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Overview of Diagnostic over IP (DOIP), Ethernet Technology and Lightweight TCP/IP for Embedded System

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Abstract- The new generation vehicle will provide connectivity and telematics services for enabling vehicle communication. The diagnostic over IP in TCP/IP means enables a connection between diagnostic tool and in-vehicle nodes using IP protocols. In vehicle diagnostics, the diagnostic tools and vehicles are separated by an internetwork. The DoIP (Diagnostic over IP) standard is used to develop a prototype for vehicle diagnostics. The main aim of using IP into the family of automotive diagnostic protocol is that the development of new in-vehicle network has led to the need for communication between external test equipment and onboard ECUs using many data link layer technologies. Ethernet technology will provide high speed data transmission. DoIP is a protocol mainly used for communication between off-board and on-board dignostic system. This will improve the opportunities of interconnecting in-vehicle networks with internet for many new applications, including online, remote automotive diagnostics. Due to the limited resource availability in embedded devices, lightweight TCP/IP implementation is adopted. AutoSAR (Automotive Open System Architecture) is the layered software architecture developed for implementing communication between ECUs (electronic control units) in vehicle and the diagnostic tools outside.

I. INTRODUCTION

New generation vehicles introduce the concept of providing communications services through the use of advanced software's and microcontrollers. Nowadays many ECUs (Electronic Control Units) are inserted in the vehicle for different purposes and they communicate with each other through buses and act like a LAN (Local Area Network). In order for these units to communicate with the outside world (internet) an IP protocol is mandatory. AutoSAR (Automotive Open System Architecture) [1] is the standard software architecture used for providing a basic infrastructure to assist with developing vehicular software, user interfaces and management for all application domains. This includes the standardization of basic system functions, scalability to different vehicles and platform variants, transferability throughout the network, consideration of availability and safety requirements, integration from multiple suppliers, maintainability throughout the entire product life cycle and software upgrades and updates over the vehicles life time. AutoSAR is jointly developed by automotive manufacturers, suppliers and tool developers. This architecture model is supported by an automated methodology to create the software executable for the ECUs, starting from the design model and the properties and physical topology of the hardware.

With the development of computer technology, embedded TCP/IP protocol stack becomes an important part of network information intelligence [2]. TCP/IP represents a protocol stack, which is composed of a series of small and special protocol including IP, TCP, UDP, ICMP, FTP, SMTP, ARP. Embedded equipment for upper network protocol stack usually chooses to use the TCP/IP protocol. TCP/IP protocol can support internal network or networks to communicate and exchange of information with the internet and world-wide networking. The characteristics of embedded TCP/IP are portable, configurable, real time, simplicity and flexibility. Due to the limitations of computing resources in ECUs, a lightweight TCP/IP implementation in embedded system is needed. Lightweight TCP/IP means reduce the functions of normal TCP/IP protocol stack. The link layer of the TCP protocol stack, network interface layer, is referred to the Ethernet physics interface and the Ethernet interface. The link layer is to drive the Ethernet interface circuit, programming network card driver and Ethernet interface according to interface circuit, so as to realize the system connects network.

The development and introduction of new diagnostic concepts and diagnostic solution offer significant potential to automotive OEMs (Original Equipment Manufacturers) and suppliers for realizing efficiency gains and quality improvement. Growing complexity in automotive electronics can only be mastered technically and economically by use of nonproprietary standards such as ODX, close cooperation and powerful tools. The DoIP standard is used to develop a prototype for vehicle diagnostics. The main aim of using IP into the family of automotive diagnostic protocol is that the development of new in-vehicle network has led to the need for communication between external test equipment and onboard ECUs using many data link layer technologies. In order to avoid the implementation and optimization of transport and data link layer protocols for each new communication equipment development, the common internetworking protocol IP is designed. Until few years ago, the opinion was that Ethernet would never be used for in-vehicle applications, with the exception of diagnostic access [3]. The Ethernet technology presents a new challenges to automotive OEMs, suppliers and development tool producers, because the internet protocol (IP) and Ethernet represents a new network technology for motor vehicles.

II. DOIP

In the case of remote vehicle diagnostics, the diagnostic tool and the vehicle are separated by an internetwork.

Through diagnostic services, the state-of-health of components and subsystems can be monitored to detect and prevent failures by means of predictive maintenance, which improves operational availability and lowers support cost.

Mathias Johanson et al. [4], explains the implementation of DoIP for remote vehicle diagnostics. The paper mainly concentrated with how the DoIP standard is used for connectivity and telematics services. The paper deals with remote vehicle diagnostics and integrated automotive diagnostics. Remote vehicle diagnostics means, it is possible to access diagnostic data from vehicle remotely, without requiring physical access to the vehicle. The integrated diagnostic systems rely on standardized interfaces for communication and system integration and to base the diagnostic software development on component-based software architecture. This facilitates re-use of software components and makes integration of components and subsystems from many different vendors possible in an interoperable way.

For communication between on-board and off-board diagnostic system, the Diagnostic over IP protocol is developed under the name ISO 13400 [3]. This will improve the opportunities of interconnecting in-vehicle networks with the Internet for many new applications, including online, remote automotive diagnostics etc.

ISO 13400-2:2012 specifies the requirements for diagnostic communication between external test equipment and vehicle electronic components using IP, TCP and UDP. This includes the definition of vehicle gateway requirements (example: for integration into an existing computer network) and test equipment requirements (example: to detect and establish communication with vehicle).

The mandatory features of ISO 13400-2: 2012 are

a. Vehicle network integration (IP address assignment).
b. Vehicle announcement and vehicle discovery.
c. Vehicle basic status information retrieval(example: diagnostic power mode).
d. Connection establishment, connection maintenance and vehicle gateway control.
e. Data routing to and from the vehicle's sub-components.
f. Error handling(example: physical network disconnect.

The optional features of ISO 13400-2:2012 are

a) DoIP entity status monitoring.
b) DoIP entity firewall capabilities.

The DoIP protocol specifies several payload types that are not directly related to diagnostics in terms of the ISO 14229 scope [15]. (Only payload types 8000 and 8001 are intended for ISO14229 diagnostics.)

In order to gain practical experiences from remote online diagnostics and to explore how this can be realized using the DoIP protocol, the authors of [4] implemented a prototype system and tested in a controlled environment. Since no vehicle with an on-board DoIP gateway was available, they decided that a DoIP gateway would be implemented on a Linux-based telematics system that could be connected to a standard vehicle's CAN buses through the OBD-II connector. The telematics platform has GPRS, EDGE and WLAN network interfaces as well as Ethernet interfaces. The DoIP entity implemented in the telematics unit handles the routing of diagnostic data between the in-vehicle (CAN) networks and the DoIP TCP connection on the wireless network interfaces.

III. ETHERNET

Present communication architecture composed of five different communication technologies (LIN, CAN, FlexRay, Most, LVDS) [5] used to interconnect 100s of different ECUs. Upcoming trend in automotive electronics with more driver assistance and multimedia features, the current low band width special technology needs to be upgraded to a homogeneous technology with cost effective production [6]. Ethernet could contribute homogeneous future communication architecture for high bandwidth applications with cost-effectiveness. Widely used, standard, protocols over IP can be used for special requirements of reliability and safety.

Many years ago, there was an opinion that Ethernet would never be used for in-vehicle applications. Camera-based driver assistance system will be the first applications to utilize ethernet technology as a system network [7]. This presents new challenges to automotive OEMs, suppliers and development tool producers, because the internet protocol and Ethernet represents a new network technology for motor vehicles.

In the existing systems CAN driver is used to assist the communication between the gateway connecting in-vehicle nodes and external test equipment such as a tablet or personnel computer. The new technology tries to support online remote diagnostics. In this case an internet services may be needed for connecting the in-vehicle ECUs to the diagnostic tools reside in remote area. So an Ethernet connection may improve the performance in it. IEEE 802.3 based wired vehicle interface standard is used for the Ethernet services. This protocol specifies the physical and data link layer requirements.

AutoSAR is the main software architecture accepted world-wide for automotive communication. AutoSAR provides specification for all its modules and how the modules are inter-related.

In an embedded system, an MCU (Micro Controller Unit) is act as a gateway for communication between in-vehicle ECUs and outside networks, and AutoSAR may be the software running inside it. Not all microcontrollers are supporting Ethernet technology. Nowadays MPC5668G [8] provide support for fast Ethernet services. So the software developers may use this opportunity for correlating hardware and corresponding AutoSAR specifications to provide Ethernet technology in automotive communication. This will improve the speed of data communication by using the high bandwidth capability of Ethernet.

Using DoIP technology, it is possible to centrally flash all ECUs connected to the various bus systems via high performance Ethernet access. System development at the OEM must validate this service. Since an ECU is used as the gateway, there is great interest in analyzing the transmission of diagnostic data in the various connected bus systems. Due to cost reasons Ethernet access is no longer provided in the production vehicle. The caliberation and reprogramming are using the existing working protocol such as CCP, XCP on CAN. In the near future, Ethernet makes it way into the vehicle, then measurement and caliberation over XCP on

Ethernet would also be very attractive in production vehicles due to its significantly higher measurement data rates.

IV. LIGHTWEIGHT TCP/IP

The focus of the lightweight TCP/IP implementation is to reduce resource usage while still having a full scale TCP. This makes lightweight TCP/IP is suitable for use in embedded systems with tens of kilobytes of free RAM and room for around 40 kilobytes of code ROM. The existing related works in the area of lightweight TCP/IP are given below.

Liao et al. proposed an optimized design and implementation of the TCP/IP software architecture based on an embedded system, which made efficient use of the available resources [9]. They also experimented with an ARM9 processor and a CS8900A wired Ethernet interface

Li and Chiang developed a TCP/IP stack called LyraNET [10]. It has a zero-copy mechanism to reduce protocol processing overhead and memory usage. In their experiment using a wired Ethernet, the protocol processing overhead of LyraNET was decreased by 23–56% compared with the Linux TCP/IP and the object code size was 78% the size of the Linux TCP/IP.

Dunkels et al. applied lwIP to wireless sensor networks and also proposed methods to increase the TCP/IP performance of the lwIP in wireless sensor networks. LwIP is representative of open source TCP/IP stacks for small embedded systems [11].

In-Su Yoon, Sang-Hwa Chung and Jeong-Soo Kim et al. [12] proposed a lightweight TCP/IP stack called Compact Wireless-TCP/IP (CW-TCP/IP). It can provide superior wireless performance for small embedded systems that have limited computing resources. CW-TCP/IP processes TCP/IP using a simple data structure called a Connection Control Block (CCB) that is suitable for small embedded systems. It has a small memory footprint and does not reference other data structures to create TCP/IP headers. CW-TCP/IP adopts TCP Veno as a congestion control algorithm to improve wireless performance. The authors conducted experiments to compare the performances of CW-TCP/IP, Linux TCP/IP and μC/TCP-IP of μC/OS-II, which is widely used as an OS for small embedded systems. The object code size of CW-TCP/IP is 26 KB, which is approximately 17% the size of Linux TCP/IP and 30% the size of μC/TCP-IP.

Guangjie Han, Maode Ma et al. [13], proposed a configurable tiny TCP/IP protocol stack integrated with Session Initiation Protocol (SIP) module for a Wireless Sensor Networks.. Using it, they customize the different protocol set of tiny TCP/IP stack based on the different resource conditions of sensor nodes. SIP is an application-layer protocol that allows multiple end points to establish media sessions with each other. SIP has some characteristics such as protocol independence, flexible naming, and support of mobility.

Chong FU, Zhi-liang ZHU, Xiao-xing GAO and Pei-rong WANG et al. [14] proposes a design and implementation scheme of a general reduced web server protocol stack which aims at the limited resources characteristic that the embedded system has. Their studies are based on AT9OS8515 single chip that uses RISC technology and RTL-8019 network interface controller hardware platform. The study covers the overall design issues and the implementation methods of core protocols in protocol stack such as 802.3, ARP, IP, TCP and HTTP

V. CONCLUSION

Overview of DoIP, Ethernet technology and lightweight TCP/IP are discussed in this paper. The AutoSAR standard enables the use of a component based software design model for the design of a vehicular system. In the near future, Ethernet technology becomes the more attractive ones to provide high data transfer rate during the communication between in-vehicle ECUs and internet through a gateway. The resource limitations of the embedded equipment force the development of lightweight TCP/IP for effective communication. The global standard, ISO 13400 is used for implementing DoIP protocols in automotive communication.

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