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Lec. 7:
Communication

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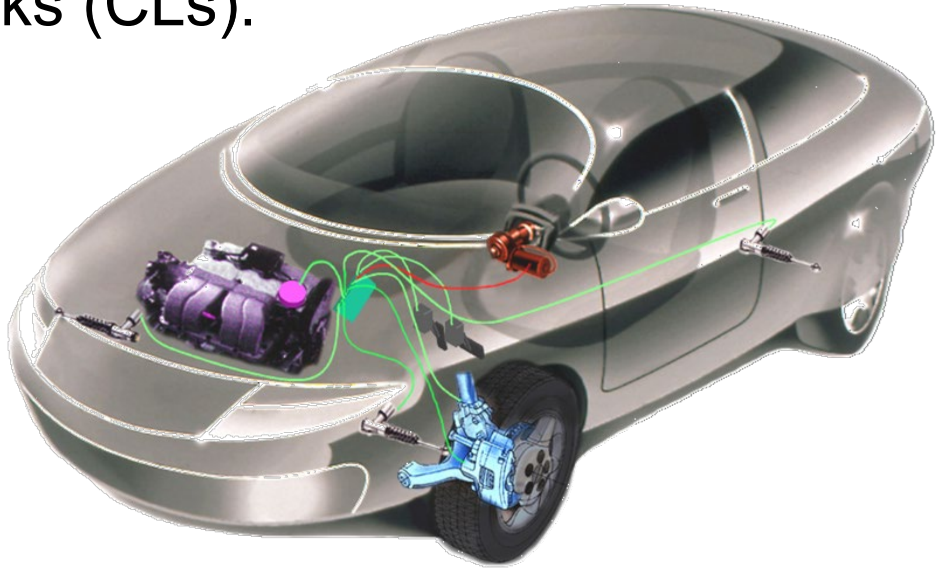
According to Peter Marwedel's Lectures

Distributed Embedded Systems

- Consist of several heterogeneous processing elements (PEs):
  - General-purpose processors (GPPs), Application specific instruction processor (ASIPs), ASICs, FPGAs, smart sensors, and smart actuators.
- These components are connected through an infrastructure of communication links (CLs).



Important Requirements

- Real-time behavior
  - Ethernet fail to meet this requirement
- Event driven communication
  - Polling based communication
    - Very predictable, suitable for real-time behavior
    - Unsuitable for emergency messages
- Scalability
  - New PEs can be added easily

CSMA/CD VS. CSMA/CA

- CSMA/CD
  - Carrier-sense multiple access/collision detect
    - cannot be used when real-time constraints have to be met.

- CSMA/CA
  - Carrier-sense multiple access/collision avoidance
  - Communication media are allocated to communication partners during arbitration phases, which follow communication phases.
  - Suitable for Real-Time systems

Example: Controller Area Network (CAN)

- Developed in 1981 by Bosch and Intel for connecting controllers and peripherals.
- Popular in the automotive industry.
  - It allows the replacement of a large amount of wires by a single bus.
- CAN components are relatively cheap and are therefore also used in other areas such as smart homes.

CAN Properties

- Differential signaling with twisted pairs
- Arbitration using CSMA/CA
- Throughput between 10kbit/s and 1Mbit/s
- Low and high-priority signals
- Maximum latency of 134 µs for high priority signals
- Coding of signals similar to that of serial (RS-232) lines of PCs, with modifications for differential signaling.

Important Features (Cont.)

- Physical Layer + Data Link Layer
- Number of nodes not limited and may be changed dynamically.
- No node addressing
  - Actually the address information is contained in the identifiers of the transmitted messages.
  - The identifiers indicate the message content and the priority of the message.

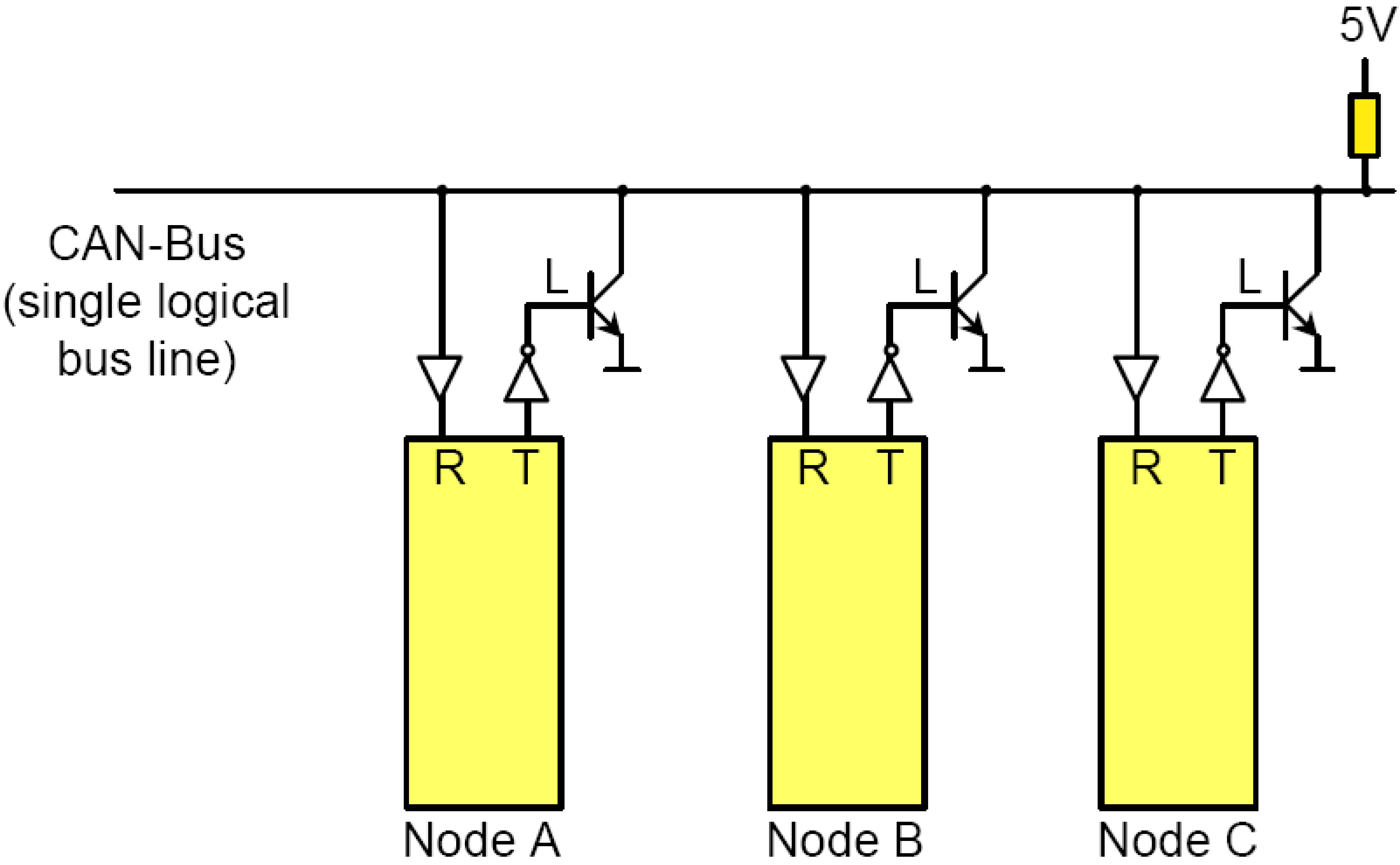
Important Features (Cont.)

- Error-detection and error handling
  - Temporary errors
    - ARQ (CRC)
  - Permanent errors
    - Automatic switch-off of defective nodes
- Maximum bus length of 40 meters (twisted pair)
- Message length = maximum of 8 data bytes per message

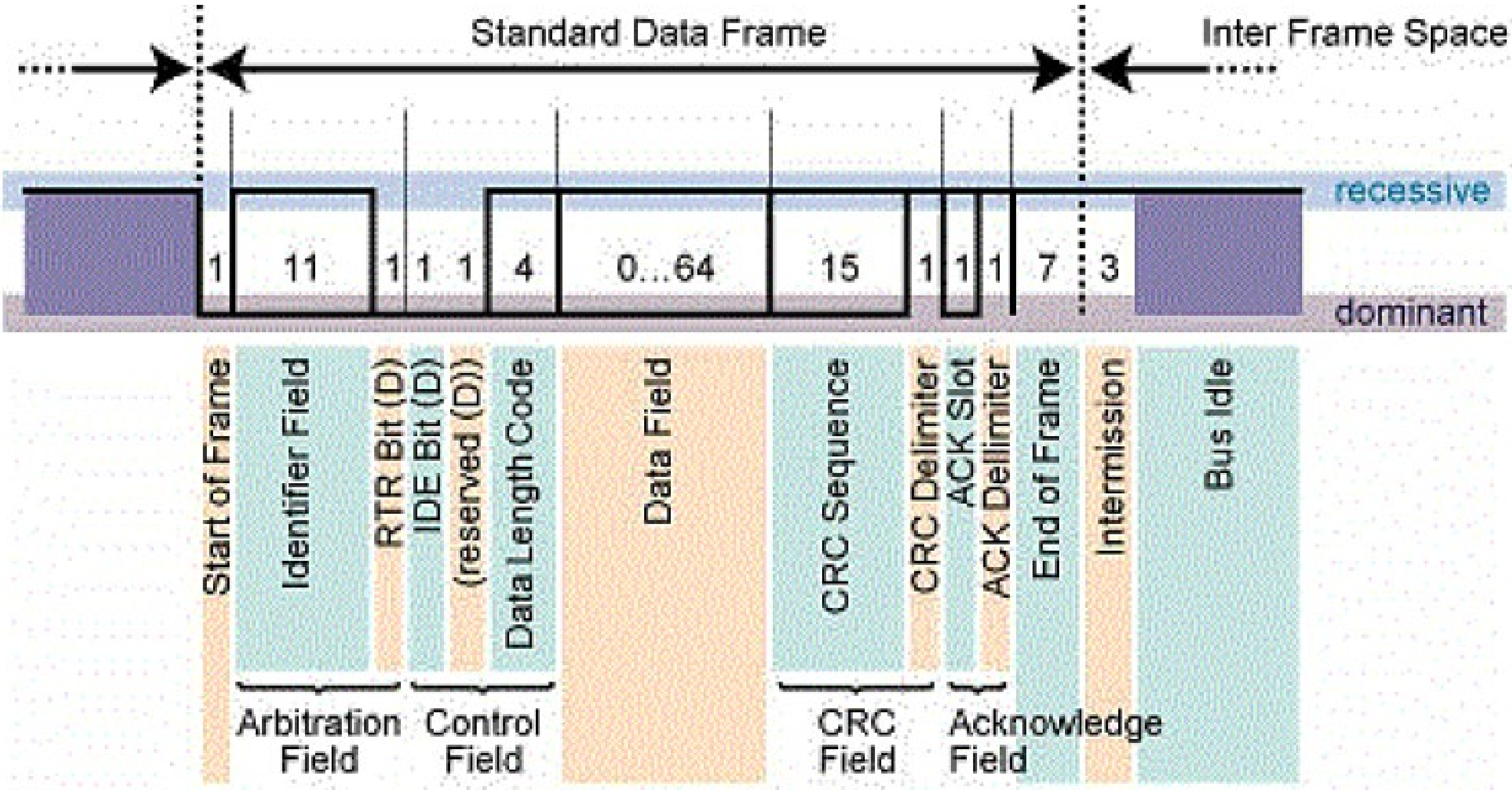
Non-Destructive Arbitration

- Collision is only allowed for arbitration (Non-destructive collision).
- The arbitration is based on the wired-AND mechanism.

Wired-AND in CAN Bus



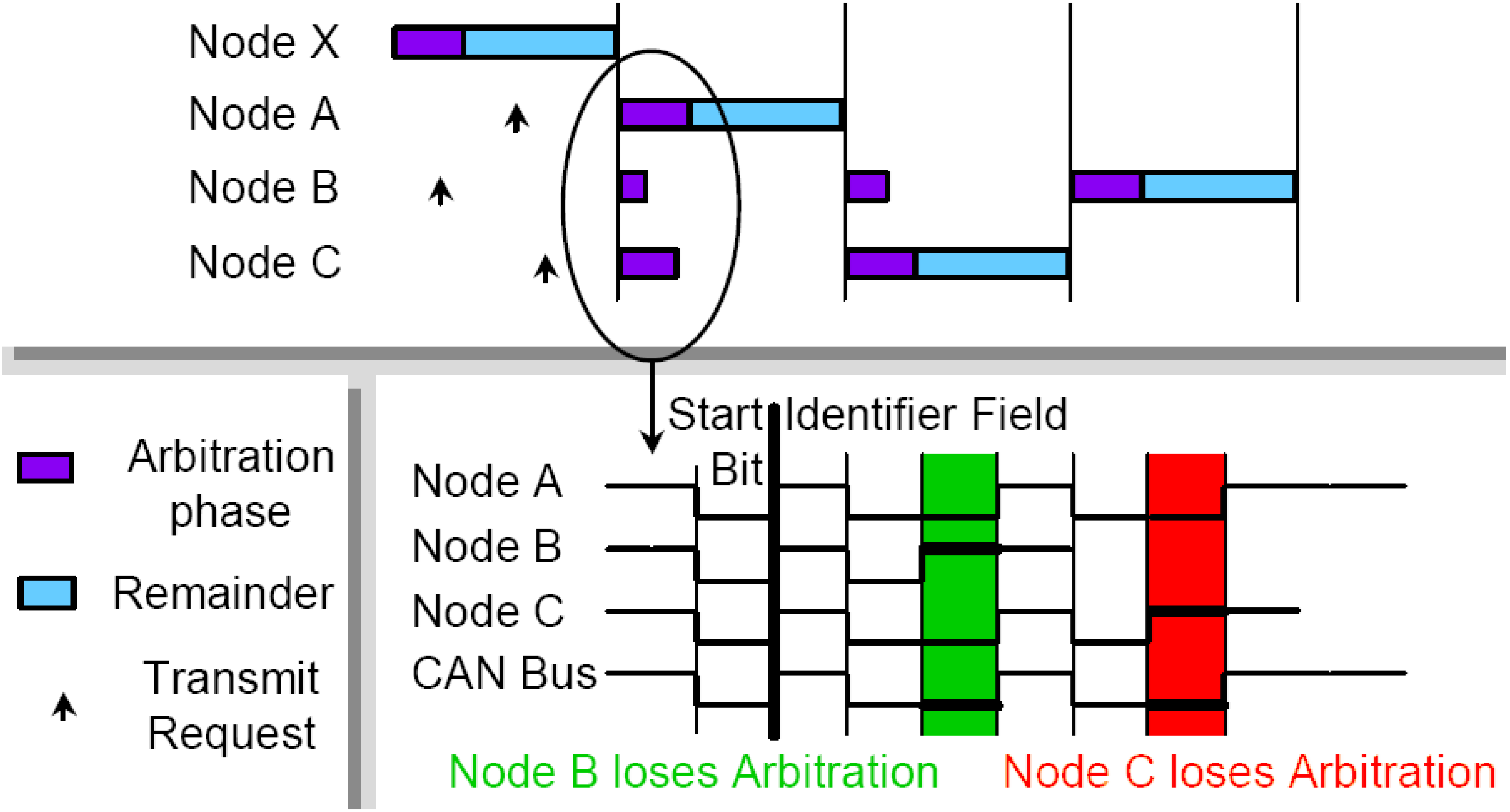
Frame Format



Frame Format

- 12-bit arbitration field= 11-bit identifier + 1-bit RTR
  - RTR = Remote transmission request
    - Distinguishes between data frame (RTR set to zero) and data request frame (RTR set to 1)
- IDE = Identifier extension

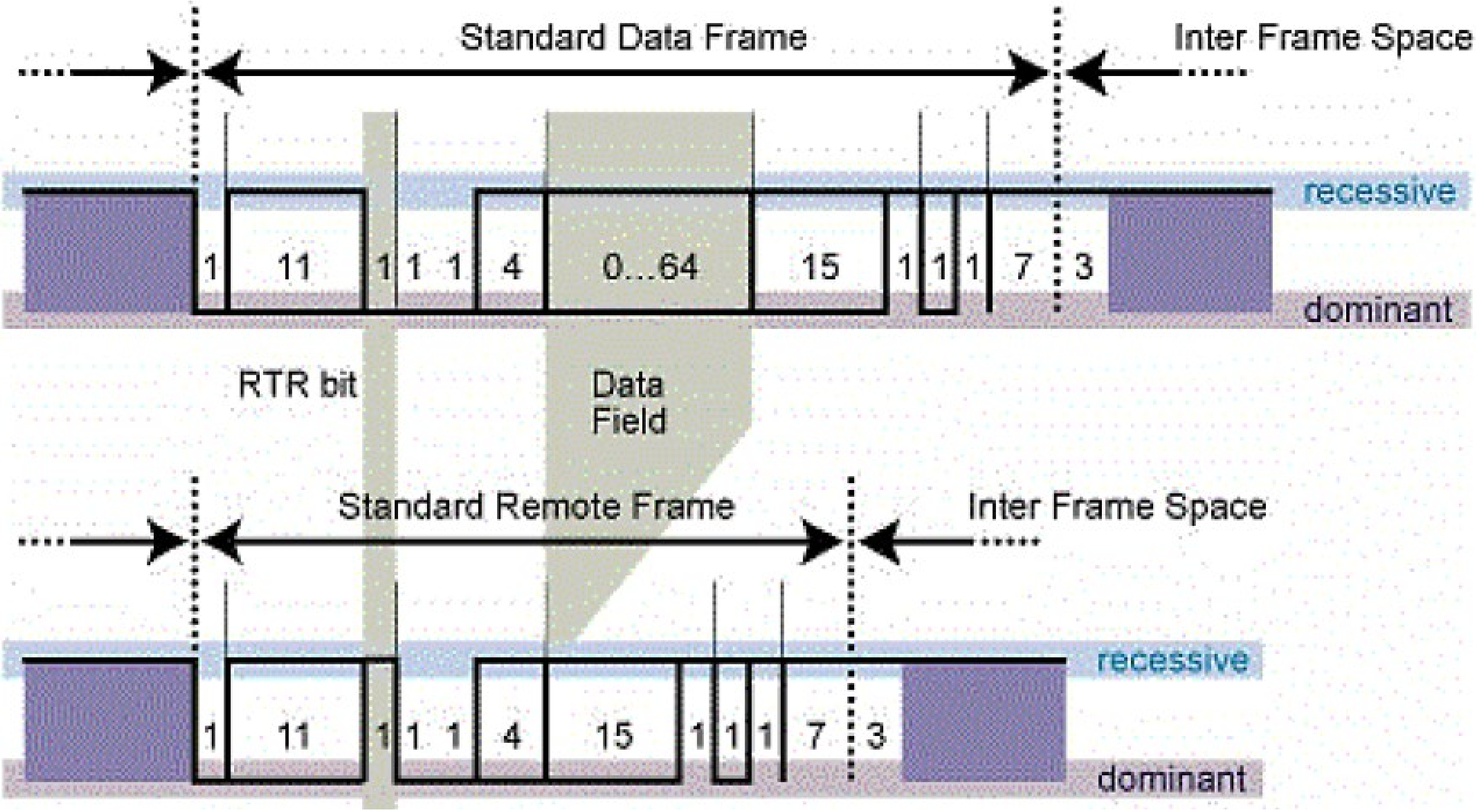
Arbitration Example



Acknowledgement Mechanism

- Like the arbitration mechanism, the acknowledgement mechanism is based on Wired-AND.
- During the ACK slot the transmitting node sends out a '1'.
- Any node that has received the error free frame sends back a '1' during the same ACK slot.
- A '0' in the ACK slot indicates an erroneous frame transmission.

Remote Frame

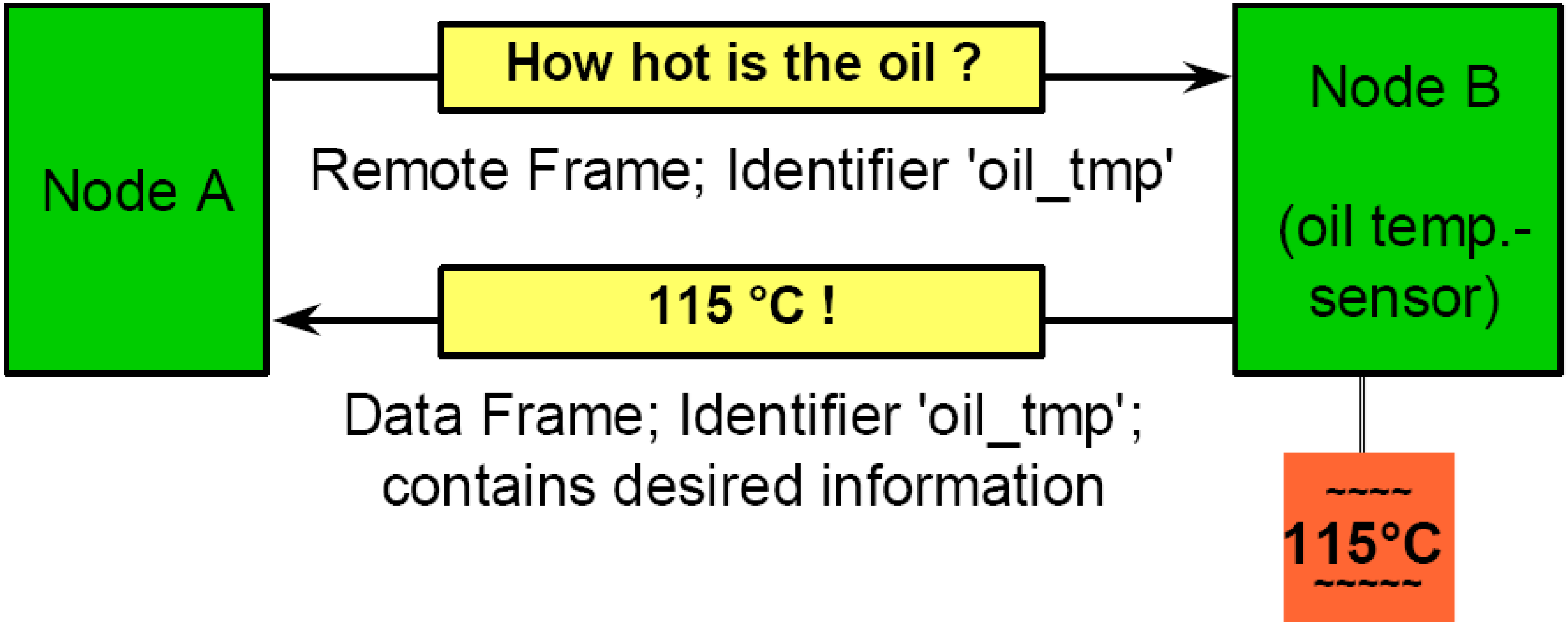


Remote Frame

- Generally data transmission is performed on an autonomous basis.
  - No remote frame
  - e.g., a sensor sends out data frames continuously.

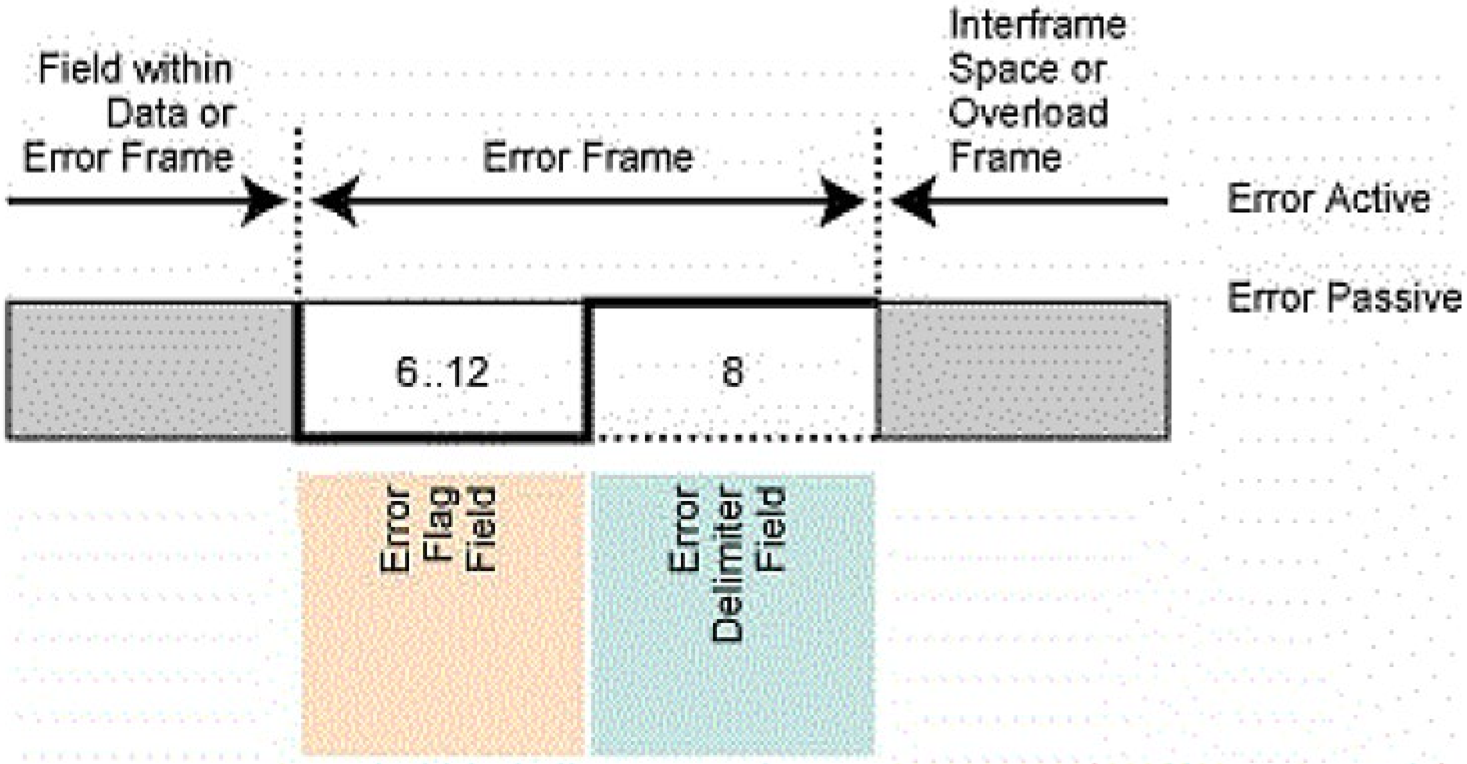
- A destination node can request the data from the source by sending a Remote Frame.
  - Request / Reply Model

Remote Frame


How hot is the oil ?
Node A
Node B
Remote Frame; Identifier 'oil_tmp'
(oil temp.-sensor)
115 °C !
Data Frame; Identifier 'oil_tmp';
contains desired information
~~~~
115°C
~~~~~

If a node wishes to request the data from the source, it sends a Remote Frame with an identifier that matches the identifier of the required Data Frame.

Error Frame


Field within Data or Error Frame
Error Frame
Interframe Space or Overload Frame
Error Active
Error Passive
6..12
8
Error Flag Field
Error Delimiter Field

Error Frame

- An Error Frame is generated by any node that detects a bus error.
- There are, two forms of Error Flag:
  - Active error flag = 6 consecutive 0
  - Passive error flag = 6 consecutive 1
- 6 consecutive 0 (or 1) violates the bit stuffing rule.
- Passive error flag is effective only when the bus master node sends it.

Summary

- Distributed Embedded Systems
  - Real-time behavior
  - Event driven communication
  - Scalability
- CSMA/CD and CSMA/CA
- Controller Area Network (CAN)
  - Important features
  - Details of frame