IEEE 802.1DG

Seamless CAN: CAN plus HSR

Presented by Professor Jong Myung Rhee

Department of Information and Communications Engineering
Myongji University, South Korea

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Motivation

The number of electronic control units (ECUs) and various sensors embedded in vehicles has increased dramatically [1]. Therefore, conventional communication protocols such as CAN, FlexRay, and LIN have reached their limits in terms of speed and bandwidth.

Therefore, traditional in-vehicle networking (IVN) protocols are expected to be replaced by novel Ethernet-based approaches with higher bandwidth performance and fault tolerance capability [2].

So, IEEE 802.11cb, which is very similar to high-availability seamless redundancy (HSR), standardization has been made.

Motivation

However, the controller area network (CAN) has long been dominantly used as a standard protocol for IVN. Also, HSR products are already available in the market.

Therefore, in this presentation, a new fault-tolerant algorithm for CAN called *Seamless CAN* is proposed, which applies HSR to CAN as an interim solution during the transition period to 802.11cb-based IVNs.

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CAN Protocol

The CAN serial communication bus was developed as early as 1983 [3], mainly to provide stable communication between electronic devices inside road vehicles.

- Nodes in a CAN network are connected to one another via a shared two-wire bus, and potential conflicts might happen when there is more than one node trying to transmit frames at the same time;
- CAN has a bit-wise arbitration mechanism (i.e., listen before talk) by comparing the identifier of each sender to allow only one transmitter after the arbitration phase.

HSR Protocol

The HSR protocol is standardized by the International Electrotechnical Commission (IEC) [4]. HSR is particularly suited for time and data critical systems that demand high availability and zero switchover time in the case of network faults.

In an HSR single-ring network, each node in the network is connected to its two nearby nodes, all together forming a ring structure.

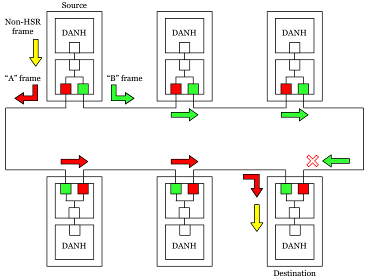

Figure 1: Example of an HSR ring.

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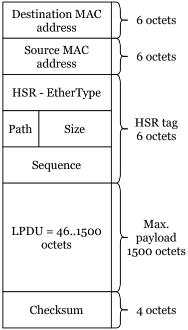
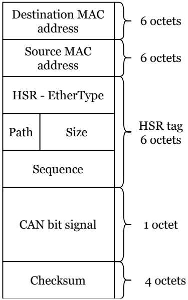
Concept of Seamless CAN [5, 6]

- Each CAN “bit” is encapsulated inside an HSR frame (i.e., becoming the payload) and its copies are inserted into the ring, following the HSR concept of work;
- The CAN bus is replaced with an HSR ring, and the CAN controllers inside CAN nodes serially transmit the bits to the CAN bus;
- What is actually stored in each HSR frame is one single bit (i.e., either bit “0” or “1”), not an entire CAN frame.



(a) HSR frame.



(b) Seamless CAN frame.

Figure 2: Comparison between a standard HSR and Seamless CAN frame.

Node Architecture

- When a bit is received from CAN node, the Seamless CAN node embeds it within the payload of an HSR frame, and sends the two duplicates of that frame in two directions on the HSR side;
- When a new frame arrives from the HSR side, the sequence number of that frame will be registered in the node memory, and the "bit" information will be delivered to the CAN node;
- A frame received from the HSR side will be dropped if it holds a sequence number that is already in the node's record.

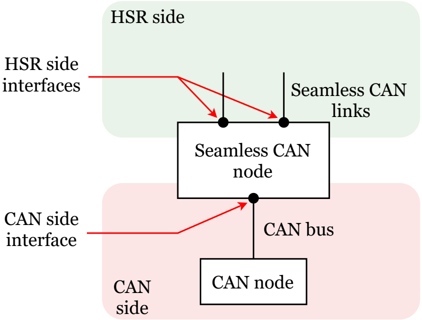
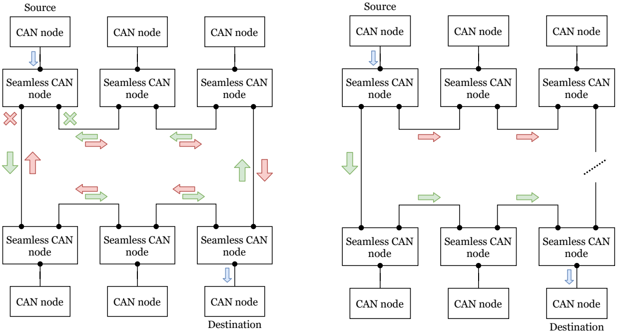


Figure 3: Seamless CAN node's interfaces.

Operational Concept

When there is a link failure in the network, although only one copy of the frame reaches the destination node, the CAN node still operates without any interruptions as activities from the Seamless CAN side are transparent to nodes on the CAN side.



(a) Healthy environment case. (b) Network failure case.

Figure 4: Single-ring Seamless CAN network in two environments.

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Failover Capability: Scenario

Two CAN nodes, namely CAN_1 and CAN_2, are connected to two Seamless CAN nodes, SCAN_1 and SCAN_2 respectively. The Err_Ind_1 node will simulate a link disconnection at $t = 150\,000$ *sim. s*, and it lasts until $t = 350\,000$ *sim. s*. In addition, the traffic through Err_Ind_1 is assumed to have a smaller transmission latency.

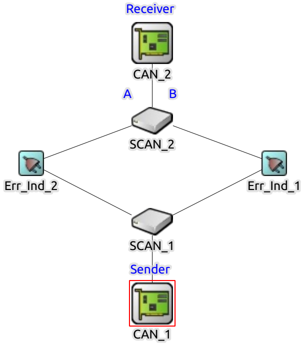

Figure 5: Seamless CAN setup in failover simulation scenario.

Failover Capability: Result

In the first $150\,000$ *sim. s*, the SCAN_2 node shows a linear reception of Seamless CAN frames completely via port B. However, at $t = 150\,000$ *sim. s*, due to a link disruption, frames reaching port A are no longer detected as previously received copies, and thus they are accepted. The link failure lasts until $t = 350\,000$ *sim. s*, and the faster link begins to deliver frames to the destination node again.

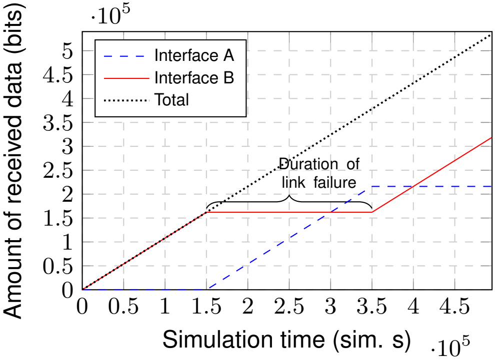

Figure 6: Seamless CAN frame reception performance in the case of link failure.

BER Measure: Scenario Setup

In each simulation, there are 90000 CAN frames or 9630000 CAN signal bits (since a frame is 107 bits long) being transmitted from the sender to the receiver. In addition, the set of BER values $\{1\text{e}{-7}, 5\text{e}{-7}, 1\text{e}{-6}, 5\text{e}{-6}, 1\text{e}{-5}, 5\text{e}{-5}, 1\text{e}{-4}\}$ is used, and the number of bit error occurrences is recorded at the end of each simulation. There are five different configurations of Seamless CAN network (i.e., 2, 20, 40, 100, and 200 nodes) in total.

BER Measure: Result

When BER is equal to $1e{-4}$, CAN bus and 200-node Seamless CAN have about 1000 errors. However, when BER is $1e{-5}$, there are 96 errors reported for CAN bus while the figure for 200-node Seamless CAN is only 11 errors. Other Seamless CAN network sizes ranging from 2 to 100 nodes all show smaller numbers of errors than CAN bus for any BER values.

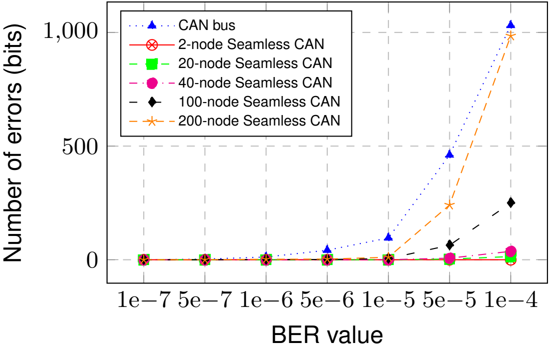

Figure 7: Seamless CAN network's bit error results in comparison with CAN bus with different BER values and numbers of nodes.

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Conclusion

A novel fault-tolerant algorithm named “Seamless CAN” is proposed for the CAN bus protocol. The proposed scheme is based on the operation concept of HSR to provide redundant solutions for time-critical in-vehicle network systems. Simulation results show that Seamless CAN shows no loss of frames in the case of link failures and significantly better BER performance.

References

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[6] J. M. Rhee, I. R. A. Altaha, D. N. Hoang, D. H. Kim, J. S. Yang, and S. Y. Park, "Seamless CAN: CAN Bus Plus High-Availability Seamless Redundancy," in *2021 International Conference on Information and Communication Technology Convergence (ICTC)*. IEEE, 2021, pp. 1284–1286.