# Research Activities for Automotive Ethernet Network

Keigo Kawahara, Masato Sato, Katsunori Aoki,
Yutaka Matsubara, Hiroaki Takada (Nagoya University, Japan)

The importance of Ethernet is increasing in automotive field recently. We are doing research about automotive Ethernet from the viewpoints of Simulation, Theoretical Analysis, Algorithm, Hardware Implementation, and Security Analysis. These research activities are described below.

## Simulation Environment

We have developed the open-source based simulation environment for CAN-Ethernet AVB (Audio Video Bridging) network in OMNeT++. This simulator consists of INET frame work (as an Ethernet model), CoRE4INET(as an Ethernet AVB model), and CAN & CAN-Ethernet gateway model that we originally developed.

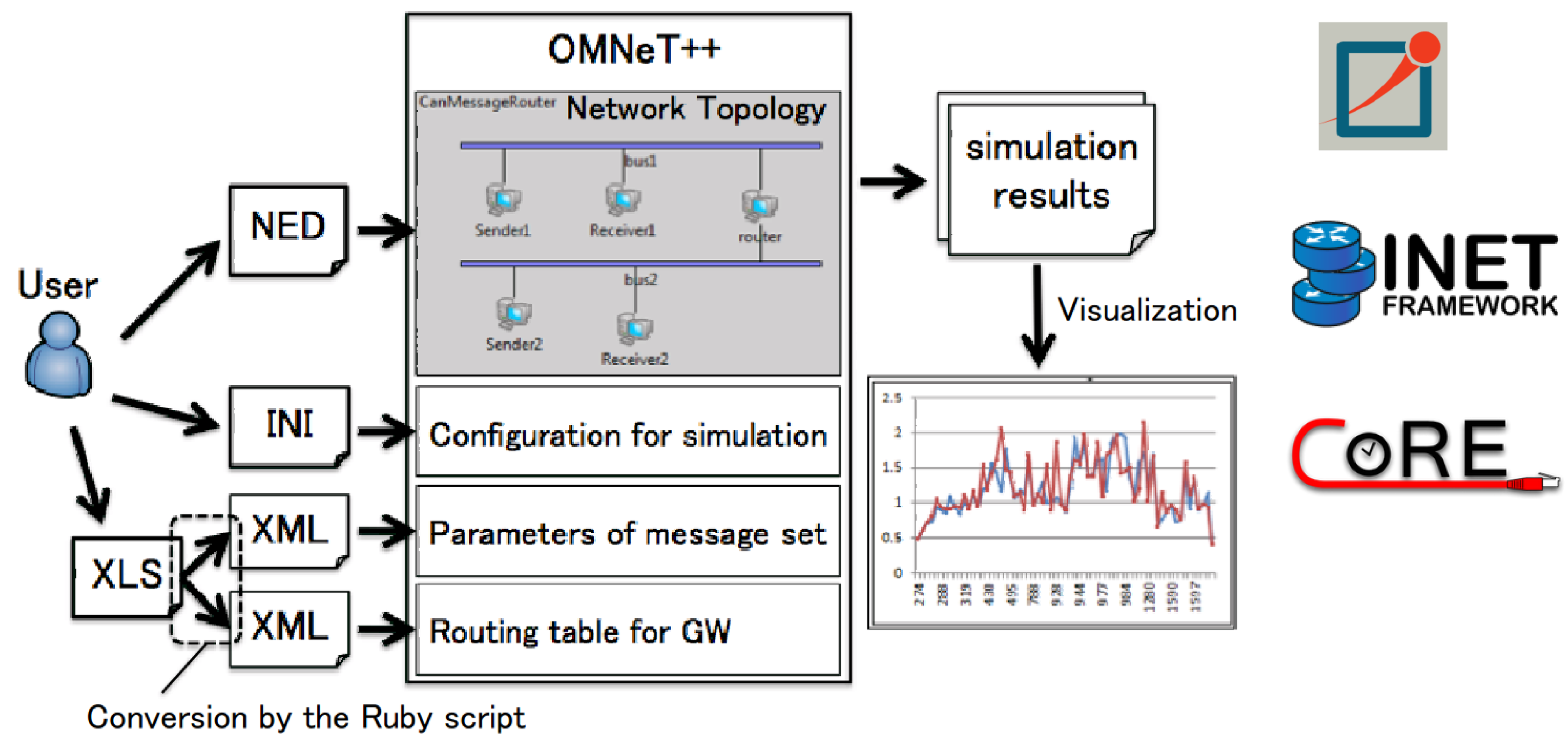


Figure 1 : Simulation Flow

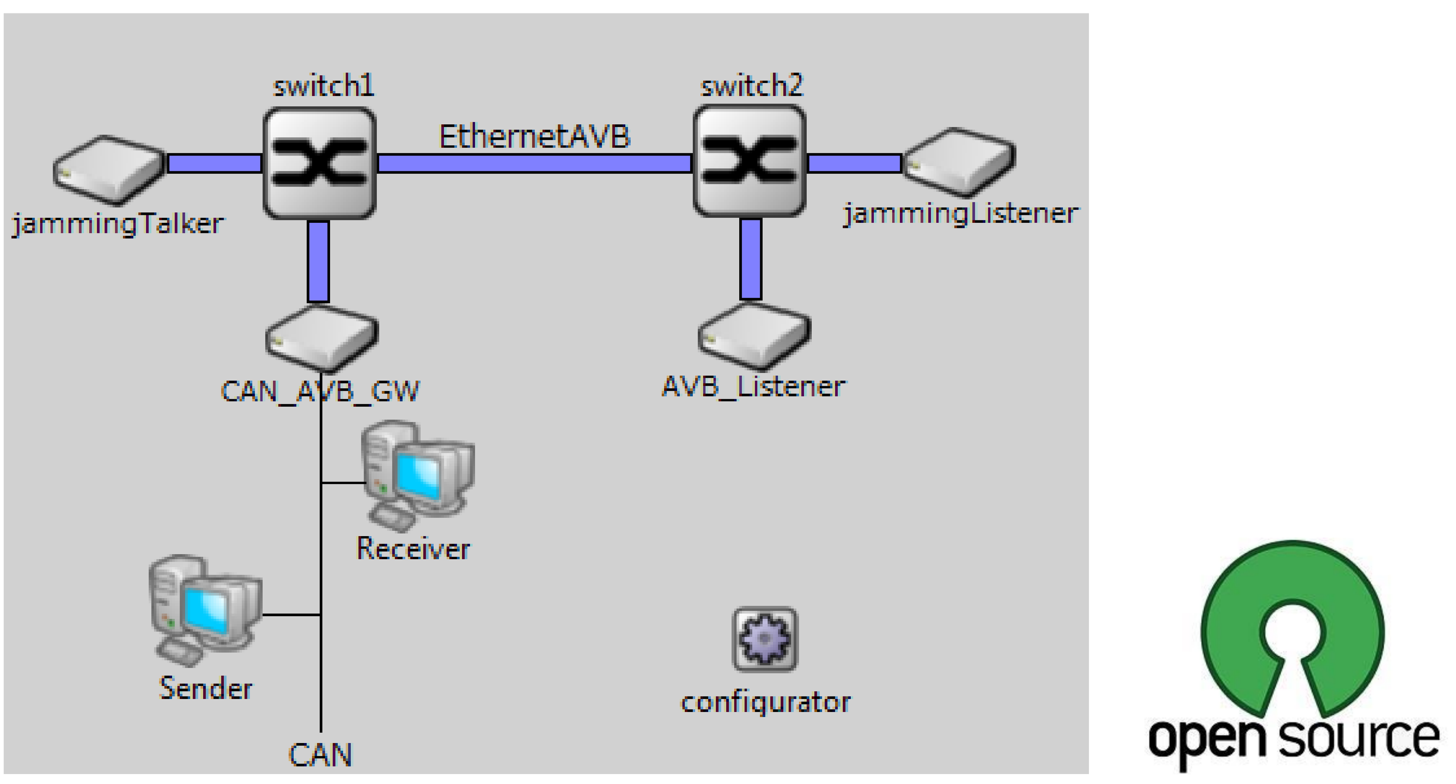


Figure 2 : CAN-Ethernet AVB Network topology on OMNeT++

## Theoretical Analysis & Algorithm

We have developed a new conversion algorithm, which is focused on conversion timing, for CAN into Ethernet AVB gateway. We analyzed the necessary bandwidth and Worst Case Response Time (WCRT) for the proposed algorithm as well as other existing algorithms. The results of the comparison show that the proposed algorithm is, theoretically, the most balanced in terms of necessary bandwidth and real-time properties.

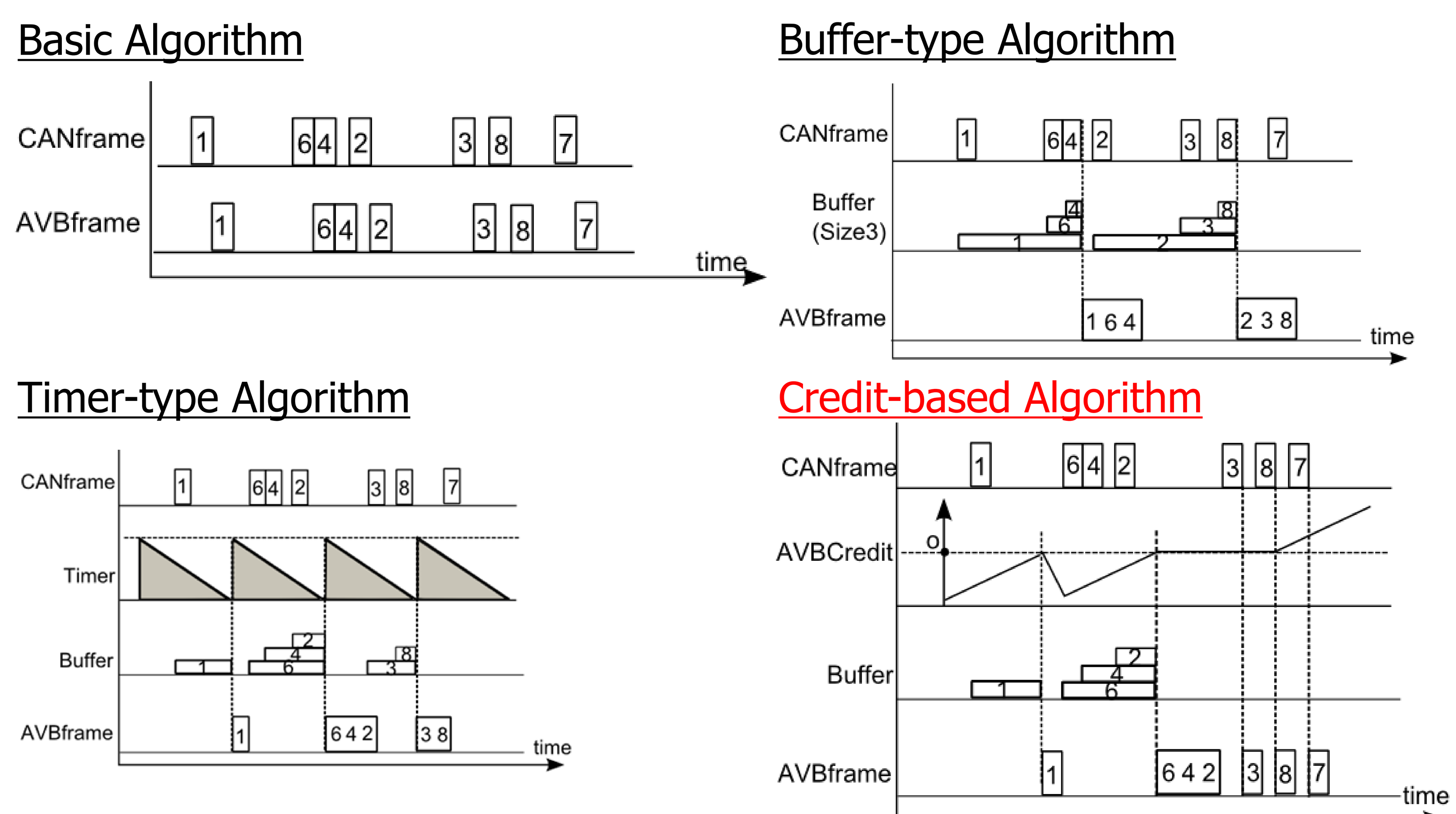


Figure 3 : Conversion Algorithms for CAN to Ethernet AVB gateway

| | Worst Case Response Time | Bandwidth |
|---|---|---|
| Basic | $R_i^{Basic} = W^{CAN} + W^{AVB}$ | $y_{basic}(t) = y_{general(z=1)}(t)$ |
| Timer | $R_i^{Timer} = W^{CAN} + W^{AVB} + t_{interval}$ | $y_{timer}(t) = y_{general(z=x_{max}\times t_{interval})}(t)$ |
| Buffer | $R_i^{Buffer} = W^{CAN} + W^{AVB} + (n-1) \times (\min_{m_j \in cg} P_j)$ | $y_{buffer}(t) = y_{general(z=n)}(t)$ |
| Credit | $R_i^{credit} = W^{CAN} + W^{AVB} + \alpha$<br>$\alpha = \max_{m_j \in classA} C_j$ | $y_{credit}(t) = y_{general(z=x_{max}\times(\alpha+\beta))}(t)$ |

$$y_{general}(t) = \begin{cases} x(t) \times (46+42) \times 8 \div z & (1 \le z \le \lfloor \frac{46}{L_c} \rfloor) \\ x(t) \times (L_c \times z + 42) \times 8 \div z & (\lfloor \frac{46}{L_c} \rfloor + 1 \le z \le \lfloor \frac{1542}{L_c} \rfloor) \end{cases}$$

Figure 4 : Theoretical Analysis for the Conversion Algorithms

## Hardware Implementation

We have developed 1Gbps Ethernet AVB Switch with FPGA. This work is based on the previous work of TUM. We have already developed Credit Based Shaping Algorithm (CBSA) of IEEE802.1 Qav, and generalized Precision Time Protocol (gPTP) of IEEE802.1AS on 4-port 1GbE switch. As a future plan, we are going to develop the Ethernet TSN protocols (i.e. IEEE802.1Qbv, IEEE802.1Qbu), or other new functions.

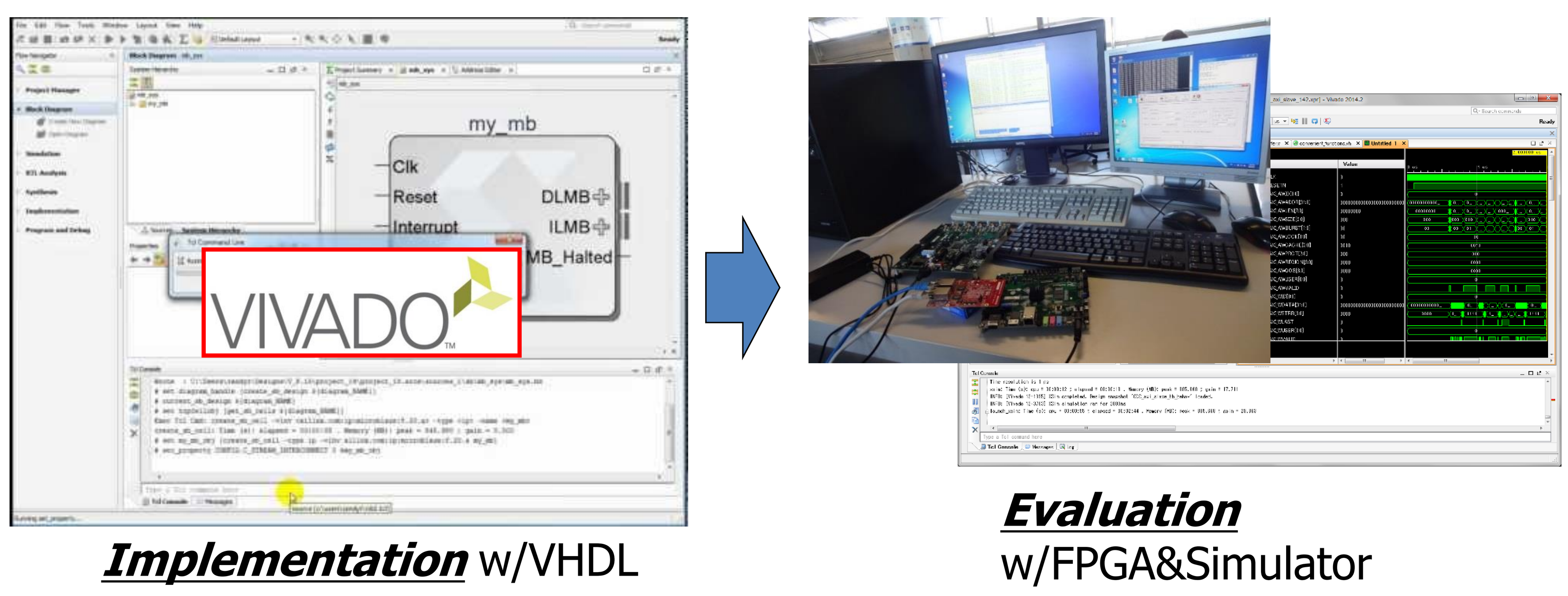


Figure 5 : Hardware Implementation Flow

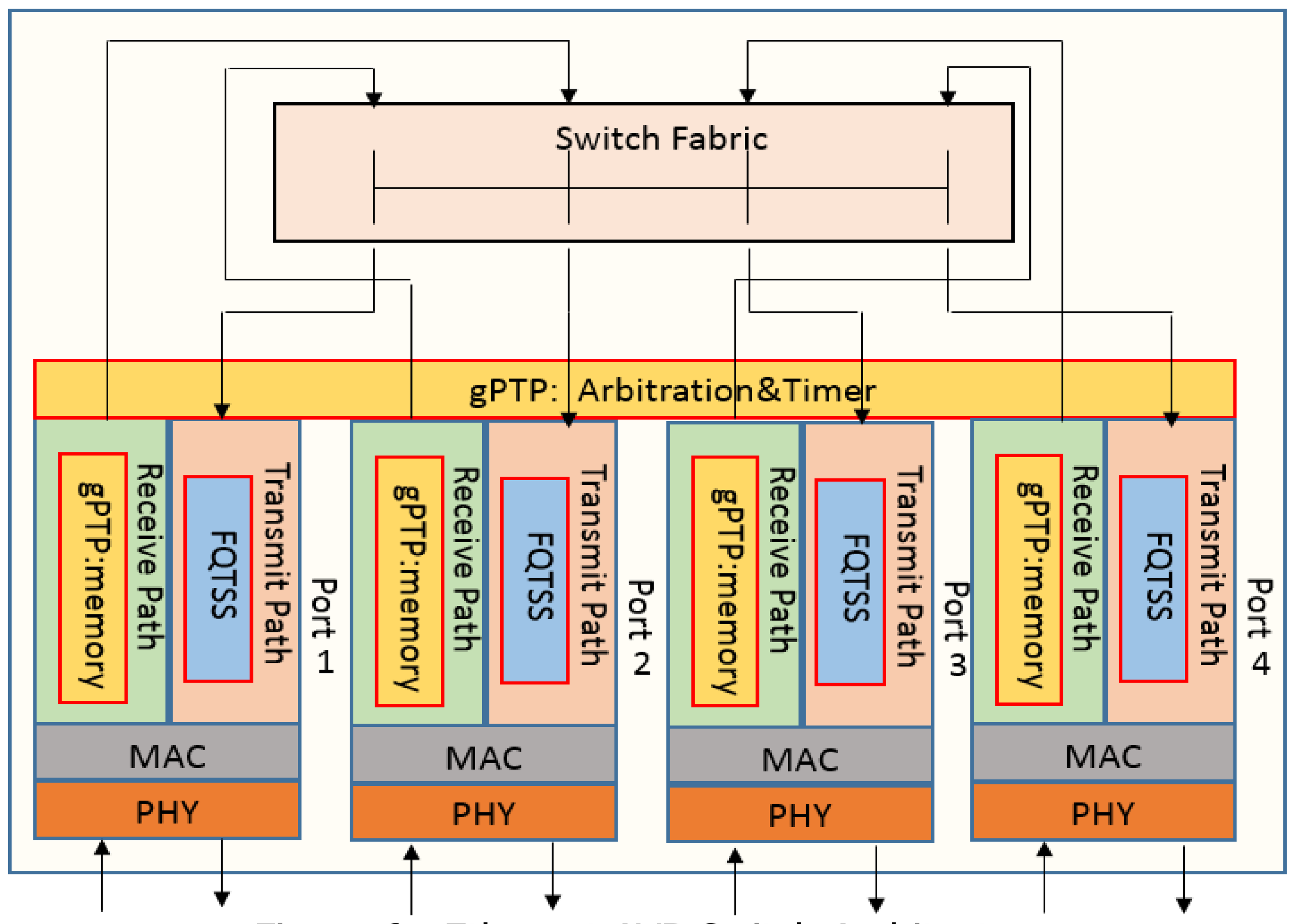


Figure 6 : Ethernet AVB Switch Architecture

## Security Analysis

Automotive embedded network security is one of remarkable research topic. We have tried to analyze security threats and vulnerabilities in Ethernet AVB network using open-source based environment. This experimental environment consists of Linux PCs with Open AVB protocol stacks. We will discuss proper security measures for automotive Ethernet network.

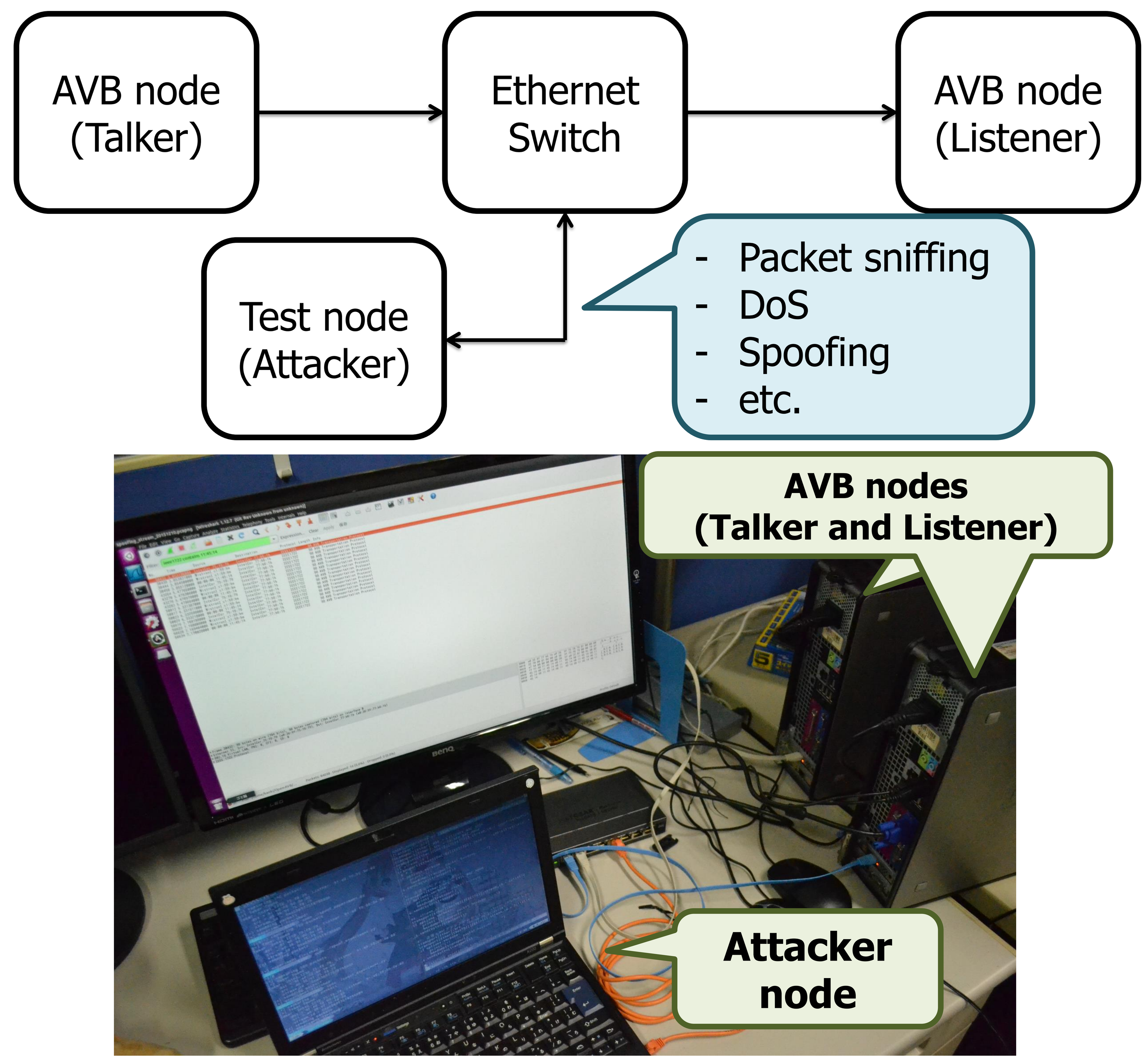


Figure 7 : Security Test Environment