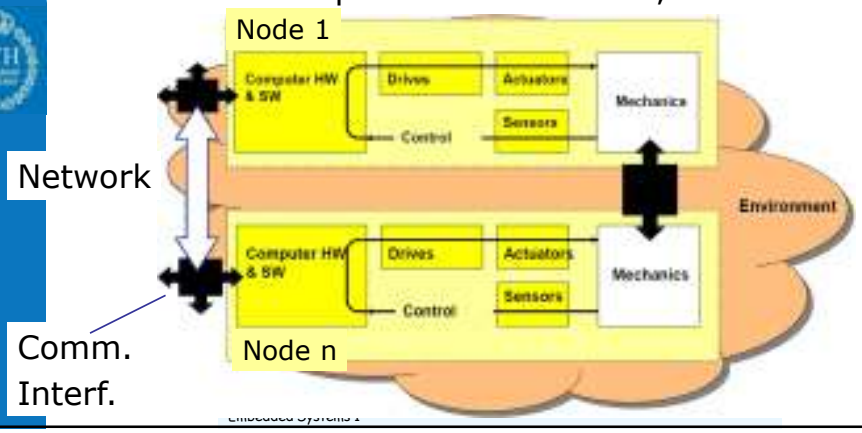
Fundamentals of Distributed Control Systems and the Controller Area Network

What Is A Distributed System?

- A set of nodes connected by the network, cooperating to achieve a common goal
  - Node: a μC +I/O + communication interface
  - One or multiple networks: wired, wireless

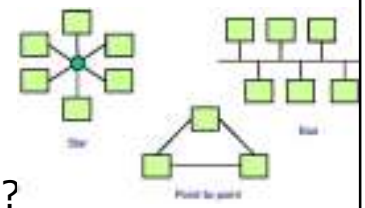


Distributed systems - prelude

- Humans make up distributed systems
- Three communicating persons
  - Direct voice communication
  - Separate phones and lines per pair
  - Phone conference

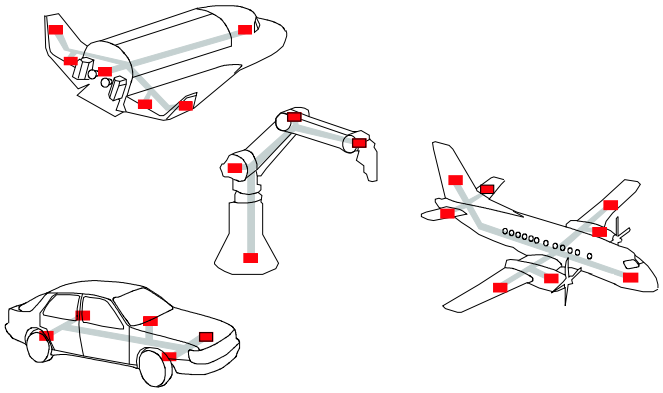
Note: Logical vs. Physical topology;
Point to point vs. Multi-/Broadcast

Types of communication



- Topology
- Periodic, sporadic, aperiodic
- Consistency constraints?
  - When, or what extent can this be tolerated?
- Timing constraints?
- Reliability constraints?
  - What should be done when communication no longer works well?
  - Acknowledged vs. Non acknowledged com.?
- Buffered vs. Non-buffered?

Why distributed systems?



Why distributed systems?

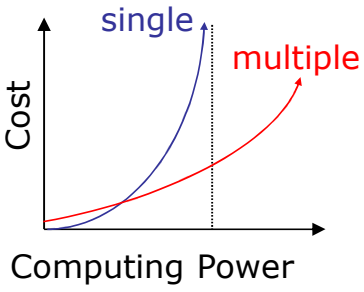
- Reduction of amount of cabling
- Modularity
- Local intelligence, diagnostics
- Performance
- Fault-tolerance
- Organizational constraints
  - Not always motivated from a systems viewpoint

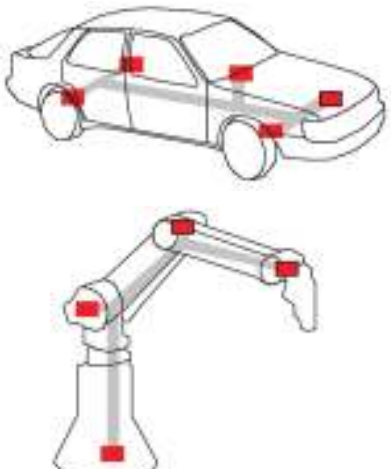
Reducing Cables with Network

- Network transfers digital signals that have strong protection against noise
  - Increase data integrity
- Reduce the cost of cables, connectors, and noise protection for analog signals
- Simplify system complexity; increase system reliability (fewer connectors)
- Shared resources and information: shared sensors, many-to-many msg.
- Promote modularity: component based system

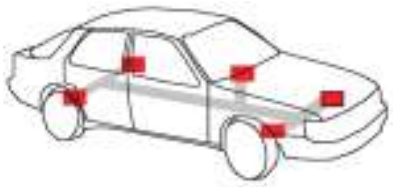
Why Multiple Processors?

- Additional computing power
- System topology





Why are there so many types of networks, technologies and protocols??



Ethernet

Wireless

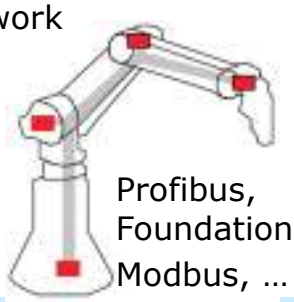
MIL1553B

BACnet, Lonworks

Controller area network

CanOpen, Volcano, J1939, …

LIN, Most, Flexray



Train Communication Network

Profibus, Foundation Fieldbus, Modbus, …

Concerns of Networking in Control Systems

- Control requires ***predictable*** delays
  - If network is used within the feedback loop, delay degrades performance
  - Temporary loss of messages means the control system will run ”open loop”
- Intricate end to end timing
  - Node computations and scheduling
  - Preparing and decoding messages
  - Node and network synchronization and scheduling multiple resources
- Inconsistency and partial failures

Distributed systems – failure modes

Nodes

- Omission
  - Fail-silent
  - Signalled failure
- Value
  - Wrong data sent
- Timing
  - E.g. too early, too late
- Interference
  - ”Babbling idiot”
- Commission
  - Unintended message

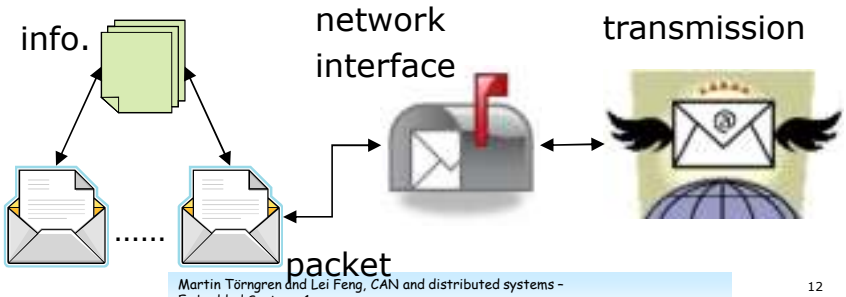
Network

- Omission
  - Transient or permanent
  - Permanent failure – special case: Network becomes partitioned!
- Value
  - Alteration of value
- Timing
  - Network failure causes delay/different delays
- Interference
- Commission

Attributes: Duration, Detectability, Symmetry

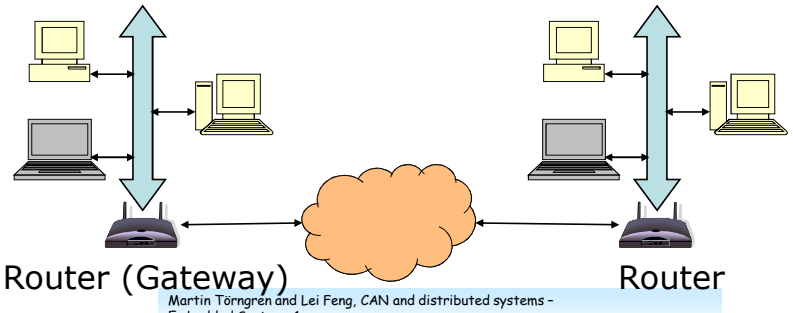
Network Basics

- To use a network, computers must:
  - Share access to a common medium: bus, radio frequency
  - Encapsulate information into packets
  - Share a common understanding of the meaning of the information



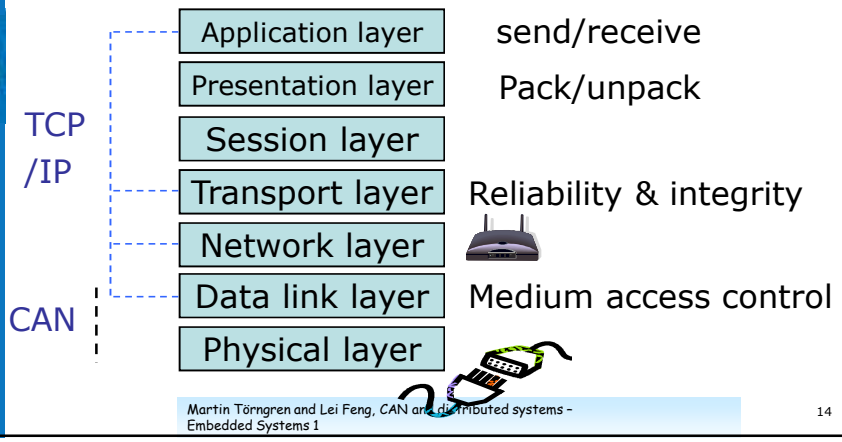
Local and Wide Area Networks

- A local area network (LAN) uses a single, common medium to connect all nodes
  - Compact area, broadband, better control
- A wide area network (WAN) is made up by interconnecting LANs



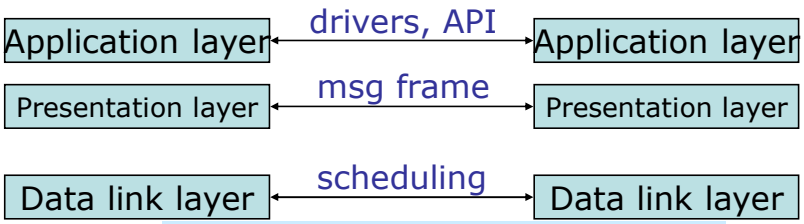
Layers of Network

- Open Systems Interconnection (OSI) model, by International Standardization Organization (ISO)



Communication Protocol

- A communication protocol is a set of agreed rules for communications between nodes
- Protocols operate at every layer
- Modularity: A layer at one node interacts only with the same layer at other nodes. Other layers are transparent



Controller Area Network (CAN)

- CSMA/arbitration on message priority (AMP)
- Collision avoidance (CA)
- Message broadcast
- If the bus is busy, a node waits until it is free
- If collision occurs, message with the higher priority continues
- No retransmission

CAN Higher-Layer Protocols

- CAN protocol defines only physical and data link layers
- Typical higher-layer protocols (HLP) are:
  - SAE J1939: automotive industry, 250 Kbps
  - CANopen: master-slave architecture, industrial automation
  - DeviceNet: industrial automation, 11 bits ID
  - CAN Kingdom: rules for defining a HLP!
- HLP additions
  - Start-up, failure handling, packaging, ”Id” usage, etc.