ETHERNET IN REDUNDANT NETWORKS
OPERATION OF IEEE802.1AS AND IEEE802.1CB

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AGENDA

▪ Automotive Ethernet – The backbone for data communication
▪ Look inside IEEE 802.1CB
▪ Look inside IEEE 802.1AS
▪ Redundant clock synchronization
▪ Summary
IN VEHICLE NETWORK AND DISPLAY SYSTEMS

There is need for QoS, time synchronization and redundancy

- Network has limitations
  - Bandwidth
  - Synchronization
  - Latency
  - Timing
  - Reliability

- QoS required
  - Speed
  - rpm
  - Energy

From 18th GENIVI AMM - Wayland-IVI-extension / Waltham Usage in Shared Graphics Environment
IN VEHICLE NETWORK
CHANGE IN STRUCTURE

Central Gateway

Domain Controller

In Vehicle Server

Challenges

Scalability

Flexibility

Bandwidth

Complexity

Distributed function

Ethernet

Mixed traffic
IN VEHICLE NETWORK
ZONE BASED ARCHITECTURE EXAMPLE

- Diverse applications with different requirements over same network, e.g.
  - Entertainment
  - ADAS
  - Sensor data
  - Control data
  - Old and new technology
  - Distributed functions

- Ethernet as backbone with features for QoS, time synch and reliability needed
IEEE 802.1 Audio Video bridging (AVB) task group was started in 2005
- Use cases in professional audio/video market
- Consumer audio/video market
- Automotive infotainment

Over the time AVB capabilities was becoming very interesting also to other groups
- Industrial
- Automotive control and sensing
- Configuration and service management

Goals:
- Open standard for audio/video transport
- Precise clock synchronization
- Bounded latency for different frame classes
- Traffic shaping to avoid bursts

Goals:
- Support all data types (Audio, Video, Sensor, Control)
- Latency improvements
- Increase transport reliability
- Increase network robustness
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<td>Stream Reservation/Network management</td>
<td><strong>IEEE 802.1Qat</strong> Stream Reservation Protocol (AVB)</td>
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<td><strong>IEEE 802.1Qci</strong> Per-Stream Filtering and Policing</td>
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Compressed list. For details visit [www.ieee802.org](http://www.ieee802.org)
IEEE 802.1CB
INTRODUCTION

- Critical data must arrive at destination
- Re-transmission would cause not acceptable delay
- My network has limited resources
- Loosing uncritical traffic is acceptable
- Should be transparent for the application layer

- IEEE802.1CB covers following failure models
  - Link loss (e.g. broken cable)
  - Package loss (e.g. CRC error)
  - Stuck transmitter (e.g. software/ hardware failure)
IEEE 802.1CB
EXAMPLE CRITICAL STREAMS

At talker side two “identical” packages are created (member streams). Sequence number and “R-Tag” is added.

Sequence generation function

Every stream from a talker undergoes identification function

Talker

Identification

Relay system

Examines sequence numbers and discards duplicates from different ingress ports.

Examine sequence numbers and discards duplicates from single ingress port. Duplicate frames if needed to all configured outputs.

Individual recovery function/ stream splitting

Sequence recovery function

Listener

Finally only one package is received by listener system and removes sequence number

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IEEE 802.1CB
EXAMPLE NOT CRITICAL STREAMS

Talker

Relay system

Listener

- Sequence generation function
- Individual recovery function/ stream splitting
- Sequence recovery function

Identification
IEEE 802.1CB OPERATION EXAMPLE

SETUP

- Camera traffic
- Control traffic
- Entertainment video

Central computer

Path planning/Motion control

Zone front left
Zone front right
Zone rear left
Zone rear right
LOOK INSIDE ECUS
PRE-SILICON DEVELOPMENT KIT VEHICLE COMPUTER 2

- Provide communication gateway solution kit for the next gen. E/E architecture
- Can start quickly of proof of concept (PoC) and prototype development with latest TSN technology

**Specification:**
- R-Car-H3
- RH850 F1KH-D8 (8M Flash)
- TSN Ethernet Switch (FPGA)
- Connectivity
  - 1Gbps Ethernet (1000Base-TX)
  - 6x100Mbps (5x100Base-T1, 1x100Base-TX)
  - 11x CAN-FD
  - 2x FlexRay / 10x LIN
  - 1x MOST150
  - HDMI
  - 2x USB2.0 / 1x USB3.0
  - 1x WLAN 802.11ac
  - PCI Express
IEEE 802.1CB OPERATION EXAMPLE
RING MODE

Primary camera traffic
Redundant camera traffic
Primary control traffic
Redundant control traffic
Entertainment video
Ethernet backbone

Zone front left
Zone front right
Zone rear left
Zone rear right
Central computer
Path planning/Motion control
IEEE 802.1CB OPERATION EXAMPLE
MESHED MODE

- Primary camera traffic
- Redundant camera traffic
- Primary control traffic
- Redundant control traffic
- Entertainment video
- Ethernet backbone

Zone front left
Path planning/Motion control
Central computer
Zone rear left
Zone front right
Zone rear right
IEEE 802.1CB OPERATION EXAMPLE
ARCHITECTURE COMPARISON

New challenges

- Jitter
- Topology
- Latency
- Bandwidth
- Port count
802.1AS – TIMING AND SYNCHRONIZATION

PURPOSE OF STANDARD

- **Purpose**: provide network with accurate, reliable, simple-to-use time
  - **Original target**: Audio/video synchronization
  - **IEEE 802.1AS** is a profile of IEEE1588v2 (subset with automotive specific extensions)
    - One or more Grand Masters (GM) provide time
    - Clock tree reconfigures automatically if GM is lost
    - Best Master Clock Algorithm (BMCA) is used to select the Grand Master

- **Operation**:
  - Grand master is the master to its slave device
  - that slave device is a master to its slave, and so on…
  - Continues synchronization on time and rate
802.1AS – TIMING AND SYNCHRONIZATION
OPERATION

Zone front left

Zone rear left

Central

Front left

$t_{\text{offset}} = \text{send} - t_{\text{rx sync}}$

$t_{\text{offset}} = 12:00:00 - 10:00:00 = 02:00:00$

$t_{\text{local}} = t_{\text{local}} + t_{\text{offset}}$

$t_{\text{local}} = 10:00:02 + 02:00:00 = 12:00:02$
802.1AS – TIMING AND SYNCHRONIZATION OPERATION

Zone front left

Zone rear left

Central

Front left

Sync req.

sent=12:00:00

12:00:00

12:00:02

12:00:02

12:02:55

12:02:55

12:02:58

12:02:58

12:02:57

12:02:57

t_offset

t_offset

t_offset used to for rate correction
802.1AS – TIMING AND SYNCHRONIZATION

Operation

\[ t_{\text{residence}} = t_{\text{sync_egress}} - t_{\text{sync_ingress}} \]

\[ \text{sent}_o = \text{sent} + (t_{\text{sync_egress}} - t_{\text{sync_ingress}}) \]

\[ \text{sent}_o = 12:02:55 + (12:03:05 - 12:02:55) \]

\[ \text{sent}_o = 12:02:55 + 00:00:10 = 12:03:05 \]
802.1AS – TIMING AND SYNCHRONIZATION

FURTHER FEATURES

- There is more about time synchronization
  - Grad master selection
  - Link delay
  - Signalizing

- Want to learn more? Check [www.ieee802.org/1](http://www.ieee802.org/1)

Important takeaway:

1. Shared time is important for A/V, sensing applications and control systems
2. IEEE 802.1AS provides a standardized way for ECU accurate time synchronization
3. Supported by most of automotive products
REDUNDANT CLOCK SYNCHRONIZATION
... I want to synchronize network using redundant paths?

- IEEE 802.1CB is not an option
  - Bridges would route synchronization frames
    - Residence time not considered
  - Receiver does not know which path was taken
    - 802.1CB is transparent to application
    - gPTP middleware could sort out frames from different paths
    - gPTP timer would need to work on two different set of information for rate correction
  - Receiver would get wrong time information
IEEE 802.1AS-rev improvement points

- Redundancy considerations
  - Single grand master transmitting copies of its clock using separate paths (like 802.1CB)
  - Allows more than one grandmaster in a system
  - Or a combination of both
- Multiple timing domains
- IEEE 802.11 support
- Support for link aggregation
- ... and many more
- Implication to hardware
  - Multiple gPTP timer instances
CONCLUSION

- We cannot rely on the network by itself

- Automotive Ethernet will be shared medium for a/v/c, safety critical not safety critical
  - TSN developed to support all data types; not just Audio and Video
  - TSN helps to achieve better performance through lower latencies
  - TSN achieves low packet loss rates by supporting various levels of redundancy

- TSN is a toolbox concept to enable auto/ video and control data transfer in safety critical applications
  - Right standards needs to be selected for each application and topology

- Most features are transparent for application but slightly impact application layer
COME AND SEE ALL THESE FEATURES IN ACTION AND DISCUSS