

# The implementation of the intelligent transport system for the real-time roadside environment information transfer

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**Abstract**— The paper proposed a novel system “RTCS (Real-Time Control System for road environment)” to prevent accidents of drivers. This paper deployed sensors on roads and used these sensors to collect information to coordinators. How to use sensors to prevent accidents in vehicular environment is an interesting issue. Vehicles are equipped with OBU (On-Board Unit) and use the OBU to query information if the coordinator or RSU (Road-Side Unit) is located in its communication range. This system also distributed events into different priority due to the different damages. For your example, RSU collects and analyzes the roadside information for the driver’s safety and which provides to an OBU and a management system according to the service priority. In the higher rank terminal, the developed IP-based set-top box application provides information such as the traffic information, road environmental information, environmental sensor station error, and etc. The system has a high potential to improve traffic in two ways. First, it collects local environmental data and passes it to a central facility to further process it and pass it to vehicles. Second, it takes care that urgent local information is passed directly and thus quickly to local vehicles which increases traffic safety. The paper presents architecture to connect a USN (Ubiquitous Sensor Network) with the ITS (Intelligent Transport System) consisting of connected OBU and RSU. The goal of the system is to provide the ITS with local environmental data gathered by the USN nodes.

**Keywords**— RTCS, ITS, USN communication, RSU, OBU

## I. INTRODUCTION

Many car companies which include General Motors of U.S., Toyota, Honda of Japan and etc., have been researching DSRC (Dedicated Short Range Communication) which reduce the cost for transportation and safety of drivers and pedestrians [1-4, 6-8]. In addition, the automotive electronics system was expanded and ITS based road transport system was constructed. There were a variety of information such as vehicle Environmental Information, road condition information, driving environment information, warning system, and etc. using these systems [13, 15-17]. Car of the electronic equipment system has a variety of apparatus like as

electronic sensors of wired and wireless environments, biometric sensor for the HMI (Human Machine Interface), short-range radar sensor for the safety of motorists while driving.

In recent years, some countries are building ITS-based road environmental information which is included such as temperature, humidity, CO<sub>2</sub>, and etc. for the safety of motorists and pedestrians. Moreover, U.S. and EU are complementary to various techniques about DSRC system [11-13].

This research indicated a design and the result of implementing the RTCS which is constructed of ITS and USN coupling. This will support safety services to pedestrian and driver. This will also support seamless service to the vehicle during driving. We coupled RSU and USN which is installed on the road. Because of this, RSU can collect the real-time road environmental information. Through this system, drivers can get various information including traffic information, local weather information, road information. Therefore, the drivers using real-time data information of a variety collected can guarantee the safety of other motorists and pedestrians.

Chapter II describes previous studies of ITS and the USN. The proposed integration of individual ITS and USN model was explained in chapter III. It is explained the benefits of USN and ITS integration in chapter III.A and the integration structure of proposed system and USN in chapter III.B. Integration architecture as the RSU communication flow was intimately discussed in chapter III.C. Test bed was constructed. Through this, network structure and network, which combines sensor networks, was in Chapter IV. Also, the structure of data frame was illustrated. The values of transmission and data throughput according to a hop and device were measured. Finally, the conclusion about the method of research and validate, were described in chapter V.

## II. CONVERGENCE OF ITS AND USN

USN and intelligent transport system are applied with a research to be various not to only the parking system [8] but also the road environmental information collection and new

traffic service offer [9]. A road information service system using USN, this is probably the best safeguard against traffic accident and deadly consequences.

The road environment service is built on the road surface sensor (temperature, humidity, ice detection). It which is based on information learned, detects the freezing of the road and indicates the driver to danger. As to the regional real-time information service, the weather prediction accuracy is higher than the general weather forecast. In addition, the aim is to prevent accidents such as local rainfall and dense fog due to unpredictable weather on the road [2-3, 11].

There are the investigation of CICAS (Cooperative Intersection Collision Avoidance Systems) and IDS (Intersection Decision Support) with the roadside sensor and the vehicle sensor for the method securing the safety of a pedestrian and driver in U.S. [17]. In addition, PReVENT safety systems in Europe uses a video and 24 ~ 60GHz UWB (Ultra Wide Band). This system is being studied in order to prevent collisions by notifying location of the vehicle to users in advance at the intersection [14-17]. And the vehicle's wireless network in conjunction with the external transportation system can prevent traffic accidents.

Japan built the AHS (Advanced cruise-assist Highway System) operated with the existing traffic technique. This system is equipped with road sensors and near field communication system of the vehicle for the purpose of securing the stability of the driver.

### III. THE PROPOSED RTCS

#### A. The integration structure of USN and the vehicle network

Sensor network technology, low maintenance cost and construction cost, can be appropriate real-time traffic prediction according to circumstances at the intersection. The driver can be delivered the delay, congestion and accident information faster than the existing TPEG (Transport Protocol Experts Group) system by using the USN. Because of this rapid information, additional accidents can be prevented.

In this study, USN role for the safety of motorists and pedestrians are presented as four kinds of services with reference to the earlier research.

- 1) The road environment offer service of USN and ITS
- 2) The road information proposal service for ensure pedestrian and driver safety by using USN
- 3) The vehicle interior information gathering and delivery
- 4) Integration and scalability provision of the existing network and vehicle

In addition, USN linked environmental monitoring information to the transportation center and the road base. It is able to provide IP-based services to near the pedestrian and the driver.

V2I (Vehicle-to-Infrastructure Communication) vehicles service is beneficial to the dense urban city such as South Korea. Also, wired network infrastructure developed in the

environment has the advantage of integration with other networks. In particular, such as V2V (Vehicle-to-Vehicle Communication) frequent changes occur in the path has the advantage of the routing and delay. In addition, distribution and allocation of IP in IP-based services are beneficial.

#### B. The integration structure of ITS and USN

Figure 1 is an integration structure of the ITS and the USN. First, USN integrates the information collected through the coordinator from node which is installed on the road. Second, the information collected will be forwarded to RSU which is linked the coordinator. Third, after RSU is processing the collected information, it passes this information on the associated vehicle's OBU. Otherwise, RSU delivers to the MC (Macro Center) or MM (Macrocell Manager) which is a regional integrated management.

USN periodically gathers road information. The coordinator which are associated with a large number of nodes, periodically collect information for delivering to RSU and for broadcasting. It can transmit information directly to the OBU in the vehicle at close range.

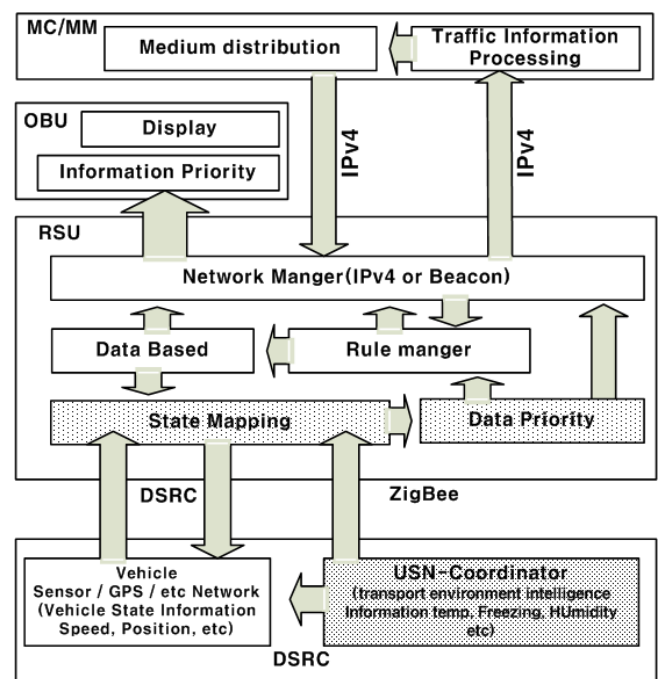


Figure 1. The network integration architecture of ITS and USN

As shown in figure 1, RSU collect information from the USN to switch to IP-based information. It delivers these information to OBU and MC/MM according to rank. In this study, Information collected through the USN is delivered to the SCH (Service CHannel). Top layer MC/MM process USN information with the new information. Information which is processed may be provided a wide area by the TPEG through the stations. USN as TEPG varies the data transfer, depending on whether the vehicle information received. State analysis of the data collects and classifies the road information of the temperature, ice and etc.

Data priority analysis of RSU determines the ranking of the data transfer. Emergency information is directly passed on OBU through the connected media. If the emergency information can not be passed through the other media, it is broadcasted through the USN node.

The collected environmental information is classified into a processing area of RSU and into an application area in MC/MM. After RSU which collect the road environmental information, determine the accuracy and availability of data, it is to analyze the data for the state.

The data priority determines data offering priority based on collected data. In this case, the technique for minimizing the congestion about the individual service demand of the connected multiple vehicle is applied. Protocol layer is coupled [21] with congestion policies. It considers the vehicle's speed and position to provide the service.

MC/MM process and classify the collected data, it transmit this information to all RSU within a macro cell. RSU which collects information periodically from MC provides the information reprocessed from MC to OBU. If RSU receive emergency information, it provides to all vehicles within a cell through a broadcast. And if RSU receives the urgent information in its own intracell, it notifies the urgent information to all vehicles within a cell. It delivers to the higher layer.

After MC receives the road environmental information and the cars information from RSU, it processes this information. The processed information was sent to the administrator and the RSU through the application layer. MC passes the accident risk information to the jurisdiction RSU. RSU sends this information to the connected drivers to prevent accidents, such as the pile-up accident, accident black spot, anti-skid, and etc.

### C. The link with coordinator and RSU

In figure 1, RSU and USN coordinator is necessary to process the collected information for resource efficiency and real-time delivery. USN information is transmitted periodically from tens of nodes. At this point the coordinator receives periodic information for a short time, no change.

Coordinator can deliver the 1/4h or every few seconds depending on the importance of information by processing information in a short time. RSU also can frequently receive the regional gathered information from a number of coordinators. Each time it is inefficient to transfer to MC. However, if there is important information, RSU and the coordinator need to pass quickly through the process such as in figure 2.

In figure 2, RSU must determine priorities on the road environment information (temperature, humidity, and freezing) to provide various services and users' safety.

If the high-ranking information is provided to OBU from coordinator, RSU analyze the state of OBU which is connected to state mapping, and then it broadcast using WSMP (WAVE Service Message Protocol) [1, 19] for accidents and emergency situations. Transmission mode in 5.8~5.9GHz modem chooses whether to transfer to the upper layer RSU as an IP mode or to transfer to OBU as a broadcast mode.

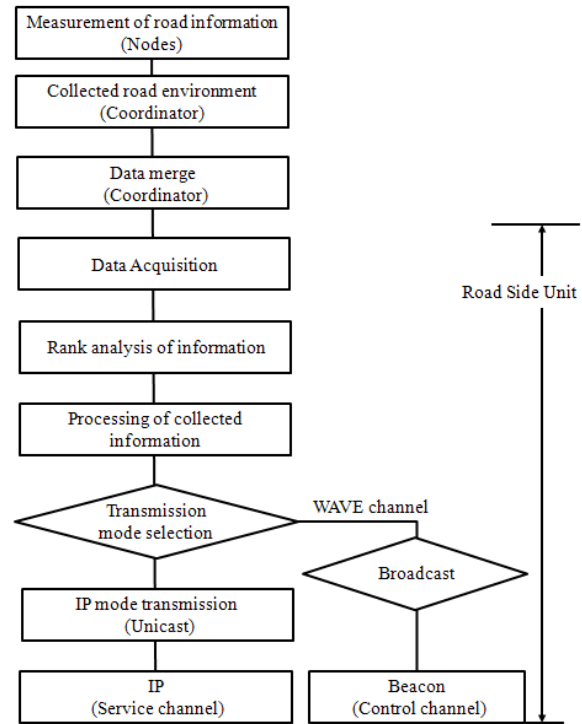


Figure 2. The transmission scheme of a coordinator and RSU

RSU receive freezing and vehicle speed information from coordinator.

When RSU receives vehicular collision hazard information or accident information from freezing, it broadcast to the OBU in beacon and IP-based.

### D. The test area and comparison of association performance

We have constructed USN test bed, such as figure 3 using figure 1. USN was built as CC2430 platform based on TinyOS 2.0. A construction was started on October 10, 2009, and the third test was conducted until November 6th.

The distance of each site of the test bed is the average 450m, and the nearest distance is 150m (C-D), the longest range is 800m (A-B). RSU of A, B, D and E area was composed of four nodes and road data collection sensors of a temperature, dust, humidity, freezing, and etc. Each node transmits the collected data to the coordinator every 30 minutes.

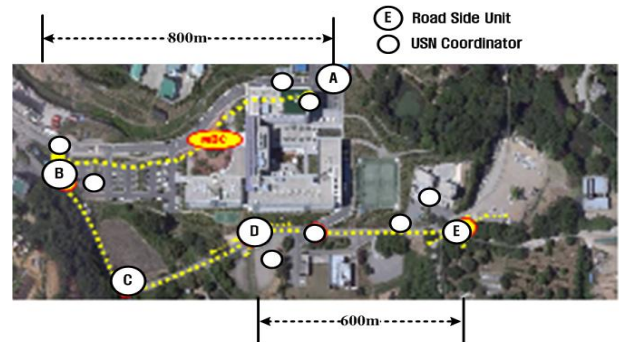


Figure 3. The network model of the test bed

Just as described in chapter III, when there is partial icing on the road, data pass to the network of the upper layers. This are provided as a services for the safety of the local user. The vehicle also link TinyOS-based CC2430 nodes which have wide range sensors of Temperature, humidity, CO<sub>2</sub>. The road icing information was a mixture of periodic and aperiodic according to the time in the roadside information.

To build the USN system, communication range and performance of each RSU 5.8~5.9GHz RF modem must be identified. The service coverage and a bandwidth according to the space of OBU were experimented. The results were shown in figure 4, 5, respectively.

Each 5.8~5.9GHz modem communication is compared the flat land area and the civic center area in which LOS (Line Of Sight) is guaranteed as shown in figure 4, 5.

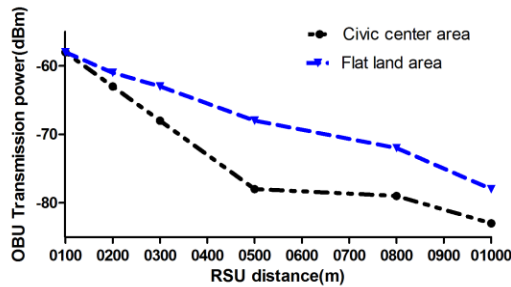


Figure 4. The intensity of the received signal according to the space and distance in RSU

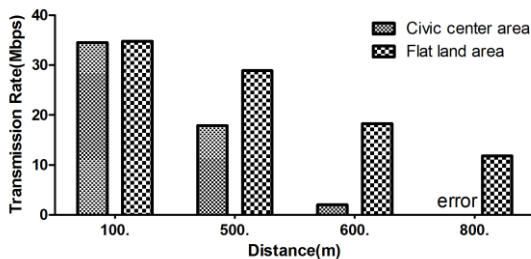


Figure 5. The communication speed according to the space

The possibility of IP-based data communication has very little chance in less than -83dBm as test result of the vehicle travelling. Beacon communication was possible only. Data communication is available within the 1km in LOS, but the maximum communication range is 500~600m in downtown. The received signal of -80 ~ -81dBm or more is required in order to IP-based communications

#### IV. THE TEST BED BUILDING AND INTEGRATION OF THE USN-BASED

The network structure of test bed was described, and integration of sensor network and test bed also explained in this section. User safety and service requirements have been reflected in the combined model of the vehicle network and sensor network.

This model has the structure of the 20byte data frame of CC2430-based, the coordinator has the same configuration as in table 1. Direction function is expanded to 2byte, it corresponds to the various wire interface communication. It is composed of the size of the maximum 40byte, the data payload can be extended to the 23byte for processing the various road environment values on nodes.

TABLE 1. THE FRAME STRUCTURE IN ROAD ENVIRONMENT

| Frame Attribute | Value   | Data Length (byte) | Attribute                                      |
|-----------------|---------|--------------------|------------------------------------------------|
| Sync            | 0xFF0F  | 2                  | Synchronization frame                          |
| Start           | 0x7E    | 1                  | Frame beginning                                |
| Length          | 0x01-FF | 1                  | Frame length                                   |
| Sensor          | 0x01-FF | 1                  | Measurement number of sensor                   |
| Direction       | 0x01    | 1                  | Delivery method of data                        |
| RSU ID          |         | 6                  | RSU MAC or IP                                  |
| Data Payload    |         | 5                  | Temperature / humidity / Mist / freezing / CO2 |
| 16bit-CRC       |         | 2                  | CRC16 bit integrity guarantee                  |
| End             | 0x7E    | 1                  | End of frame                                   |

The test bed structure of USN set to a scenario. And the sensor which is installed to the road, checks the road freezing.



Figure 6. The collected road environmental information at MC, MM and OBU

It is shown in figure 7 that the data transfer time in which the collected information from USN arrives to the RSU through hop. It is useful to the single-hop transmission because a distance between hop is 30~70m and the diameter of the fourth line road is about 24m.

The time which is collected from the coordinator of RSU, is required from 1,000ms to 2,200ms in one-hop. However, the time delay which is sent to heterogeneous network, is large in RSU, because the time which is collected from the coordinator is the very short time of 100~400ms.

The delay in collection and retransmission can be shown that two-hop is two times greater than one-hop in a node.

## V. CONCLUSIONS

The USN technologies were fused to ITS-based. The real-time information which was collected on the roadside was processed in the higher layer. In this way, the new information was provided. And connection with USN and the vehicle network has provided expansion of the network service area and safety of motorists and pedestrians.

This research provided the associated service method of USN and traffic service. We built the test bed for a validation. In addition, it was designed to be expandable with the coupling or the standalone method of the backbone network base through the IPv4 communication between RSU and the coordinator with later. In the future, it is planning to be proceeded that the communication coupling system research using the vehicle electronic device system and 5.8~5.9GHz.

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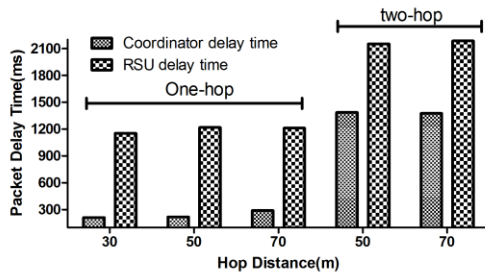


Figure 7. The transfer time between the device using USN

Consequently, the urgent information which is delivered to a vehicle from the coordinator is collected from sensor nodes which are installed on the roadside. This is more efficient than the information passes on the vehicle through the RSU. If the roadside information is provided as OBU through RSU, it will require at least 2ms.

It should be considering the standard attributes of RSU when information of within one cycle is passed to OBU in the competitive method [1] of the high speed driving vehicle. This is a problem. There is enough time to transfer emergency information of the roadside through the coordinator because RSU and OBU's service range is around 500m and the vehicle average driving speed is 60km in downtown.

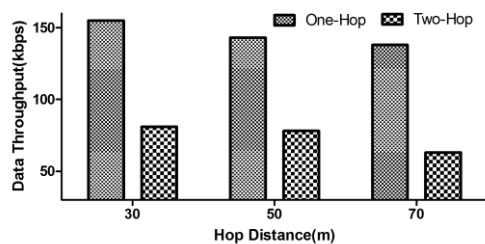


Figure 8. The Data throughput according to a distance

There are different between one-hop and two-hop in data throughput. But there are no problems in the multi-hop transmission because the environmental data information is 30 ~ 60byte.

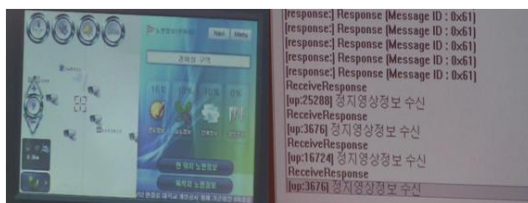


Figure 9. The collection and expression of the road information in OBU

Figure 9 shows that the information of is collected on the road, is transmitted with IPv4 base to the coordinator and RSU. In addition, it were shown that the UI (User Interface) terminal transmission and the RSU receive linked to OBU.

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