Embedded Communication

18-849b Dependable Embedded Systems

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February 9, 1999

Required Reading: Communication Protocols For Embedded Systems, Koopman and Upender,
Embedded Systems Programming, 7(11), November 1994, pp 46-58.

Best Tutorial: Data Communication, NUREG/CR-6082, G. Preckshot, Lawrence Livermore Laboratory,
August 1993

Authoritative Books: Real-Time Systems, H. Kopetz, Kluwer Academic Publishers, 1997, Chapters 7-8

Overview

- ♦ Background: System Types
- ♦ Key Concepts
  - • Event vs State Based Communication
  - • Best Real-Time Protocol?
  - • Error Detection/Diagnostics
- ♦ Tools / Techniques / Metrics
- ♦ Connections
- ♦ Conclusion
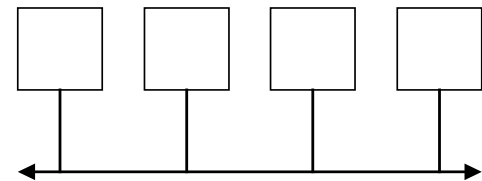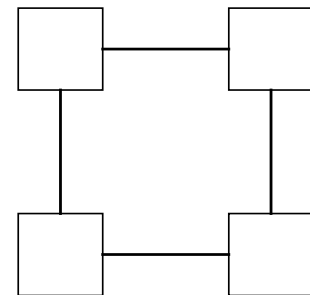- ♦ Paper Discussion
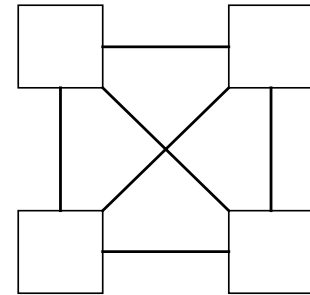
Background: System Types

♦ **Point to Point: Data Links**

  • Simple

  • Reliable

  • Easy to meet real-time deadlines

♦ **Shared Media: Data Highway**

  • Reduction in wiring

  • Easily extendable

  • Added protocol complexity

Event vs State Based Communication

♦ Event - Transmit changes only
- Effective use of BW
- Every message is important
- Alarm flood problem

♦ State - Transmit whole state
- Less efficient
- Network load is fixed
- Static scheduling is possible
- Can tolerate missed message
- Must hold state for short events (pulse-stretch)

Best Real-Time Protocol?
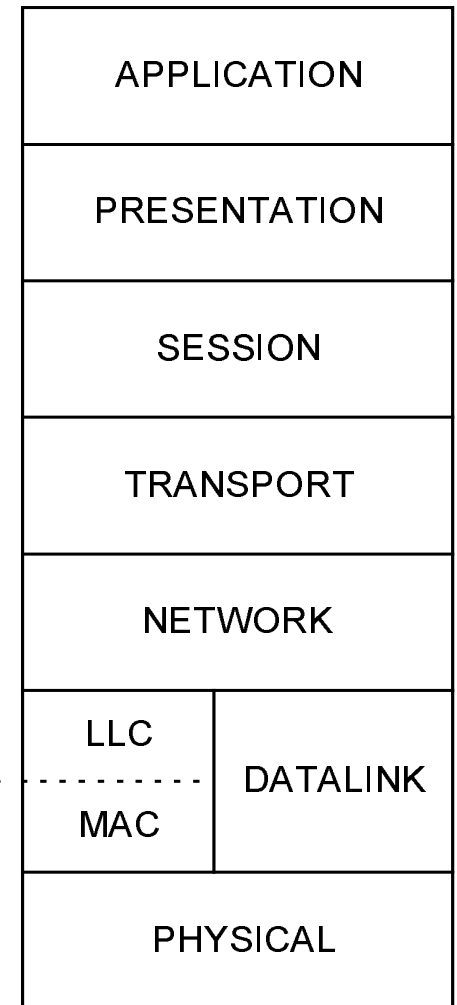
◆ Fundamental Conflicts (Kopetz)
  - External Control vs Composability
  - Flexibility vs Error Detection
  - Sporadic vs Regular Data
  - Spontaneous Service vs Interface Simplicity
  - Prob. Access vs Replica Determinism

◆ Examples (standard protocols)
  - CSMA/CD - Ethernet
  - CSMA/CA - CAN
  - Polling - BitBus
 - Token Passing - Token Bus
 - TDMA - ARINC 629

◆ Interoperability => higher layers

APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK

LLC
MAC
DATALINK

Embedded System Focus

PHYSICAL

5

Error Detection / Diagnostics

| Error Type	Defense
channel noise	CRC fiber optics
stale message	time-stamp
repeated message	serial number
station run-on	anti-jabber circuit
failure propagation	surge protection redundant network fiber optics
memory errors	checksum
intermittent errors	statistical counters
interface H/W failures	loopback testing
cable breaks	dynamic reconfiguration

CPU

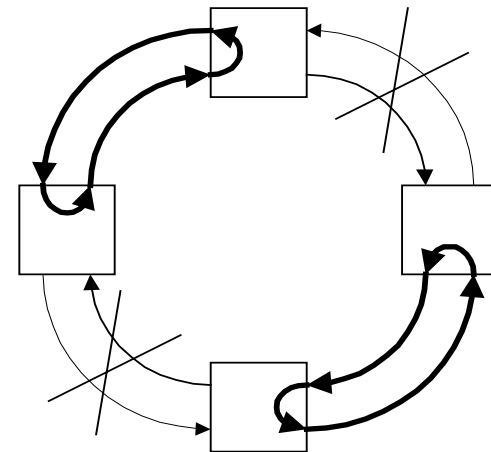NIC

Channel

NIC

CPU
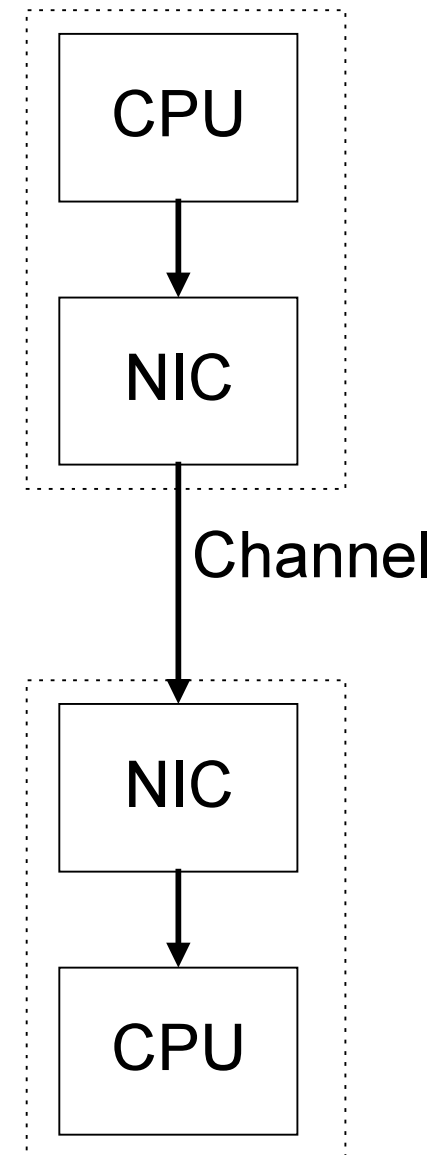
Dynamic Reconfiguration Example
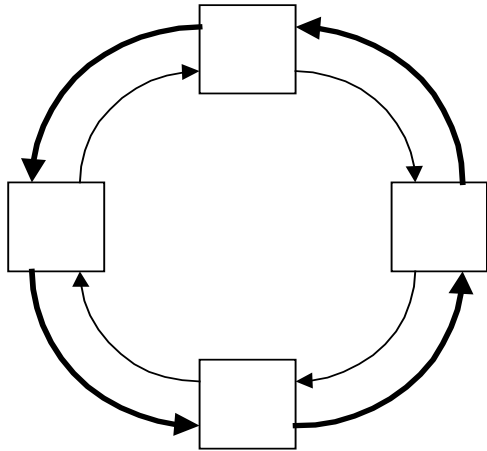
Normal Operation
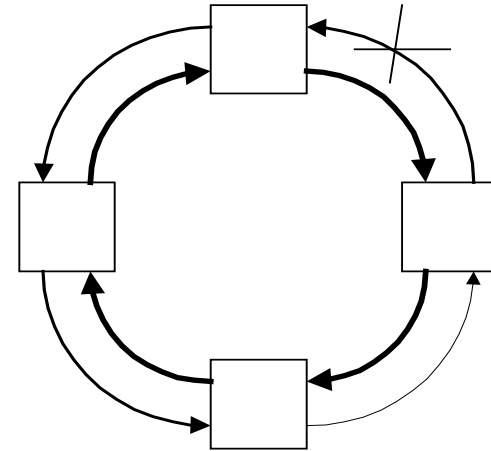
Single Break
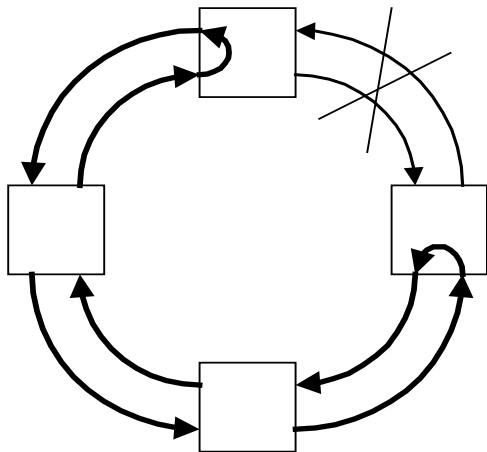
Double Break

2 Double Breaks

Tools / Techniques / Metrics

◆ Protocol Analysis/Verification Tools

- Petri Nets, Lotos, SDL, Z…

◆ Protocol Selection / Evaluation

- NUREG/CR-6082 provides guidance

◆ Metrics

- Data Rate
- Throughput vs Load
- Delay vs Throughput
- Worst Case Utilization
- Error Rates

Connections

- ◆ I/O
  - Field busses
- ◆ Distrib. Dependability
  - Comm. Architecture
- ◆ Real Time
  - Schedulability
- ◆ Fault Tolerant Computing
  - Redun, Error Detection
- ◆ Error Coding
  - Reliability, SNR, Compression, Error Detect
- ◆ Formal Methods
  - Protocol Verification
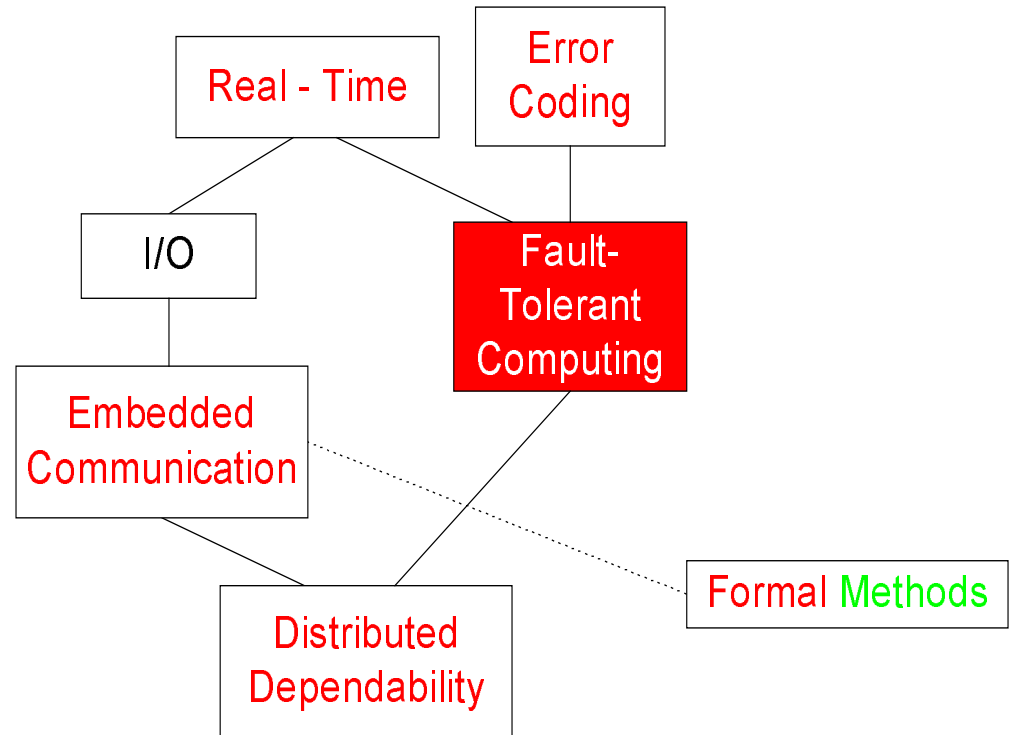
Conclusions

♦ State based for Critical Systems

♦ Media access => real-time and failure mode properties

♦ Protocol selection driven by real-time issues, technology, media access properties

♦ Low-level protocol focus may change due to interoperability issues

♦ Consider all error modes of system

♦ Other Issues Not Covered

- Clock Synchronization important for event based

- Mixing syncronous (real-time) and asynchronous (non-critical) data on a network

Paper: Embedded Protocols

- ◆ Good overview of media access
- ◆ Comparison of more than 3 protocols is hard to find in literature