Communication in Distributed Embedded Systems

Embedded System Engineering VO
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Overview

• Distributed Systems Motivation
• OSI Communication Model
• Physical Layer
• Data encoding

One Definition of a Distributed System

“A distributed system is a collection of individual computing devices that can communicate with each other”
(Attiya & Welch’98)

Motivation for Distribution

• System parts are situated far apart from each other (e.g., automated factory/building/vehicle, mine)
• Parallelism (e.g., grid computing)
• Fault Tolerance (e.g., redundant nodes and channels)
• Modular Design (e.g., PCI bus extensions)

ISO OSI Communication Model

Application
Transport
Session
Presentation
Application
Network
Transport
Session
Presentation
Transport
Network
Transport
Network
Transport
Network
Physical
Link
Physical
Link
Physical
Link
Physical
Link
Data Encryption, Data Compression, Error Detection/Correction
Data Link Layer provides the mechanisms for managing the dialogue between end-user application processes.
Physical layer provides the hardware interface to the physical medium (wires, fiber optic cables, etc.)
Data packet encoding/decoding, error handling, packet sequencing

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ISO OSI Communication Model

• Layered model makes sense if following assumptions are made:
  – Point-to-point communication
  – Event-triggered communication
  – Comm. protocol with acknowledgments (ACK) - explicit flow control
  – Real-time performance - do not care
• OSI model does not fit well
• Distributed embedded systems usually implement:
  – Application layer (Layer 7)
  – Link layer (Layer 2)
  – Physical layer (Layer 1)

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Channel Capacity

\[ C = B \cdot \log\left(1 + \frac{P_s}{P_n}\right) \]

• Shannon-Hartley Theorem - the maximum amount of error-free
digital data that can be transmitted over a communication link with
a specified bandwidth in the presence of noise interference
• B channel bandwidth –
  – a relative range of frequencies that can carry a signal on a
transmission medium
  • Telephone: 3 KHz, TV 6 MHz, Satellite TV 17-72 MHz
• P_s signal power, P_n noise power, P_s/P_n signal-to-noise-ratio
• Result is Baud rate of channel (not bit rate; depends on encoding)

Bandwidth

• Digital systems: Bandwidth indicates the number of bits
that can traverse a channel in a unit time, e.g.,
  – Ethernet 100 Mbit/sec
  – CAN 1 Mbit/sec
• Bandwidth is determined by the physical characteristics
of the channel
  – EMI constrains
  – MAC

Propagation delay

• The time interval it takes for a bit to travel from one end
of a channel to the other end.
  – channel length
  – Transmission speed of the wave
    • cable is 2/3 speed of light (200 000 Km/sec)
    • 0.5 µsec for 100 meter cable length

RS 232 Interface

• Point-to-Point communication
• Signals with respect to GND
• 30-60 m maximum cable length
• Specified up to 115.2 Kbit/sec
• Standard PC interface
  – COMs resp. TTY's
  – Sub D9 or Sub D25
• Inexpensive
RS 422/485 Interface
- Differential signals (Twisted pair)
- Up to 1 km cable length
- Up to 10 Mbit/s (25 Mbit/s chips available)
- Data speed x Cable length < 10^8 m Bit/sec
- RS 422
  - Point-to-Point communication
- RS 485
  - Multipoint communication
  - 1200 meters at 200kbps or 50 meters at 10Mbps
  - Up to 32 devices with input impedance 12k
  - Up to 128 devices with input impedance 48k

Automotive Physical Layer Standards
- ISO 9141 k-line
  - two wires designated the K-line and L-line
  - The voltage level on the wire determines the state.
  - When a node is powered - in the 1 state.
  - For a node to transmit a 0, it pulls the desired line to ground and holds it there for 1-bit time.
  - The K-line is bidirectional and shared by all nodes
  - Single wire
  - 6-18 V voltage, robust against shortages
  - Automotive body electronics

Automotive Physical Layer Standards
- Controller Area Network (CAN)
  - Automotive domain, together with CAN protocol
  - Recessive/dominant state
  - Bus length up to 5000 m
  - up to 1 Mbit/sec (0...40m)
  - Bit rate depends on bus length and vice versa
  - Arbitration logic

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Physical Layer
- Specifies the transmission codes such as
  - coding of the bit patterns in the physical channel.
  - Transmission speed
  - Physical shape of the bit cells
  - Sometimes the protocol is dependent on the physical layer (e.g. CAN).

Physical Layer: Bit Encoding
- Non Return to Zero (NRZ)
- (Always) Return to Zero (PWM)
- Manchester Encoding
- Modified Frequency Modulation (MFM) Encoding
- Tristate Encoding
Non Return to Zero (NRZ)
- “1” is high, “0” is low
- Non synchronizing code: no signal transitions if data stream contains only “1”s or “0”s
- Bit stuffing (CAN)

(Always) Return to Zero (PWM)
- Pulse width modulation
- “0” is short pulse, “1” is long pulse
- Synchronization point at every bit cell
- Range can be extended to multiple or analogue values
- Required Baud rate is at least three times higher than bit rate
  (Feature size 1/3)

Manchester Encoding
- Transition in the middle of each bit cell
- “0” is high/low, “1” is low/high
- Synchronization point at every bit cell
- Required Baud rate is at two times higher than bit rate (feature size 1/2)

Modified Frequency Modulation (MFM)
- Data and clock points
- Data points: “0” no signal change, “1” signal change
- Clock points: change if more than two “0” in a row
- Enables continuous re-synchronization
- Feature size of 1

Tristate Encoding
- Three possible states (low, zero, high)
- “1” after “0” is high, “0” after “1” is low
- “1” after “1” toggles between high and zero
- “0” after “0” toggles between low and zero
- Continuous re-synchronization, feature size of 1

Summary
- Distributed embedded system requires communication
- Layered model
  - Physical layer (electrical properties)
  - Data encoding
Vielen Dank für Ihre Aufmerksamkeit!

Noch Fragen?