Controller Area Networks

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• CAN bus: Connecting embedded systems in cars
• CAN standard specifies multiple access and link control
Connecting embedded systems in cars

- **CAN High-Speed** connecting controllers in the engine compartment, e.g. ESP controller (1Mbit/s, up to 40m)
- **CAN Low-Speed** bus for comfort functions, e.g. air condition, seat and window control (up to 125kbit/s)
Networking with CAN (Controller Area Network)

- CAN bus is also used for controller networks in automation.
- Most important features: Highly fault tolerable and low latency.
CAN protocol layers

- **Physical Layer**: e.g. “bit timing”
- **Data Link Layer**: bus access, packet format, data link control, error detection
Line coding

- CAN requires a physical link with two states: recessive and dominant.
- CAN uses **NRZ** (No Return to Zero)
- **Bit stuffing**: insert a complementary symbol after a sequence of 5 ones or 5 zeros.
CAN packet format

- **Data Frame**
  Data transmission from one node to node or many receiving nodes, always initiated by the transmitter.

- **Error Frame**
  Whenever a node detects a transmission error it broadcasts an error frame to all other nodes.
**Data Frame**

- **SOF** (start of frame) and **EOF** (end of frame) to indicate start and end of a data frame
- **Data Field**: Actual payload data
- **CRC** (Cyclic Redundancy Check) and **ACK** (Acknowledge Field) are used for error detection and acknowledgment of correctly received packets
- **Arbitration Field** controls medium access
Medium access and priority – give way!

• Every node may start with data transmission as soon as the bus is idle.

• To avoid collisions CAN uses **CSMA/CD+AMP** (Carrier Sense Multiple Access/Collision Detection + Arbitration on Message Priority) = **CSMA/CA** (Collision Avoidance)
Medium access and priority – give way!
• **Bit Monitoring**  
  Every sent bit has to be monitored by the sender. Hence, most errors are immediately detected.

• **Message Frame Check**  
  Every receiver checks whether the data frame format is violated, e.g. EOF has to be consistent with the data length field.

• **Bit-Stuffing errors**  
  Detect bit patterns that violate the bit stuffing rule.

• **CRC (Cyclic Redundancy Check)**  
  CAN uses a 15 bit CRC parity field.
Error detection and error correction

Repetition code of length 7

Code words differ in all 7 positions -> Hamming distance 7

We can detect up to 6 transmission errors

Or we can correct up to 3 error
Transmission with retransmissions
• The used CRC code allows to detect up to 5 randomly distributed bit errors, but it is possible to detect up to 15 burst errors.

• A CAN message carries at most 8 byte payload.

• The probability of a successful transmission is much higher with short message than with longer data packets.
Some remarks

• The important advantage of short data packets is the small delay for messages with high priority. With CAN the maximum latency for the message with highest priority is at most 130 µs with a data rate of 1 Mbit/s.

• CAN is highly fault tolerable due to the cascaded system of error detection mechanisms.