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ETHERNET TSN NETWORK DEMO OPERATION

Redundancy in a zone based architecture

The purpose of the demonstrator is to show different networking configurations, the effects of link failures to it, and finally countermeasures that could be taken to increase the quality and availability of the network traffic in a real vehicle. Keeping functionality alive is an important aspect for advanced driver assistance systems and fully automated cars.

Demonstrator configuration and operation

The demonstrator consists of two remote controlled cars equipped with two cameras each to operate as autonomous driving vehicles. The second major element is a network of five ECUs representing a zone architecture with two front, two rear and a central ECU. The cars sent the video streams of their cameras to the front left and right ECU using wireless technology. These ECUs forward the video stream via the Ethernet TSN network to the central computer. Here the path planning is done and motion control commands are generated to be send via the TSN network to the rear left (steering) and rear right (speed) ECUs which control the cars using the original remote control unit.

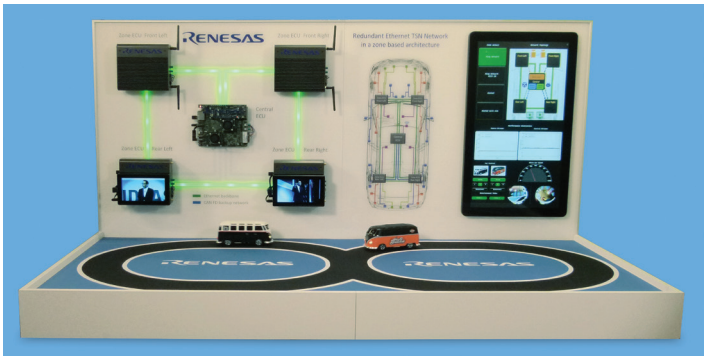

Figure 1

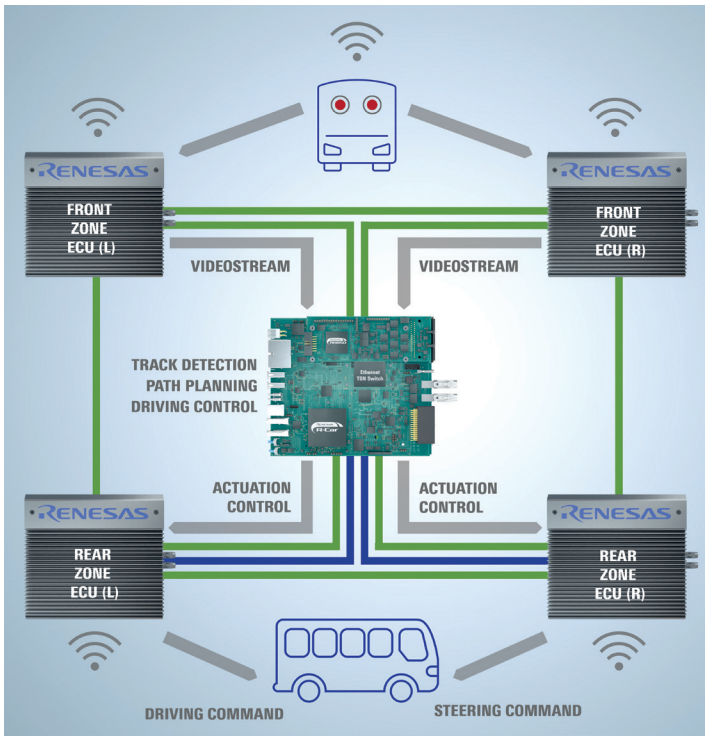

Figure 2

The second car on the track is equipped with the same functionality and controlled in the same way. Path planning and motion control is done on a separate, not visible ECU. In addition, the rear ECUs have a screen attached to it to show entertainment videos stored in the central ECU.

The demonstrator can operate in four different modes to mainly show reliability and fault tolerant behaviour of an Ethernet network. The ECUs have an Ethernet TSN switch integrated that supports 802.1CB, also known as Frame Replication and Elimination for Reliability (FRER). When this feature is enabled, all mission critical traffic (camera video, speed setting, driving commands) is replicated in the switches. All other, not critical traffic (e.g. entertainment video) is not replicated.

The different modes are controlled by the touch screen which sends re-configuration messages to the ECUs. Illuminated LED stripes indicate the active links between the ECUs. In case of a simulated link failure, the routing destination in the switch for this port gets disabled and the LED stripes indicate a broken link by red colour.

Communication principles

The routing configuration is set in a way that messages are always transmitted using the shortest path between sender and receiver. Figure 2 shows this communication using a simple ring topology without redundancy operation.

There are in total 6 different relevant communication streams in the system. Two independent camera streams are coming from the cameras via the front left and front right ECU with the central ECU as target. Two control streams are generated by central ECU, they convey steering and speed commands. These four streams are considered as mission critical. In addition, the central ECU generates two independent entertainment video streams (not shown in Figure 3). All streams originating at the central ECU are targeting the rear left and rear right ECU respectively. When using Ethernet as transport medium, TCP/IP is used as transport protocol. For the video traffic UDP was used as transport protocol.

Critical streams are replicated using 802.1CB. Figure 4 shows an example how the traffic gets replicated for one of the camera streams and the steering angle. In addition to the standardised replication function using 802.1CB, the demonstrator is also capable to perform replication and elimination in software and transmits a replication of the Ethernet frame over a redundant CAN network. On the receiver side unnecessary duplicates are removed by a software.

The entertainment video stream is not considered as critical traffic and frame replication and elimination is not applied here. The general strategy for the operation of the car in this demonstration is that when at least one link fails, the car goes into an emergency mode if mission critical messages are still going through the network. In case messages necessary for the driving functions are not received, the car stops immediately.

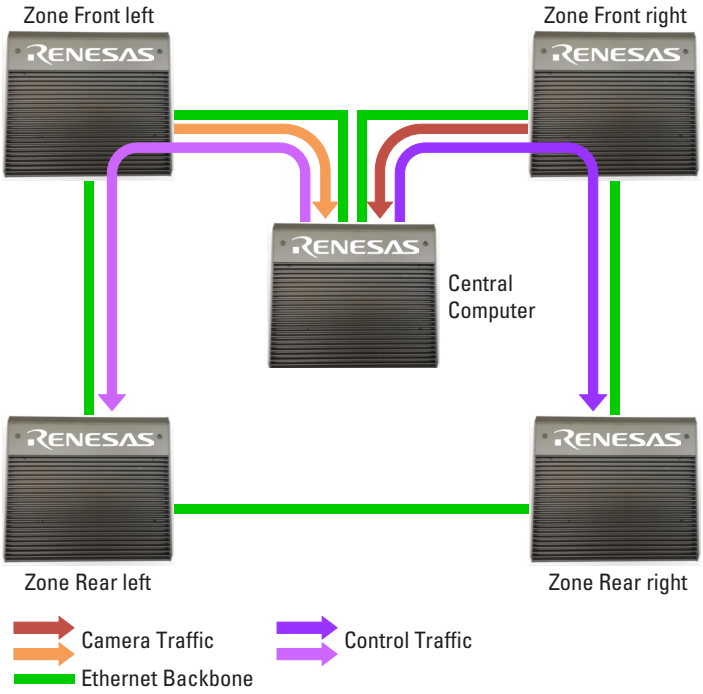

Figure 3

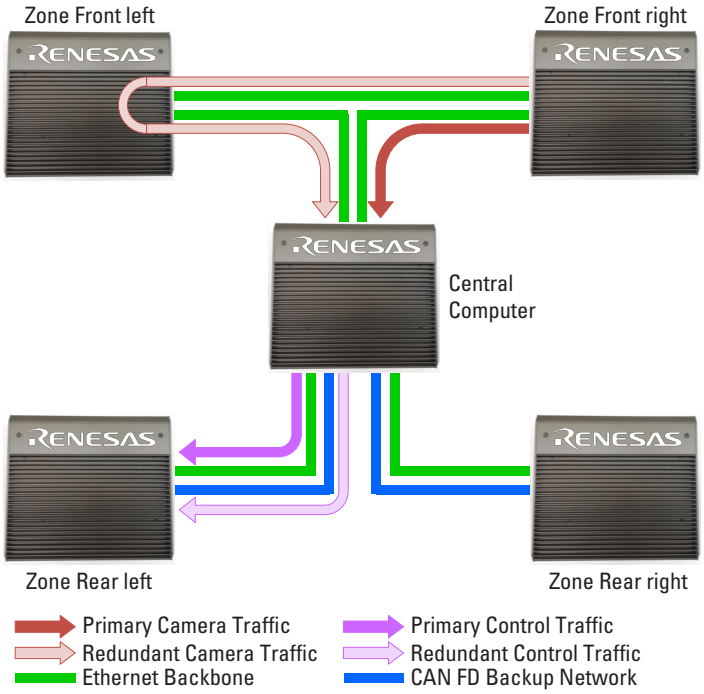

Figure 4

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