance. In Europe more than half of the number of car-to-car accidents is due to this kind of collision. The other application is front-tail collision in invisible situation such as traffic congestion over the curved circulation. In fact, this kind of collision is the second cause of accidents in Europe, Japan and U.S.

A. Scenario1:Cros-road collision

Fig.4.1 illustrates the safety application system which we have been developing using WAVE device. The scenario of this application is that OBU2 of less priority road will join to road with higher priority when OBU1 enjoys downloading camera image at time t0. When approaching crossroad at t1, OBU1 begins to emit its presence around by broadcast message. OBU2 can receive the broadcast message when it enters RSU2 area. Then OBU2 gets to realize the presence of car (OBU1) approaching and passing by the crossroad soon. The driver of OBU1 can do proper reaction to that situation in advance, e.g., slowing down the speed or stopping.

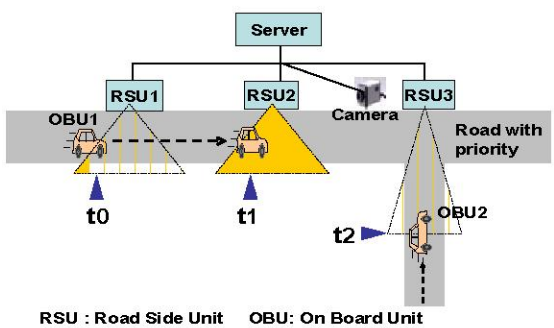


Fig. 4.1 Scenario of cross road collision

Fig. 4.2 is a sequence of crossroad scenario according to WAVE draft specification. The first process by WAVE Announcement (WANC) transmission from RSU1 to OBU1 on CCH starts to advertise offered services available on SCHs and other parameters concerning physical characteristics just after OBU1 enters within radio area of RSU1. Under RSU1 area, it set up SCH for receiving camera image following indication of WANC. At time t1, OBU1 moves into RSU2 to receive WANC, and it transmits emergency message of its presence to its vicinity since it approaches within certain distance from the cross road. The emergency message from OBU1 is broadcasted to OBU2 through RSU3. A driver of OBU2 is warned OBU1 approaching including speed, distance and so on.

Regardless of normal application data, safety application data is transmitted anytime in our system without switch to CCH because of dedicated 11p module for CCH. Consequently no loss of safety application is guaranteed due to dual wireless device. The warning has the highest priority to the driver.

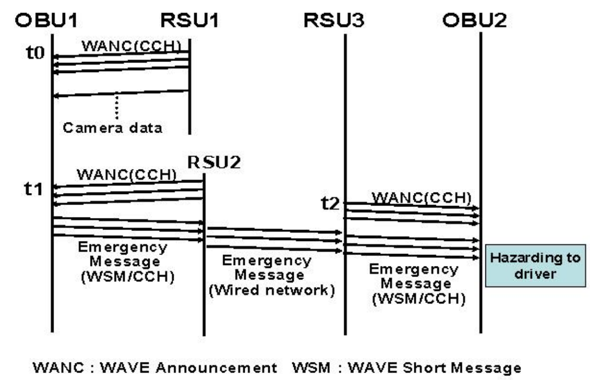


Fig. 4.2 Sequence of crossroad scenario

B. Scenario2: Front-tail Collision

The front-tail collision scenario is illustrated in Fig.4.3. In this scenario, a driver of OBU1 is warned or hazarded it in advance before enters winding road that there is traffic jam just after winding road to avoid sudden braking or front-tail collision with a car which is located at the end of congestion.

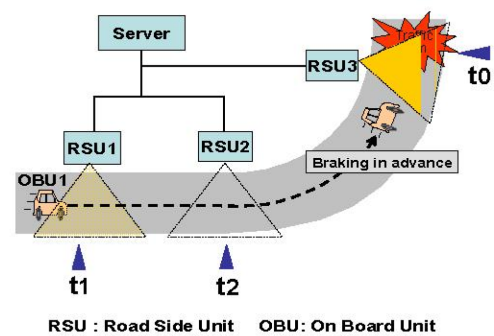


Fig.4.3 Scenario of front-tail collision

Fig.4.4 shows a sequence of front-tail collision scenario according to WAVE draft specification. At time t0, traffic congestion has occurred around RSU3 radio area. RSU3 detects the congestion to be sent to RSU1 and RSU2 in broadcast. OBU1 enters RSU1 radio area at t1 that it starts to receive congestion information. At this location of OBU1, warning to its driver only is made to inform the situation. At t2, the driver is provided the message that congestion becomes heavy and longer. Consequently hazard of "Stop immediately, please !" is emitted to the driver. OBU1 will judge the message to the driver considered the distance and relative speed with car in congestion.

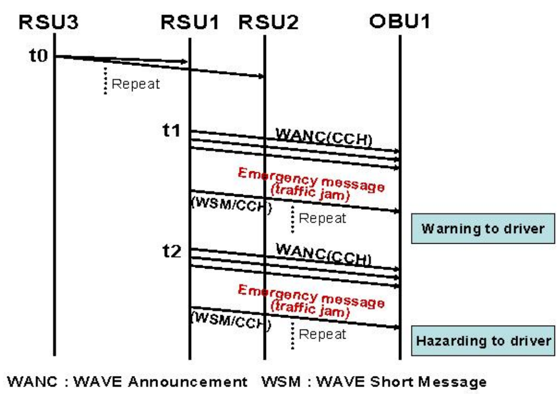


Fig.4.4 Sequence of front-tail collision scenario

C. *Evaluation plan*

We plan to evaluate following items in real field in order to validate the feasibility of WAVE device and its interested applications and to discover future issues for real deployment

(1) Application performance

■Delay time of application execution

[Scenario1]

Delay time : from t1 to the time of hazarding to driver.

[Scenario2]

Delay time : from t1 to the time of warning to driver , and from t2 and the time of hazarding to driver

■User adaptability test for system validity on real usage

Fig.4.5 is a sample of display to the user driver

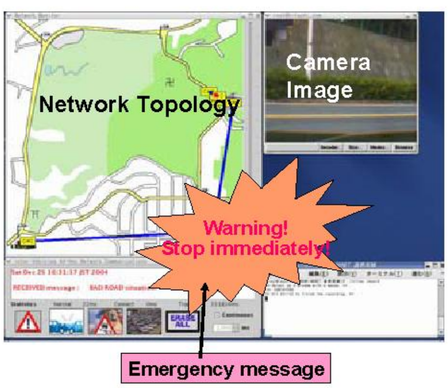


Fig.4.5 Display at OBU2 for scenario 1

(2) Network performance

■Connection establishment delay at network layer

[Scenario1]

Delay time of SCH: from t1 to the time of receiving camera image.

Delay time of CCH: from emission time of OBU1 to receiving time of OBU2

[Scenario2]

Delay time of CCH : from emission time of RSU3 to receiving time of OBU1

■Packet loss rate on WSM and IP layer

Total count to received count of WANC and WSMP message

(3) 11p performance

■Connection establishment delay at MAC layer

■frame loss rate vs. wireless link quality (CCH/SCH)

V. Conclusion

In this paper, we introduce developing WAVE device and its applied scenarios for safety application. Main characteristic of WAVE device is dual 11p wireless device for CCH and SCH respectively, which is expected to attain stable operation, reliable communication and higher performance. For future work, we validate the feasibility WAVE system through safety application in real situation.

References

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