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A Unified Framework of Data Exchange Mechanism in an Intelligent Transportation System

S.C. Wang, S.H. Pan, Y.L. Lo, K.Q. Yan

***Abstract*—An intelligent transportation system (ITS) incorporates a variety of equipment and devices that all work in mutual harmony. However, each piece of equipment or device has its data format and protocol. Therefore, they cannot directly exchange data with each other. In this research, a unified framework for data exchange in an ITS is proposed. The proposed mechanism serves to receive data from several equipments outside of cars, repackages the received data and then dispatches the data to devices inside the cars. Based on this framework, data in equipment and devices can be interchanged (with each other) to accomplish data sharing in an ITS.**

***Index Terms*—Intelligent Transportation System, Integrated Platform, User Friendly, Data Exchange**

I. Introduction

Intelligent Transportation Systems (ITSs) make use of advanced detection, communications, and computing technology to improve the safety and efficiency of our surface transportation networks. ITS is a program of technology applications and integration that allows system operators and users to better manage and optimize the capacity used by the transportation system. ITS allows for the use of information technologies to collect data on the status of our highways, traffic signals, transit vehicles, trucks and trains, and integrates data in ways that affect and improve the operation of the system.

Interest in ITS stems from the problems caused by traffic congestion and the need for a synergy of new information technology for simulation, real-time control, and communications networks [1],[4]. Traffic congestion has been increasing worldwide; it is the result of increased motorization, urbanization, population growth, and changes in population density. Congestion reduces efficiency of transportation infrastructure and increases travel time, air pollution, and fuel consumption.

With ITS, the devices and equipment work together. However, each device and piece of equipment has its own data format and protocol, such as GPS, TMC, Wi-Fi, or Bluetooth [2],[3]. They cannot directly exchange data with each other; therefore, a framework has been designed herein by which to exchange messages between device and communication systems [1]. In addition, this framework can consolidate variant communication protocols similar to web service. Therefore, it can adapt any kind device to use a multi-communication system, as well as collect varied information from devices, and send all of the information to the ITS center for data analysis or for transmission to another vehicle [2].

This research employed ITS to design a Unified Framework Data Exchange Mechanism (UFDEM for short) for the physical, security, processing and interfacing four layers. Each layer includes some components working with each other to exchange data between equipment and devices in the framework.

The second part of this paper deals with the issue concerned; the third part introduces the method and framework of this research; and the fourth part is the conclusion and suggestions for future research.

II. Literature Review

The term ITS refers to efforts to add information and communications technology to transport infrastructure and vehicles in an effort to manage factors that typically are at odds with each other. The technologies applied by ITS vary, from basic management systems, to monitoring applications, and more advanced applications that integrate live data and feedback from a number of other sources. Some of the constituent technologies typically implemented in ITS, are described in the following sections [4].

A. Wireless communications

Various forms of wireless communications technologies have been proposed for intelligent transportation systems. Short-range communications (less than 500 yards) can be accomplished using IEEE 802.11 protocols, specifically WAVE or the Dedicated Short Range Communications standard being promoted by the Intelligent Transportation Society of America and the United States Department of Transportation [4]. Theoretically, the range of these protocols can be extended using Mobile ad-hoc networks or Mesh networking [1].

Long-range communications using infrastructure networks such as WiMAX (IEEE 802.16), Global System for Mobile Communications (GSM), or 3G have been proposed. Long-range communications using these methods are well

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S.C. Wang is with the Chaoyang University of Technology, Taiwan, ROC (e-mail: scwang@cyut.edu.tw).
S.H. Pan is with the Chaoyang University of Technology, Taiwan, ROC (e-mail: vincentpan@cyut.edu.tw).
Y.L. Lo is with the Chaoyang University of Technology, Taiwan, ROC (e-mail: yllo@cyut.edu.tw).
K.Q. Yan is with the Chaoyang University of Technology, Taiwan, ROC (corresponding author to provide phone: 886-4-2332-3000; fax: 886-2374-2369; e-mail: kqyan@cyut.edu.tw).

established, but, unlike the short-range protocols, these methods require extensive and very expensive infrastructure deployment. There is a lack of consensus as to what business model should support this infrastructure [8].

B. Computational technologies

Recent advances in vehicle electronics have led to a move toward fewer, more capable computer processors on a vehicle. A typical vehicle in the early 2000s has between 20 and 100 individual networked microcontroller/programmable logic controller modules with non-real-time operating systems. The current trend is toward fewer, more costly microprocessor modules with hardware memory management and Real-Time Operating Systems. The new embedded system platforms allow more sophisticated software applications to be implemented, including model-based process control, artificial intelligence, and ubiquitous computing. Perhaps the most important of these for Intelligent Transportation Systems is artificial intelligence.

C. Floating car data/floating cellular data

Virtually every car contains one or more mobile phones. These mobile phones routinely transmit their location information to the network, even when no voice connection has been established. This allows them to be used as anonymous traffic probes. As the car moves, so does the signal of the mobile phone. By measuring and analyzing triangulation network data, in an anonymous format, the data is converted into accurate traffic flow information. With more congestion, there are more cars, more phones, and thus, more probes. In metropolitan areas, the distance between antennas is shorter and, thus, accuracy increases. No infrastructure needs to be built along the road; only the mobile phone network will be leveraged.

D. Sensing technologies

Technological advances in telecommunications and information technology coupled with state-of-the-art microchips, RFID, and inexpensive intelligent beacon sensing technologies have enhanced the technical capabilities that will enhance motorist safety benefits for intelligent transportation systems globally. Sensing systems for ITS include both vehicle- and infrastructure-based networking systems, e.g., intelligent vehicle technologies. Infrastructure sensors are indestructible (such as in-road reflectors) devices that are installed or embedded in the road, or surrounding the road (buildings, posts, and signs for example) as required, and may be manually disseminated during preventive road construction maintenance or by sensor injection machinery for rapid deployment of the embedded radio frequency powered (or RFID) in-ground road sensors. Vehicle-sensing systems include deployment of infrastructure-to -vehicle and vehicle-to-infrastructure electronic beacons for identification communication; they may also offer the benefits of CCTV automatic number plate recognition technology at desired intervals in order to increase sustained monitoring of suspect vehicles operating in critical zones.

ITS strategies apply a broad range of information and communication technologies to make surface transportation networks safer, more secure, more efficient, more reliable, and more environmentally friendly. Systems optimize the capacity of transportation infrastructure through real-time monitoring of operations and by reacting expeditiously to any anomalies. ITS conserves resources and can potentially forestall the need to expand capacity.

III. RESEARCH

In an ITS, there are many kinds of information and transmission types, for example GPS, TMC, Wi-Fi, GSM/GPRS, or Bluetooth (Figure 1). Since users must use the corresponding devices to receive and use data from different types of transmission, or such data cannot be used. For example, users cannot receive and use the GPS data if they do not have any GPS receiver. So, a unified ITS framework for data exchange is proposed in this research. The framework that transfers data between equipment and devices is prefigured first. In addition, the data is dispatched to the corresponding device. Finally, the security issue is considered as well.

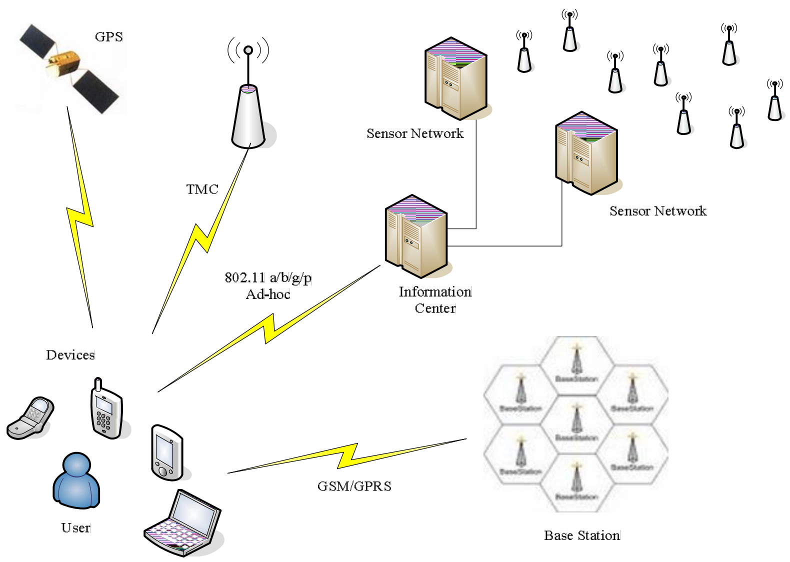

Figure 1: Equipment and devices in an ITS environment

A. Unified Framework Data Exchange Mechanism (UFDEM) framework

Figure 2 shows an overview of the UFDEM framework. The solid line means that the data are received from equipment outside of the cars, and they are finally transmitted to devices inside the car. In addition, the dotted line means the data was received from a device and was transmitted to equipment outside of cars. There are four layers in UFDEM: physical, security, processing and interface layer.

The data flow charts of the framework are shown in Figure 3. From equipment to devices, data are received from equipment by physical layer. Then, if the received data are encrypted, the data will be decrypted by passing through the decryption component. When data are transmitted to an assembler component, the data will be decomposed and repacked into unified XML form data. Finally, the packed data are transmitted to devices by interface layer. If data from devices are transmitted to equipment, the data are first transmitted to a disassembler component by interface layer. Then, the data are encrypted via an encryption component if the transmitted data require more security. Finally, the data are transmitted to equipment by the physical layer.

The first layer of UFDEM is the physical layer. It contains some components that can receive or send data by wireless communication technologies out of cars, like GPS, GSM, TMC, Wi-Fi, or Bluetooth.

- GPS component: It is used to receive the GPS signals from satellites.
- GSM/GPRS component: This component is used to receive or send data to the base station of cell phone by GSM or GPRS technologies.
- FM component: It is used to receive the TMC signals from the TMC base station.
- Wi-Fi component: This component is used to receive or send data to the base station by Wi-Fi technologies like 821.11a/b/g/p. In addition, it can also be used to send or receive by ad-hoc technology, so that this framework can be used for communication between more than two cars by VANET technology.
- Bluetooth component: This component is used to receive or send data to the base station by Bluetooth technologies.

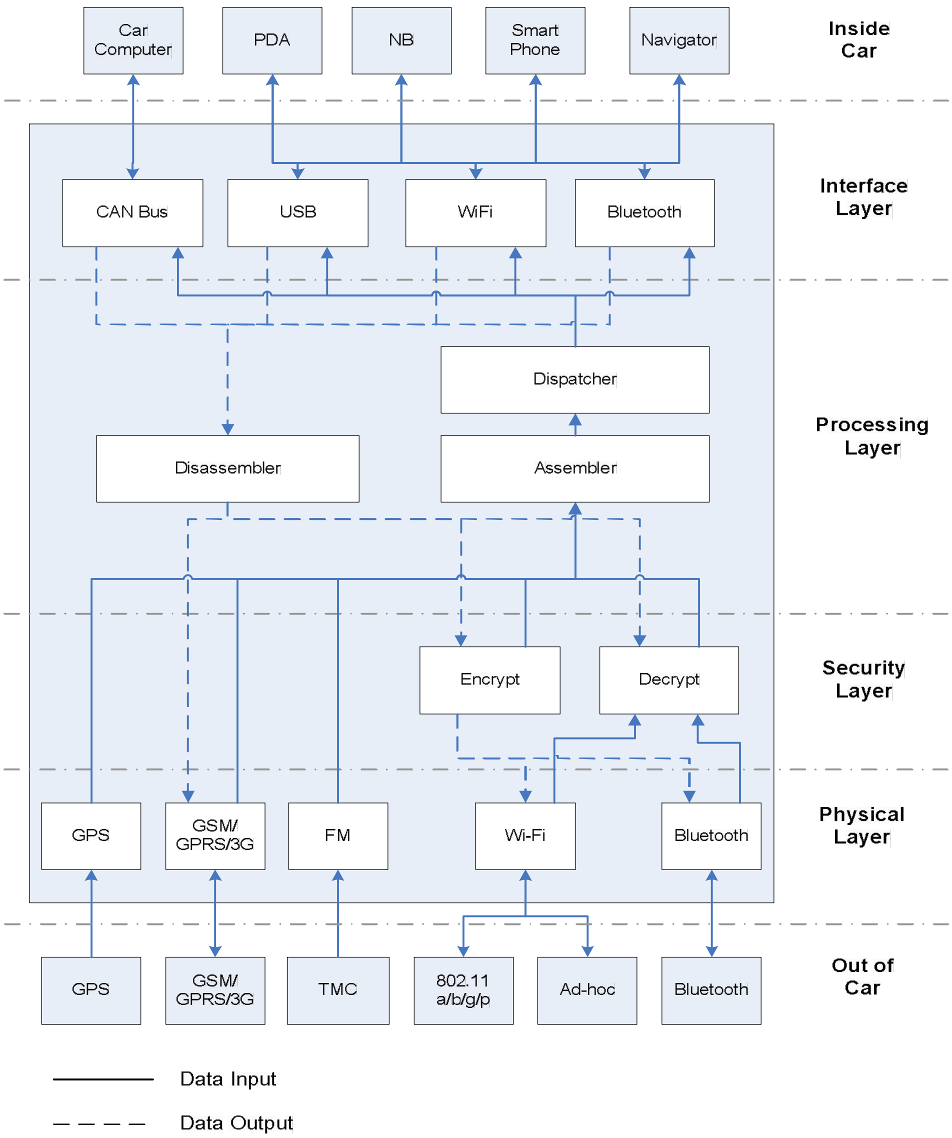

Figure 2: UFDEM framework

The second layer of UFDEM is the security layer. It is used to decrypt data received from outside, or to encrypt data that will be sent outside. Therefore, there are included decryption and decryption components in this layer, and are described as follows.

- Decryption component: According to the security issue, when the data are received from Wi-Fi or Bluetooth, the data might be encrypted. So, the decryption component in the framework is used to decrypt the data.
- Encryption component: If the data that is transmitted out to equipment is sensitive, the data can be encrypted to ensure its security.

Both decryption and encryption components are used to decrypt or encrypt sensitive data in Wi-Fi and Bluetooth technology.

The third layer of UFDEM is the processing layer. This layer is used to process the data received from outside or in the preparation to send to equipment out of the cars. On the receiving side, it contains assembler and dispatcher component to process data. In addition, on the sending side, there is a disassembling component in it. The three components are described as follows.

- Assembler component: Because the protocols in different transmit technologies are different, a component to eliminate the difference between equipments is used. This component is used to collect and repack data received from equipment. In addition, it will pack this data into an XML data type, and then pass the packed data to next component, the dispatcher component.
- Dispatching component: After the data are repacked by assembler component, the data will be transmitted to devices linked to this framework. However, such devices differ. Therefore, a dispatching component in the framework is used to transmit data to devices.
- Disassembler component: In this framework, data is XML type data; therefore, the data cannot be directly transmitted to equipment. So, the disassembling component is used to unpack and transfer data to the original protocol. In addition, due to the limitation of linkage routes, the disassembler component is just used to transmit data out by GSM/GRPS, Wi-Fi or Bluetooth technology.

The fourth layer of the UFDEM is the interface layer. There are four components in this layer. The components are used to communicate with each device that is inside the car, like the car computer, PDA, NB, smart phone, or navigator.

- CAN bus: The CAN bus is a balanced 2-wire interface running over a Shielded Twisted Pair (STP), Un-shielded Twisted Pair (UTP), or Ribbon cable. The Bit Encoding used is Non Return to Zero (NRZ) encoding (with bit-stuffing) for data communication on a different two wire bus. The use of NRZ encoding ensures compact messages with a minimum number of transitions and high resilience to external disturbance. Via CAN bus, the framework can communicate with the car's computer [7].
- USB: Universal Serial Bus is a serial bus standard to interface devices to a host computer. USB was designed to allow many peripherals to be connected using a single standardized interface socket and to improve the plug-and-play capabilities by allowing hot swapping, that is, by allowing devices to be connected and disconnected without rebooting the computer or turning off the device. Other convenient features include providing power to low-consumption devices without the need for an external power supply and allowing many devices to be used without requiring manufacturer specific, individual device drivers to be installed.
- Wi-Fi: Wi-Fi is the trade name for the popular wireless technology used in home networks, mobile phones, video games and more. In particular, it covers the various IEEE 802.11 technologies. A Wi-Fi enabled device such as a PC, game console, mobile phone, MP3 player or PDA can connect to the Internet when within range of a wireless network connected to the Internet. The coverage of one or more interconnected access points, called hotspots, can comprise an area as small as a single room with wireless-opaque walls or as large as many square miles covered by overlapping access points [2],[5].
- Bluetooth: Bluetooth is a standard and the communication protocol primarily designed for low power consumption, with a short range based on low-cost transceiver microchips in each device. Bluetooth enables these devices to communicate with each other when they are in range. The devices use a radio communications system so they do not have to be in line of sight of each other, and can even be in different rooms as long as the received transmission is powerful enough. Bluetooth device class indicates the type of device and the support services whereby the information is transmitted during the discovery process [6].

B. Data-exchanging scheme

Because the data and protocols between devices and equipments are different, a unified data format in XML for exchanging data in framework is proposed. The data-exchanging scheme is shown in Figure 4. In the scheme, IDENTIFY block is the first block; it includes Id tag to identify the system type on different vehicles. The Time tag takes the date and time information related to the data exchange. In addition, the Blocks tag is used to declare the total number of blocks that follows the IDENTIFY block.

Blocks following the IDENTIFY block are the exchanging data for each protocol in ITS, like GPS, GSM, GPRS, TMC, Wi-Fi or Bluetooth. Each protocol has its own block to record data in it. Therefore, each block has different tags inside. Not all of the blocks need to be used at the same time; the framework just includes the needed protocol block to make the data exchange. Therefore, the exchanged data could remain as small as possible. In addition, there are two properties in the main tag of each block. One is Version property, which is used to distinguish the contents of the same blocks. According to the flexibility of the framework, users can design or add their own tags in blocks, and the version information can be identified by the version property. The other property is Encrypt, which is used to distinguish whether or not the data in this block is encrypted. If the data in the block is encrypted, then the property is set to true, or set to false.

C. Security issue

In all ITS operations, communication between and among various information systems, (e.g., between road conditions monitoring and traffic management centers or between different agencies responsible for transportation systems) as well as communication with the users of the system is critical to successful deployment. The same types of communication have been cited as critical components of improved homeland security systems; thus, there is synergy between ITS and homeland security.

IV. Conclusion and Future Work

In this study, a unified framework in ITS for data exchanging is proposed, called UFDEM. With UFDEM, information or data from equipment can be transmitted and used in different devices. For example, the GPS or TMC data can be used on car computer, notebook, cell phone or PDA. Therefore, users can use data wanted even when they do not have the corresponding devices. In addition, the flexibility was considered in designing the UFDEM. The UFDEM can be improved by adding new components in physical or interface layers to transmit data with new equipment or devices and new protocol blocks in data exchanging formats.

References

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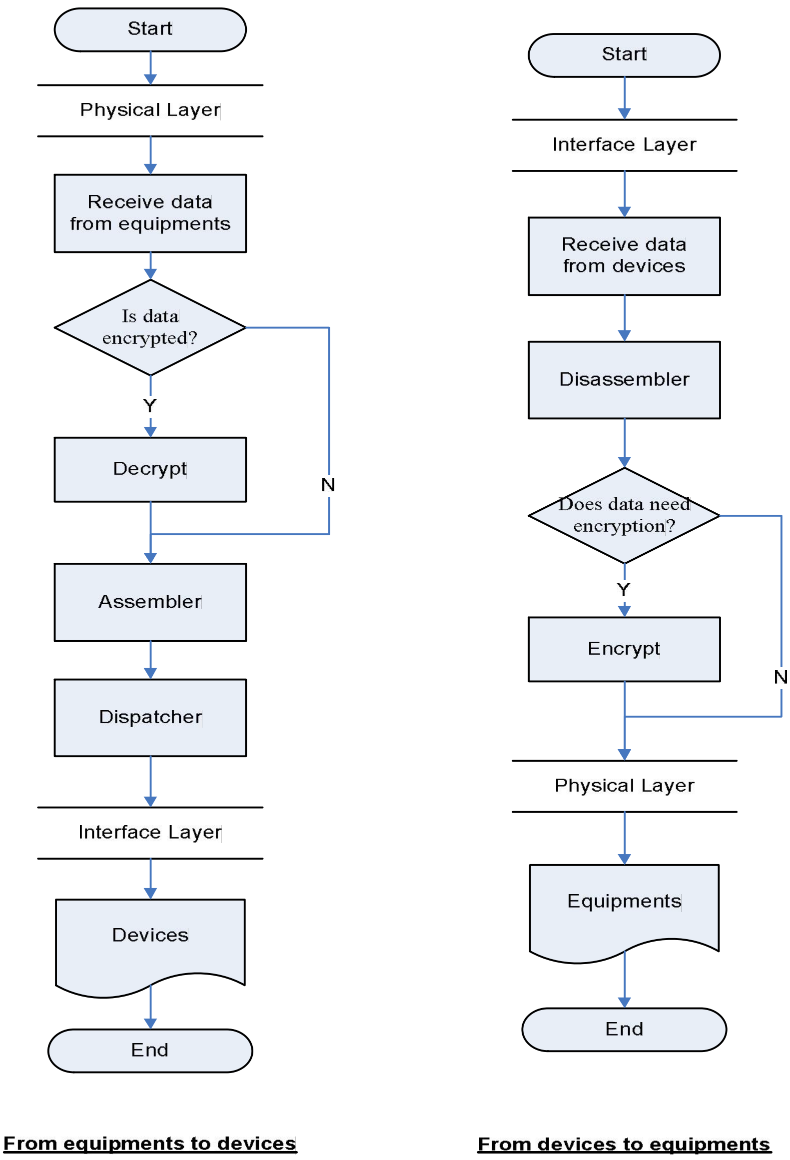

Figure 3: Data flow charts of framework

```
<IDENTIFY Version=” 1.0” Encrypt=” false” >
        <Id>1</Id>                                  #system id
        <Time>2008/10/1 10:47:20</Time>             #data making date and time
        <Blocks>6</Blocks>                          #number of blocks
</IDENTIFY>
<GPS Version=” 1.0” Encrypt=” false” >
        <Protocol>NMEA-0183</Protocol>
        <GGA>$GPGGA,055148,2407.8945,N,12041.7649,E,1,00,1.0,155.2,M,16.6,M,X.X,xxxx,*47</GGA>
        <RMC>$GPRMC,055148,A,2407.8945,N,12041.7649,E,000.0,000.0,061196,003.1,W*69</RMC>
        <GSA>$GPGSA,A,3,01,05,09,17,21,2,26,39,,,,1.9,1.0,1.7,*33 </GSA>
        <GSV>GPGSV,3,1,09,01,27,299,43,………*70</GSV>
</GPS>
<GSM Version=” 1.0” Encrypt=” false” >

        <Data>…</Data>                              #GSM data
</GSM>
<GPRS Version=” 1.0” Encrypt=” false” >

        <Data>…</Data>                              #GPRS data
</GPRS>
<TMC Version=” 1.0” Encrypt=” false” >
        <PI>…</PI>                                  #program identification
        <Group>…</Group>                            #message type identification
        <B0>…</B0>                                  #version code
        <TP>…</TP>                                  #traffic program
        <PTY>…</PTY>                                #programme type
        <TF>…</TF>                                  #multi group messages
        <DP>…</DP>                                  #duration and persistence
        <D>…</D>                                    #diversion advice
        <PN>…</PN>                                  #+/- direction
        <Extent>…</Extent>                          #event extension
        <Event>…</Event>                            #event code
        <Location>…</Location>                      #location code
</TMC>
<WIFI Version=” 1.0” Encrypt=” false” >
        <Type>a/b/g/p/adhoc</Type>                  #wireless type
        <Protocol>TCP/UDP</Protocol>                #protocol
        <IPVer>4/6</IPVer>                          #IP version
        <SourceAddr>…</SourceAddr>                  #source address
        <DestAddr>…</DestAddr>                      #destination address
        <SourcePort>…</SourcePort>                  #source port
        <DestPort>…</DestPort>                      #destination port
        <Data>…</Data>                              #data
</WIFI>
<BLUETOOTH Version=” 1.0” Encrypt=” false” >
        <ID>…</ID>                                  #device ID
        <Version>…</Version>                        #bluetooth version
        <Profile>…</Profile>                        #device proflie
        <Data>…</Data>                              #data
</BLUETOOTH>
```

Figure 4: Data-exchanging scheme in XML