10 Mbps Single Pair Ethernet
(10SPE – 10 BASE-T1S)

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IEEE Ethernet & IP @ Automotive Technology Day
Motivation

- **Ethernet/IP-based Network everywhere**
  - WWW, IT, Automation, IoT, Cars etc.
  - Scalable bandwidth, various PHY layer options, proven SW stacks

- **Security and safety are essential**
  - Security framework
  - Safety framework

- **Service-oriented architecture manages complexity**
  - Encapsulation of functions and data
  - Unifies communication
  - Re-usability and movability of services

- **Innovative applications drive data rates**
  - Legacy implementations run out of steam
Why is Ethernet needed?

Legacy

PHY

Stack

CAN

CAN

FlexRay

...

Ethernet

PHY

10BASE-T1S | 100BASE-T1 | 1000BASE-T1 | NGAUTO | ...

Stack

Ethernet, IP, SomeIP
Why not 100BASE-T1?

- 10BASE-T1S enables multi-drop (bus line)
  - No switches
  - Less cables
  - 10 Mbps shared
  - Half-duplex
  - Up to at least 8 nodes
  - Up to at least 25 m
  - Stubs up to 10 cm
  - Arbitration scheme for optimized data throughput and transmission latency
Optimized data throughput on the bus line

- **Goals**
  - Full bandwidth utilization
  - Reduce latency
  - Quality of Service (QoS)

- **Principle**
  - Avoid physical collisions on the medium by organizing the media access
    - Called Physical Layer Collision Avoidance (PLCA)

- **How it is done**
  - Only the PHY that owns a transmit opportunity is allowed to send data
  - Transmit opportunities are given in a round robin manner
  - A new cycle of transmit opportunities is started when the master node sends a BEACON
  - Works on top of Carrier Sense Multiple Access/Collision Detection (CSMA/CD)

Transmission Cycle

![Transmission Cycle Diagram](image-url)
Impact on Cabling

<table>
<thead>
<tr>
<th>Benefits of 10BASE-T1S</th>
<th>10BASE-T1S</th>
<th>Legacy</th>
</tr>
</thead>
<tbody>
<tr>
<td># PHYs</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td># Connectors ECU</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Cabling</td>
<td>1 bus line</td>
<td>4 cables</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>10 Mbps</td>
<td>&lt; 10 Mbps</td>
</tr>
<tr>
<td>Ethernet-based network</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Gateways</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

- Fewer PHYs
- Fewer connectors and less connector space on ECU
- Less cabling, extendability, scalability
- More bandwidth
- Seamless integration into overall Ethernet architecture
- Eliminates need to translate messages
Scalability

- Minimum required connector space at ECU
- Bus line can be expanded by additional sensor units
- Assembly options don’t change central ECU

Example: Ultrasonic and Short Range Radar
## Example Radar/Ultrasonic Sensing

<table>
<thead>
<tr>
<th></th>
<th>Ultrasonic</th>
<th>Side Radar</th>
<th>Front Radar</th>
</tr>
</thead>
<tbody>
<tr>
<td># Sensors</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>0.3 Mbps</td>
<td>1.5 Mbps</td>
<td>3.5 Mbps</td>
</tr>
<tr>
<td>L1 Packet Length</td>
<td>84</td>
<td>148</td>
<td>148</td>
</tr>
<tr>
<td># Packets per Sensor per Second</td>
<td>446</td>
<td>1267</td>
<td>2956</td>
</tr>
<tr>
<td>Latency</td>
<td>624 us</td>
<td>624 us</td>
<td>624 us</td>
</tr>
</tbody>
</table>
Example: Hands Free Microphones

- Three Sensors on one PCB
- Two PCBs connected to an ECU
- 1722 AVTP as transmission protocol
## Example: Hands Free Microphones

<table>
<thead>
<tr>
<th></th>
<th>Per PCB</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong># Sensors</strong></td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td><strong>Sample Frequency</strong></td>
<td>48 kHz</td>
<td>48 kHz</td>
</tr>
<tr>
<td><strong>Samples per Packet</strong></td>
<td>3*24</td>
<td>3*24</td>
</tr>
<tr>
<td><strong>L1 Packet Length</strong></td>
<td>206</td>
<td>206</td>
</tr>
<tr>
<td><strong># Packets per second</strong></td>
<td>48 kHz / 24 = 2000</td>
<td>4000</td>
</tr>
<tr>
<td><strong>Latency (= sample collection + packet transmission)</strong></td>
<td>500 us + 2 * 165 us = 830 us</td>
<td>830 us</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>3.3 Mbps</td>
<td>6.6 Mbps</td>
</tr>
</tbody>
</table>
Application Overview

- Hands free microphones
- Active speakers
- Noise vibration harshness
- Parking ECU
  - Radar
  - Ultrasonic
- Engine ECU
- Body ECU
- Active suspension
- Steering/braking system
- Charging units for electric cars
- Traffic sign recognition
Conclusion

- **Key Features**
  - Multi-drop
  - No collisions
  - Deterministic low latency

- **Enabling expansion of Ethernet technology to many additional applications**