Telematics Gateway and Power Saving Method for Electric Vehicles

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Abstract—**Based on the characteristics of electric vehicles (EV), this paper proposes a conceptual framework utilizing the Controller Area Network (CAN) bus technology, OBD-II connector and the existing telematics service systems to construct a novel telematics gateway for EV. Vehicle gateway interface has been applied to telematics service systems for many years but not to EV. The proposed framework of telematics gateway establishes a three layers' architecture, namely, the physical layer, data link layer, and application layer. The telematics gateway needs to resolve two issues: One is to simplify the framework of EV gateway interface and the other is to ensure the application scenarios for power saving and location based service (LBS). Using the framework of telematics gateway, the entire service network can meet different application scenarios for EV.**

***Index Terms*—EV, framework, CAN bus, OBD-II, telematics gateway, location based service (LBS)**

I. INTRODUCTION

The evolution of telematics can be divided into three generations [1]. The first generation: vehicle to zero (V2Z) is a basic and independent telematics service system. The second generation: vehicle to infrastructure (V2I) is now the popular telematics service system in the world. The third generation: vehicle to extension (V2X) which includes V2V, V2I and V2P (vehicle to person) is the developing telematics for many value-added applications but under the limitation of mobile network bandwidth. The existing telematics server systems consist of server applications, a short messaging service center (SMSC) connection component, the related servers' connection component, HTTP, and TCP/IP. The server applications provide client applications in a vehicle with telematics services such as emergency service, remote door unlocking, and remote vehicle diagnostic service through the wireless application protocol (WAP) gateway in a mobile network. Most of the existing telematics services have been dependently developed and provided on specific systems of a mobile network. This creates a situation where services may not be available on other mobile networks. Also, telematics services are used only for engine vehicles [2][3].

Energy and environment are the two fundamental problems of the modern world's sustainable development. With the development of economy, the quantities of vehicle maintained a rapid yearly growth and the problem of energy and environment becoming more austere day by day. Electric motor car has many advantages such as non-polluting, high energy efficiency, energy diversification, simple structural parts, and convenient to maintain *etc*. It is a good way to relieve the energy and environment problem which becomes more and more serious. In order to decrease weight, the electric motor cars have adopted electric equipment as much as possible to replace the traditional mechanical and hydraulic equipment. The increase of electric equipment not only decreases the weight of car, but also brings forward a higher demand to the car's communication system [4]. To date, CAN bus is the most mature and developable bus technology. It is a serial communicational network that can efficiently support distributed control and real-time control. Controller Area Network has many special characteristics so that it can be popularly applied in cars [5][6][7]. CAN-bus technology SAE J1939 and controlling the nodes through distributed control method have been proposed to build an electric motor car's body network system [1]. The telematics service system proposed by this article has the advantage of providing value-added applications of power saving and location based service for EV.

In the telematics service system, vehicle gateway interfaces with OSI model 7 layer's protocols including the CAN bus and OBD-II have been studied and applied to engine vehicles but not to EV [8][9][10]. With the modern world's development of green technology and green ITS, telematics service system and EV have become very important issues for environmental protection. Therefore, this paper proposes a novel and conceptual framework of telematics gateway for EV using CAN bus, OBD-II connector and vehicle gateway interface in the telematics service system. The proposed framework of telematics gateway establishes a three layers' architecture, namely, the physical layer, data link layer, and the application layer. The telematics gateway needs to simplify the conceptual framework of EV gateway interface. In addition, application scenarios of power saving and LBS are proposed to verify the benefits of telematics gateway interface. Moreover, other value-added application scenarios also can be realized on the conceptual framework of telematics gateway for EV.

The rest of this paper is organized as follows. In Section II, the preliminaries of vehicle gateway interface and basic telematics gateway for EV are introduced. Section III then thoroughly discusses the proposed conceptual framework of telematics gateway. In Section IV, using proposed framework of telematics gateway, two application scenarios with telematics gateway are presented and the benefits for EV are verified. Conclusions are finally drawn in Section V along with recommendations for future research.

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II. PRELIMINARIES

Vehicle gateway interface, CAN bus and OBD-II are three standard control technologies and have been implemented in vehicle telematics service system for many years. The proposed framework of telematics gateway establishes a three layers' architecture, namely, the physical layer, data link layer and application layer based on CAN bus, OBD-II connector, and vehicle gateway interface in telematics service system. The features of CAN bus, OBD -II, vehicle gateway interface and basic telematics gateway interface for EV are treated in four parts as follows.

A. CAN bus

CAN is a multi-master broadcast serial bus standard for connecting electronic control units (ECUs). Each node is able to send and receive messages, but not simultaneously. A message consists primarily of an ID — usually chosen to identify the message-type or sender — and up to eight data bytes. It is transmitted serially onto the bus. This signal pattern is encoded in NRZ and is sensed by all nodes.

The devices that are connected by a CAN network are typically sensors, actuators, and other control devices. These devices are not connected directly to the bus, but through a host processor and a CAN controller.

If the bus is free, any node may begin to transmit. If two or more nodes begin sending messages at the same time, the message with the more dominant ID (which has more dominant bits, i.e., zeroes) will overwrite other nodes of less dominant IDs, so that eventually (after this arbitration on the ID) only the dominant message remains and is received by all nodes.

Bit rates up to 1 Mbit/s are possible at network lengths below 40 m. Decreasing the bit rate allows longer network distances (e.g., 500 m at 125 kbit/s). The CAN data link layer protocol is standardized in ISO 11898-1 (2003). This standard describes mainly the data link layer — composed of the logical link control (LLC) sublayer and the media access control (MAC) sublayer — and some aspects of the physical layer of the OSI reference model. All other protocol layers are the network designer's choice.

B. OBD- II

OBD-II is an improvement over OBD-I in both capability and standardization. On Board Diagnostic (OBD) systems are incorporated into the computers on-board new vehicles to monitor vehicle components and systems. The second generation of OBD requirements, which is known as OBD-II, has been fully in effect since the 1996 year. OBD-II system monitor virtually every component that can affect the performance of a vehicle. The OBD-II standard specifies the type of diagnostic connector and its pinout, the electrical signaling protocols available, and the messaging format. It also provides a candidate list of vehicle parameters to monitor along with how to encode the data for each parameter. The information contained in the on-board computing systems of modern vehicles, using the OBD-II standard, could be very beneficial to the owner/operator. The information would be useful in determining when to service a vehicle or just the current status of the vehicle. In addition, the information could be used to improve the performance of the vehicle by better understanding the relationship between driving habits and performance. Diagnostic information could be downloaded and transmitted via cell phone to service personnel to aid in remote repairs.

There are five signaling protocols (SAE J1850 PWM, SAE J1850 VPW, ISO 9141-2, ISO 14230 KWP2000, ISO 15765 CAN) currently in use with the OBD-II interface. Any given vehicle will likely only implement one of the protocols. Often it is possible to make an educated guess about the protocol in use based on which pins are present on the J1962 connector. All OBD-II pinouts use the same connector but different pins are utilized with the exception of pin 4 (battery ground) and pin 16 (battery positive).

C. Vehicle Gateway Interface

The vehicle gateway interface with OSI model 7 layer's protocols included CAN bus and OBD-II standards is important and suitable in telematics service systems. The vehicle gateway interface can collect raw data from sensors' network and mobile network. Then, it transforms probe data collection, controls and transfers to produce useful services information. Therefore, effective application scenarios can be finished for the telematics/ITS services. The block diagram of general vehicle gateway interface is shown in Figure 1 [8]. Where BCM denotes body control module, ECM denotes engine control module.

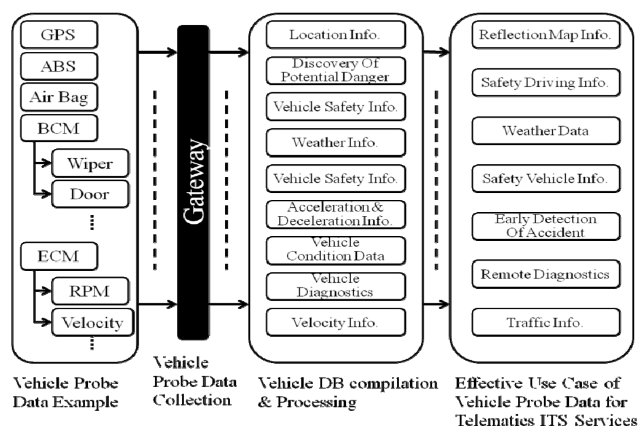


Figure 1. Vehicle gateway interface

D. Telematics Gateway for EV

Based on vehicle gateway interface given above, the basic structure of telematics gateway interface for EV is shown in Figure 2. Due to the characteristics of EV in the sensors' network and mobile network, the telematics gateway is evidently different from vehicle gateway interface on the probe data collection and services information.

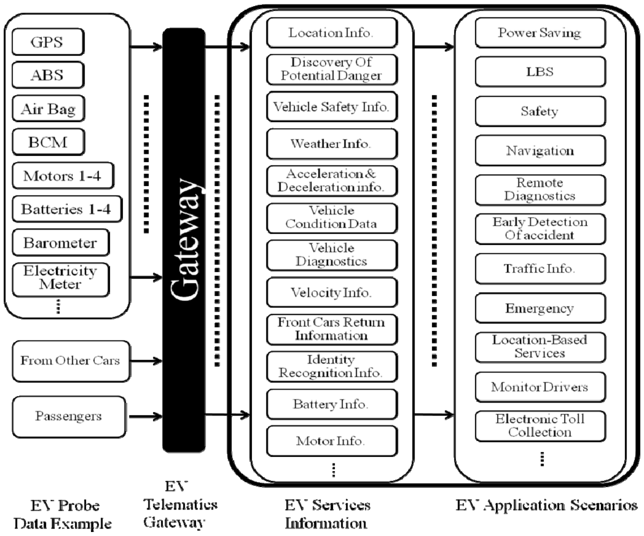


Figure 2. Telematics gateway for EV

Using this telematics gateway interface for EV, one can get raw and useful information from different sensors: GPS、ABS、 Air Bag, Battery, Motor, Diagnostics and Vehicle Body Control *etc*. Therefore, the useful information can be processed and applied to feasible and different application scenarios. For examples: power saving, LBS (location base service) and safety *etc*.

III. PROPOSED FRAMEWORK OF TELEMATICS GATEWAY

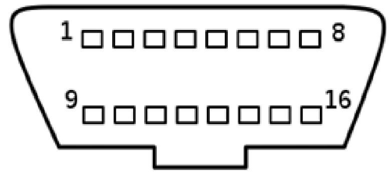
The features of proposed telematics gateway interface for EV based on the structure of Figure 2 are summarized as follows.

1. Three standard control technologies
   (1) CAN bus
   (2) OBD-II connector
   (3) Vehicle gateway interface in Figure 1
2. General purposes
   (1) Diagnostics
   (2) Information communication and technology
3. Application scenarios
   (1) Power saving
   (2) LBS (location based service)

The proposed conceptual framework of telematics gateway interface can resolve two issues: One is to simplify the framework of EV gateway interface and the other is to ensure the application scenarios for power saving and location based service. This framework will be divided into two parts: probe data port and multilayer architecture.

A. Probe Data Port

The proposed telematics gateway interface includes a probe data port using OBD-II connector compatible. The definition of the proposed data port is depicted in Figure 3.



1.	Manufacturer discretion. GM: J2411 GMLAN/SWC/Single-Wire CAN.
2.	Bus positive Line of SAE-J1850 PWM and SAE-1850 VPW
3.	Ford DCL(+) Argentina, Brazil (pre OBD-II) 1997-2000, USA, Europe, etc.
4.	Chassis ground
5.	Signal ground
6.	CAN high (ISO 15765-4 and SAE-J2284)
7.	K line of ISO 9141-2 and ISO 14230-4
8.	—
9.	—
10.	Bus negative Line of SAE-J1850 PWM only (not SAE-1850 VPW)
11.	Ford DCL(-) Argentina, Brazil (pre OBD-II) 1997-2000, USA, Europe, etc.
12.	—
13.	—
14.	CAN low (ISO 15765-4 and SAE-J2284)
15.	L line of ISO 9141-2 and ISO 14230-4
16.	Battery voltage

Figure 3. The probe data port

The main data communication adopts pin 6 and pin 14 with CAN bus standard. In this paper, telematics gateway interface presents 9 categories of sensors code for different application scenarios of EV. The 9 categories of sensors code include GPS, ABS, Air Bag, Battery, Motor, Diagnostics, Vehicle Body Control, Barometer, and Electricity meter are shown in Table 1. Category 1- GPS includes latitude, longitude, time and date. Category 2- ABS includes tire pressure and slide. Category 3- Air Bag includes collision. Category 4 – Battery includes system status, level input, output voltage, output current, temperature, state of health and state of charge. Category 5 – Motor includes input voltage, input current *etc*. Category 6 – Diagnostics includes error codes, alarm *etc*. Category 7 – Vehicle Body Control includes batteries protection, automatic door locks *etc*. Category 8- Barometer includes Atmospheric pressure and slope. Category 9- Electricity meter includes power storage. The Category 1-9 is dependent on the types of sensors and can be collected, processed, and applied to different application scenarios. For example: Category 4 – Battery and Category 5 – Motor can provide the services information of voltage, current, torque, rotation speed and electric energy states for power saving scenario.

Table 1. 9 categories of Sensors code

Name	Description
Category1 - GPS	
Lat	Latitude
Lon	Longitude
COG	Course over Ground

T	Time
D	Date
Category 2 - ABS	
TP	Tire pressure
Sli	Slide
Category 3 - Air Bag	
Col	Collision
Category 4 - Battery	
B(1-4)SS	Batteries 1-4 System Status
B(1-4)LI	Batteries 1-4 Level Input
B(1-4)OV	Batteries 1-4 Output Voltage
B(1-4)OC	Batteries 1-4 Output Current
B(1-4)T	Batteries 1-4 Temperature
B(1-4)SOH	Batteries 1-4 State of Health
B(1-4)SOC	Batteries 1-4 State of Charge
Category 5 - Motor	
M(1-4)IV	Motors 1-4 Input Voltage
M(1-4)IC	Motors 1-4 Input Current
M(1-4)LV	Motors 1-4 Load Value
M(1-4)T	Motors 1-4 Temperature
M(1-4)RPM	Motors 1-4 RPM
RTSM(1-4)S	Run Time Since Motors 1-4 Start
VS	Vehicle Speed
Category 6 - Diagnostics	
FDTC	Freeze Diagnostic Trouble Codes
DTWMILO	Distance traveled with Malfunction Indicator Lamp on
DTSCC	Distance traveled since codes cleared
TRWMILO	Time run with Malfunction Indicator Lamp on
TSTCC	Time since TC cleared
Category 7 - Vehicle Body Control	
ADL	Automatic door locks
DLI	Door lock inhibit
Category 8 - Barometer	
AP	Atmospheric pressure
Slo	Slope
Category 9 - Electricity meter	
Pow	Power storage

B. Multilayer Architecture

The conceptual framework of telematics gateway interface is an open system interface, and establishes a three layers' architecture, the physical layer, data link layer and the application layer, as shown in Figure 4.

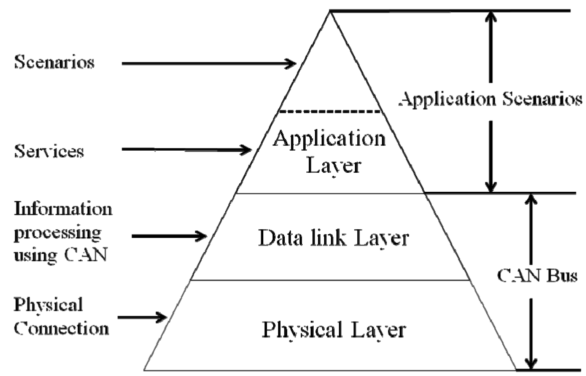


Figure 4. Multilayer architecture

The Physical Layer and its associated wiring using OBD-II connector compatible with CAN bus standard form the interconnecting path for information transfer between Data Link Layers. The physical Layer protocol elements include voltage and current levels, media impedance, and bit/symbol definition and timing.

The primary function of the Data Link Layer based on CAN bus standard is to convert bits and/or symbols to validate error free frames or data. The services provided are serialization (parallel to serial conversion) and clock recovery or bit synchronization. An important additional service provided by the Data Link Layer is error checking. When errors are detected, they may be corrected or higher layers may be notified.

At the top of telematics gateway interface is the Application Layer with versatile services information for different application scenarios. This layer establishes the relationship between application input and output devices, including what is expected of human operators. This layer documents the high level description of different application scenarios.

IV. Application Scenarios

Based on the conceptual framework of telematics gateway interface given above for EV in Section III, two application scenarios include power saving and LBS (location based service) are evaluated as follows. Besides, other application scenarios along with services information will be done in the near future.

A. Power Saving Scenario

First, the telematics gateway interface gets useful probe data on voltage, current, torque, rotation speed, electric energy capacity, and slope *etc* from sensors' network and mobile network. Then, the telematics gateway can transform probe data collection, control and transfer to produce useful and versatile services information using 9 categories of sensors code in Table 1. Therefore, adequate services information into power saving procedure, one can obtain suitable real-time information for drivers to control electric vehicles for the purpose of power saving scenario. Based on telematics gateway interface given above in Figure 2, the conceptual block diagram of telematics gateway interface for power saving application scenario is shown in Figure 5.

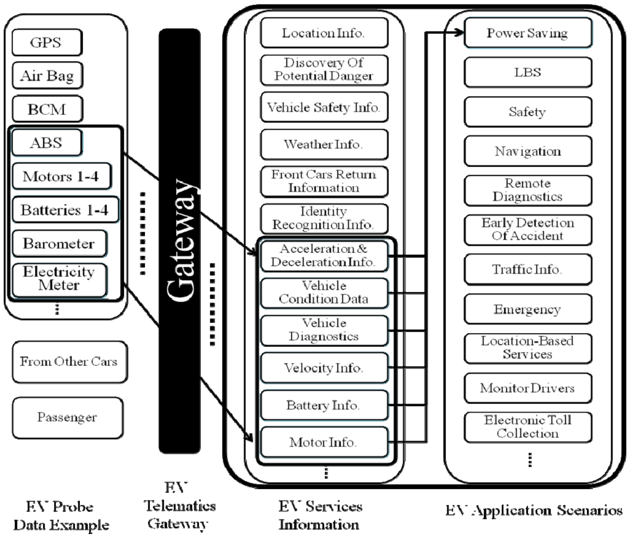


Figure 5. Power saving application scenario

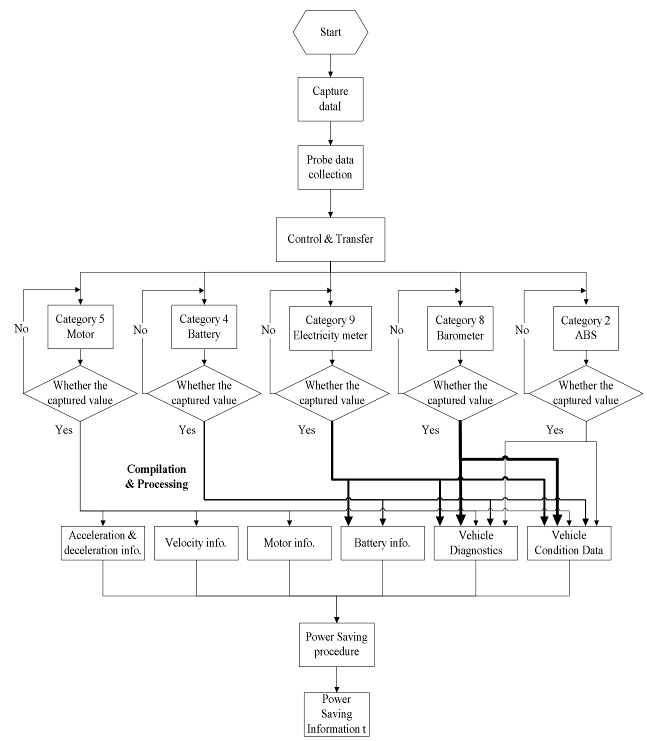


Figure 6. Flow chart of Power saving application scenario

The mapping flow chart of power saving application scenario is depicted in Figure 6. Among the flow chart, one can find a power saving procedure after adequate services information finished. The power saving procedure is implemented by existing motor and EV control theory, and is dependent on EV present services information about motor & battery attributes, power storage states, tire pressure, and slope *etc*.

B. LBS Scenario

Based on the present location data collection of electric vehicle from sensors' network and mobile network, the conceptual framework of telematics gateway can give suitable and convenient suggestions to drivers for safety, maintenance, and power charge *etc*. For example, when a vehicle has not enough power energy, telematics gateway interface can give information of the nearest power charge station and initiate the constant power motor driving mode for driver to get power charge and to achieve power saving effect. The basic block diagram of telematics gateway interface for LBS application scenario is shown in Figure 7.

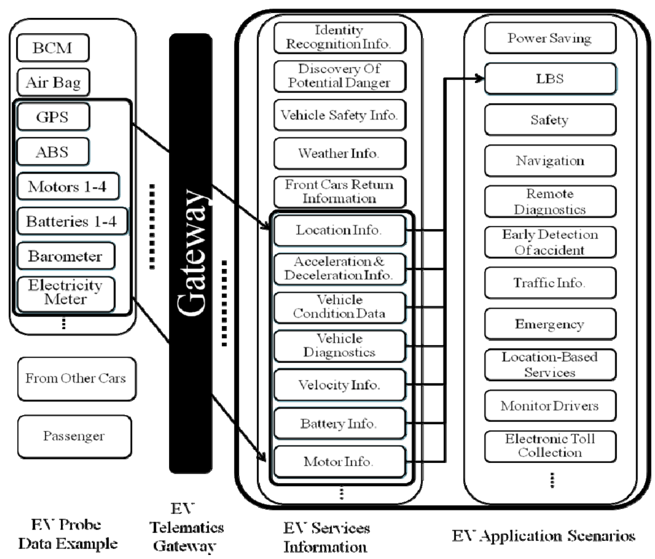


Figure 7. Telematics gateway for LBS application scenario

The mapping flow chart of LBS application scenario is depicted in Figure 8. It is similar to the flow chart given above. Among the flow chart, one can find a LBS procedure after adequate services information finished. The LBS procedure is implemented by existing location, motor and EV control theory, and is dependent on EV present services information about GPS, motor & battery attributes, power storage states, tire pressure, and slope *etc*. Therefore, adequate services information into LBS procedure, one can obtain suitable real-time information for drivers to control electric vehicles for the purpose of LBS application scenario.

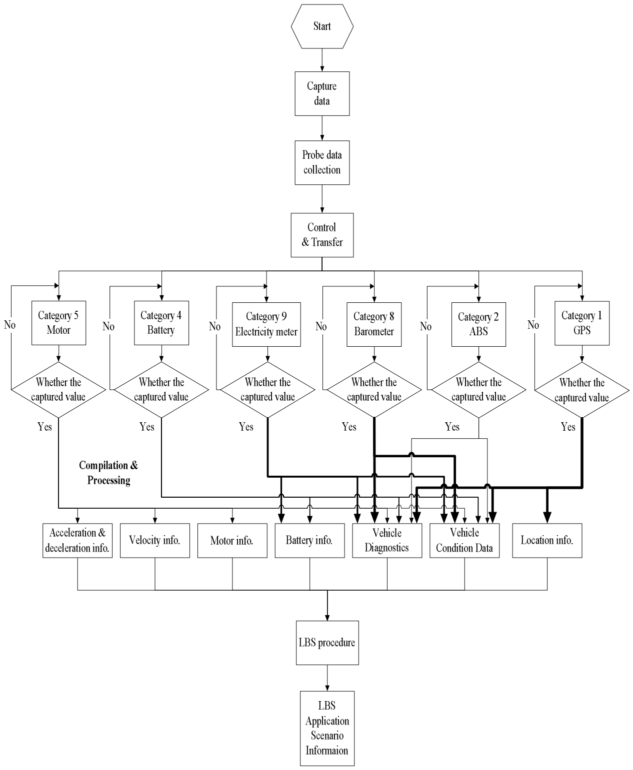


Figure 8. Flow chart of LBS application scenario

V. CONCLUSION

This paper proposes a conceptual framework of telematics gateway consists of a novel interface for EV by incorporating CAN bus, OBD-II and general vehicle gateway interface in the telematics service systems. In information and communication technology, CAN bus, OBD-II and general vehicle gateway interface are standard technologies, and have been applied to vehicles for many years but not to EV. The proposed telematics gateway has resolved two issues: One is to simplify the framework of EV gateway interface, and the other is to ensure the application scenarios for power saving and location based service (LBS). The preliminary framework of telematics gateway has been defined and satisfies power saving and LBS applications for electric vehicles in this study. Future works should include the incorporation of other application scenarios and control functions for temperature, driving automation *etc*. into the telematics gateway interface.

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