Networks in automotive systems: the potential for Optical Wireless integration

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ABSTRACT
Vehicular communications have become an attraction field to researchers in different sectors; from electronic systems, then communication technologies, automotive control systems, to network topology developers. Control, audio and video signals are circulated within a vehicle using wired and wireless networks. Optical Wireless (OW) technology has started to be used in intra-satellite links and aircraft, since it offers high bandwidth and resistance to electromagnetic interference (EM). As more electronic systems are being within a vehicle, EM exists, especially in the engine compartment. Thus it is an attractive proposition to use OW in cars.

In this paper, a review of control and multimedia systems in vehicles is presented. An overview of implementing OW in vehicles for future automotive communication technologies will also be discussed.

Keywords: Optical Wireless, Intra-vehicle, control system, multimedia system

1. INTRODUCTION

The use of communication networks in vehicles began in the early 1990's. Specific applications of different car needs has led to the development of sizeable automotive networks such as the Controller Area Network (CAN), Local Interconnect Network (LIN), Time-Triggered Protocol (TTP), FlexRay, Bluetooth, Media-Oriented System Transport (MOST), and so forth.

As vehicle communication networks are becoming more popular, both wired and wireless connections have made new demands on research and innovation in this field, especially wireless connections. Congestion and limitation of RF bandwidth due to international agreements prevents the growth of the RF wireless system. Optical wireless yet holds the potential of delivering high data rates, unlicensed spectrum, security and low cost. Consequently, optical wireless is believed to be a feasible choice for numerous applications in wireless communications in vehicles.

2. INTRA-VEHICLE NETWORKS

Intra-vehicle networking involves various types of network which can be categorized into wired- and wireless networks, as in Figure 1. All these networks are used to communicate between various control systems in the vehicle, as well as providing telematics. Previously, vehicle control systems used copper wire-based systems, but this type of system will have effects on the electromagnetic environment, and are not suitable for carrying high speed information. The use of electronics systems, and the demand for high bit rate transmission has led to the use of optical busses in vehicles [1][2].

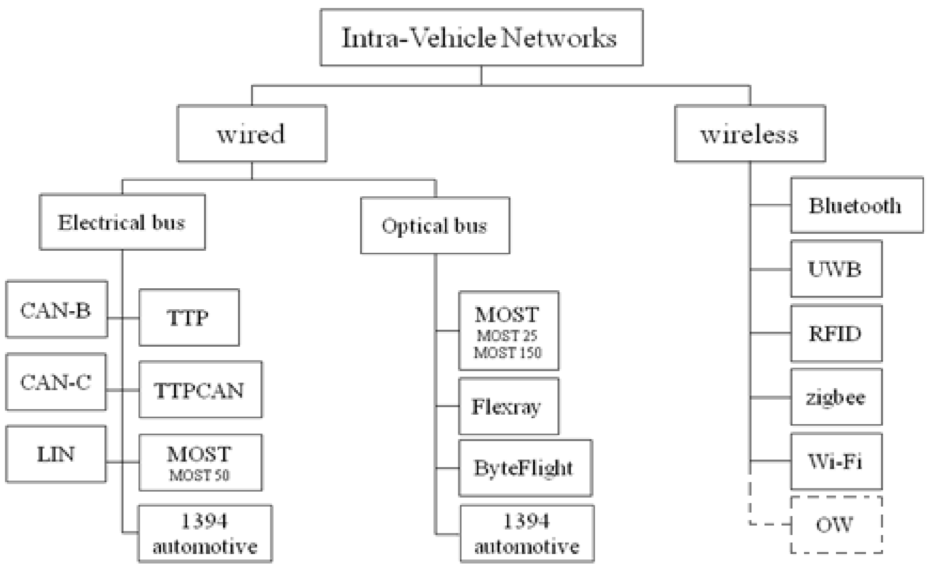

Figure 1 Intra Vehicle Network

3. CONTROL SYSTEM IN VEHICLE

The main control systems in a vehicle can be summarised as follows [2]-[7]:

Controller Area Network (CAN): the CAN protocol is a most common standard used for in-vehicle networks. CAN versions support different data rates, such as 125 KBit/s and 1 MBit/s, for low- and high speed CAN respectively. Normally CAN are used in drivetrain and comfort/convenience domains for engine management system, electronics transmission, ABS/EPS, as well as body comfort, and convenience electronics networking.

Local Interconnect Network (LIN): a LIN is a low speed serial bus network (25 KBit/s), and can be considered as an alternative to a low speed CAN. LIN is being used mainly in simple applications in the comfort/convenience electronics area.

Time-Triggered Protocol (TTP): the TTP was developed as a time triggered event solution. TTP is available in two versions, TTP/A and TTP/C. TTP/A is a master/slave TDMA protocol, whilst TTP/C is a fully distributed TDMA protocol. The specific transfer data rate is unspecified, but typically up to 10 MBit/s.

Flexray: This network was developed for time and safety-critical applications; it was deployed across all domains especially for X-by-wire systems. Flexray is a protocol that combines time- and event-triggered control mechanisms, and uses a comparatively high data rate at a maximum of 20 MBit/s.

ByteFlight: This optical data bus was designed for time and safety-critical applications and is able to carry 10 MBit/s data. It is deployed in drivetrain and safety application, especially for airbags (airbag sensor network). The protocol combines time- and event driven control mechanisms.

4. MULTIMEDIA SYSTEM IN VEHICLE

The multimedia system has evolved in car manufacturing from being a simple radio to sophisticated entertainment systems that need to interconnect, such as the CD player, rear-view camera, and the navigation display [8]. It can be used in conjugation with the CAN protocol to form an integrated in-vehicle audio and video communication [9].

Multimedia Signals Properties

In order to stream audio and video effectively, an in-vehicle multimedia system should be able to read and transmit different media coding formats, including digital audio broadcasting (DAB) and digital video broadcasting (DVB).

Voice: Two examples of audio coding standards are : stereo and MPEG-2:

Stereo: For a sampling rate of 44.1KHz and 16 Bit quantization, the data rate = 44.1 KHz x 16 Bits x 2 channels (stereo) = 1.4 MBit/s. For MP3, the used compression rate is 128 KBit/s .

MPEG-2: MPEG-2 is a coding standard found on a DVD for audio signals. The data rate for six channels is about 400 KBit/s.

Video: Different graphic/video standards are driven by different formats. A rough overview of used graphic/video standards can be summarised in Table 1.

Table 1 Overview of common graphic/video standards [10]

Standard	Resolution	Frame/Hz	MPixel/s	RGB 24 (MB/s)
VGA	640 x 480	60p	18.4	442.4
PAL	720 x 576	50i	10.4	249.8
Full HD	1920 x 1080	60p	124.4	2986.0

In-Vehicle Multimedia Protocols:

MOST: the MOST protocol is considered as an efficient synchronous network for streaming data (entertainment system) as well as for asynchronous packet data (Internet information), with low administrative overhead [11]. It was built on the Domestic Data Bus (D2B) standard [12].

It was established to ensure the availability of fast, short-delay networking with high bandwidth for infotainment applications, and to provide real-time networking for safety applications. MOST topology is logical ring and it can be implemented on a physical or star network [10]. Differential Manchester Coding is used for the line coding.

MOST versions:

MOST 25: This version uses 3 channels (asynchronous, synchronous and control information), and the maximum data rate it can achieve is 25 MBit/s. MOST 25 uses an optical physical layer; Plastic Optical Fiber (POF) has resistance against Electro-magnetic Interference (EMI), its weight is small, and it has negligible heat emission.

MOST50: is more flexible in channel assignment than MOST25 [13]. The maximum data rate it can achieve is 50 MBit/s while it uses the electrical transmission over an Unshielded Twisted Pair (UTP), unlike MOST25.

MOST150: is the most recent version of MOST protocol. The maximum data rate is 150 MBit/s. The similarity between MOST25 and MOST150 can be seen in using the same Physical Layer (POF) which makes

MOST150 the new version of MOST25. MOST150 can fully support real time radio, compressed video and asynchronous data to transport simultaneously [14].

1394 automotive standard: It offers high bandwidth (400 MBit/s). Also, it can transmit isochronous data (real time) and asynchronous data as well [15]. This standard is suitable for different optical and copper physical layers: POF, HPCF, STP, STQ, COAX and UTP, as illustrated in Figure 2.

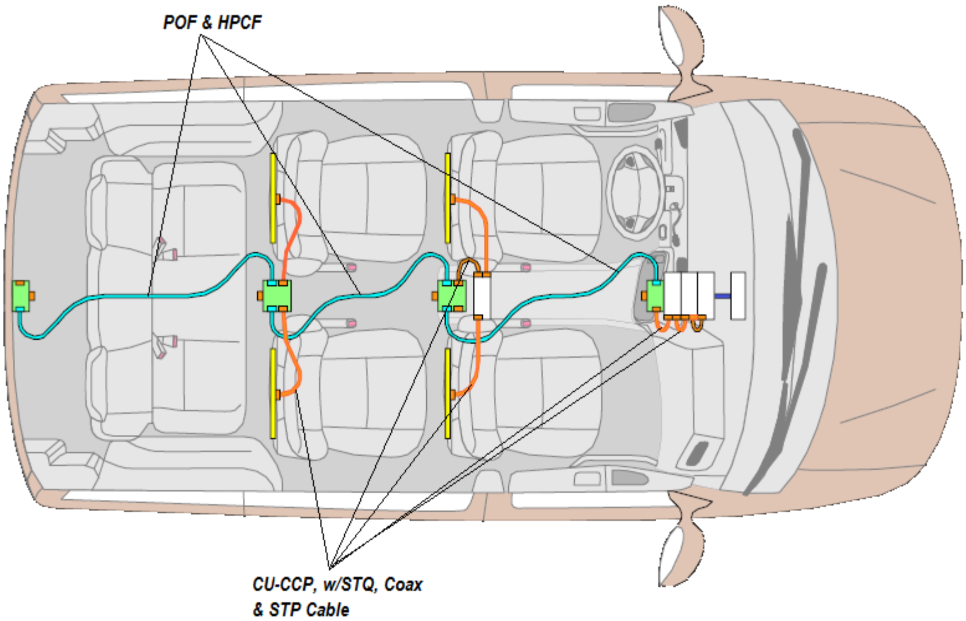

Figure 2 Physical Layer in 1394 Standard [15]

5. CURRENT SYSTEM DRAWBACKS

There are some disadvantages of in-vehicle networking systems that limit their performances. For instance, electrical buses are prone to electromagnetic disturbances, the bus line cannot be too long, a low signal quality is available, as well as not being suitable for high speed data transmission. This leads to the use of an optical data bus which is primarily not sensitive to electromagnetic disturbances and cross talk effect between lines, significantly higher transmission speeds, as well as cost and weight savings by reduced wiring [6][16].

The demand for wireless communications has been increasing recently. At present, the networking system in the vehicles is not solely the point-to-point cable network. In general, there are five potential wireless networks that are being considered for intra- and inter-vehicles applications, namely Bluetooth, UWB, RFID, Zigbee and Wi-Fi. Most of these networking systems are used for multimedia and infotainment purposes, and there are few other applications that aggressively look forward to implement wireless communications in vehicle systems [17]. Unfortunately, only Bluetooth has been built into various vehicles recently. Zigbee, UWB and Wi-Fi have not yet been implemented in any vehicles, and are still being researched. Since most other wireless system use RF which has known limitations, thus it is possible to introduce a new candidate, being Optical Wireless, into the environment. Optical wireless yet holds the potential of delivering high data rates in a secure manner, and uses unlicensed spectrum [18][19]. The relatively low cost of infrared components, such as optical emitters and photodiodes makes optical wireless system cheap. Moreover, the existence of power-efficient baseband modulation schemes is an additive advantage. Consequently, optical wireless is believed to be a feasible choice for numerous applications of wireless communications within vehicles.

6. IMPLEMENTING OPTICAL WIRELESS IN VEHICLE ENVIRONMENT

The idea of implementing OW technology in automotive applications has started by building OW links for satellites and aircraft [20]. Optical wireless links for intra-Satellite communications (OWLS) have been developed by implementing several projects such as ATENNA, MINERVA and the project that is led by INTA/ESA. In aircrafts OW is used in cabins [21][22]. In vehicles, several pathways are possible to transfer light such as: doors (point to point systems can be implemented), the engine compartment (MIMO performance should be predicted in this case), and the internal cockpit of the car (where unstable obstacles can be present such as passengers) [23].

The most recent study about optical wireless channel in the car cabin is presented in [24] where power and bandwidth distribution in different parts of the car are defined. The rapid development of optical wireless communication and LEDs in the visible spectrum has broadened the future of implementing this technology in the vehicle with the aim of replacing CAN.

7. CONCLUSION

To conclude, OW infrastructure can be built within vehicles in order to benefit from free-space propagation of light waves in the near infrared band as a transmission medium for communication. High data rates can be achieved easily in cars, since the distance between transmitter and receiver is relatively short. In addition, if the OW is going to be used in the car structure (doors or engine compartment) then eye safety constraints should not be a limiting factor.

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