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?

- 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

![Diagram showing single vs. multiple processors with cost and computing power comparison]
Why are there so many types of networks, technologies and protocols??

Controller area network
CanOpen, Volcano, J1939, ...
LIN, Most, Flexray
Train Communication Network

Ethernet
MIL1553B

Wireless
BACnet, Lonworks

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

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## 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)

  - Application layer: send/receive
  - Presentation layer: Pack/unpack
  - Session layer: Reliability & integrity
  - Transport layer: Medium access control
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.