Design of Safety Warning Notification Service at Crooked Roads Using Wireless Sensor Network in Telematics Environment

JaeJun Yoo, KyoungBok Sung, JungDan Choi, ByoungTae Jang

USN Based Telematics Research Team, Telematics.USN Research Division,
Electronics and Telecommunications Research Institute
{jjryu, kbsung, jdchoi, jbt}@etri.re.kr

Abstract

In this paper, we design a prototype service in Telematics environment for providing safety warning notification at crooked roads efficiently using wireless sensor network. Through this study, we 1) analyze several requirements to be satisfied in the services, 2) design and implement the service architecture based on the requirements.

Keywords: Wireless Sensor Network, Telematics, Safety Warning

1. Introduction

Recently, as sensor network technologies which can realize the ubiquitous computing concept have been being researched and developed actively, convergence of existing applications and technologies and the sensor network technologies has been being a key issue in several industrial and scientific fields. Such research and development for convergence usually combine heterogeneous technologies to make more advanced or valuable applications or services. LBS (Location Based Services) which use location information of users or mobile terminals as fundamental data and provide some services based on the data, and Telematics which have connection points of automotive technologies and information or communication infrastructure in small space, that is a vehicle, can be good examples of the convergence services because we need to combine positioning mechanisms, for instances GPS network or cellular network, to get location information of LBS users and cohesion methods for coupling communication environments in vehicle spaces with several application technologies. As convergence services using sensor networks in Telematics environments, "intersection collision avoidance", "vehicle location determination", "on-road warning notice", "vehicle movement trace", "road-surface condition reporting" [1][2][3][4] are being researched and developed.

In this paper, as a kind of convergence services, we design a prototype service in Telematics environment for providing safety warning notification at crooked roads efficiently using wireless sensor network. Through this study, we 1) analyze several requirements to be satisfied in the services, 2) design and implement the service architecture to provide the safety warning notification service based on the requirements.

This paper is structured as followings. In section 2, we explain overall structure and scenarios of safety warning notification service to be designed and implemented and core requirements of the service. In section 3, we show the system architecture to provide the service by suggesting some mechanisms and methods to solve the requirements and we conclude this paper in section 4.

2. Safety Warning Service Using WSN

2.1 Service Scenario

Although the scope of safety warning notification service can be define in general environments including vehicles, roads, and widespread situations among them, to make the structure and explanation in this paper more evident, we suppose that the target roads where the safety warning notification service will be served are crooked roads or blind regions where are usually more dangerous sites to vehicle drivers.

Figure 1 show the overall system structure for providing the safety warning notification services at crooked roads. With the safety warning notification service, to acquire sensor data about vehicle movements, one or more sensor networks are deployed on surfaces of crooked roads. One sensor network consists of several sensor nodes for sensing vehicle movement and several sink nodes for transmitting the sensor data. A sensor node is equipped with magnetic sensors detecting changes of magnetic fields which are generated by moving vehicles. The sensor node extracts existence of a vehicle from the changed magnetic data by using signal processing methods and computes several additional sensor data about vehicle movement such as speed and direction. The acquired and computed data are transmitted to a base station through several hops of sink nodes. A base station collects those data from the sensor network, analyzes and calculates them to determine whether a dangerous situation can occur or not, and if it is possible, sends alert messages to VMS (Variable Message Signboard) or Telematics terminal in a vehicle for a driver to avoid the danger.

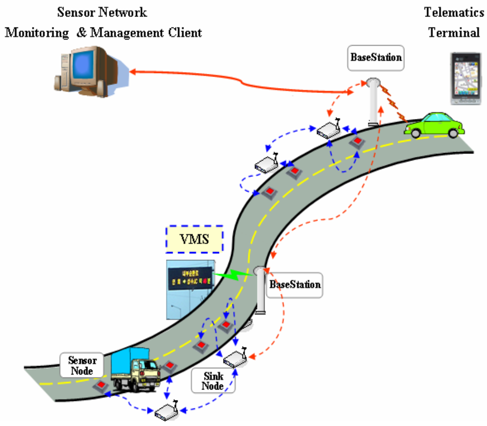

Figure 1. System Structure of safety warning service

Here, a base station not only determines that there are probabilities of dangerous situations but also manages sensor data acquired from the sensor network with limited H/W resources, controls external equipments such as VMS, and communication devices and monitors the sensor network to maintain it efficiently. A sensor network monitoring client provides some methods to control and to monitor installed overall system and service status in remote sites.

Figure 2 shown below presents operation sequence flow among several entities in the service system such as sensor node, sink node, base station, VMS, and telematics terminals.

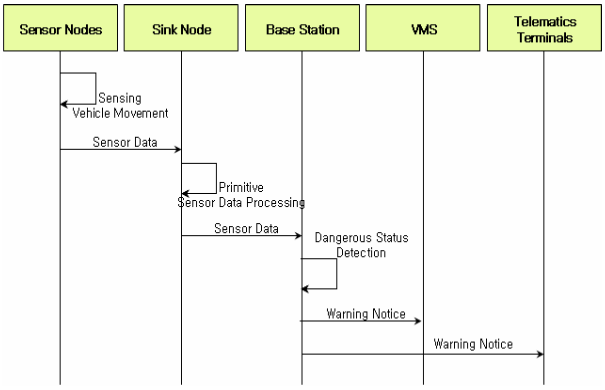

Figure 2. Operation sequence flow for safety warning service

When designing the mentioned safety warning notification service, the key requirements to be considered carefully can have some variations according to installation sites or several properties of deployment environments. For example, service requirements for safety warning notification in some blind area such as crooked roads can be different from those in straight high-speed way. Because a vehicle moves more slowly at crooked roads in general than at highway, sensor data processing time to be satisfied at crooked roads can be longer. Such time limit in data processing can affect complexity of algorithms to be adopted in a base station. Therefore, average vehicle speed can be a critical consideration point in designing the safety warning notification system. This is also same about average number of passing vehicles and number of lanes on roads.

2.2 Key Requirements

When designing safety warning notification service, we have to consider followings as key requirements and issues.

- Energy Efficient Operations in Sensor Nodes
  When designing and implementing a wireless sensor network and it's applications, energy efficiency in the sensor network is a core consideration point, because, generally we suppose that the environment where a sensor network is deployed or installed is so hash that we can't replace batteries of sensor nodes or we can't supply external power to them, and lifetime of sensor nodes determines lifetime of services which uses the sensor networks [5]. The energy efficiency problem can have more weight when it is adopted in telematics environments since in telematics environments, sensor nodes have to sense more frequent events, that is, vehicles, than that in previously supposed circumstances.

- Accurate Vehicle Detection
  Because the safety matter is related to life of a person, accuracy of services is very important. That is, a possible dangerous situation can be detected without exception. To make the safety warning service more accurate, first of all, we need to sense and to process sensor data clearly. Therefore, sensor data verification such as noise filtering step is important.

- Reliable Sensor Data Transmission
  As another aspect to satisfy requested accuracy of the safety warning notification, reliable and trusted sensor data transmission is also needed. Sensor networks deployed and installed on surfaces of roads use wireless communication, in which data loss and transmission latency can occur frequently. However, such problems severely degrade quality of sensed data, that is, accuracy of data processing. Therefore, we need to have some reliable and efficient transmission mechanism in sensor networks.

- Real-time and Efficient Processing of Sensor Data
  A base station collects data about vehicles from several sensor nodes and determines whether some dangerous situations such as vehicle collisions can occur or not by analyzing the collected sensor data and circumstance information, for example geographic or spatial information about roads where the sensor network is deployed. In the several processing steps in a base station, sensor data manipulation can be very complex if many constraints and several kinds of data needed, to get final processing results have to be considered. However, a warning message to notify dangerous situation has to be alarmed in limited time, therefore, we should design and implement time-critical sensor data processing algorithms.

- Effective Sensor Network Deployment and Sensor Node Packaging
  Sensor networks for providing safety warning notification service generally are deployed or installed on surfaces of roads. However, such sensor networks can be obstacles against safe driving. Therefore, the sensor networks have to be designed very carefully considering circumstances of roads and performance to be required for the designed services. Moreover, the sensor nodes have to be packaged with enough endurance capability against external damages.

3. Service System Architecture

3.1 Overall Architecture

Figure 3 show the overall system architecture to provide the safety warning notification service. As previously mentioned, the service system is mainly composed of sensor networks including sensor nodes and sink nodes, a base station, a remote monitoring client, and service disposal devices such as VMS and telematics terminals in moving vehicles.

A sensor node mainly consists of two magnetic sensor for sensing position and movement of a vehicle, RF module for communicating with a sink node, CPU and main memory for processing magnetic signals, and a small battery in H/W aspect, and is chiefly composed of operating system (Nano-qplus), fundamental data filtering module, and network pack processing module for supporting specified network protocols and network topologies in S/W aspect. A sink node has same configuration as a sensor node has except for magnetic sensing devices. A sink node is structured to support dynamic configurations of communication protocols and topologies.

A base station consists of several functional parts in S/W aspect – 1) sensor data acquisition and fundamental processing part which interacts with installed sensor networks, 2) storage and analysis part which saves and manipulates the acquired sensor data and other data to be managed for additional processing, and extracts some useful information by analyzing managed data using pre-defined algorithms, and 3) service provider and management part which converts the processed results to deliverable format for VMS and Telematics terminals, and constantly checks the service status. A base station supposes the sensor data gathered from sensor networks as a stream of simple event message, because data generation and transmission in several sensor nodes and sink nodes has properties of data stream in the view of a base station. Such an abstraction of sensor data can be helpful when we design overall architecture of a base station functionally. H/W of a base station should be carefully designed in optimized fashion to make maximum performance considering around circumstances and dynamic situations. We are designing a prototype H/W of a base station, but its detail is out of scope of this paper, so we don't explain H/W architecture of a base station. When testing the implemented base station S/W, we used an embedded environment which is composed of embedded Linux operation system and virtual S/W platform to simulate the base station H/W using pre-defined constraints.

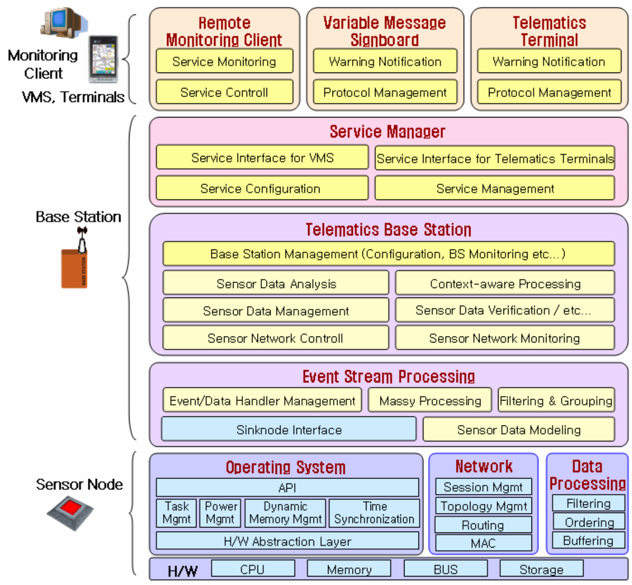

Figure 3. System architecture for safety warning service

Additionally, a remote monitoring client, VMS and Telematics terminals mainly consist of a communication module to send and to receive data packets from and to a base station and display module to dispose some data or messages to users or to managers in S/W aspect.

3.2 Sensor Node and Sensor Network

To enhance energy efficiency in sensor nodes, we adopted event driven operation mechanism in sensor nodes. Different from normal sensor node operation that repeats active and sleep status with even-length time slots to reduce power consumption, event driven sensor node operation is normally in sleep status and activated by external event such variation of magnitude of magnetic field. In the sleep status of event driven sensor node operations, all parts of a sensor node except for magnetic sensor are in sleep status. Such an event driven sensor node operations can greatly reduce power consumption because active time of a sensor node can be smaller. Moreover with the event driven sensor node operation, data loss which occurs when a senor node is sleep and a vehicle is passing simultaneously can be reduced significantly. The main pseudo-code of event driven sensor node operations is shown in Figure 4. The event driven sensor node operation shown in Figure 4 also includes additional meta-message transmission to check whether a sensor node lives or failed.

```
algorithm sensor_node_operation
   initialize sensor node;
   while(energy E remains) do
     start timer T;
     sleep node except magnetic sensor until INTERUPT
     occurs by detecting a vehicle or expiring timer T;
     wait an INTERRUPT;
     activate sensor node;
     if INTERRUPT.from = magnetic sensor then
       MSG = detection data from magnetic sensor;
     else if INTERRUPT.from = timer T then
       MSG = hello message
     end if
     transmit MSG to sink node;
     reset timer T;
   end while
end sensor_node_operation
```

Figure 4. Event driven sensor node operation

As another key requirement to be considered when designing the safety warning notification service, to satisfy the demand for "accurate vehicle detection", we designed basic sensor data processing module such as noise filtering using given threshold value used to determine what a noise is.

Moreover, to satisfy the request for "reliable sensor data transmission", we adopted hybrid-form of two different network routing topologies and layouts – 1) star topology and static routing, from several sensor nodes to a sink node and 2) mesh formed topology and dynamic routing (multi-hop), from a sink node to a base station. Fast and efficient operations in a sensor node is the main reason of star topology and static routing between a sensor node and a sink node, and fault tolerance is the key factor of mesh topology and dynamic routing among sink nodes in transmitting the sensor data to a base station.

In this paper, although we adopted hybrid form of two kinds of topology and routing methods according to sensor data transmission entities, that is, sensor nodes and sink nodes, it can be broken into more parts to achieve optimized performance in sensing vehicle and in transmitting the sensed data. As a future work, we will research more itemized hybrid network configuration.

3.3 Base Station

To satisfy the demand of "real-time and efficient processing of sensor data" requirement, we divided a base station into several functional modules, that is, sensor data acquisition & processing module, sensor data management & storage module, sensor data recognition and analysis module, sensor network monitoring & management module, and sensor data service interface module, as shown in Figure 5 and put some limitations on each step of sensor data processing in each module. The limitations can be various items, and the value related to the limitations on each module can be dynamically adjusted. For example, total time of sensor data processing can be divided into several slots and each processing time slot can be a limitation factor to be kept on each module. We will research about extraction of several limitation items in processing sensor data and formulation of performance measures on the items in the future.

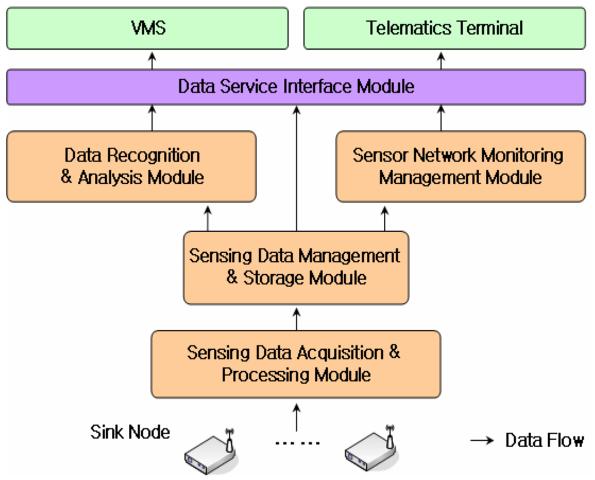

Figure 5. Module structure for processing sensor data in base station

3.4 Safety Warning Service

The processed results got from a base station is transmitted to VMS or Telematics terminals in safety warning notification message format. VMS communicates with a base station by using wired or wireless LAN because a VMS will be installed close to a base station and fast communication speed is demanded. Message transmission from a base station to a moving Telematics terminal is provided by CDMA since we need to communicate with a mobile entity, and it has to be a widespread form to reduce service cost. However, CDMA has a weak point, that is, call setup time which is considerably long time is needed. This defect of CDMA can be overcome by previous initialization for call setup mechanism when a vehicle enters safety warning service regions, such as crooked roads, which can be known by keeping geographic data of service regions.

4. Conclusion

In this paper, we designed and implemented safety warning service as a kind of convergence services based on wireless sensor networks in telematics environments. Through this study, we 1) analyzed key requirements to be considered and designed carefully and 2) designed a prototype system for safety warning notification service based on the analyzed requirements.

References

1. Eunkyu, L., Minsoo, K., ByungTae, J., MyoungHo, K.: A Design of Telematics Framework on Ubiquitous Sensor Networks, W2GIS, 2005
2. Sinem, C., Sing, Y.C., Pravin, V.: Sensor Networks for Monitoring Traffic, In Allerton Conference on Communication, Control and Computing, 2004
3. Wenjie, C., Lifeng, C., Zhanglong, C., Shiliang, T.: A Realtime Dynamic Traffic Control System Based on Wireless Sensor Network, 2005 International Conference on Parallel Processing Workshops (ICPPW'05), 2005
4. Marcin, K., Aline, S., Vinny, C.: Sensor networks for smart roads, IEEE PerCom Workshops, 2006
5. Joseph, P., Robert, S., David, C.: Telos: Enabling Ultra-Low Power Wireless Research. 4Th Intl. Conf. on Information Processing in Sensor Networks; Special track on Platform Tools and Design Methods for Network Embedded Sensors (IPSN ’05/SPOTS). (2005)