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The application of Inter-Vehicle Communication system to ITS

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1. Introduction

Since the concept of ITS (Intelligent Transportation System) was put forward in 1991 by the U.S. Department of Transportation, it has been viewed as a promising way to tackle modern traffic problems. The creation of ITS depends on the integration of four components: travelers, control centers, intelligent vehicles and field infrastructure, which calls for effective communication architectures. To address the requests, U.S. came up with four communication systems as table 1: WAWC (Wide Area Wireless Communications, FFC (Fixed-point to Fixed-point Communications), IVC (Inter-vehicle Communications), and DSRC (Dedicated Short Range Communications), among which, IVC is in the earliest research phase (US Department of Transportation, 1997).

	Travellers	**Control Centres**	**Intelligent vehicles**	**Field infrastructure**
Travellers	WAWC	FFC	WAWC	
Control Centers	FFC	FFC		FFC
Intelligent vehicles	WAWC		IVC	DSRC
Field infrastructure		FFC	DSRC	DSRC

Table 1. ITS Communication Architecture

Though many applications of IVC system have been identified, most research has been focused on the data transmission protocols (Kiyohito, 2001). How to further apply it to ITS, or the implementation of the application layer in the communication system, on the other hand, are rarely examined.

2. IVC

In an IVC system, vehicles form mobile ad-hoc networks and communicate with each other to get real time information, thus enable the driver to access information that are hard to acquire or measure by on-board sensors. The study of IVC systems can be dated back to the 1980’s. However, since some techniques as Internet, wireless LANs and GPS were not available by then; most of the proposed solutions are outdated. Besides, the main objective of early research was to enable data transmission between two vehicles, multi-hop systems were excluded (Fujimoto and Nakagawa, 1998; Yashiro and Kondo, 1993).

Recent research classifies IVC systems as single-hop IVC systems (SIVC) and multi-hop ones (MIVC) by whether or not the information is retransmitted at intermediate hops. SIVC can be used for applications like collision avoidance; while MIVC is suitable for those requiring long range communications, such as traffic monitoring, route guidance, and so on.

An IVC system has some important features. First, since it is highly distributed, it is highly resilient to disruption and able to provide reliable information services. Second, no infrastructure is required. All needed are some IVE (in-vehicle equipment): CPU, wireless transceiver, GPS, system interface, memory, map data and certain sensors (depend on different application). Moreover, its low information delay satisfies applications with real time constrain, e.g. safety applications.

3. Applications to ITS

The intelligence of a transport system lies both in intelligent infrastructure and intelligent vehicles.

3.1 Intelligent vehicle

Being an intelligent vehicle means it can provide the driver with various assistances. For example, collision notification, road warning, route guidance are typical applications, where IVC system plays an important role. In these applications, cars may disseminate information about collision or bad road condition, or local traffic information to other cars in a predetermined ZOR(zone of relevance, the area a data package should be sent to), either in event driven mode or periodically. In a route guidance application, the area of ZOR can be much larger than the first two applications, so that each car gathers enough traffic information on different roads to enable real time route optimization.

3.2 Intelligent infrastructure

Intelligent infrastructure is designed to deal with problems as emergency management, freeway management, etc. Traffic data collection and processing are usually involved when it comes to decision making. The accuracy and efficiency of data collection are essential, especially in the case of traffic flow management. Various approaches for traffic data collection have been proposed, including fixed vehicle detectors, videos and probe vehicles (or so-called floating cars). The application of vehicle detectors is limited because of high investment costs. Probe vehicles could be good complement for fixed detectors, but their effectiveness depends on the right choice of the size of the sampling area and sampling method.

Inter-vehicle communication, however, provides a new approach to the problem. In an IVC system, any vehicle equipped with IVE can work as a probe vehicle, without any other special equipment. It is due to the fact that each vehicle can receive real time data of the other vehicles like location, speed, acceleration, thus is capable of deducting accurate real time traffic information, at least within its vicinity. In a MIVC system, the known area can be large enough for traffic monitoring application. Then the information could be transmitted to roadside infrastructure or control centers for further data processing.

4. Key techniques

4.1 Data transmission protocol

As is mentioned before, many efforts have been made in this area. Since there is no international standard yet, various schemes on each communication layers have been proposed. The choice of schemes usually depends on different applications, especially the routing and forwarding algorithm and the addressing strategy on the network layer.

4.2 Traffic modelling

Traffic modelling is crucial for a successful IVC application. A good model identifies necessary traffic parameters, including contents of the package to be transmitted among cars, transmission rate and frequency, ZOR and so on. Few work has been done in this area. Sihem and Mounir (2006) have made some efforts in similar sense, but only for collision warning application, which is far from enough. Most existing traffic modeling researches are for computer simulation purpose, like Victor and Benjamin (1994).

4.3 Data aggregation

An effective data aggregation strategy will not only decrease transmitted data volume and increase the network throughput, but also improve the accuracy and efficiency of the IVC system. For example, in an traffic monitoring application, the system concerns more about the speed of the traffic flow rather than a single car on that road segment. Here we propose a distributed segment-based data aggregation strategy which is employed by each car in the system.

4.4 Security and Privacy

It is essential to find the right balance between security and privacy of an IVC system once it becomes pervasive. However, only a few papers have dicussed these issues, mostly for very specific problems (Hubaux and Capkun, 2004). More general security architectures are needed.

5. Experiment

The above mentioned techniques will be applied to an IVC system to deliver a typical ITS application, dynamic route guidance. Due to the cost and difficulties involved in deploying large vehicular test beds, we will evaluate their performance via a wireless network simulator JiST/SWANS, along with a mobility module for vehicles on city streets, STRAW. Since this research is based on our former work in multicast IVC protocol, a distributed robust geocast protocol will be employed in the simulation.

5.1 JiST

JiST (Java in Simulation Time) is a Java-based discrete-event simulator that runs over a standard Java Virtual Machine (JVM). In JVM's execution model, referred to as actual time execution, the progress of an application and the passing of time are independent. In order to execute applications with more predictable performance models, real time execution model is introduced, in which the program's progress is dependent on the passing of time. In simulation time execution, however, the progress of time depends on the progress of the application. The model is useful especially for evaluating the application performance where the consumed time is a key index.

By developing simulation in a JiST environment, we can write normal Java codes, while take strict control of the advance of time via the sleep(n) system call. In essence, every instruction takes zero time to process except sleep, which advances the simulation clock forward by exactly n simulated time quanta (Rimon, 2004).

5.2 SWANS

SWANS is a Scalable Wireless Ad hoc Network Simulator built atop the JiST platform, a general-purpose discrete event simulation engine (Rimon, 2004). In an IVC system, vehicles (nodes) communicating with each other form a wireless ad hoc network. And SWANS contains software components to form complete wireless network configurations. Different amounts of mobile nodes can be placed on a field and form a network configured by SWANS. Various IVC protocols can be employed and tested in SWANS to improve the efficiency of data communication in the network.

Our former work was focused on developing an efficient protocol for the IVC system, and a distributed robust geocast protocol has been implemented in SWANS, which constitutes the basis of this research (Joshi, 2006).

5.3 STRAW

STRAW (Street Random Waypoint) is a mobility model for vehicular ad hoc networks, which constrains node movement to streets defined by map data and limits their mobility according to vehicular congestion and simplified traffic control mechanisms (David and Fabian, 2005). As an add-on module to SWANS, STRAW makes the modeling of vehicles more accurate and realistic.

The delivery of the application, dynamic route guidance, involves a lot of interaction with both SWANS and this module.

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Biography

Yan Lei is the director of Beijing spatial information Integration and 3S application key lab and China image science and technology academy, IEEE senior member. He received his PhD in Department of Precision Instruments and Mechanology, Tsinghua University. Now he is a professor at the Institute of RS&GIS, Peking University. His main research focus is photography and remote sensing imaging, navigation ontrol and LBS (location based services).

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