ES623 Networked Embedded Systems

OSI Protocols for Real-time

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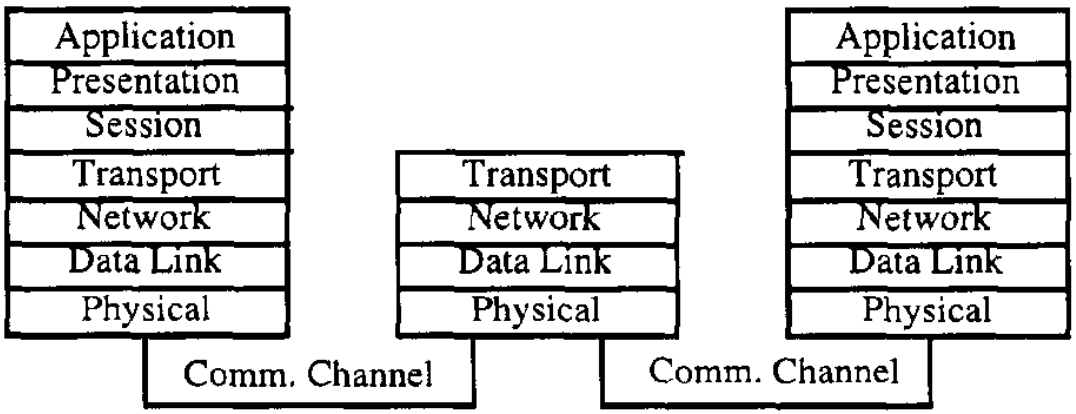
OSI Models

- Provides a standard conceptual reference architecture so that two computers that are located anywhere in the world can communicate with each other via diverse interconnected computer networks



OSI Models

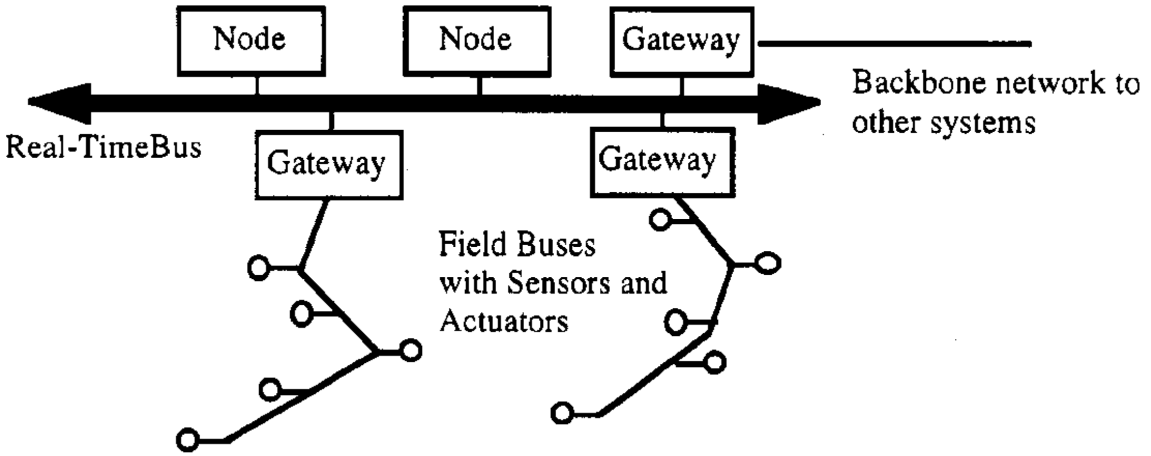
- Each layer encapsulates a protocol that is devoted to communication, using the services of the lower layer, and providing more powerful services to the higher layer

- Often used as implementation architecture

- Assumptions in OSI conforming Protocol:
  - Two communication partners maintain point-to-point connection
  - Messages are event-triggered
  - Commn. Protocols are of PAR type with explicit flow control
  - Real-time performance (no issue of latency and latency jitter)

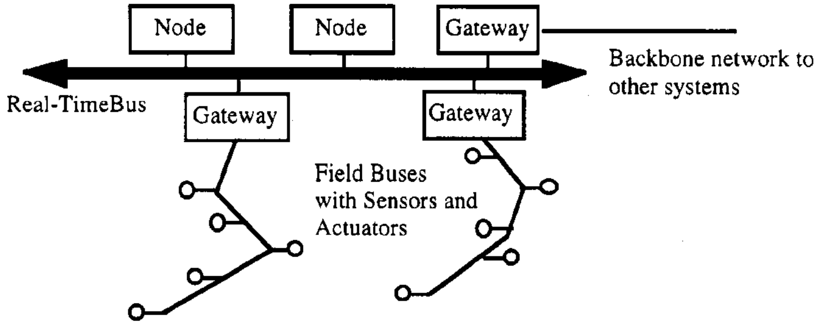
Real-Time Communication Architecture

- Three types of communication networks
  - Field bus
  - Real-time network
  - Backbone network



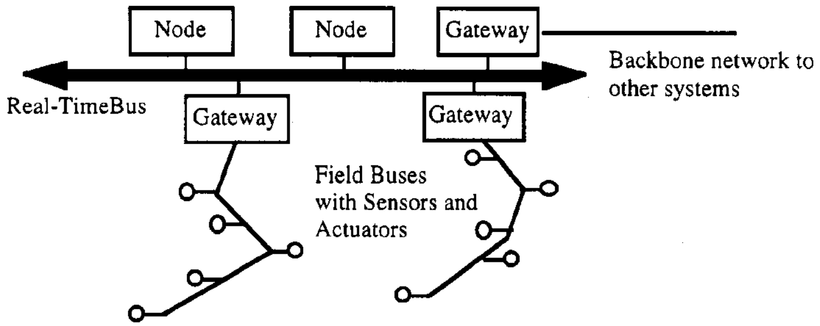
Field Bus

- To interconnect a node of distributed computer system to the sensors and actuators in controlled object
- Act as central field bus controller
- Field bus messages have a short data field, containing state data, typically two bytes in length, and are transmitted periodically with strict real-time requirements for latency and latency jitter.
- Precise clock synchronization required
- Fault tolerance is not a major issue, since reliability bottleneck is in sensors and actuators.



Real-Time Network

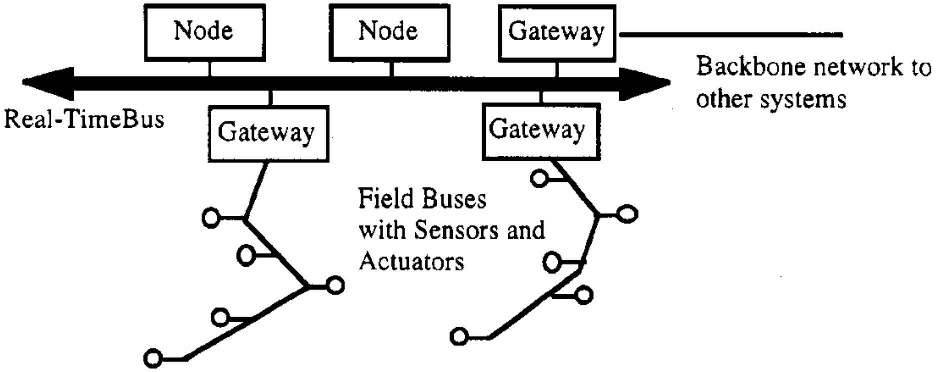
- Core of the real-time cluster
- Provides the following services to the nodes in cluster:
  - Reliable and temporally predictable message transmission with low latency and minimal latency jitter
  - Support for fault-tolerance to handle replication
  - Clock synchronization
  - Low latency for detecting node failures
- To avoid a central point of control failure, the real-time network should be based on distributed control



Backbone Network

- To exchange non time-critical information between the real-time cluster and the data-processing systems

- Examples of such information are production schedules, data collected regarding product quality and production times, and standardized production reports.



Comparison of service characteristics of three types of networks

Service Characteristic	Field Bus	Real-time Network	Backbone Network
Message semantics	state	state	event
Latency/jitter control	yes	yes	no
Typical data field length	1- 6 bytes	6 - 12 bytes	> 100 bytes
Clock synchronization	yes	yes	optional
Fault-tolerance	limited	yes	limited
Membership service	maybe	yes	maybe
Topology	multicast	multicast	point-to-point
Communication control	multi-master	distributed	central or distributed
Flow control	implicit	implicit	explicit
Low cost	very important	important	not very important

- OSI architecture is suitable for the implementation of the non time-critical backbone network, but is not adequate for the time-critical real-time network and the field bus

Fundamental Conflicts Protocol Design

External Control versus Composability

- Consider a distributed real-time system consisting of a set of nodes that communicate with each other.

- Each node has a host computer with a communication network interface (CNI) that connects the host to this communication network.

- Composability in the temporal domain requires that:
  - The CNI of every node is fully specified in the temporal domain,
  - The integration of a set of nodes into the complete system does not lead to any change of the temporal properties of the individual CNIs, and
  - The temporal properties of every host can be tested in isolation with respect to the CNI.

External Control versus Composability

- If the temporal properties are not contained in the CNI specification, then it is not possible to achieve composability in the temporal domain.
- If the temporal properties of the CNI are fully specified, then low level composability can be achieved.
- There is, always the possibility that the application functions interact in an unpredictable manner that precludes high-level composability.

External Control versus Composability

- Example: Consider the call forwarding option of a telephone answering machine.
  - If a number of these machines are connected in a cycle, then a call will be forwarded indefinitely, a situation that cannot be detected at the low-level communication interface.

- In an event-triggered system, the temporal control signals originate external to the communication system, in the hosts of the nodes. It is thus not possible to achieve low-level temporal composability

Flexibility versus Error Detection

- Flexibility implies that the behavior of a node is not restricted *a priori.*
- *In an architecture without replication, error detection is only* possible if the actual behavior of a node can be compared to some *a priori knowledge* of the expected behavior.
- If such knowledge is not available, it is not possible to protect the network from a faulty node.

Sporadic Data versus Periodic Data

- A real-time protocol can be effective in either the transmission of periodic data or the transmission of sporadic data, but not with both

Single Locus of Control versus Fault Tolerance

- Any protocol that relies on a single locus of control has a single point of failure - evident for a communication protocol that relies on a central master
- If the station holding the token fails, no further communication is possible until the token loss has been detected by an *additional time-out mechanism, and the token has been* recovered.

Probabilistic Access versus Replica Determinism

Media-Access Protocols

- Medium access strategy of a communication protocol specifies which node is allowed to access the single communication channel at a particular point in time, thereby determining many properties of the architecture of a distributed real-time system.

- Characteristics of a Communication Channel:
  - Bandwidth
  - Propagation delay
  - Limit to Protocol efficiency

Bandwidth

- Indicates the number of bits that can traverse a channel in unit time.
- determined by the physical characteristics of the channel
- For example, in car, it is not possible to transmit more than 10 kbit/sec over a single-wire channel or 1 Mbit/sec over an unshielded twisted pair because of EMI constraints.
- In contrast, optical channels can transport gigabits of data per second.

Propagation delay

- *The time interval it takes for a bit to* travel from one end of the channel to the other end.
- determined by the length of the channel and the transmission speed of the wave (electromagnetic, optical) within channel.
- The transmission speed of an electromagnetic wave in vacuum is about *300 000 km/sec, or 1 foot/nsec.*
- *Because the transmission speed of a wave in a cable* is approximately *2/3 of the transmission speed of light in vacuum, it takes a signal* about *5 µsec to travel across a cable of 1 km length.*
- *bit length of a channel is used to denote the number of bits that can traverse* the channel within one propagation delay.

Limit to Protocol efficiency

- In a bus system, the data efficiency of any media access protocol to a single channel is limited by the need to maintain a minimum time interval of one propagation delay between two successive messages.
- Assume the bit length of a channel to be bl *bits and the message length to be* m *bits.*
- *Then an* upper bound for the data efficiency of any media access protocol in a bus system is given by:

$$data\ efficiency < m/(m+bl)$$

CAN Protocol

- Carrier Sense Multiple Access Collision Avoidance Protocols (CSMA/CA) are distributed medium-access protocols that avoid the occurrence of collisions, e.g., by bit arbitration.
- CAN (Control Area Network) Protocol is a good example of a CSMA/CA protocol that is targeted for automotive real-time Applications
- CAN message consists of six fields

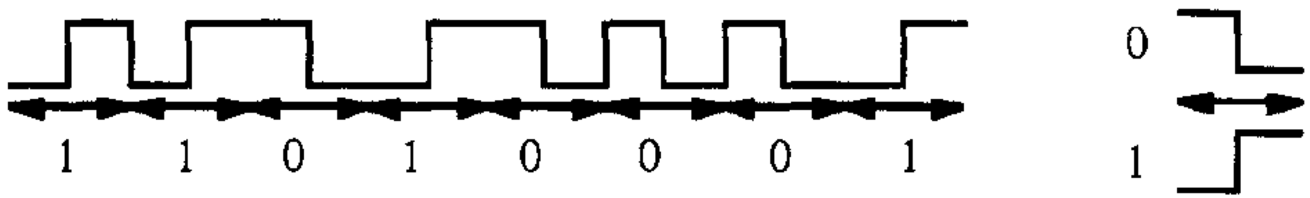
Field	Arbitration	Control	Data Field	CRC	A	EOF
bits	11	6	0-64	16	2	7

Transmission codes – NRZ code

- A simple encoding technique is the NRZ (non-return-to-zero code) where a "1" bit is high and a "0" bit is low.
- a *non-synchronizing code because it is* impossible for the receiver to retrieve the ticks of the clock of the sender from a monotone transmission signal.
- can be used in an asynchronous communication environment, but it cannot be used in a synchronous environment without adding "artificial" transitions by inserting additional bits (*bit stuffing) into* the transmission sequence to support the synchronization of the receiver.
- Bit stuffing makes the length of a message data-dependent, which reduces the data efficiency.

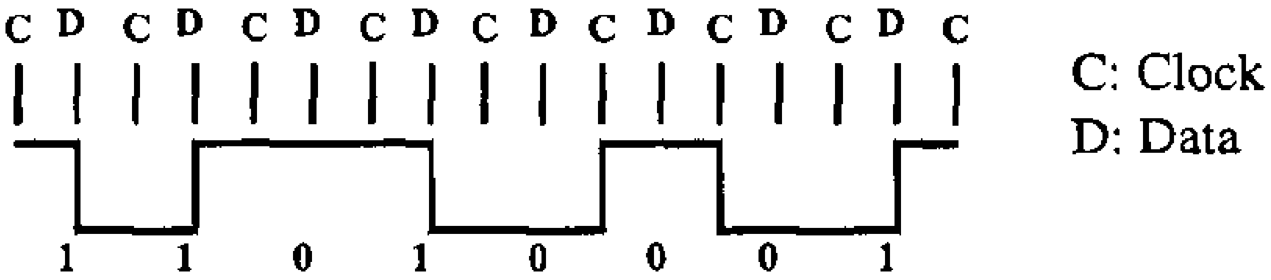
Manchester Code

- A bit stream encoded by a Manchester code has a synchronization edge in every bit cell of the transmitted signal.
- Encodes a "0" as a high/low bitcell and a "1" as a low/high bitcell.
- **Encoding of the bit sequence "1101 0001"**



Modified Frequency Modulation (MFM)

- The MFM code is that has a feature size of one bit cell and is also synchronizing
- The encoding scheme requires to distinguish between a data point and a clock point.
- A "0" is encoded by no signal change at a data point, a "1" requires a signal change at a data point.
- If there are more than two "0"s in sequence, the encoding rules require a signal change at clock points.



Encoding of the bit sequence "1101 0001" in MFM.