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Realization of communication with SOME/IP stack over Ethernet

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List of Abbreviations

ADAS Advanced Driver Assistance Systems

ARP Address Resolution Protocol

ARXML AUTOSAR XML

API Application Program Interface

AUTOSAR Automotive Open System Architecture

AVB Audio Video Bridging

BSW Basic Software

CAN Controller Area Network

CRC Cyclic Redundancy Check

DDS Data Distribution Service

DoIP Diognastic over IP

ECU Electronic Control Unit

eSOC Embedded Service-Oriented Communication

Eth Ethernet

IEEE Institute of Electrical and Electronics Engineers

IoT Internet of Things

IP Internet Protocol

ISO International Organization for Standardization

IVN In-vehicle Networking

LIN Local Interconnect Network

MAC Media Access Control

MII Media Independent Interface

MOST Media Oriented Systems Transport

OABR Open Alliance BroadR-Reach

OEM Original Equipment Manufacturer

OS Operating Systems

OSI Open System Interconnection

PDU Protocol Data Unit

PHY Physical Layer

POSIX Portable Operating System Interface

RPC Remote Procedure Calling

RTE Runtime Environment

SDU Service Data Unit

SOA Service Oriented Architecture

SoAd Socket Adaptor

SOME/IP Scalable service-Oriented MiddlewarE over IP

SWC Software Component

TCP Transmission Control Protocol

UDP User Datagram Protocol

V2X Vehicle-to-Anything communication

1 Introduction

Communication is essential in modern vehicles to establish a link between the ECUs in the network. In addition, as the number of ECUs and high-performance controllers grows, so does the need for more bandwidth than traditional in-vehicle networks such as CAN, Flexray, and MOST can provide. With the introduction of Ethernet into the automotive domain, bandwidths of up to 1 Gb/s can now be achieved within the vehicle network. The use of Ethernet benefits systems such as ADAS and infotainment significantly. However, in order to transmit and receive data at a significantly high data rate, a robust communication control mechanism is required. The use of Ethernet benefits systems such as ADAS and infotainment substantially. However, in order to transmit and receive data at a remarkably high data rate, a robust communication control mechanism is required. With the growing interest in POSIX-based systems in the automotive domain, service oriented architecture (SOA) plays an important role in meeting the needs of technology-driven applications. The core of SOA is remote procedure calling (RPC) and the Client-Server mechanism. To realize these concepts, there is a need for a middleware that is specifically designed to run automotive applications smoothly. To accomplish this, SOME/IP middleware was introduced in the automotive context. As more applications migrate to Adaptive AUTOSAR, SOME/IP is well suited to serve as a communication control protocol alongside existing communication technologies.

In this report, a detailed study of the SOME/IP technology is conducted. In order to understand the working of SOME/IP technology, the open source library vsomeip offered by GENIVI is used. A demonstrator consisting of target hardware running with different underlying architectures such as x64, armv7 and armv8 is setup. The devices are connected with each other on a network using Ethernet. The working is realized by running applications based on vsomeip stack on theses hardware devices. Also, a troubleshooting guide consisting of the commonly faced issues and faults while using the SOME/IP technology have been documented as a reference document.

2 Literature Survey

2.1 Communication technologies in Automotive Domain

More than 100 ECUs connect via in-vehicle buses in modern vehicles[2]. As a result, there is a greater need than ever for a dependable communication network with high bandwidth. In order to meet these requirements, BMW implemented Ethernet for the first time in vehicles in 2013. At the same time, it is important to note that the incorporation of Ethernet as an in-vehicle networking system does not imply that traditional communication networks such as CAN, LIN, and MOST are rendered obsolete. Because these networks are robust, inexpensive, time-tested, and provide necessary performance for many applications, Automotive Ethernet will not completely replace them, but will supplement them to provide even more cost, performance, and feature benefits. Table 2.1 shows the important characteristics of automotive networks in comparison with the Ethernet.

Property	**Ethernet**	**CAN**	**FlexRay**	**MOST**	**LIN**
Bandwidth(Mb/s)	>100	1	20	150	0.02
Nodes	Scalable	30	22	64	16
Network Length	15m per link	40m	24m	1280m	40m
Topologies	Star, Tree	Bus	Bus,start	Ring,Star	Bus
Cost	High	Low	Low	High	Very low
Cabling	UTP	UTP	UTP	Optical,UTP	1-wire

Table 2.1: Comparison of important characteristics of automotive networks [1, p.202]

2.2 Ethernet in the Automotive Domain

In the year 1980, consumer-oriented Ethernet was introduced. However, Ethernet use in the automotive domain did not begin until 2013. This was due to EMC emissions levels being higher than those required for vehicle use. The introduction of BroadR-Reach twisted pair cables meant that the stringent EMC performance regulations were met and that the cables could finally be used in the automotive domain. Initially, Ethernet 100BASE-TX was used for OBD and updating the ECUs' flash memories[3]. It has also been used for applications relating to infotainment and camera systems over the years. With an increasing number of sensors in a vehicle, data acquisition and high-speed communication become essential. In the current

scenario, Automotive Ethernet appears to be the most viable solution for meeting these requirements. Also, Automotive Ethernet is said to be the next-generation in-vehicle networking systems when connecting application domains, transporting different kinds of data (control data, streaming, etc.)[3].

2.3 Ethernet as backbone in vehicles

Traditionally, CAN, LIN, FlexRay, and MOST are used as in-vehicle communication technologies[4]. Although Ethernet is a relatively new to the automotive domain, it offers several desirable properties such as high bandwidth, interoperability, robustness, low cost and seamless integration with the TCP/IP stack[4]. Because it is a peer-to-peer network with full duplex communication, each ECU can communicate with one another at 100 Mb/s bandwidth. However, in order to meet the delay requirements, complementary technologies such as AVB for in-vehicle communication are required.

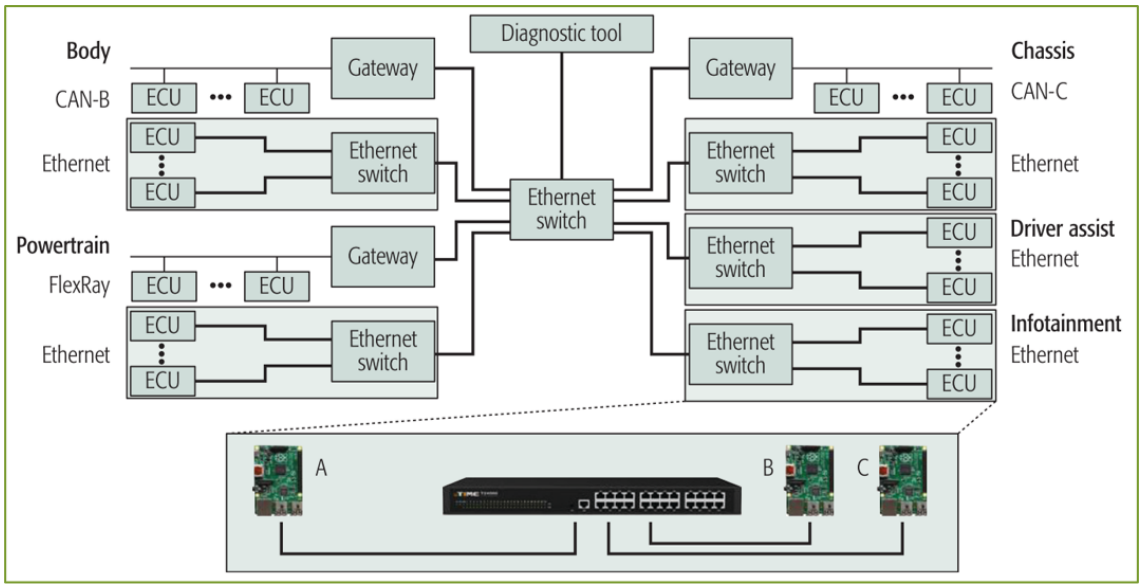


Figure 2.1: Ethernet as a backbone for in-vehicle communication[4]

Figure 2.1 is an example of an in-vehicle network with Ethernet as a backbone. Low-speed networks such as CAN, LIN, and Flexray are connected to Ethernet via a switch using gateways[4]. This facilitates the establishment of a link between ECUs that are integrated with Ethernet as the native protocol and have higher bandwidth requirements for their applications, allowing message sharing across domains. With the introduction of IoT in the automotive industry, a switched Ethernet network serves as the foundation technology for implementing V2X communication.

2.4 Service Oriented Architecture

Automotive Ethernet has resulted in a paradigm shift in the development of automotive systems. Because scalability is one of the primary advantages of using Automotive Ethernet, newer protocols and technologies that provide smooth, flexible, and scalable software solutions are required. SOA is one of the tried-and-true web services technologies that can be applied in the automotive context to support the growing complexity of automotive software. Given the resource limitations of ECUs, the SOA protocols designed for high level machines and servers cannot be directly used for the automotive software. In order to bridge the gap and reuse the concepts of the existing SOA model, new protocols are needed to be developed. AUTOSAR provides a standardized specifications for a protocols such as SOME/IP and DDS which works by incorporating the concepts of the SOA model. The details of these technologies are discussed in the following section.

2.5 Middleware in the automotive domain

The increasing complexity in the automotive applications means there is a need for standardized middleware that can provide common services and common interfaces to the application software components[8]. Middleware is a software layer that connects and manages application components running on distributed hosts[7]. In practice, a middleware is composed of a collection of existing communication protocols and carmarker-specific layers[8]. In the context of communication control, the middleware's role is to provide a layer of abstraction between the application software and the network.[10]. AUTOSAR has standardized specifications for middleware such as SOME/IP and DDS. Apart from this several other middleware based on CAN protocol such as eSOC[8] are available for use in the automotive context.

2.5.1 SOME/IP

"Scalable service Oriented MiddlewarE over IP" abbreviated SOME/IP represents a middleware that was created for automotive use cases [5]. The compatibility with AUTOSAR was a necessity regarding SOME/IP at least on wire-format level [5]. SOME/IP communication is an exchange of messages between different devices like ECUs over IP [5]. The SOME/IP protocol aims to define a uniform middleware for IP-based communication within vehicles. Table 2.2 represents the organization of the SOME/IP middleware in the ISO/OSI model.

7 6 5	SOME/IP
4	TCP/UDP
3	IPv4/IPv6
2	Eth.MAC/IEEE DLL
1	Ethernet PHY

Table 2.2: Simplified ISO/OSI model of Automotive Ethernet stack for communication control

The protocol builds on top of an existing TCP/UDP stack, adding another level of abstraction for application communication by enabling locality transparency. This property denotes the fact that an application has no knowledge of which network node provides the desired function or information. If the desired function or information is available on the same ECU, a local connection is established between the software components [10]. When the information, on the other hand, is on another node on the same network, the middleware performs the necessary network communication and provides the data to the application.

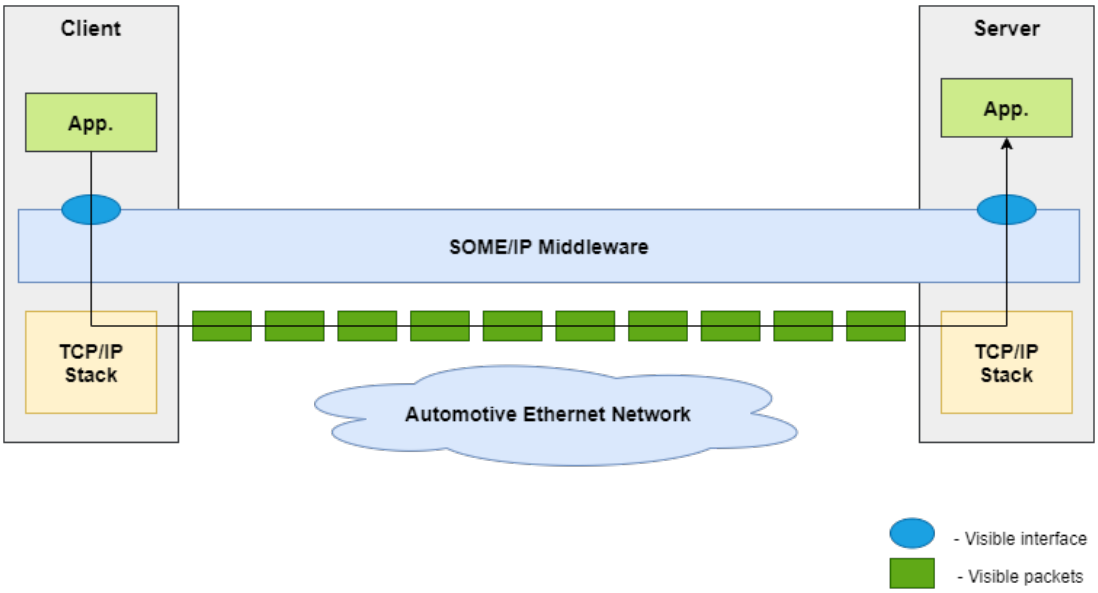
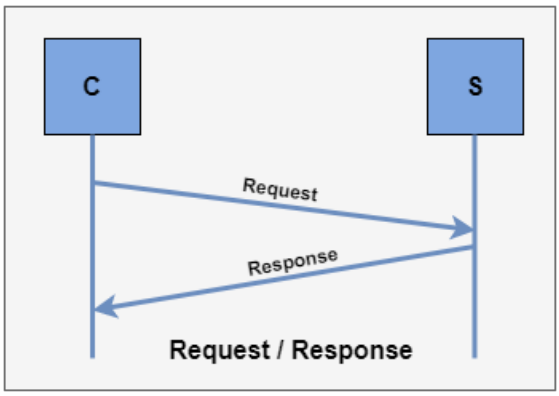


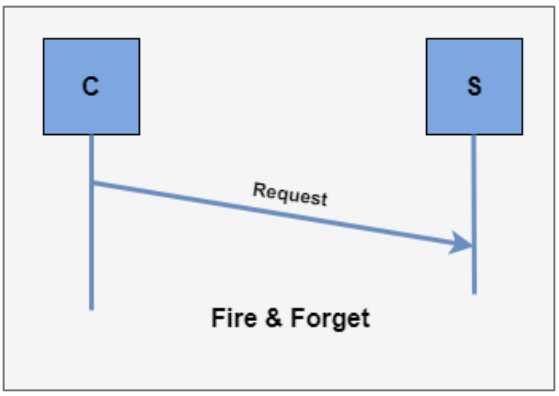
Figure 2.2: SOA representation with SOME/IP middleware

Figure 2.2 depicts a high-level overview of the SOME/IP transformer. It is based on the client-server mechanism used in service-oriented architecture. This enables a variety of methods for sending and requesting data between the client and server via RPCs and Publish-Subscribe models. The following section describes the specifics of these communication methods.

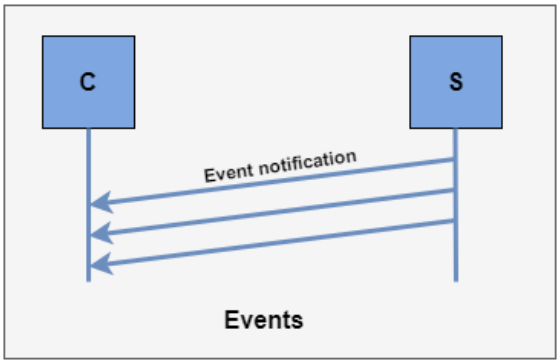
Communication methods



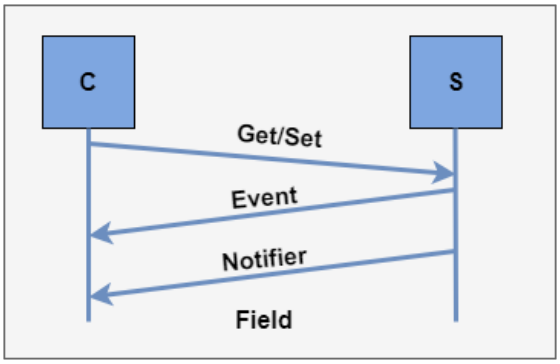
(a) "Request-Response"'-RPC: method call with response message



(b) "Fire & Forget"'- RPC: Method call without a response



(c) "Publish-Subscribe - Events"': Event notifications



(d) "Fields"': Set or read out the data fields of another service.

Figure 2.3: SOME/IP communication types between clients and servers

3 Implementation

To demonstrate the use of the SOME/IP technology, several devices (target controllers) are connected within a network and communication is established between them using Ethernet. In this chapter, the requirements to visualize the technology are explained and also the procedure to setup the demonstrator is discussed in detail.

3.1 Concept

Figure 3.1 depicts the physically interconnected hardware in the hardware setup. The prototype is made up of a computer running a virtual machine, a Raspberry Pi 3b+, and an Odroid XU4. A routing device connects the devices to the same network via ethernet cables. These devices represent the target ECUs within a vehicle that are responsible for performing specific functions based on information exchanged with SOME/IP as the underlying technology.

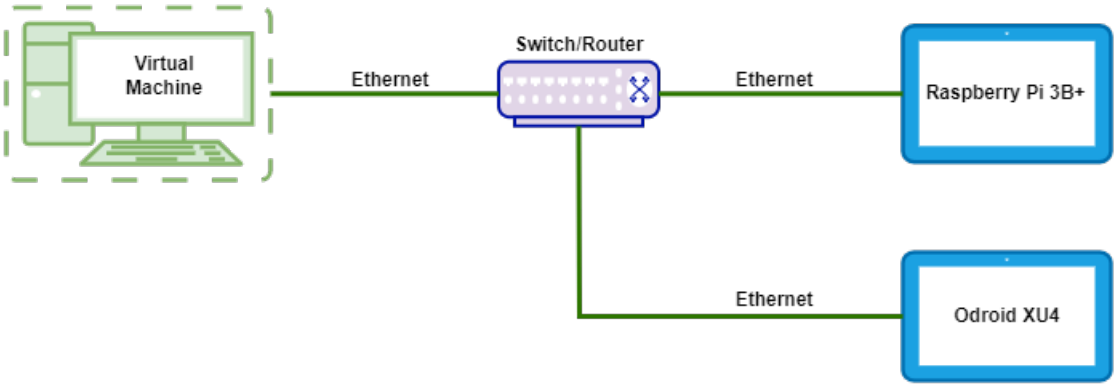


Figure 3.1: Visual representation of hardware setup

In order to implement the applications to visualise the usage of technologies several open source stacks such as scapy-someip [12], the GENIVI vsomeip stack [11], Rust based SOME/IP implementation [13] were investigated. COVESA's (formerly known as GENIVI's) vsomeip stack appeared to be the most appropriate of the currently available implementations for this activity as it is based on POSIX and uses C++ programming language for the implementation. With the trend toward using Adaptive AUTOSAR[14] in application software development, it makes sense to realize the concepts in a POSIX-based environment.

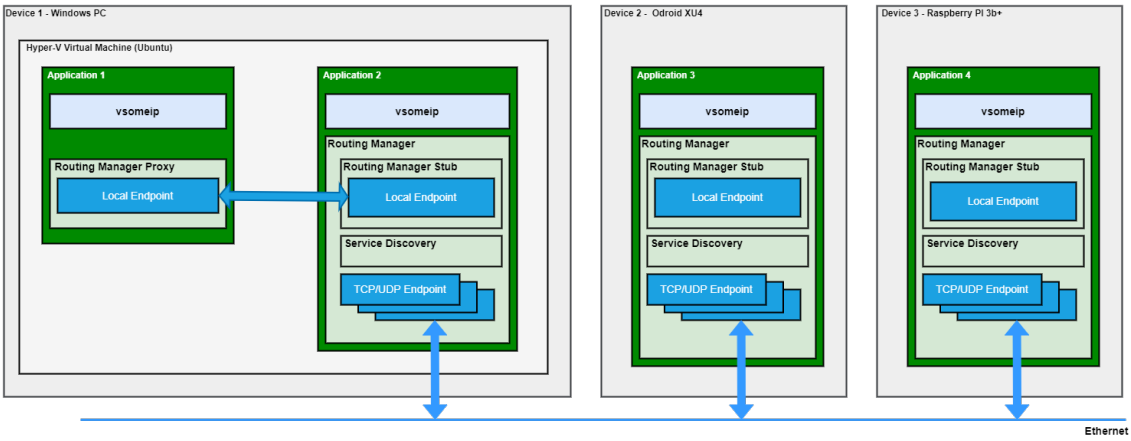


Figure 3.2: SOME/IP concept

3.2 Environment

3.2.1 Operating system

Linux OS

3.3 Target Hardware

3.3.1 Virtual Machine

3.3.2 Raspiberry Pi 3b+

3.3.3 Odroid XU4

3.4 Software

3.4.1 Target Libraries

GENIVI vsomeip stack

Other dependencies

Boost

3.4.2 Tools

Qt Creator

Describe in brief about Qt Creator

CMake

Describe in brief about CMake

PuTTY

PuTTY is an SSH and telnet client, developed originally by Simon Tatham for the Windows platform[15]. PuTTY is open source software that is available with source code and is developed and supported by a group of volunteers[15]. This tool is required to run the terminals for Raspberry Pi3b+ and Odroid XU4 remotely on the host machine. This enables to smoothly switch between the target devices when running the applications on the target hardware respectively.

3.5 Cross-compilation

Every development board is embedded with a specific amount of RAM, storage capacity, input and output peripherals and other hardware components. Hosting the target environment on multiple boards can be complicated and time consuming. Furthermore, building target libraries on these boards can take a long time and may fail in some cases. To address these issues, it is worthwhile to setup a generic build environment on a single platform and build the projects for different targets accordingly. This process is called as cross-compilation. In this section, the process to setup a cross-compilation environment on the Linux platform is illustrated and along with it, the procedure to cross-compile boost libraries for Raspberry Pi and Odroid XU4 target platforms is demonstrated respectively.

3.5.1 Installing cross compilers on the host machine

In this section, the basic requirements to setup a cross-compilation tool-chain is described. Also, based on the requirements for the demonstration of the SOME/IP technology, build process for libraries such as Boost, CommonAPI, vsomeip and other relevant libraries are described in detail.

In order to cross-compile, appropriate tool-chain packages has to be first setup in the host environment. The commands from the following listings are required to be run in a terminal window in the Linux machine. Please note that an active internet connection is required to download the packages from the server.

Listing 3.1: Command to install packages for ARM 32-bit (armv7) tool-chain

```
user@machine:~$ sudo apt-get install gcc-arm-linux-gnueabihf
      g++-arm-linux-gnueabihf
```

Listing 3.2: Command to install packages for ARM 64-bit(armv8) tool-chain

```
user@machine:~$ sudo apt-get install gcc-aarch64-linux-gnu
      g++-aarch64-linux-gnu
```

Listing 3.3: Command to install other required packages

```
user@machine:~$ sudo apt-get install build-essential
      manpages-dev openjdk-8-jdk libssl-dev wireshark
      g++-aarch64-linux-gnu
```

Installing Boost libraries

3.6 Demo Application

3.6.1 Server Application

3.6.2 Client Application

3.6.3 Comunication establishment between devices

Configuration

4 Results

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4.0.1 Server Application Output

4.0.2 Client Application Output

4.0.3 Troubleshooting guide

5 Conclusion

Conclusion

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