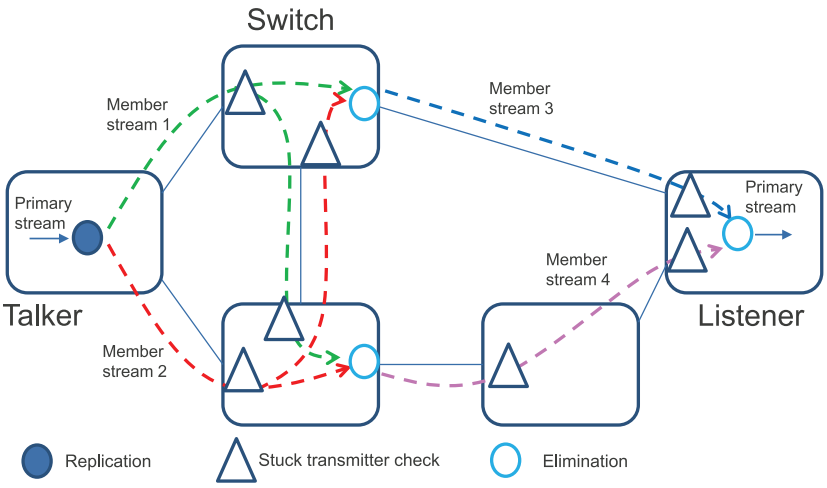
RENESAS
BIG IDEAS FOR EVERY SPACE

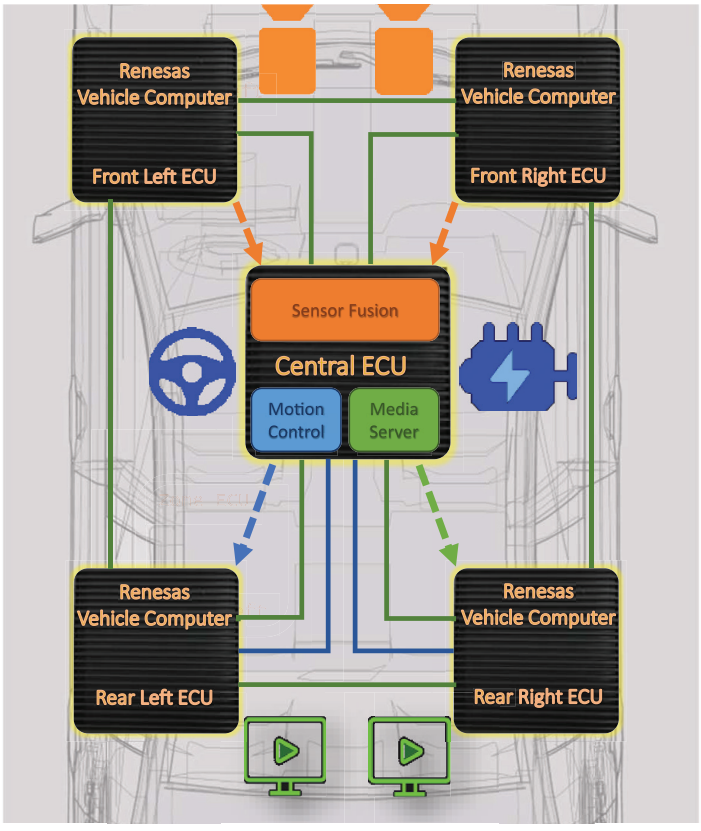
ETHERNET TSN NETWORK

Redundancy in a zone based architecture

IEEE802.1CB-2017 specification is also known as Frame Replication and Elimination for Reliability (FRER), it aims to increase probability of packet delivery across network for link loss, packet loss and stuck transmitter. Critical streams are identified (stream identification) and then undergo replication (sequence generation and replication) and elimination (individual and sequence recovery) while passing through the network.



- Critical stream (called primary stream) from talker to listener is identified and copied into member streams (same information as primary stream but separate identity) and forwarded across network
- At ingress port of switch, member streams are identified and replicated for forwarding



- These member streams are again identified while going out of a switch port and duplicates are eliminated so that only one of the member streams is output on a port
- As stream travels across, this process continues and eventually listener eliminates duplicates except one and converts it to the original primary stream

Demo Setup

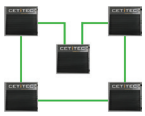
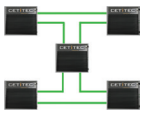
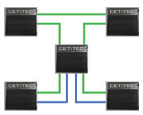
Innovative E/E Architectures are being realised in automotive which could not be imagined only few years ago. Central computing, service oriented architecture and zone based architecture are examples. Those architectures will be Ethernet centric and potential failures on a link or within system ECUs need to be addressed for critical functions. Renesas has created a demo setup with five of its Vehicle Computers (VC2). They are connected in such a manner so that different physical topologies could be realised. All VC2s are connected via Ethernet links (green). Three of the VC2s are also connected via CAN links (blue).

This demo setup is intended to mimic a simplified zone based architecture which takes sensor information to a central computer and calculate actor information to be send back to zone controllers. Networking behaviour in several topologies with focus on redundancy can be observed.

ETHERNET TSN NETWORK / REDUNDANCY IN A ZONE BASED ARCHITECTURE

Ring Topology (no redundancy): Topology chosen to represent classical structure with no CB functionality. It is preferable topology at the edge due to reduced number of links.
Ring Topology (with CB): Ring structure can facilitate CB due to full duplex nature of Ethernet network. Bandwidth in such network is worst. Maximum protection to one link could be achieved.
Meshed Topology (with CB): Fully redundant and totally realized with Ethernet. System would be fully functional in case of one link failure and even could be functional with two specific link failures. System cost in such network is highest.
Meshed with CAN Topology: Same as meshed network but part of network is realized via CAN. This is cost effective solution for achieving redundancy. Only low bandwidth part of network could be employed with CAN. Frame replication and elimination with CAN protocol could be easily achieved with software due to low bandwidth (hardware solution not considered).

Demo Observations

Topology	Diagram	Reliability	Bandwidth Utilisation	Latency		Comment
				No failure	Failure	
Ring Topology (no redundancy)		Not possible	Low	Low	Not functional	Bandwidth is equal to lowest link speed
Ring Topology with CB		Possible	Worst	Low	High	Double traffic on every link for same functionality
Meshed Topology with CB		Possible	High	Low	Medium	Different link speeds could be mixed without affecting all traffic
Meshed Topology with CB including CAN		Possible	Medium	Low	Medium	Cost optimization, diversified redundancy

Renesas carried out CB implementation in both hardware and software for a switch and evaluated with different configurations for comparison. Main performance parameters for comparison were CPU load and Switch throughput.
CPU load with hardware implementation was none during operation mode whereas CPU load with software implementation was quite high and Switch throughput reduced drastically. This is expected as each member stream need to be handled by CPU.
CB implementation in software makes sense at the edge nodes where only duplication or elimination is required and CPU is anyway handling these frames as talker or listener.

Conclusion

When addressing x-by-wire applications, network redundancy in the past was only possible by using FlexRay or CAN. Next generation networking would revolve around Ethernet. Future architectures and applications would demand more and more fail safe and reliable networks. Redundant links between ECUs and redundant clock domains are a must. Network redundancy is also a necessary condition for system redundancy.
IEEE802.1CB is a standardised way to employ network redundancy mechanism in hardware for efficient performance. Redundant network automatically leads to higher bandwidth requirement and higher cost whereas latency is not impacted.

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