Course Objectives

1. To introduce the student to the major concepts involved in wide-area networks (WANs) and local area networks (LANs).
2. To develop an understanding of modern network architectures from a design and performance perspective.
3. To expose students to some of the current technologies.

Course Objectives

4. To provide an opportunity to do network programming using TCP/IP.

5. To clarify network terminology.

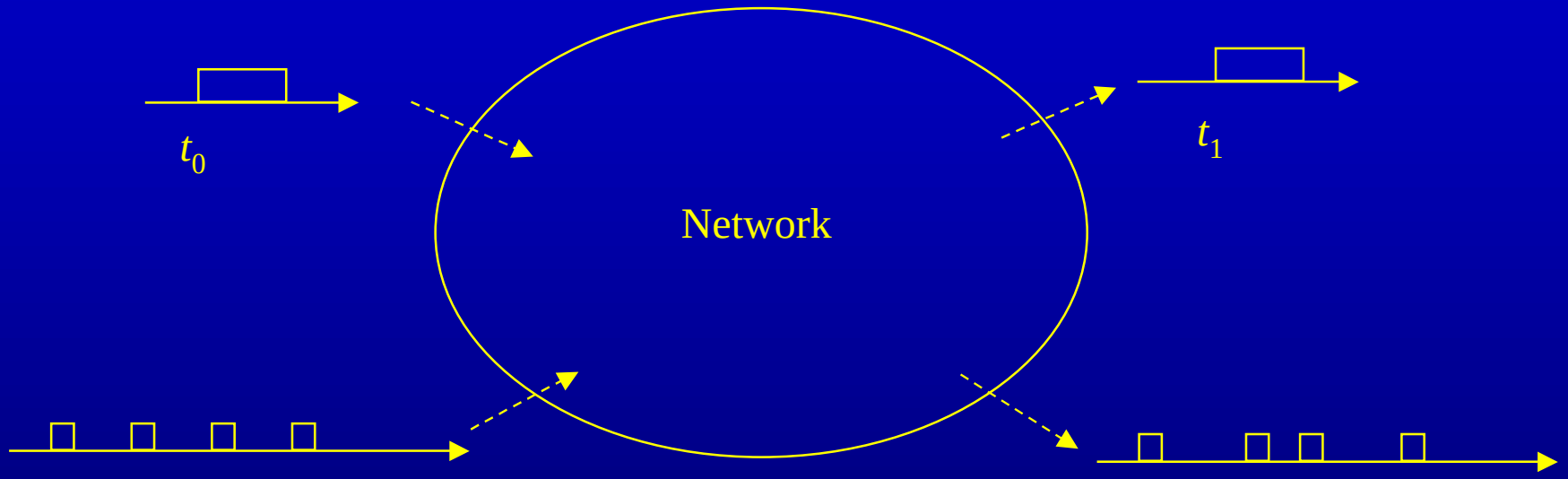
6. To facilitate an understanding of the current literature.

Definitions

computer network :: [Tanenbaum] an interconnected collection of “autonomous” computers.

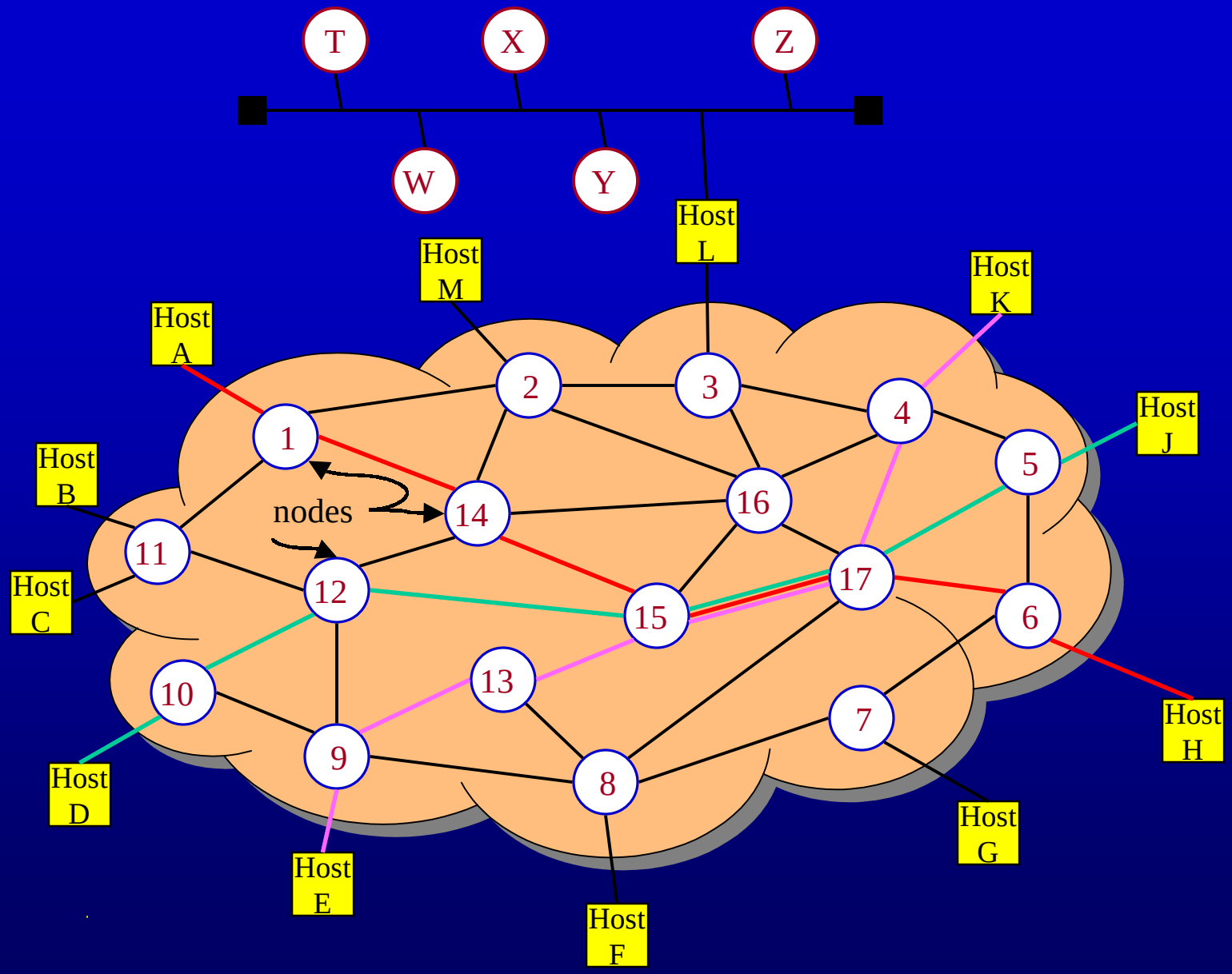
[LG&W] *communications network ::a set of equipment and facilities that provide a service.*

distributed system :: the existence of multiple autonomous computers is <u>transparent.</u>



Leon-Garcia & Widjaja: *Communication Networks*

Figure 1.6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nodes

Classifying Networks by Transmission Technology

broadcast :: a single communications channel shared by all machines (addresses) on the network. *Broadcast can be both a logical and a physical concept (e.g. Media Access Control (MAC) sublayer)* .

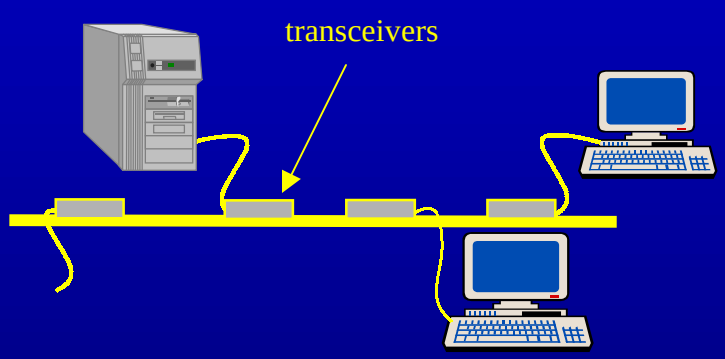
multicast :: communications to a specified group. *This requires a group address.* (e.g. – multimedia multicast).

point-to-point :: connections made via *links* between pairs of nodes.

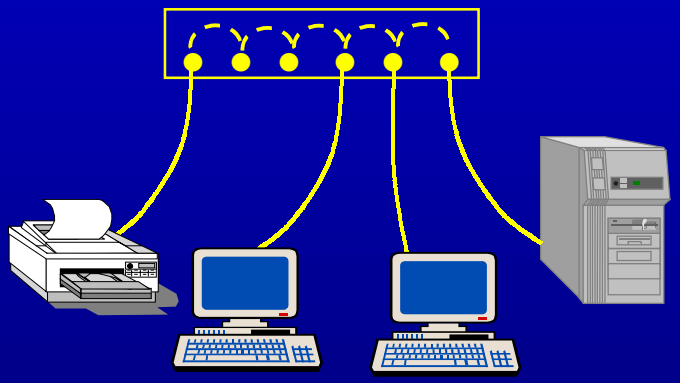
Network Classification by Size

- LANs {Local Area Networks}
  - Typically physically broadcast at the MAC layer (e.g., Ethernet, Token Ring).
- MANs {Metropolitan Area Networks}
  - campus networks connecting LANs logically or physically.
  - often have a backbone (e.g., FDDI and ATM)

LANs



Ethernet bus



Ethernet hub

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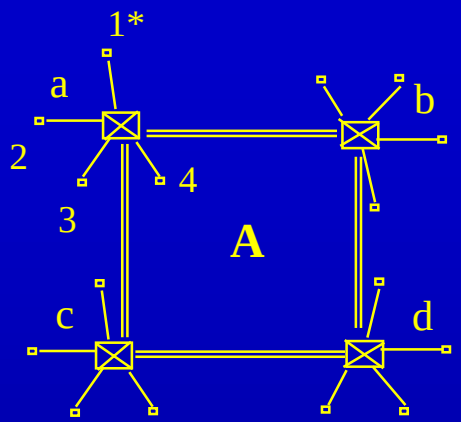
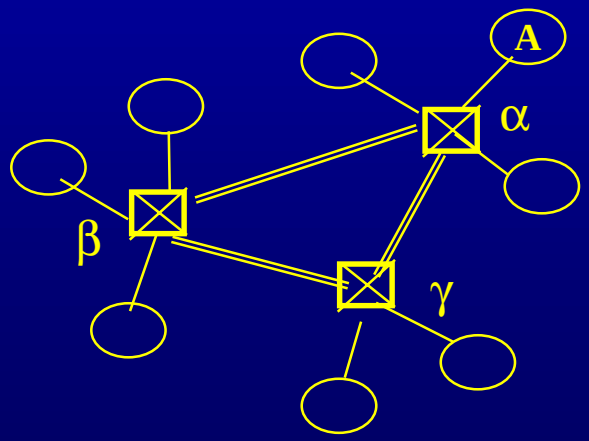
Figure 1.17

MAN



Metropolitan network **A** consists of access subnetworks a, b, c, d.

Hierarchical Network Topology

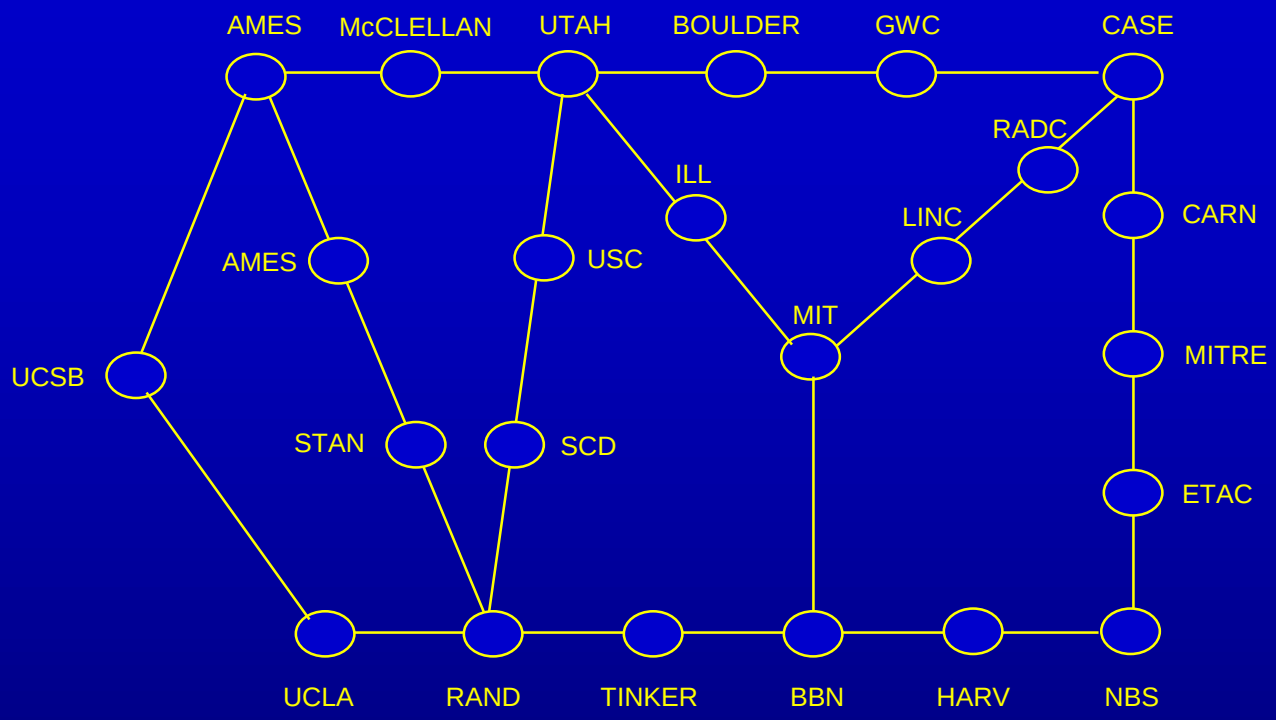


National network consists of regional subnetworks α, β, γ.

Metropolitan network A is part of regional subnetwork α.

Network Classification by Size

- WANs {Wide Area Networks}
  - *also referred to as "point-to-point" networks.*
  - ARPANET → Internet
  - usually hierarchical with a backbone.
  - Enterprise Networks, Autonomous Systems
  - VPNs (Virtual Private Networks).



ARPAnet circa 1972

point-to-point network

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Figure 1.16

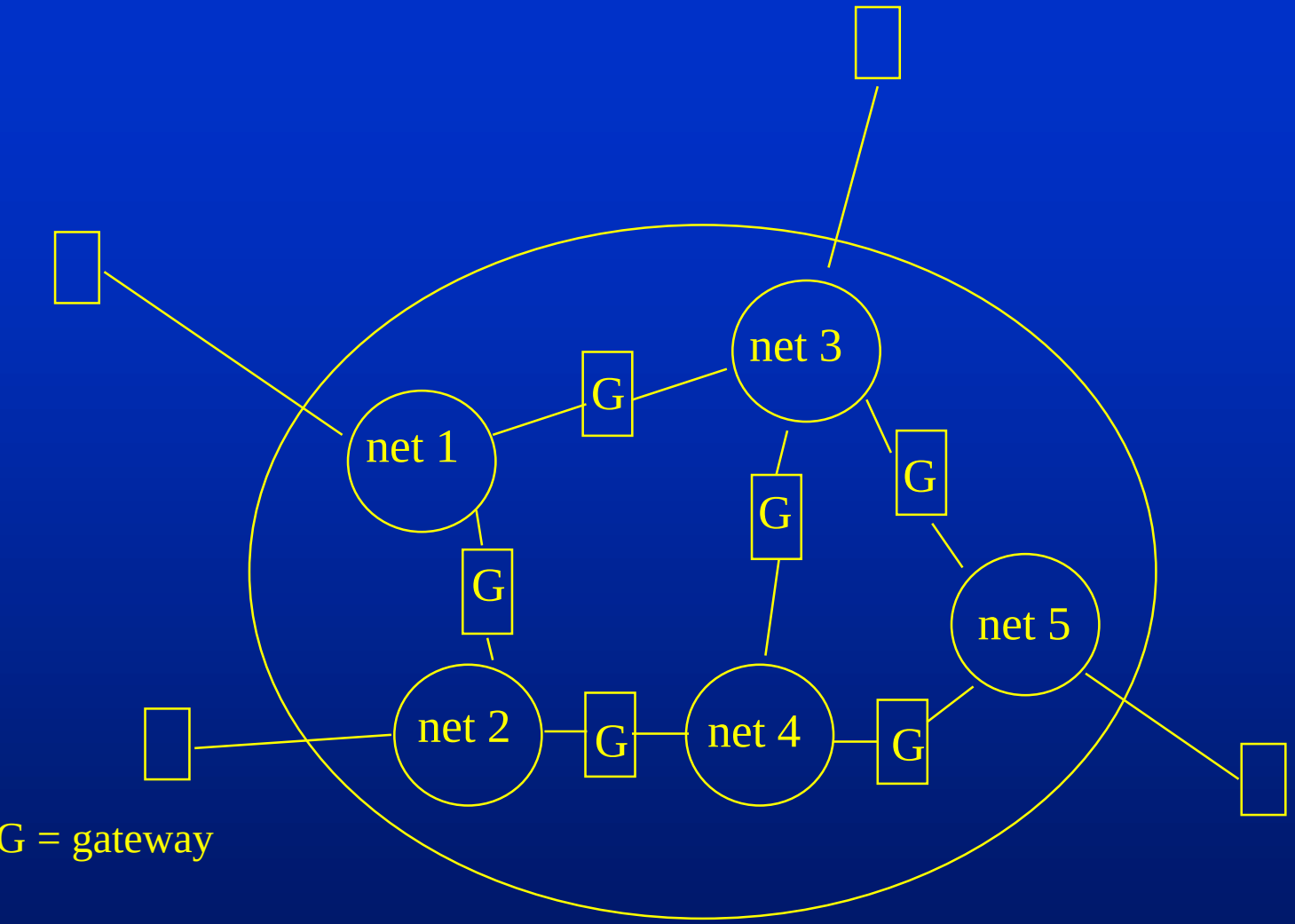

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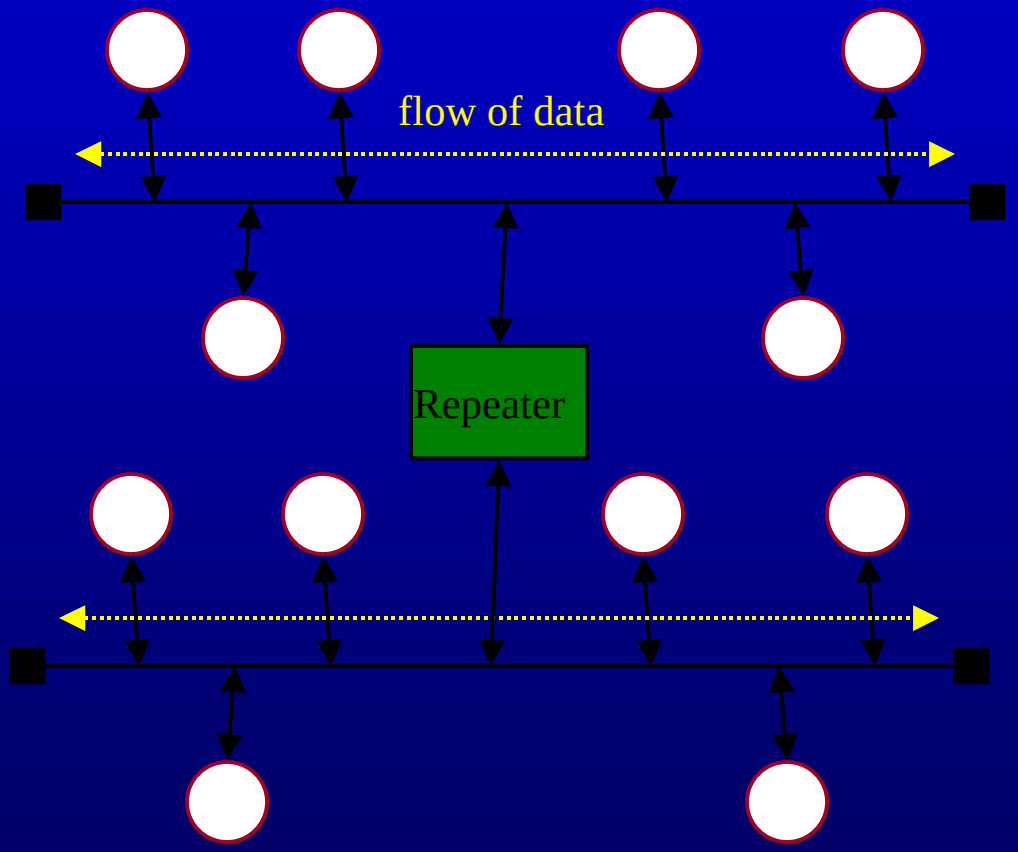
Figure 1.18

Network Classification by Topology

Bus

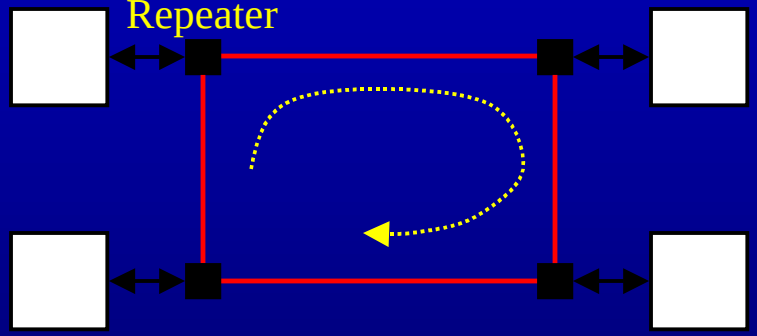


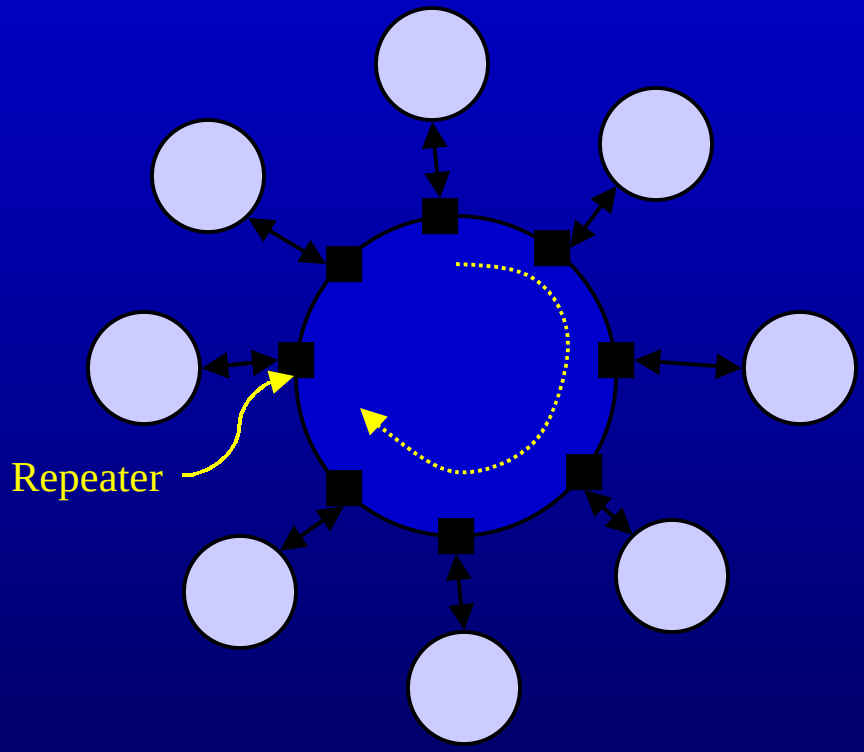
Bidirectional flow

assumes baseband cable

Network Classification by Topology

Ring

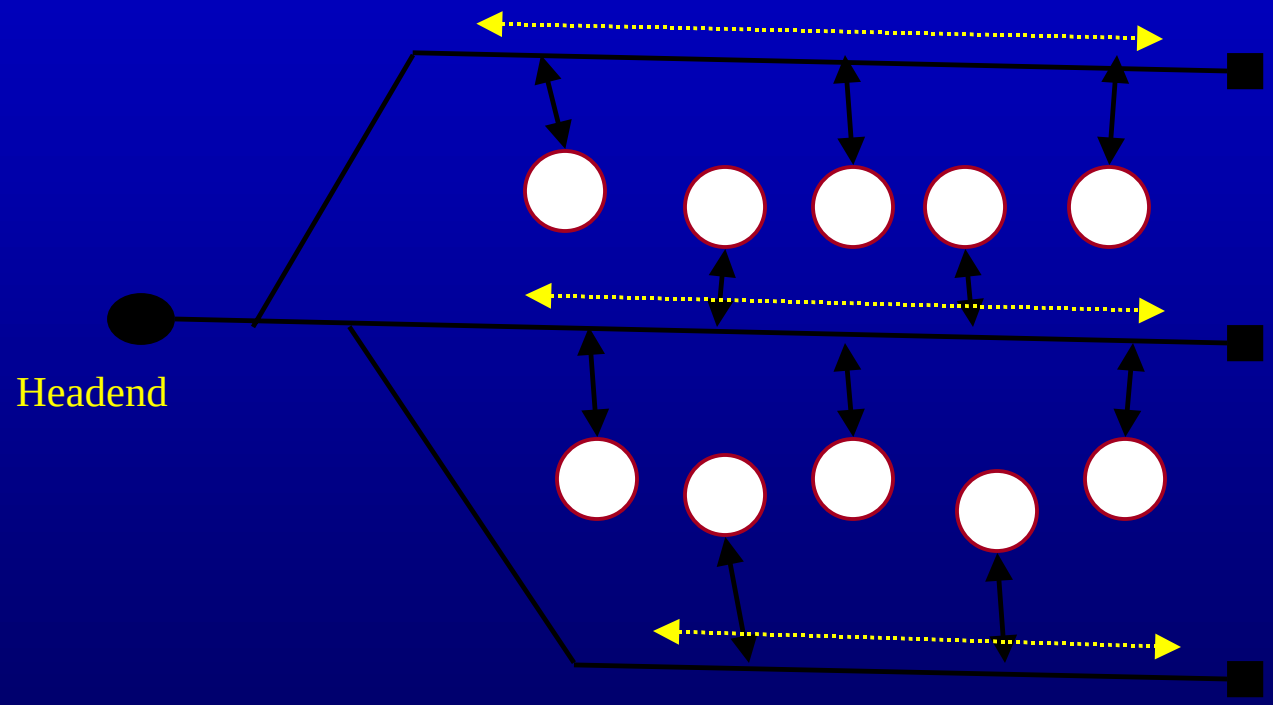




Note - *a ring implies <u>unidirectional</u> flow*

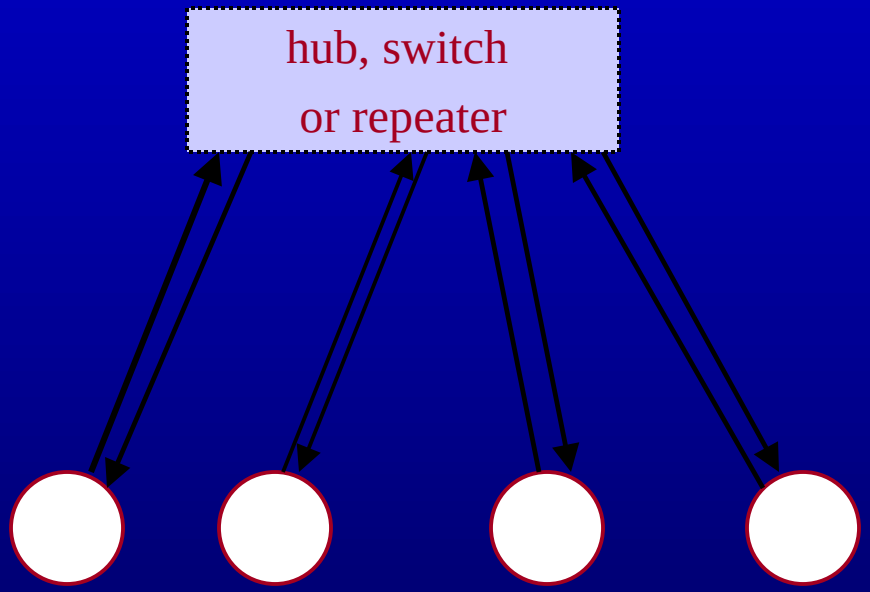
Network Classification by Topology

Tree



Network Classification by Topology

Star



Performance Metrics
(General Definitions)

- Utilization :: the percentage of time a device is busy servicing a “customer”.
- Throughput :: the number of jobs processed by the “system” per unit time.
- Response time :: the time required to receive a response to a request (round-trip time).
- Delay :: the time to traverse from one end to the other in a system.

Network Performance

- channel utilization – the average fraction of time a channel is busy [e.g. Util = 0.8]
  - when overhead is taken into account (i.e., excluded from *useful* bits, channel utilization is often referred to as channel efficiency
- throughput – bits/sec. successfully transmitted [e.g. Tput = 10 Mbps]

Network Performance

end-to-end packet delay :: the time to deliver a packet from source to destination.

{most often we are interested in the packet delay within the *communications subnet*}

This delay is the sum of the delays on each

subnet link traversed by the packet. Each link delay consists of four components [Bertsekas and Gallager]:

Packet Delay

1. The *processing delay* [PROC] between the time the packet is correctly received at the head node of the link and the time the packet is assigned to an outgoing link queue for transmission.
2. The *queueing delay* [QD] between the time the packet is assigned to a queue for transmission and the time it starts being transmitted. During this time, the packet waits while other packets in the transmission queue are transmitted.

Packet Delay

3. The *transmission delay* [TRANS] between the times that the first and last bits of the packet are transmitted.
4. The *propagation delay* [PROP] between the time the last bit is transmitted at the head node of the link and the time the last bit is received at the tail node. This is proportional to the physical distance between transmitter and receiver.

End-to-End Packet Delay

Link packet delay = PROC + QD + TRANS + PROP.

end-to-end packet delay = sum of ALL link packet delays.

Be Careful !! *end-to-end* can be defined either from Host-to-Host or only within the subnetwork.