Smart Computing Review

Implementation of VANET-based Warning Generation System using Cellular Networks, GPS, and Passive RFID Tags

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Received September 9, 2012; Revised November 22, 2012; Accepted November 25, 2012; Published December 31, 2012

Abstract: Vehicular communication systems are a key part of an intelligent transportation system, while vehicle safety communication is a major target of vehicular communication. Other features that augment vehicular ad hoc networks are enhanced driving experience, including but not limited to, active navigation and weather information, real-time traffic information and a plethora of other autonomous and automated systems. However, our focus will be warning generation systems, which can help reduce fatalities if deployed in an efficient and fail-safe manner on motorways and highways. This paper describes a collective information system for collection and delivery of traffic information aimed at supporting fast, efficient and secure travel of people and transport of goods. Based on that information, authorities are able to assess vehicles' sudden motion and movement changes and can generate warning/alert messages (for emergency/police vehicles) for post-accident scenarios. In this paper, the use of a radio frequency identification (RFID) system for vehicular communication has been proposed and an extended RFID system and infrastructure for vehicle safety communication through emergency phone towers (EPTs) and cell phones is suggested. In order to communicate, vehicles may be equipped with a cellular phone, RFID, and/or a global positioning system (GPS), whereas RFID readers may be mounted on EPTs, which are already installed on motorways. It also provides a demonstration on flow of information within the system; the simulation results are also included.

DOI: 10.6029/smartcr.2012.06.002

Keywords: ITS (Intelligent Transportation System), VANET, Traffic Information System, Vehicle Safety Communication (VSC), Vehicle to Infrastructure (V2I)

Introduction

Currently, most vehicle information provision systems in an intelligent transportation system (ITS), such as a vehicle information and communication system (VICS) and dedicated short-range communication, utilize licensed radio wavelengths [6]. These information-provision systems operate at a very large scale and are also very costly to maintain. Simultaneously, a lot of work is in progress for roadside communication with vehicles (vehicle to infrastructure, or V2I). To provide support for ITS applications, the Institute of Electrical and Electronics Engineers is working on draft amendments to 802.11p.

We are researching an information-provision system based on smart phones, emergency phone towers (EPTs), and radio frequency identification (RFID) to solve these issues. In the existing infrastructure of motorways/highways, the time required to authenticate and associate a basic service set is too long to be employed by vehicular ad hoc networks (VANETs). Although there are numerous EPTs already available on the both sides of the motorways for emergency calls (e.g. for reporting accidents, broken down vehicles, etc., and informing authorities regarding other difficulties faced by travellers) these EPTs are powered by solar energy. In the case of V2I, these EPTs can be involved. These EPTs, RFID tags, and/or smart phones can be engaged for transmitting data, since voice is already being transmitted over these EPTs. This goal can be attained by simply installing RFID readers on these EPTs, and RFID tags on vehicles. There are already many vehicles with RFID tags intended for electronic-tolling.

The communication distance between RFIDs and reader-writers (R/W) that can be obtained with current RFID technology is sufficiently long for this purpose [6]. The tag memory contains information about the tagged vehicle, e.g., class, on-board cell number, physical dimensions, on-board ITS sensors (if any), proprietary data, etc. The basic philosophy behind such a system is to make use of EPTs for low-cost sensing and data relaying. This paper describes an information collection and warning-generation system based on the collected information. We have implemented and tested our proposed system on the Islamabad-to-Lahore M2 Motorway in Pakistan, shown in Figure 7. There are two setups under which our system operates:

Case 1 (Data acquisition via RFID Tags)

- Spotting vehicles on the road
- Collecting information stored on vehicles' RFID tags
- Merging EPT information with collected information and forwarding this information to a control room
- Assembling and providing traffic congestion information, and
- Providing information to police/emergency vehicles

Thanks to modern improvements in wireless communications, mobile positioning technologies and mobile devices from these developments, individuals can use mobile information systems and services at any place and at any time, when and where it is necessary to support their business, tourist, and recreational activities. These systems are aware of location, context and situation of mobile users and thus are referred to as location-based and context-aware services [1]. Mobile information systems are successfully used in vehicle tracking, navigation and mobile commerce/business application domains. In this paper we also present the mobile information-providing system intended to provide real-time location information (i.e., latitude and longitude) to our server by using some mobile application. There are many free applications available for this purpose (e.g., GSM Tracker and NaviZone) and the phases for this task can be abridged as following:

Case 2 (Data acquisition via smart phones)

- Collecting information via cell phone (with the help of a preconfigured global system for mobile communications [GSM] tracker application)
- Storing the collected information in a database and creating simulations particularly designed for this purpose
- Assembling and providing traffic congestion information, and
- Providing information to police/emergency vehicles

The communication in a VANET could be vehicle-to-vehicle (V2V) or vehicle-to-infrastructure communication. VANETs are meant for vehicle communication, driver safety, warning alerts and many other applications. More and more vehicles would be equipped with wireless communication devices and advanced processing capabilities in the future. These devices enable vehicles to share and exchange information either by V2V or V2I communication. Many [1] [2] have been developed based on the concepts of mobile ad hoc networks and VANETs.

The rest of this paper is arranged as follows. Related technologies are outlined in Section 2. Section 3 conveys an overview of the scheme, and the information-provision systems are also categorized. Our proposed system, flow and structure of information, and information-provision methods are described in Section 4. In Section 5, we explain niceties of our field test. After that, we review the system behavior and security issues in Section 6. Section 7 shows the benefits of the proposed strategy with respect to current circumstances. Finally, we summarize this paper and touch on future plans in Section 8.

Related Technologies

The vehicle information and communication system is the main ITS scheme for information-provision systems in Japan. A problem with a VICS is that it is a one-way broadcast system, and an in-car transmission system is necessary to enable a vehicle to send information [6].

Hull and colleagues [7] describe a distributed mobile sensor computing system (CarTel). In addition to other purposes, the authors focus on the option of rapidly prototyping intra-vehicular sensor networks with a simple programming interface. The aim is to centralize and simplify the development of mobile sensor network applications. CarTel should be a structure that empowers the awareness of applications without considering distribution or mobility.

There are many other interesting software engineering studies on vehicular applications from Jonsson and colleagues [8], in which the authors focus on information accuracy in in-car information systems. In particular, they consider the relevant issue of designing an in-vehicle information system that does not negatively affect cognitive processing and driving performance by delivering inappropriate and/or inaccurate information to the driver.

Cars can be interconnected and can establish a peer-to-peer network [9]. In particular, Rybicki and colleagues propose an alternative approach for developing traffic and weather monitoring applications that relies on the use of mobile devices within the car to get mobile access to the internet. Thus, the authors mainly focus on the issue of connectivity.

Jerbi and colleagues [4] describe a pedestrian-safety scheme that uses active RFID tags in the ultra high frequency range.

Finally, the possibility of scaling VANET applications to wide area networks is considered by Li [10] and Gerla and colleagues [11].

Overview of the scheme

In our proposed system, we use RFID tags along with EPTs and cell phones. RFID is a new developing information technology in logistics, comparable to those traditional barcodes used in logistics, which has many advantages. Compared with traditional means of identification, it has the advantage of quick and easy operation without the need for human intervention to complete the information input process, and the identification of active RFID is more accurate in a dynamic environment. It is widely used in warehouses and stations.

The vehicles that are authenticated via passive RFID tags that pass through the RFID-enabled toll booths (service points) will be registered in the system, with a welcome short message service (SMS) as feedback. Three subscription levels are:

- RFID + SMS
- RFID + SMS + General Packet Radio Service/ Enhanced Data rates for GSM Evolution (here a web server will send the client location updates when the system authenticates the vehicle via the RFID, then sends an SMS to the registered number (RN). This will fire up the client-side application. The system will be a GPRS fall-back to SMS + RFID).
- RFID + SMS + GPRS/EDGE + GPS/A-GPS (in addition to the aforementioned service category, the location updates will be more precise and accurate with the use of GPS.)

In our proposed system, the data from the vehicle will be sent to the central control room in following ways:

- via cell phone (using applications like NAVI ZONE, GSM Tracker, etc.)

- via emergency phone towers (installed on the road side) + RFID reader

The data sent by the vehicles will be collected by the main server, which will then process this data and get the required information on the basis of facts in the data.

At present, RFID readers are installed at all entrances/interchanges of motorways. RFID is already being used for some vehicular communication services [1]. There are several RFID products in the market for vehicle identification at higher speeds, even at 200 km/h [3].

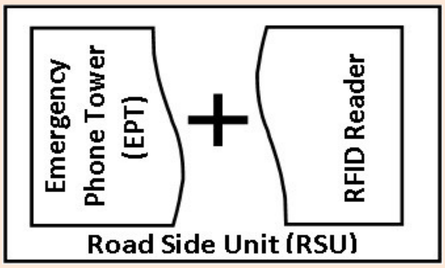

Figure 1. Block diagram of Road Side Unit (RSU)

RFID is chosen for enabling vehicular communication to achieve vehicle safety, since it is a common market product with application potential and extendibility. It is also a cheaper technology. Another important reason to use RFID is that this technology is already in service for e-tolling by the motorway authority (MA).

An RFID tag reader is fitted on the EPT forming a roadside unit (RSU) (see Figure 1) to gather information from a vehicle's tag and then send this information to the central server or control room.

Proposed System

Our proposed system utilizes two configurations: 1) an EPT and RFID scheme, and 2) a cell phone with GSM Tracker application scheme. We review our proposed schemes in this section.

Figures 2 & 3 show how information is transmitted in the proposed system. The EPTs with RFID readers (RSUs) will read the information from the tag of the passing vehicle, then this information will be forwarded to the MA. This information is then compiled and displayed on the system specifically developed for this project.

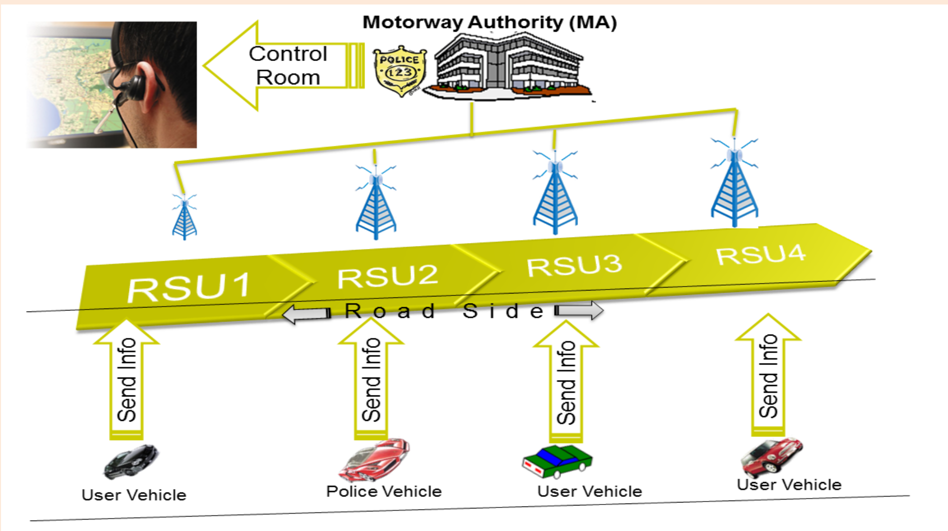

Figure 2. Information provision of the proposed system (Case 1)

Figure 4 shows the system components relevant to information provision between a registered vehicle and the server. The Web server will send client location updates when the system authenticates the vehicle via the RFID (with help from the e-tolling system), then sends an SMS to the RN. This will fire up the client-side application (e.g., GSM Tracker) on the cell phone of the user, since the cell phone is travelling with the vehicle. Therefore, we can retrieve the updated location of the user either by auto-update enabled in the client-side application or by simply sending another SMS containing the specified code (e.g., "loc?"); in return, the application will send the updated location to the specified web server.

Once the updated location of the vehicle is acquired by the server, this vehicle can be easily simulated on the system according to its informed location.

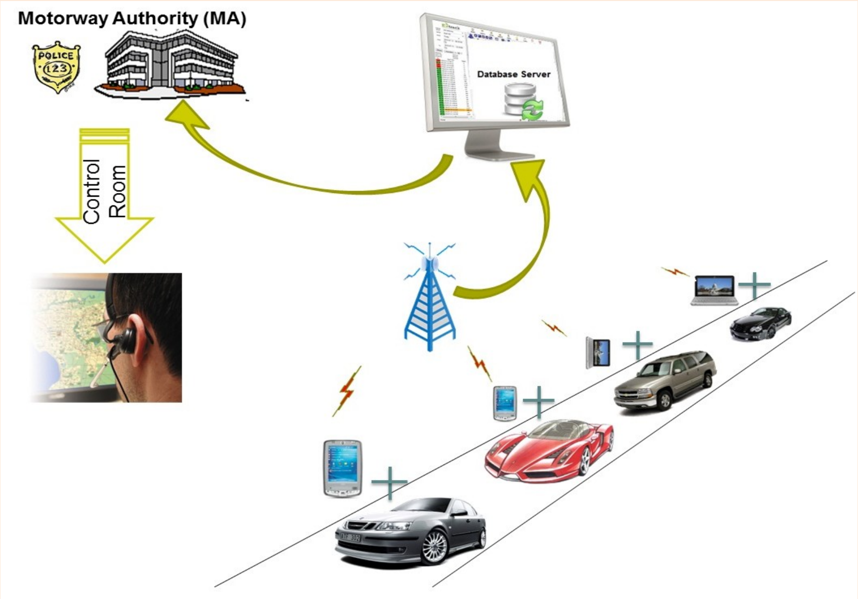

Figure 3. Information provision of the proposed system (Case 2)

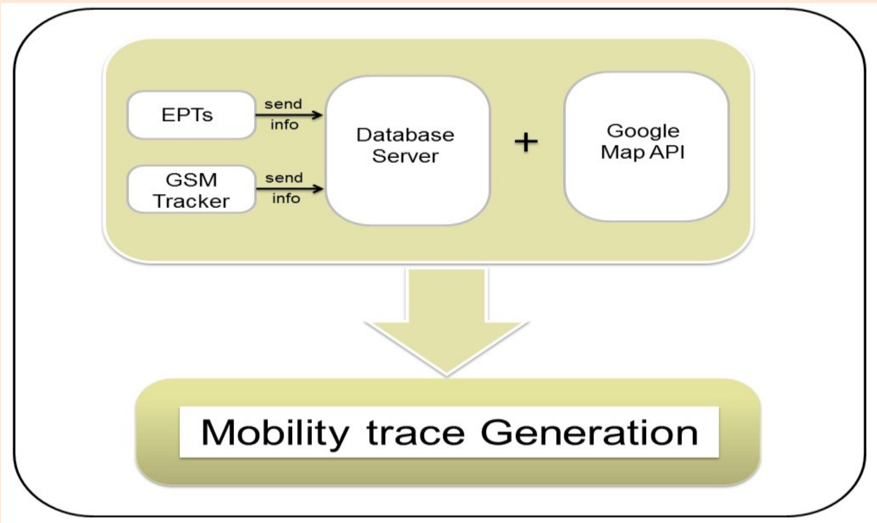

Figure 4. Components of the proposed system

Field Test

The objective of the field test is testing the robustness of the whole system, the accuracy of locating vehicles, and some key parameters that can reflect performance of the whole system. The field test was conducted using Case 2 (explained earlier). There was a preinstalled GSM tracker application on the cell phones in the vehicles used in the field test. With the help of this GSM tracker application, our server fetched the current location (latitude, longitude) of each vehicle used in the field test. This information was then stored in the database, as well as a simulation of the vehicle created according to this stored information and shown in Figure 6.

The test is like a racing game. This simulation is developed in C# using the Google map application programming interface. With the help of this simulation interface, the motorway authorities can easily track any vehicle on the motorway in real time. According to Case 1 described above, some tag readers are mounted on EPTs. Via these EPTs, the real-time information of a vehicle can be returned and stored in the database. This information can then be further utilized for viewing vehicle simulations in a real-time environment.

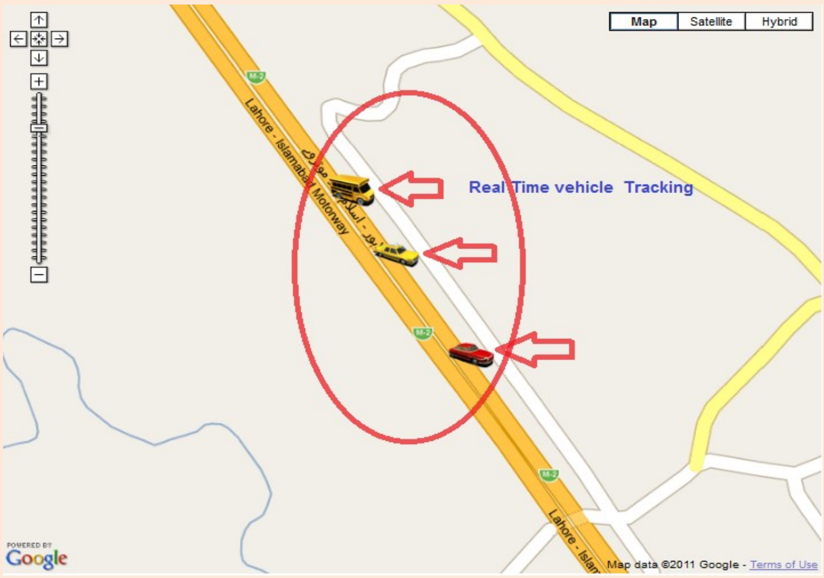

Figure 5. Map chunk of the field test area

Figure 6. Vehicles simulated with their real-time locations.

The field test was performed on Motorway M2, Islamabad to Lahore, Pakistan, on its Islamabad interchange. The targeted area of this project is shown in Figure 7. We first tested the system setting using three vehicles; we let the vehicles through the interchange, then the GSM tracker application started returning real-time locations to the server. This information was stored in a database and simulated (parts of which are shown in figures 5 and 6).

Figure 7. M2 Motorway from Islamabad (A) to Lahore (B)

System Evaluation

■ Overview of system behavior

Mobile location-based and context-aware information systems have important use in navigation, fleet management, traffic control, emergency management, tourist and business guides, mobile games, etc. Mobile information systems for traffic and transport monitoring and management are mainly based on static data about road network conditions, road surface status, weather conditions, traffic information, etc. By implanting our system, MAs and other road operators can easily generate dynamic traffic information about the events that occur in real time, with the help of real-time simulations, which can significantly improve their efficiency and performance. The road authorities/operators can gather various types of information, such as slippery road, obstacles on the road, and positions of radar patrols etc. which can help them to improve road network management and traffic control. This information is available through mobile and RSUs (Road Side Units) per the block diagram in Figure 1.

■ Security and privacy related issues related issues

We also understand that we should consider security issues and main issues related to information writing. In our proposed system, anyone can write information to any RFIDs. However, we must avoid illegal writing and ensure the integrity of data written in RFIDs. Consequently, important information requires strict authentication and authorization, while some information does not.

Benefits of the Proposed Stratagem

The proposed architecture has many advantages. First, it is exceptionally low cost; passive tags are under 10 cents (which are already installed in most cases for e-tolling etc.). Second, with each vehicle tagged, certain convenient ITS applications (e.g., real-time traffic updates) can be articulated in a cost-effective manner. Lastly, it can support ITS safety and convenience (management applications, traffic conditions, congestion alerts for authorities, etc.). There is no such automated system installed for authorities that can keep them informed regarding real-time road situations.

Conclusion and Further Work

In this paper, we proposed the integration of EPTs for automatic vehicle identification in an RFID-based traceability system. For this implementation, each EPT will have a reading point combination called an RSU, and each vehicle will also have an RFID tag. The reader will record information from each vehicle's RFID and forward it to the control room. Cell phones are also used to automatically detect vehicle locations. By integrating these RFIDs on EPTs and simulating them, the system is now fully automatic—road operators can view the traffic from their control room with minimum investment. This system is based on the service platform for the mobile and e-tolling system called METS, which provides services for moving vehicle data management, context management, geomobility, and traffic information integration and sharing [5].

Social networks can be used to generate and disseminate valuable traffic information to travelers and participating users. For example, information on traffic congestion, traffic accidents, radar patrols, and road conditions can be obtained and disseminated as user-generated content via social networks. In the next phase, the information received by RSUs can be broadcast to approaching vehicles, where this information is displayed on the onboard display unit of the vehicles. There are many options available for utilizing this information in more advantageous ways. An important direction for further research is exploring the possibility of automatically detecting relevant traffic events and traffic conditions using sensors integrated in the mobile device or the vehicle itself. By using GPS data sampled at regular intervals and knowing an average travel time on road segments, a mobile client application can detect traffic congestion and calculate dynamic travel time, which can be reported to the server and other users.

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