CONTEXT-AWARE ROUTING ARCHITECTURE ON TELEMATICS SENSOR COMMUNICATION NETWORK

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ABSTRACT:

It is evident that advancement of ubiquitous technologies in the near future guarantees more convenient and plentiful living. With regarding to car life, we dream of an automatic driving without any effort of operation. This paper touches the realization issue, a convergence of wireless sensor network and Telematics specializing on an information routing mechanism between participating components in Telematics sensor communication network. We list up new requirements of wireless sensor network deployed for Telematics services. Then context-aware routing architecture is proposed in order to solve these constraints, in which a network topology for routing can be dynamically configured according to the combination of context models of network components.

KEY WORDS: wireless sensor network, Telematics, context aware, routing protocol, network topology

1. INTRODUCTION

A ubiquitous society has been a proposing theme for the next living environment, and a great number of people have devoted themselves to advancement of associated projects. Among them, wireless sensor network has become an attractive candidate: an ordinary service environment where sensor nodes are randomly deployed around a target area to acquire sensing records and a base station collects and utilizes such ubiquitous information. Researches on wireless sensor network have actively studied in the areas of hardware, operating system, communication, middleware, and application with fundamental design factors of fault tolerance, scalability, production costs, hardware constraints, network topology, environment, transmission media, and power consumption. Telematics services provide a vehicular portal service supporting emergency rescue, car navigation, remote vehicular diagnosis, the Internet, e-mail, the movie, and the shopping. Recently, Telematics technologies have been under development in such fields as communication, location determination, interoperability, and infrastructure (Kim, 2005).

There are currently few Telematics services using sensor network technologies even though other application projects, such as habitat monitoring and battlefield surveillance, have already shown experimental development and prototypes. However, it seems clear that recent sensor network technologies make it possible to support such capabilities as acquisition of sensor-based raw data, vehicle location determination, and wireless networking between inter-vehicles, which are fundamental technologies for the next Telematics services. Therefore, this will promote a development of sensor network-based Telematics application systems.

This paper touches the issue, a convergence of wireless sensor network and Telematics specializing on an information routing mechanism between participating components in Telematics sensor communication network. The outstanding characteristic of the network is the type of the components that participate in communication; traditional wireless networks normally have a provider and a consumer. On the other hand, it consists of sensor nodes, a service station, and vehicles, which requires more complicated routing schemes that can understand surroundings. In order to address the problem, this paper proposes a context-aware routing architecture where Telematics contexts are modeled based on several criteria: position, information content, task, mobility, and energy constraint. Each Telematics context model dynamically configures the routing topology in the Telematics sensor communication network to guarantee reliable data transmission in real time.

The rest of this paper is organized as follows. Section 2 reviews a basic concept and research issues of wireless sensor network placing special interest on routing algorithms. In Section 3, a sensor network environment customized for Telematics services is described. Section 4 introduces a new sensor network topology composing three different Telematics components, and proposes a routing architecture working well on the Telematics sensor communication network. Finally, we conclude this paper in Section 5.

2. WIRELESS SENSOR NETWORK

2.1 Wireless Sensor Network (WSN)

WSN is an ordinary service environment where tiny sensor nodes are randomly deployed around a target area and sense surrounding values, and a base station utilizes such ubiquitous information. A distinguished feature of the sensor network compared with a general communication network is its automatic collection of distantly scattered information. In other words, sensor nodes can acquire surrounding data and transmit their sensing data toward a base station through their neighbours based on a predetermined automatic mechanism, and then a user can access to the replica database to create a new service. A great number of researches on WSN have currently studied in the fields of hardware, operating system, communication, middleware, and application.

2.2 Multihop Wireless Routing Schemes

Sensor nodes are normally scattered through a wide target area where some of them cannot directly communicate with a sink node. Therefore, it is necessary for each sensor node to support a multihop networking algorithms. Major design principles for network layer issues of sensor networks have been summarized as follows (Akyildiz, 2002; Ganesan, 2004).

1. Power consumption problem
2. Highly data-centric to the real world data.
3. Management schemes for data aggregation.
4. Location awareness and associated geographical routing protocols

With regarding to routing schemes, a number of algorithms have been proposed and under verification: from optimal versions of traditional ad hoc routing techniques to newly devised protocols for specific-aimed operation in WSNs.

Ad hoc On-Demand Distance Vector (AODV) routing protocol is a typical scheme from traditional techniques (Perkins, 2003). As a reactive mechanism, it is activated only when needed to send data to destination: route discover and maintenance. It shows light overhead without having control messages maintaining a routing table and provides flexible operation to dynamic topology changes due to link break.

Cluster Tree composes of a network coordinator, cluster heads, and ordinary network nodes. A data, at first, enters into a network via a coordinator, and then transmitted to a cluster head to which a destination node is attached as a child node. Tree method can reduce communication cost because every node needs to maintain their routing tables.

Small Minimum Energy Communication Network (SMECN) is proposed by (Li, 2001) to compute a subgraph of the sensor network that contains the minimum energy path when a communication network is given.

Gossiping, as a derivation of flooding, does not broadcast but send incoming packets to a randomly selected neighbor (Hedetniemi, 1988). It avoids the implosion problem by just having one copy of a message at any node, however it takes a long time to propagate the message to all sensor nodes.

Sensor Protocols for Information via Negotiation (SPIN) addresses the deficiencies of classic flooding by negotiation and resource adaptation. It is based on data-centric routing where sensor nodes broadcast an advertisement for the available data and wait for a request from interested sinks (Heinzelman, 1999).

In (Sohrabi, 2000), Sequential Assignment Routing (SAR) creates multiple trees where the root of each tree is one hop neighbour from the sink. This allows a sensor node to select a tree for data to be routed back to the sink according the energy resources and additive QoS metric.

Low-Energy Adaptive Clustering Hierarchy (LEACH) is a protocol that minimizes energy dissipation in a sensor cluster network (Heinzelman, 2000). It randomly selects sensor nodes as clusterheads, so the high energy dissipation in communicating with the base station is spread to all participants in the sensor network.

In Directed Diffusion, the sink broadcast an interest, a task description, to all sensor nodes; it is a data-centric routing (Intanagonwiwat, 2000). As the interest is propagated throughout the sensor network, the gradients from a source back to the sink are set up. When the source has data for the interest, the source sends the data along the interest's gradient path.

3. TELEMATICS SENSOR ENVIRONMENT

This section investigates basic concepts of Telematics sensor environment from the viewpoint of service.

3.1 Telematics Service Model on Sensor Network: Traffic Safety System

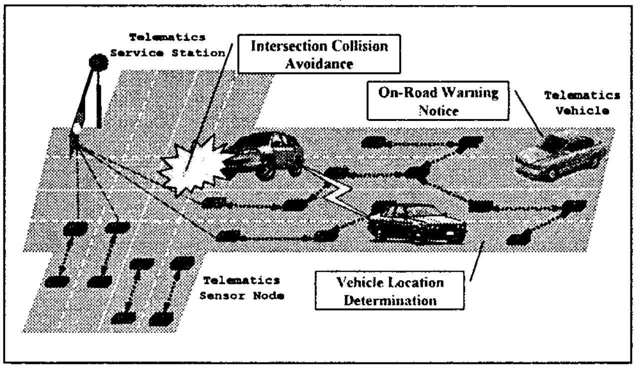

Figure 1. Telematics sensor environment: service models and elementary components.

A traffic safety system can help drivers by providing traffic and vehicle information such as a location, speed, and direction with sensor nodes deployed on roads and related facilities of traffic light and street light. Figure 1 shows examples of possible service models for a traffic safety system where sensor networks technologies are used. These services basically assume an infrastructure containing sensor nodes installed on roads, a service station collecting sensing data and providing services, and a vehicle equipped with Telematics terminal.

Intersection Collision Avoidance (ICA): ICA service consists of sensor nodes and a service station near an intersection and Telematics vehicles approaching to the intersection. The service station collects vehicle data acquired from sensor nodes, and broadcasts the information to all vehicles approaching to the intersection. Then, Telematics terminal in each vehicle estimates a collision probability at the intersection, and notifies the driver of the risk.

Vehicle Location Determination (VLD): VLD service provides more accurate and real-time location determination functionality. By passing over sensor nodes on a road, vehicles can get their location information more correctly than GPS.

On-Road Warning Notice (OWN): OWN service deals with unavoidable problems at a tunnel inside, above a bridge, and a highway by notifying invisible and unexpected risks in advance. In case of a tunnel, a service station gathers road circumstance information such as freezing, breakage, and dropped goods acquired by sensor nodes. Then it broadcasts the information to Telematics vehicles before they enter into the tunnel.

3.2 Network Components in TSE

Given a road condition, elementary components in a network should be changed for systematic operation. Description of service models in previous subsection gives hints for a new configuration of Telematics sensor environment: Telematics sensor node, Telematics service station and Telematics vehicle also shown in Figure 1.

Telematics Sensor Node: A Telematics sensor node acquires sensor records, and transmits the data to service stations. It has two distinctive properties; it can be attached on a lane or paved into a surface of roads, and it communicates with vehicles.

Telematics Service Station: A Telematics service station gathers sensor records from numerous sensor nodes and to deliver to vehicles in real-time.

Telematics Vehicle: A primary activity of a Telematics vehicle is communication with other components when moving with fast speed. It can receive raw data or applied service data from them and at the same time, it transmits vehicle-own data such as speed and time to them.

4. TELEMATICS SENSOR COMM. NETWORK

4.1 Telematics Sensor Communication Network

In terms of a data communication in Telematics sensor environment, this paper introduces *Telematics Sensor Communication Network (TSCN)* consisting of three components described in previous section: Telematics sensor node, Telematics service station, and Telematics vehicle. Figure 2 shows an overall look of TSCN whose components and topology are compared with conventional wireless networks.

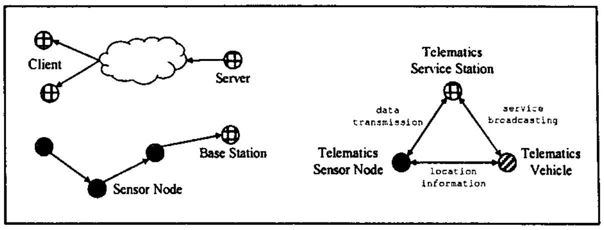

Figure 2. Telematics sensor communication network is compared with conventional wireless networks.

Contrary to traditional wireless networks, generally having a provider and a consumer: <server, client>, <sink, node>, <peer, peer>, TSCN constructs a triangular topology in which each component has different characteristic from others. In figure 2, the shape inside a circle identifying a network component describes its operational functionality. A grid symbol shows a powerful machine that equips a full version of software platform and processes more complicated network events. An example can be a server in the Internet that can deal with huge volume of web-based data such as multimedia stream. A black symbol shows a micro-system that contains a tiny engine required only for the simplest part of tasks. A smart sensor node or a RFID tag can be a sample of such a tiny device. The last oblique symbol shows a new moveable terminal capable of sensing surroundings, communicating with static sensor devices, and being provided on-line Telematics services. A vehicle travelling along roads can be an example of such a component.

Considering performances on Telematics sensor environment, the most important point should be on safety problems because trivial errors are able to cause irrevocable accidents. In this sense, we draw up a list of six primary constraints that Telematics sensor communication network should consider: real-time transaction, reliability, accuracy, fault tolerance, synchronization, and sensitivity. Even though power consumption problem is one of the most important issues in WSN, it becomes a secondary requirement in Telematics sensor environment. And hardware robustness, scalability, light-weight design, and production cost are also included in the additional research areas.

4.2 Context-Aware Routing Architecture (CARA)

In order to achieve reliable and real-time property, this paper proposes a *Context-Aware Routing Architecture (CARA)* where a network topology for routing can be configured according to the combination of context models of network components. When deployed, each component begins identifying its own context model based on the condition determined by a few criteria. The criteria determining a context model in a component are its position, information content, functionality, mobility, and energy constraint.

Position: A position indicates a type of each component that can be one among a Telematics sensor node, a Telematics service station, or a Telematics vehicle. According to a different functionality of each component, it is significant to determine who participates in configuring network topology.

Information Content: Information content is about what kinds of data the component handles. Packets travelling in TSCN can be a raw data such as sensor records and a service data reproduced by analyzing and customizing the raw data. In addition, control packets to maintain the network can be considered. In order to avoid losing packets having high priority due to network congestion or resource competition, a network should keep providing optimal routing topology.

Task: Transaction of a component such as acquisition, provision, or usage as well as sending, receiving, or forwarding data can be a criterion of task. As communication process generally consumes a great amount of resources and directly affects service performance, a network should schedule a dynamic routing path based on component's communication task.

Mobility: The next one is mobility of a component: high, low, or no mobility. It is easily expected that the fastest component, currently a Telematics vehicle, has its velocity more than 60Km/h, therefore routing or data path could be unstable due to communication interruption or duplication.

Energy Constraint: The last criterion is energy constraint (high, medium, or low energy level). This must play an important role in a context model because an energy condition in a component has an effect on the routing topology. In order to avoid energy depletion of a specific component located at a hot spot and to prolong a network lifetime, a centralized mechanism monitoring energy status of related components should be considered for maintaining seamless topology.

After the identification of components, an initial routing topology is configured. The primary mechanism of the configuration is a path reservation where data can go through the optimized routing path that supports a reliable transmission in an expected time period. The network environment is changed by such service operations that Telematics sensor nodes acquire road information, Telematics vehicles join in or leave from TSCN, and Telematics service stations provide various services. This makes the network reconfigure its routing topology to maintain the optimized routing path by rearranging context models of components.

5. CONCLUSION AND FURTHER WORKS

This paper touched a routing architecture that could be applied into Telematics services. We reviewed a basic concept of wireless sensor network and its research issues. A specific interest would be on routing schemes, thus several proposed algorithms were recalled. Then, we introduced Telematics sensor environment showing representative models and elementary components for traffic safety system. Finally, this paper proposed context-aware routing architecture required for Telematics sensor communication network. It is expected that more sophisticated network technologies for Telematics sensor environment can be advanced on the architecture.

For the further research works, we consider development of routing protocols and management algorithms on CARA. It is known that fulfilment of both real-time processing and data reliability at the same time is not easy work. However, we believe that when accomplishment can be seen, ubiquitous car life also can be achieved.

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