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Hybrid testbed for simulating in-vehicle automotive networks

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ABSTRACT

This paper presents a novel method of automotive network simulation which is being used in an ongoing research effort to design cost effective, flexible in-vehicle networks suitable for use in multi-camera, high bandwidth environments. The simulation platform uses a hybrid simulation approach, and allows the coexistence of real network traffic streams and simulated network traffic. This approach provides a number of advantages, such as allowing for the injection and extraction of real network streams from a simulated network topology. We present details of the testbed architecture and compare its performance to that of native systems. We also demonstrate that results obtained are in line with those in the literature. Finally, we describe novel experiments and applications made possible using the developed simulation platform and how it can be used in the evaluation and development of automotive video applications.

1. Introduction

Contemporary road vehicles contain very sophisticated in-vehicle electronic systems and associated in-vehicle communications infrastructure. An increasing trend in the automotive industry has been to equip vehicles with cameras to augment existing safety systems. This is driven by a combination of increasingly stringent regulatory requirements and also consumer demand for safer vehicles.

Whether the motivation for the introduction of single or multiple cameras as standard equipment in vehicles is due to legislation or a consumer demand for improved safety systems, it is likely that even entry level vehicles will soon contain camera systems as standard equipment. It is therefore important to investigate the impact these systems might have on the performance of in-vehicle communications infrastructure.

Modern vehicles contain a vast array of devices which generate network traffic. Audio and video entertainment devices, safety control systems, engine bay sensors, body electronics, and cameras mounted in the vehicle are examples of such traffic sources. This data is communicated to Electronic Control Units (ECUs) in the vehicle for processing. In the current generation of vehicles several technologies are used to interconnect these devices within a single vehicle [1].

Recently, a range of approaches have been developed to model the behaviour of these types of networks, notably by Lim et al. [2,3], Hintermaier et al. [4] and Alderisi [5]. A review of these approaches can be found in [6]. The focus of this paper is on introducing and analysing a novel simulation technique and platform for the evaluation of automotive networks,

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Table 1
Comparison of current and proposed automotive technologies.

Protocol	Typical bitrate	Transmission medium	Topology
LIN	19.2 Kbps	Single wire	Point to point
CAN	500 Kbps	Twisted pair	Bus
FlexRay	20 Mbps	Twisted pair/Optical fibre	Bus/Star
MOST	150 Mbps	Optical fibre	Ring/Various
LVDS	655 Mbps	Twisted pair	Point to point
Ethernet	100 Mbps	Twisted pair/Optical fibre	Various

rather than on proposing novel topologies or scheduling algorithms. We propose that the integration of real time automotive video network streams into the simulated testbed (for the purposes of this work we use the term testbed to mean a hybrid network simulation platform which integrates both virtualised and simulated nodes) allows for more realistic and useful simulations. We do this by simulating, using a hybrid approach and the integration of traditional traffic generators and real video network streams onto a novel simulation platform.

The motivation for the development of this platform is as a powerful tool to assist in the testing and development of automotive video systems and novel Advanced Driver Assist Systems (ADAS) algorithms. To illustrate the utility of the platform more clearly to the reader, we give the following motivating examples of scenarios for which the developed platform is and has been useful.

- Video ADAS applications can be tested in real time on a hybrid simulation network early in their development. These results can be used to gain a better understanding of how the algorithm will perform in a real vehicle at an early stage.
- Failure scenarios can be easily and clearly demonstrated and tested at each point in an algorithms development, allowing researchers to investigate the effects of packet loss or high jitter values on image quality for ADAS applications, or the effects of link loss on ECU load.
- Subjective tests on automotive video ADAS applications can be carried out, for example, measuring the subjective effects on image quality of network issues.

While this platform does not seek to completely replace real world testing of these algorithms, it has proven to be a useful and powerful tool in the development of a variety of automotive video systems and ADAS algorithms [57] as well as providing a deep insight into the human considerations that must be taken into account when developing automotive systems. An example of such an application is explored in more detail in Section 7. It is in this that the core novelty of the platform lies.

The remainder of this paper is structured as follows, Section 2 contains a brief overview of the requirements of various traffic types typically found on an automotive network. Section 3 discusses the use of Ethernet as a replacement technology for the protocols and standards currently used in the automotive space and Section 4 details previous work related to this topic in the literature. Section 5 describes the methodology used in carrying out simulations modelled on a candidate next generation automotive network while Section 6 explores important timing considerations that are relevant to platforms such as this. Section 7 shows how simulation results are validated by those already in the literature while Section 7.3 illustrates the power of the presented platform and details its use in an automotive image quality subjective test. Finally Section 8 outlines our conclusions and plans for future work.

2. Automotive network traffic

In this section we provide a short introduction to some common automotive networking technologies.

Controller Area Network (CAN) [7] is an automotive specific standard, developed by Robert Bosch GmbH, released in 1986. It allows for a maximum speed of 1 Mbps at lengths of up to 40 m, though speeds of 512 Kbps are more common in automotive deployments [8].

Media Oriented Systems Transport (MOST) [9] was developed to primarily support networking of multimedia data. The maximum possible bandwidth as defined by the MOST150 standard is 150 Mbps.

Local Area Interconnect (LIN) [10] is an automotive specific network communication bus for very low bandwidth applications. It is intended as a cheaper alternative to CAN.

FlexRay [11] is an automotive networking standard that was developed by the FlexRay consortium which disbanded in 2009. The main advantages of FlexRay are its higher maximum data rate (20Mbps) and its deterministic behaviour.

Low Voltage Differential Signalling (LVDS) [12] is also used in automotive applications. While not explicitly developed for automotive applications, the high bandwidth made possible by LVDS over twisted pair copper cabling (up to 655 Mbps) has made LVDS an attractive option for automotive camera manufacturers.

Finally

Often, several of these communication technologies will be used in a single vehicle. As noted in Table 1, there is significant diversity in the capabilities of these technologies and this in itself is a significant motivator of interest in the use of a common communication standard in the next generation of in-vehicle networks.