REAL TIME COMMUNICATION

- Real time applications are increasingly being implemented on distributed platforms.
  - Cost-effective to have a distributed solution using many pieces of cheap hardware rather than having a centralized, sophisticated and costly machine.
  - Many real time applications are inherently distributed with different sensors and actuators of a system placed at geographically separate locations.
  - Fault tolerance is desirable for safety critical applications.
- Real time communication is the one where the applications make specific quality of service demands to the communication network and the network once it accepts a connection guarantees the requested service quality.

Examples of Real Time Communication in Applications

- Manufacturing Automation
- Automated chemical factory
- Internet based banking applications
- Internet Telephony

TYPES OF NETWORKS

- CAN (Controller Area Network)
  - Typically used to connect the different components of embedded controllers.
  - In an automotive system the different components such as engine, breaks etc are connected and controlled through a CAN.
  - The end-to-end length of a CAN is usually less than 50 meters.
  - A special requirement on CAN is to handle noise.
  - Because of its robustness, CAN has expanded beyond its automotive origins and can now be found in industrial automation systems, trains, ships, agricultural machinery, elevators etc

- LAN (Local Area Network)
  - A LAN is used to connect a number of computers within an organization to share data and other resources.
  - LANS typically operate at data rates exceeding 10Mbps and many present day LANs (gigabit Ethernets) operate at 1 Gbps.
  - LANs are usually implemented using broadcast networks

- Internet
  - A worldwide system of computer networks.
  - A network of networks in which users at any one computer can, if they have permission, get information from any other computer and sometimes talk directly to users at other computers using VoIP.

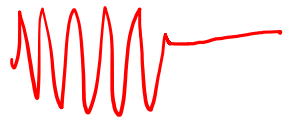
Quality of Service (QOS)

- Real time applications need guarantees regarding the service quality from the underlying network for their satisfactory operations.
- Delay
  - A successful delivery of a packet by a communication network in a real time application depends not only on receiving the packet intact, but also on the time at which it is received.
- Delay Jitter
  - Difference between the maximum and minimum delays that packets encounter in a packet-switched network.

- Bandwidth
  - Indicates the rate at which a connection would be serviced by the network
- Loss rate
  - Denotes the percentage of all transmitted packets that may be lost during transmission. (delay bound violation, buffer overflow, data corruption)
- Blocking probability
  - The probability of a new connection is rejected by the admission control mechanism of a network

Traffic Categorization

- CBR Traffic
  - Arises due to Constant Bit Rate data generation.
  - Data transmission involved in hard real-time applications.
  - Example: periodic data generated by sensors.

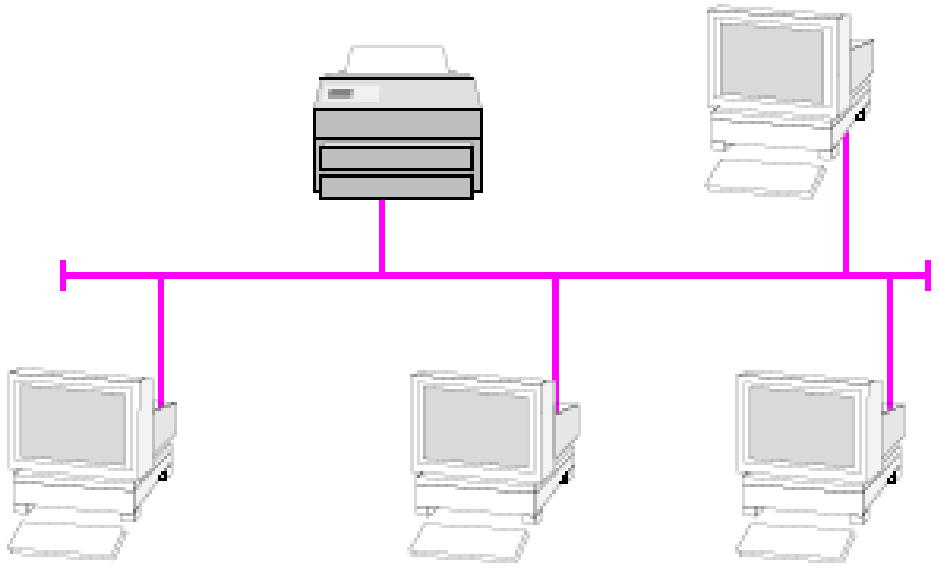


- VBR Traffic
  - Consists of different rates of data generation and transmission at different times.
  - Example : compressed audio and video signals.
- Sporadic Traffic
  - Variable sized packets are generated in bursts.
  - Example: traffic generated by alarm messages.

REAL TIME COMMUNICATION IN A LAN

- In a LAN there is a single shared channel and only one node can transmit at any time.
- The *access arbitration policy* of a network determines when a node can transmit on the channel.
- The *transmission control policy* determines how long the node can transmit.
- These two policies are together called *access control techniques* and form the *Media Access Control (MAC)* layer protocol.

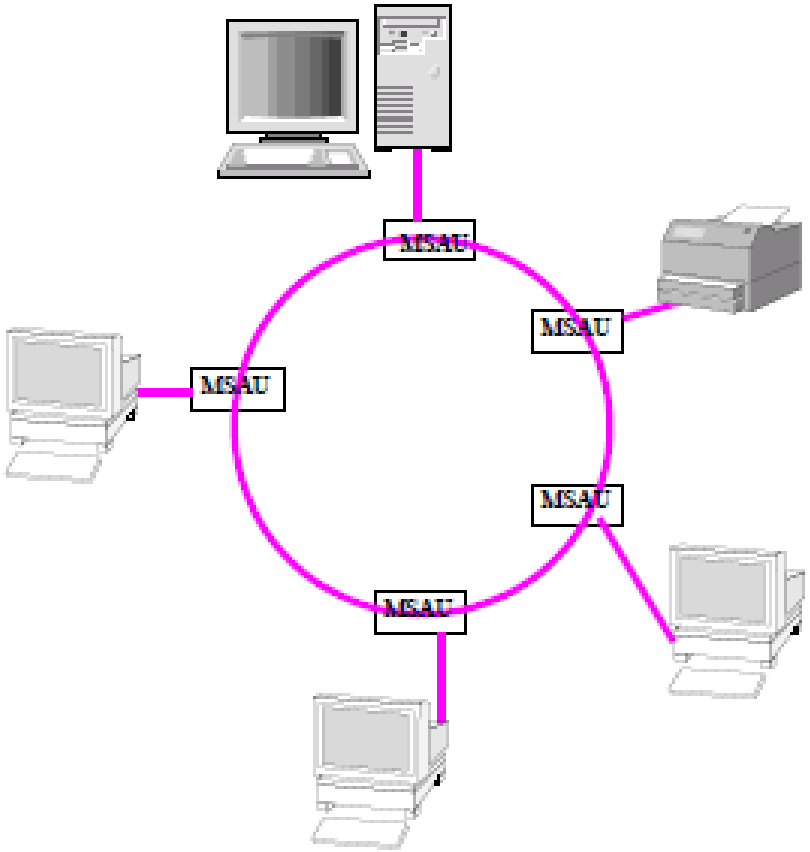
LAN Architectures :Bus-based Architectures



LAN Architectures

- Bus based architectures
  - Nodes are connected to the network cable using T-shaped network interface connectors.
  - Terminating points are placed at each end of the network cable.
  - There is a single shared channel for which the transmitting nodes contend.
  - Most commonly used protocol is Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
  - A collision entails retransmission of the corrupted data.
  - Large propagation delays increase the probability of collisions.
  - Ethernet is a LAN standard based on CSMA/CD access control.

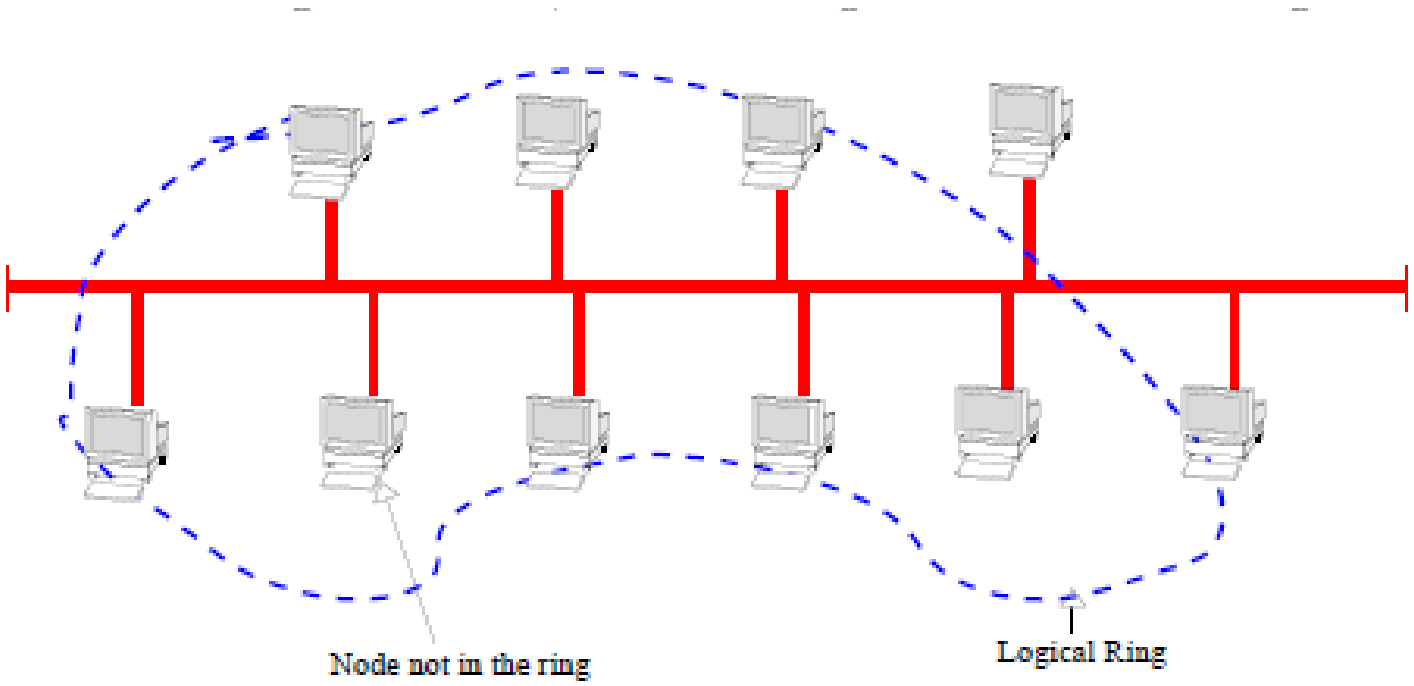
Ring Architecture



Ring based Architectures

- The nodes are arranged in a ring and the nodes transmit in turn usually for certain predetermined periods of time.
- Often preferred in real-time applications.
- Any break in the ring can bring the whole network down.
- Ring is a poor fit to the linear topology normally found in most assembly lines and other applications.
- A token bus architecture is a bus based architecture, where the stations on the bus are logically arranged in a ring with each station knowing the address of the station to its left and right.

Logical ring in a token bus



- When the logical ring is initialized, the highest numbered station gets a chance to initiate its transmission.
- After completing transmission for a predetermined time, the station passes the frame transmission permission to its immediate (left or right as per convention adopted) neighbor by sending a special control frame called token.
- The token propagates around the logical ring.
- The physical order in which the stations are connected to the cable is not important.
- MAC protocol also provides for adding stations to, and removing stations from the logical ring.

Soft real time communication in a LAN

- Soft real-time communication can be used to support soft real-time application in a LAN.
- They ensure prioritized treatment for real-time messages so that the message deadline miss ratio can be kept to a minimum and the real-time messages can be provided statistical guarantees on delay bounds.

Hard real time communication in a LAN

- Hard real time applications often involve transmission of CBR traffic such as periodic sensor signals.
- In LAN hard real time communications are normally supported using
  - Global priority based protocol
  - Calendar based protocol
  - Bounded access protocols

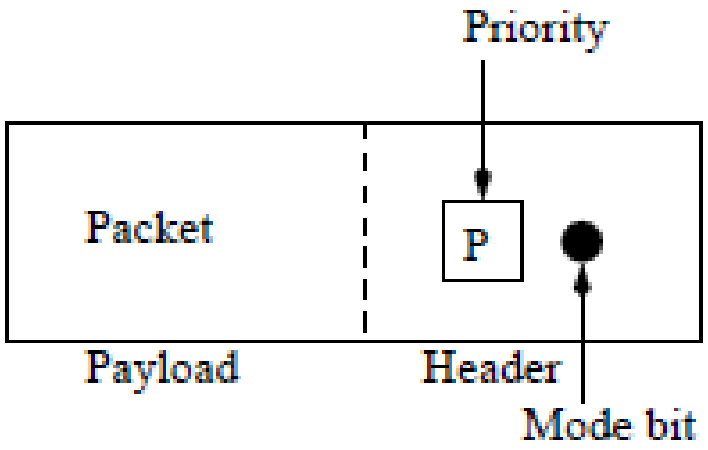
- Global Priority Protocols
  - Each message is assigned a priority value.
  - Ensures that at any time the channel is serving to the highest priority message in the network.
- Bounded Access Scheduling
  - Real time guarantees to messages are provided by bounding the access time of every node to the channel.
  - The time for which a packet may have to wait before it is transmitted is bounded.

- Calendar based scheduling
  - Every node maintains a copy of the calendar that indicates which node is permitted to transmit during which time period.
  - Traffic sources can reserve time interval for packet transmission by broadcasting.
  - When a node needs to transmit a message for which no reservation was made, it finds a free slot by consulting the calendar and reserves the required time interval by broadcasting the reservation information to all nodes.
  - Simple, efficient and works very well when all messages in the system are periodic and predictable

IEEE 802.5

- IEEE 802.5 is a priority based token ring protocol.
- The header of a token contains two fields: a priority field and a mode field.
- Token alternates between two modes: a reservation mode and a free mode
- In reservation mode, packet transmission occurs.
- The priority of the message that is being transmitted is registered in the header of the token.

- A node having a higher priority message registers its priority in the priority field of the header.
- When the token returns to the sending node, it puts the token in free mode and releases it.
- As the token passes through the ring, the node that made the reservation seizes the token puts it into reservation mode and starts transmitting.



Bounded Access Protocol

- **RETHER**
  - RETHER stands for Real-time ETHERnet.
  - RETHER enhances TCP/IP and provides real-time performance guarantees to real –time applications without modifying existing Ethernet hardware.
  - Network transmissions can occur in two modes: CSMA/CD mode or RETHER mode
  - The network switches transparently to RETHER mode when there are real-time sessions and back to CSMA/CD mode when all real time sessions terminate.

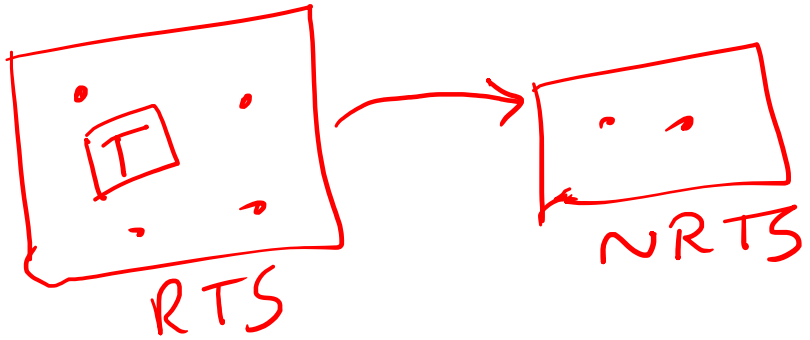
Protocol Description

- In the absence of any real time messages at the nodes, nodes compete for the channel using the usual CSMA/CD protocol of the Ethernet.
- When the node receives a real-time request from a local application, it broadcasts a switch to RETHER message on the Ethernet unless the network is not already in Rether mode.
- Every node that receives this message responds by setting its protocol mode to RETHER mode.

- The transmitting node waits for the ongoing packet transmission to complete.
- It then sends an acknowledgement back to the initiator, indicating its willingness to switch to RETHER mode and that there is no data left in the backoff phase of CSMA/CD protocol.
- Upon receiving of all the acknowledgments, the initiating node creates a token and begins circulating it. This completes a successful switch to RETHER mode.

- The RETHER mode uses a time token scheme to provide bandwidth guarantees.
- At any time there is only one real time request per node and each real time request specifies the required transmission bandwidth in terms of the amount of data it needs to send during a fixed interval of time called MTRT- Maximum Token Rotation Time.

Rether Protocol



- The control token circulates among two sets of nodes, the real time set (RTS) and the non real time set (NRTS)
- Only nodes that have made a bandwidth reservation belong to RTS.
- The last node in the RTS passes the token to the NRTS.
- Let MTRT be the mean token rotation time and MTHTi be the mean token holding time for node Ni.
- The token is then tagged with a TimeToDeadline field such that

$$TimeToDeadline = MTRT - \sum_{i \in RTS} MTHT_i$$

- Every new real time request goes through an admission control procedure that determines if it is possible to accept the request.
- Admission control is performed locally on each node : Admit real time request if

$$\sum_{i \in RTS} MTHT_i + MTHT_{new} + TBNRT \leq MTRT$$

↑ new node

- Where TBNRT is the bandwidth reserved for the NRT set.
- Admission control is not performed until the node receives the token.
- When a real time node wants to terminate its real time connection, it merely removes itself from the RTS information on the token

IEEE 802.4

- IEEE 802.4 protocol is applicable to token ring networks where TTRT (Target Token Rotation Time) is used as design parameter.
- TTRT is the expected time between two consecutive visits of the token to a node.
- Individual nodes are allocated a portion of TTRT, known as its synchronous bandwidth according to the timing characteristics of the periodic messages originating at each node.
- The time needed to transmit an asynchronous frame is called asynchronous overrun and it reduces the effective bandwidth available to transmit synchronous messages.

- TTRT can be expressed as TTRT = Θ + holding time at nodes, where Θ is the propagation time.
- Suppose of all messages that the different nodes in the network can originate, node Ni has the message that has the smallest deadline Δ. We can fix TTRT to be:

$$TTRT \leq \frac{\Delta}{2}$$

- Each node Ni is assigned a synchronous bandwidth Hi, which is the maximum time the node Ni is allowed to hold the token to transmit periodic messages.
- Token holding times at individual nodes is the synchronous bandwidth allotted to the node.
- As soon as a node receives the token, it starts a timer set to its synchronous bandwidth and releases the token upon expiry of the timer.

- The synchronous bandwidth allocated to a node Ni is given by

$$H_i = TTRT * \frac{C_i/T_i}{\sum C_i/Ti}$$

- Where Ci is the size of the message (in bits) that node Ni requires to transmit over Ti interval, and Ci/Ti is the channel utilization due to the node Ni.