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OVERVIEW OF TELEMATICS: A SYSTEM ARCHITECTURE APPROACH

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ABSTRACT−In the mid 1990s, the combination of vehicles and communication was expected to bolster the stagnant car industry by offering a flood of new revenues. In-vehicle computing systems provide safety and control systems needed to operate the vehicle as well as infotainment, edutainment, entertainment, and mobile commerce services in a safe and responsible manner. Since 1980 the word "telematics" has meant the blending of telecommunications and informatics. Lately, telematics has been used more and more to mean "automotive telematics" which use informatics and telecommunications to enhance the functionality of motor vehicles such as wireless data applications, intelligent cruise control, and GPS in vehicles. This definition identifies telecommunications transferring information as the key enabling technology to provide these advanced services. In this paper, a possible framework for future telematics, which is called an Intelligent Vehicle Network (IVN), is proposed. The paper also introduces and compares a number of existing technologies and the terms of their capabilities to support a suite of services. The paper additionally the paper suggests and analyzes possible directions for future telematics from current telematics techniques.

KEY WORDS : Vehicle telematics, Intelligent vehicle network, In-vehicle network architecture

1. INTRODUCTION

Telematics technologies might indeed deliver an enticing variety of in-vehicle services, which may still revolutionize the experience of driving. Telematics may help carmakers obtain an ongoing revenue stream and help regulators progress towards intelligent transportation system and their associated benefits of pollution reduction, reduced transit times, and reduced road fatalities. Also for consumers there should be an effective service price reduction via economies of scope and the less quantifiable benefits associated with access to safety and security services. There is a very interesting report published by ATX Technologies about customers' desire for advanced technologies (Wallace, 2000). Through surveying their telematics subscribers, ATX Technologies confirmed the popularity of telematics systems. Approximately 70 percent of the subscribers indicated they would ask a telematics system on their next vehicle. Over 80 percent would recommend the telematics system to a friend or acquaintance.

It is important to understand the definition of telematics and what constitutes a telematics-enabled automobile. Since 1980 the word "telematics" has meant the blending of telecommunications and informatics (Zhao, 2002). This definition identifies telecommunications transferring information as the key enabling technology to provide these advanced services. Also from a hardware standpoint we expect, in general, the following conditions are required for future telematics (Mattias, 1998):

- In-vehicle processor with application programs.
- Bus-based or wireless networking.
- Safety unit and dynamic navigation.
- Self-diagnostic device with user-friendly interfaces.
- Enterainment and multimedia devices.
- Emergency support, etc.

In this paper, we introduce current telematics technologies and propose a possible framework for future telematics, which is called Intelligent Vehicle Network (IVN). For current technologies, we introduce and compare a number of existing technologies and the terms of their capabilities to support suitable services. In addition, the paper suggests and analyzes possible directions for future telematics from current telematics techniques.

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The structure of this paper is as follows: In section 2 which is composed into four sub-sections, we introduce and compare a number of existing technologies and the terms of their capabilities to support a suite of services; A possible framework for future telematics, which is called an Intelligent Vehicle Network (IVN), proposed in this paper is discussed in section 3; and section 4 suggests and analyzes possible directions for future telematics from current telematics techniques and concludes this study.

2. CURRENT TELEMATICS TECHNOLOGIES

In this section, we introduce and compare a number of existing technologies and the terms of their capabilities to support suitable services. These technologies can be generally divided into four parts, in-vehicle networking (IN), intelligent transport system for driver's safety, vehicle diagnostics system, and in-vehicle entertainment system.

2.1. In-vehicle Networking (IN)

Many vehicles already have a large number of electronic control systems. The growth of vehicle electronics is partly the result of the customer's wish for better safety and greater comfort. And it is partly the result of the government's requirements for improved emission control and reduced fuel consumption. The complexity of the functions implemented in these systems needs an exchange of the data between each device. With conventional systems complex (William *et al.*, 1997), data is exchanged by means of dedicated signal lines, but this is becoming increasingly difficult and expensive as control functions become ever more. Moreover, a number of systems are being developed that implement functions covering more than one control device. For overcoming these problems, various methods have been carried out.

The candidate protocols of IN should satisfy the conditions, which are simple wire, easy to use, wide application range, flexibility and low cost.

In the following, the protocol, which is developed or being developed, is introduced and compared by terms of its characteristics and advantages.

2.1.1. D2B (Domestic Digital Bus)

Philips Consumer Electronics developed Domestic Digital Bus, or D2B for short, in 1988, and the standard was published in 1991. Originally developed with home audio in mind, it later became apparent that D2B was suitable for in-car use (Sweeney, 2002).

D2B Transfer Technology has the advantage of low cost, no interference and reliable operation, and no quality loss of the signal.

2.1.2. Bluetooth

Bluetooth is a short-range general-purpose wireless networking standard. Originally intended as a wire replacement for connections between computers, PDA (personal digital assistants), cell phones, and other devices, it has grown to become a personal area network (PAN) standard the applications of which grow daily (Khan, 2001).

Bluetooth Transfer Technology has the advantage of low cost, low power, good at Wide Area Network (WAN)/ Local Area Network (LAN) access points, support both voice and data, and operate in a license free band 2.45 GHz (Chaari *et al.*, 2002).

2.1.3. CAN (Controller Area Network)

CAN, Controller Area Network, is a serial bus system designed for networking 'intelligent' devices as well as sensors and actuators within a system. CAN was originally developed for passenger car applications. CAN is a serial bus system with multi-master capabilities, which means that all CAN nodes are able to transmit data and several CAN nodes can request the bus simultaneously. The serial bus system with real-time capabilities is the subject of the ISO 11898 international standard and covers the lowest two layers of the ISO/OSI reference model (Wense, 2000).

CAN protocol has the advantage of very little cost and effort to expend on personal training, low-cost controller chips can be employed in data link, and high transmission reliability/Short reaction times.

2.1.4. LIN (Local Interconnect Network)

In June 1999, five major European car manufacturers, one semiconductor supplier, and one tool vendor agreed on a specification for a class - multiplex protocol called LIN (Local Interconnect Network) (MOST Cooperation, 1999).

LIN message structure has the advantage of only master node determines scheduling, no arbitration takes place, schedule determined by a table, and latency & transmission are well known.

2.1.5. MOST (Media Oriented Systems Transport)

MOST, Media Oriented Systems Transport, was developed in conjunction with DaimlerChrysler, Becker, BMW, and Oasis beginning in 1997. It can be looked at as a successor of D2B even though D2B is an independent system that will continue in other applications. With the ever-increasing number of devices in vehicles, it was apparent that a new form of data transfer had to be developed to cope, and MOST is the result (Parnell, 2003).

MOST protocol has the advantage of ease of use, wide application range, synchronous bandwidth, asynchronous bandwidth, flexibility, synergy with consumer and PC industry, low implementation cost, and open systems interconnect reference model.

2.1.6. IDB-1394
The IDB (Internal Data Bus) Form manages the IDB-C, IDB-1394 buses, and standard IDB interfaces for OEMs for the development of after-market and portable devices. Based on the CAN bus, IDB-C is geared toward devices with data rates of 250 Kbps. Applications for IDB-C include connectivity through consumer devices such as digital phones, PDAs, and audio systems (Hadeler and Mathony, 2000).

2.1.7. System comparison
The requirements with respect to data transfer rate, protocol mechanism, reliability, fault tolerance, and costs are dependent of their applications and have led to the development and introduction of different network types. Figure 1 shows the characteristics of in-vehicle networks (Juliussen, 2003).

2.2. Intelligent Transport System
In the field of vehicle telematics, an intelligent transport system project has been developed to improve the driver's safety and driving comfort on any type of roads. This section introduces N.A.I.C.C. (Navigation Aided Intelligent Cruise Control) system that is presented by (Lauffenburger *et al.*, 2000). Generally, the purpose of an N.A.I.C.C. system is the driver alarm and the velocity control. In order to achieve this purpose, the N.A.I.C.C. system is based on a positioning module, a map-matching algorithm, a digital map database, a real-time velocity estimator, and a speed prediction module.

The appropriate speed can be predicted by considering the road characteristics. When the appropriate speed is calculated, the constraints are provided data such as driving style and speed reference. The sensors mounted on the vehicle and the real-time velocity estimator provides some information to the constraints. Each module's definition and detail content is described at the following paragraphs.

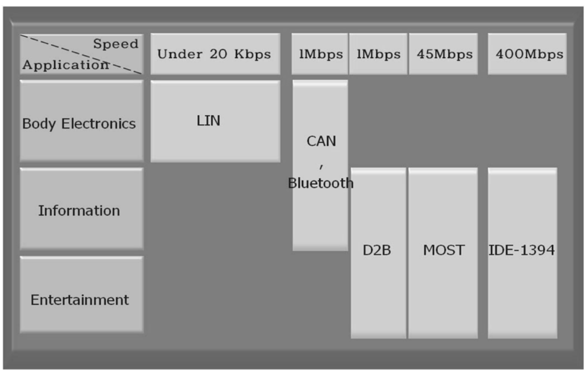


Figure 1. Characteristics of in-vehicle networks.

2.2.1. The positioning module
Positioning information is obtained by multi-sensor integration and fusion. Each sensor has its own capabilities and independent failures. The reason for multi-sensor integration and fusion is to compensate for the failures. The positioning module is based on GPS (global positioning system) system (Guo *et al.*, 2001) and Dead-Reckoning (Redmill *et al.*, 2001; Calafell *et al.*, 2000) data fused via filtering methods such as Kalman filters. Dead-Reckoning (DR) method and GPS systems operate together to compensate for their failures because the DR method uses relative positioning techniques and GPS the system is absolute positioning techniques. The positioning module is very important in the N.A.I.C.C. system, because most accurate vehicle positioning is best performance of the N.A.I.C.C. system. Therefore, the fusion algorithm (Lauffenburger *et al.*, 2000) has been implemented for accurate vehicle positioning. The fundamental concept of fusion algorithm increases accuracy by using the DR method when Differential Global Positioning System (DGPS) is used in an inappropriate environment. In other words, this algorithm uses the DGPS data when the signals are available and switches to the DR method when the number of visible satellites is not sufficient to ensure an accurate position.

2.2.2. The digital map database
In the N.A.I.C.C. system, the digital map database (Claussen, 1993) is an important system that relates to matching the trajectory and the known road or determining the optimal speed. The road curvature provided by the digital map database is used to determine whether the vehicle is located on a straight road or not and to predict the optimal speed. The Bezier curves approximation method (Venhovens *et al.*, 1999) allows a parametric description of the curve. This approximation method enables any type of curve to be defined. Therefore, the storage memory for a digital map database is not important compared with a traditional database structure. The basic concept of approximation is to consider every road as a bend, a straight line having a particular bend with an infinite radius of curvature.

2.2.3. The map-matching module
As presented in section 2.2.1 the fusion algorithm switches to the DR method when the DGPS is not sufficient to ensure an accurate position. Once the DR method is active, the system will gather an accumulative error. Thus, the DR position must match the nearest point on the digital map. The map-matching module for the N.A.I.C.C. system is based on an algorithm using only

geometric information called Geometric Point-to-Point Matching. The basic concept of Geometric Point-to-Point Matching is to match the point provided by the positioning module to the nearest point of a Bezier curve in the digital map database. This is more efficient than a traditional point-to-point algorithm because it is only necessary to calculate the distance between the dead-reckoned point and each point in the database to find the nearest point (Caves *et al*., 1991).

2.2.4. The speed prediction module

As shown earlier, the purpose of the N.A.I.C.C. system is the driver alarm and the velocity control. The optimal speed predicted by the speed prediction module (Holzmann *et al*., 1997) is compared with the estimated vehicle speed, and the system warns the driver of an inappropriate speed. At the same time, the system automatically adjusts the vehicle speed via a cruise control system (Ioannou *et al*., 1993). The speed prediction module requires some specific information to calculate the appropriate speed. Finally, the determination of the velocity is modeled by a finite state machine and adapted to the N.A.I.C.C. system.

The N.A.I.C.C system will play an important role in the future, not only to assess macroscopic traffic situations, but also to build microscopic road geometry databases. Communication technologies with an appropriate bandwidth, latency, and coverage need to be developed in order to enable the N.A.I.C.C. On the GPS side, there is a clear need for accurate low-cost receivers in combination with an extensive network of differential corrections.

2.3. Vehicle Diagnostics System

Vehicle diagnostics systems have been developed as design controls for system faults, which may result in failure modes. The final goal of diagnostics systems is to provide to the vehicle the best possible performance of all the electronics systems placed in the vehicle. Low cost displays and processors allow sophisticated diagnostics information to be accessed and displayed in the vehicle without requiring additional service-bay tools. In addition, inexpensive wireless wide-area networks allow remote access to the vehicle's electronic systems and thus allow for services such as predictive maintenance (Cirilo *et al*., 2000). This section introduces architecture of remote diagnostics system.

2.3.1. The vehicle electronic architecture & diagnostics system

The vehicle electronic architecture (Amberkar *et al*., 2000) has two modules. An engine control module is responsible for capturing the electric signals of the sensors' management and the ideal amount of fuel to be injected on the exact moment through the time of opening and closing of the injection valves. Another module is responsible for receiving the electronic signals of the footpedal accelerator and also of providing other functions of the cabin, such as engine brake, power take off, management of the sent or received information from the instrument cluster, and others. Besides, these modules can also interact with other existent ECU (Electronic Control Unit)'s in the electronic architecture responsible to manage specific functions of the vehicle, such as brakes, maintenance, gearbox and retarders, door controls and immobilizers.

In general, vehicle diagnostic systems are composed of an on-board diagnostic system, an off-board diagnostic system, and wireless communications. The on-board diagnostic system (Shultz *et al*., 2002) performs presentation of diagnostics information to the vehicle operator, other telematics applications, transmission of vehicle information, reactions to updates of vehicle parameters, and maintenance of security for access to vehicle diagnostic systems. Thus, the vehicle diagnostic system requires access to vehicle information that is provided from a data bus on-board the vehicle. The off-board diagnostic system gives necessary information to perform a preventive and corrective maintenance of the vehicle in the workshop. In the off-board diagnostic system, much diagnosis information requires more technical knowledge. Wireless communication is used to interface between the on-board and off-board diagnostic system for vehicle diagnostic systems. The progress of wireless communication increases the capabilities of vehicles to self-diagnose known failure modes that they have been pre-programmed to detect.

2.3.2. Architecture of integrated diagnostics system

Architecture of integrated diagnostics system (Campos *et al.*, 2002) is composed of the enterprise, application, and client.

The enterprise data layer is composed of the vehicle specific configuration database, vehicle diagnostic content database, and the vehicle test specification database. These databases support the lower level diagnostic applications. The lower level diagnostic applications need to interface with other enterprise information systems. In order to interface with other enterprise information systems, the J2EE (Borland, 2003) framework provides a connector API (Application Program Interface), which is used to create adapters to provide common access to the enterprise layer. The enterprise data layer also captures the summary data that is being collected from all of the diagnostic sessions. Thus, the diagnostics experiential database contains not only the information about the symptoms of a vehicle problem, but also a history of the diagnostic steps. This information can be used to optimize the diagnostic processes that are used to resolve future problems.

The application server layer performs hosting diagnostic applications, managing diagnostic sessions, sending diagnostic bundles to diagnostic clients, pre-processing and sending configuration data to the client-side diagnostic applications, downloading configuration data to vehicle processors, and downloading new software to vehicle on-board processors. The remote diagnostic scenario is a subset of the total diagnostics infrastructure needed to support the vehicle fleet during its lifecycle. For the remote diagnostics scenario, the diagnostic application developer will have to perform a trade-off between on-board and off-board processing. The obvious benefit of this architecture is that every unit in the fleet could receive a software update without having to return to the base location.

Client devices and applications perform hosting on-board diagnostic applications, executing diagnostic bundles delivered from the remote server, reading data from processors on the vehicle data bus, sending data to the remote server, writing configuration parameters to processors on the vehicle data bus, downloading new software to vehicle processors, and commanding processors to actuate devices under their control. The client architecture provides secure and controlled access to the vehicle data bus through the implementation of custom bundles for server messaging and vehicle communications interface.

Vehicle diagnostics systems may be the most important telematics application for the auto manufacturers because vehicle diagnostics system has potential savings in operational cost, warranty cost, and design improvements.

2.4. In-vehicle Entertainment System

An in-vehicle entertainment system (Schopp and Teichner, 1999) is a system integrator that displays data efficiently for the driver and other passengers. The input data include navigation information from a GPS and maps, entertainment systems, mobile phones, and in some regions, road-tolling systems, that can be updated. The output data include driver and passenger screens and audio.

An in-vehicle entertainment system must include traffic information systems, Internet/Web access, electronic game consoles, mpeg music download capability, digital radio reception, and mobile commerce services. The optical bus system enables further integration of computing functions and computing applications, which require interactivity for Internet access and games. These applications can be connected via gateways to PC platforms. A gateway is a router between the different electrical and optical buses in a vehicle. Gateways to the optical bus may connect the mobile phone, the media changer, the navigation unit and other devices to a PC in the vehicle, at the same time may give displays for the front and rear seats access to the PC unit.

An in-vehicle entertainment controller is composed of processor, telematics, interface, and entertainment, as shown Figure 2. The processor provides all of the control functions of the system. The GPS, wheel sensors, and tachometer interfaces receive navigational, wheel-speed, and engine-speed information and pass it to the LCD graphics controller for display. The entertainment unit provides access to the automobile's CD-ROM player, where MP3 music files are stored. The system's navigational data, as used by the GPS system, can also be stored here. MP3 music files are sent to the automobile's audio system for playback via the audio interface. The interface unit provides the controller access to all of the automobile's driver-information and entertainment systems, such as the on-board-computer, via the Ethernet interface.

3. INTELLEGENT VEHICLE NETWORK(IVN)

In this paper, a possible framework for future telematics, which is called an Intelligent Vehicle Network (IVN), is

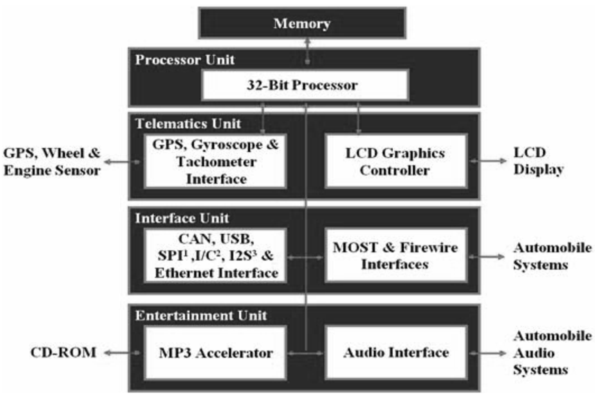
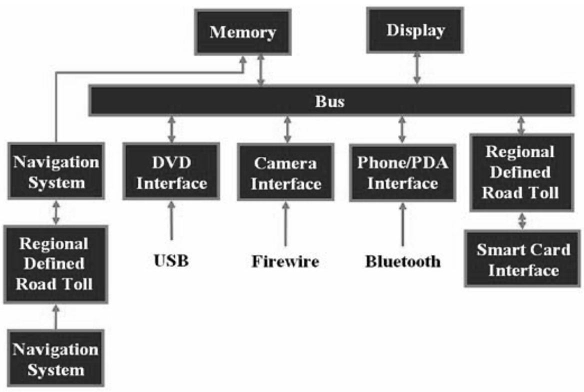


Figure 2. Configuration of the in-vehicle entertainment system.



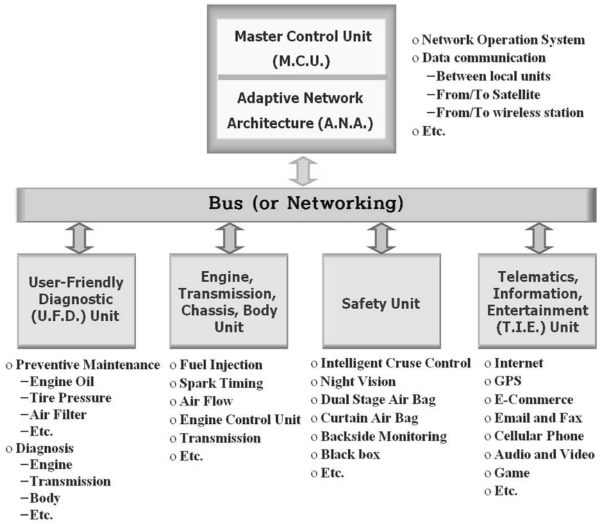


Figure 3. Intelligent vehicle network.

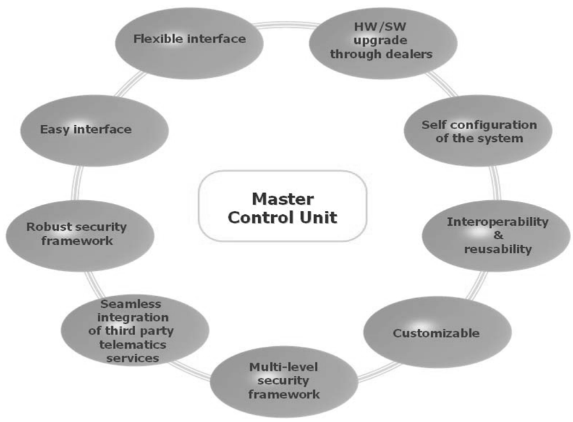


Figure 4. The requirement of master control unit.

proposed. The IVN consists of a Master Control Unit (MCU), an Adaptive Network Architecture (ANA), an In-vehicle network, a User Friendly Diagnosis (UFD) unit, a safety unit, and an entertainment unit. Figure 3 shows the relationship between units.

3.1. Master Control Unit (MCU)

In this section, a description is given of MCU, which is a platform of the telematics systems that manages many customized services such as information, entertainment, and wireless Web connection, it also displays/announces information of a vehicle's conditions and controls a sub-unit's behavior.

The detailed conditions required for an MCU are shown in Figure 4. That is, the interface to the sub-units is always made through an in-vehicle network connection. The format of the requests and responses are standardized.

Defining the interface as a network connection makes the interface programming independent and flexible. Because the software life cycle is shorter than a vehicle's, the MCU can be upgraded easily after installation through wireless communication. The communication with the driver must be supported by various methods, such as a user-friendly graphic interface and voice recognition.

In the Table 1, the platforms Microsoft Car.Net and Sun Microsystems Java platform are introduced (Rogers *et al*., 2000). Figure 5 shows the concept of relationship between MCU and Adaptive Network Architecture (ANA).

3.2. Adaptive Network Architecture

This section describes the overall architecture of an adaptive network. The fast improvement of the networks has led to the change of service from text based media applications to multimedia applications. In these conditions, two factors should be considered.

Firstly, service specific network environment should be provided. According to a media type, different transmit systems and different levels of Quality of Service (QoS) are used. Secondly, networks should have an

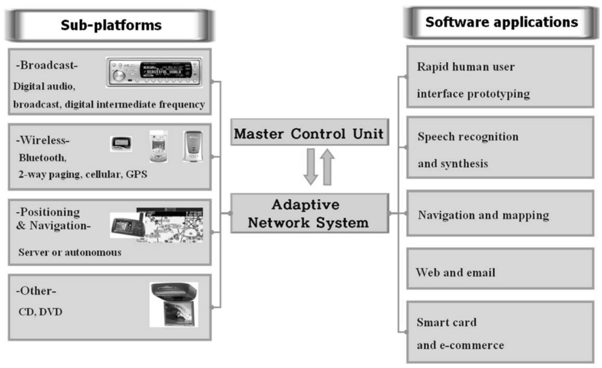


Figure 5. Master control unit & adaptive networkarchitecture.

Table 1. The comparison of car.net and java.

The Microsoft Car.Net platform	Sun Microsystems Java platform
• A potential platform for delivering Telematics applications	• Available for a wide variety of devices
• An XML/internet centric framework	• Neutral language platform
• The most widely known user interface	• Extensive standard libraries

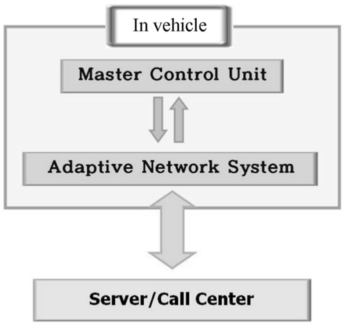


Figure 6. Adaptive network architecture.

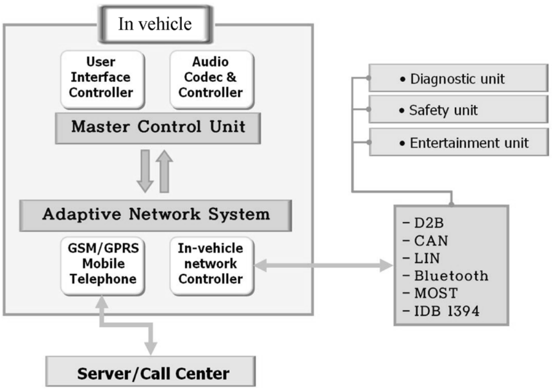


Figure 7. Adaptive network architecture decomposition.

ability to adapt against the change of QoS.

At present, a lot of research on adaptation in mobile networks are carried on, as are the studies on QoS management and adaptation. An adaptive network architecture is proposed here. An example model of Adaptive Network Architecture is shown in Figure 6. The vehicle contains an MCU and an ANA and connects across an air-interface by wireless communication to a server and call center system (Noh *et al*., 2001; Ciocan, 1990).

The vehicle subsystems can also be presented in more detail, as shown in the example in Figure 7. The user interface controller represents the audio-video display and input methods such as buttons, touch screen, and voice. Communication between the in-vehicle components and the exterior is managed by the ANA.

4. THE FUTURE OF VEHICLE TELEMATICS AND CONCLUSIONS

During the last two decades, the automobile has made the transformation from an analogue machine with mostly mechanical and hydraulic control systems to a digital car with a rapidly growing volume of computer-based control systems. Vehicles in the future will have significant increases in capability and demands for wireless communications resources. Applications include vehicle status and maintenance information, navigation information, entertainment, and concierge services. To meet these needs, the vehicle must have the capability to allocate and prioritize communications resources in response to the needs of applications (Arnholt, 2000).

The telematics connection in the vehicle of 2010 very likely will incorporate most of the leading-edge items that can be found in many high-end vehicles today or will be in the not-too-distant future: a built-in GPS and wireless phone link and a connection to all of the vehicle's on-board sensors and an in-vehicle display unit

Table 2. Prospect of the automobile telematic system.

	Current offering	Future offering
Safety and security	· Automatic collision notification · Roadside assistance · Remote door unlock · Embedded voice service	· Basic auto diagnostics · Medical profiling · Voice recognition
Mapping/Traffic	· On-board turn by turn directions · CD based electronic maps · GPS location tracking · Dynamic route guidance	· Real-time traffic information · Location based services · Off-board, real time navigation info
Entertainment	· Satellite radio · Stand-alone devices	· Chat · Streaming media · Web browsing · Mp2/MPEG download · Mobile-commerce · Games
Communications	· Hands free voice dialing	· Voice mail · Mobile office · E-mail · Video phone · Personal data synchronization · Vehicle service appointments

or portable display units similar to current PDAs (personal digital assistants) (Greer, 2001).

Automotive system engineers have begun evaluating different types of advanced wireless technologies for inclusion in their future models. Driven by the profound success of cellular and personal communications systems (PCS), information access is the key to providing new consumer value. And wireless is the only way to get it in an automobile. In the coming years, expect to see all of Table 2: (Telematics Research Group, 2002).

Continued technology improvements and cost declines will drive the telematics industry. Telematics hardware, software, and services will improve dramatically in the next ten years due to telematics and automotive electronics advances, and also from technology improvements in the computer, tele communications and consumer electronics industries. The role of future telematics will increase the interaction between the driver, the vehicle and the environment. There are still many huddles to overcome, such as costs for hardware devices, bandwidth of air carriers and operating costs. We believe these will diminish over the next few years.

In this paper, we have introduced and compared a number of existing technologies and the terms of their capabilities to support a suite of services. In addition, the paper has suggested the possible framework for the architecture of future telematics. Telematics can be a key to making car sharing or public transport work. Also the use of telematics can be very effective in making the zero and low emission vehicles an attractive alternative for the end users.

This paper will have a major impact on the work of telematics consultants and policy makers who will be able to rapidly understand the configuration of new architecture and techniques in the management and planning of transportation areas.

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