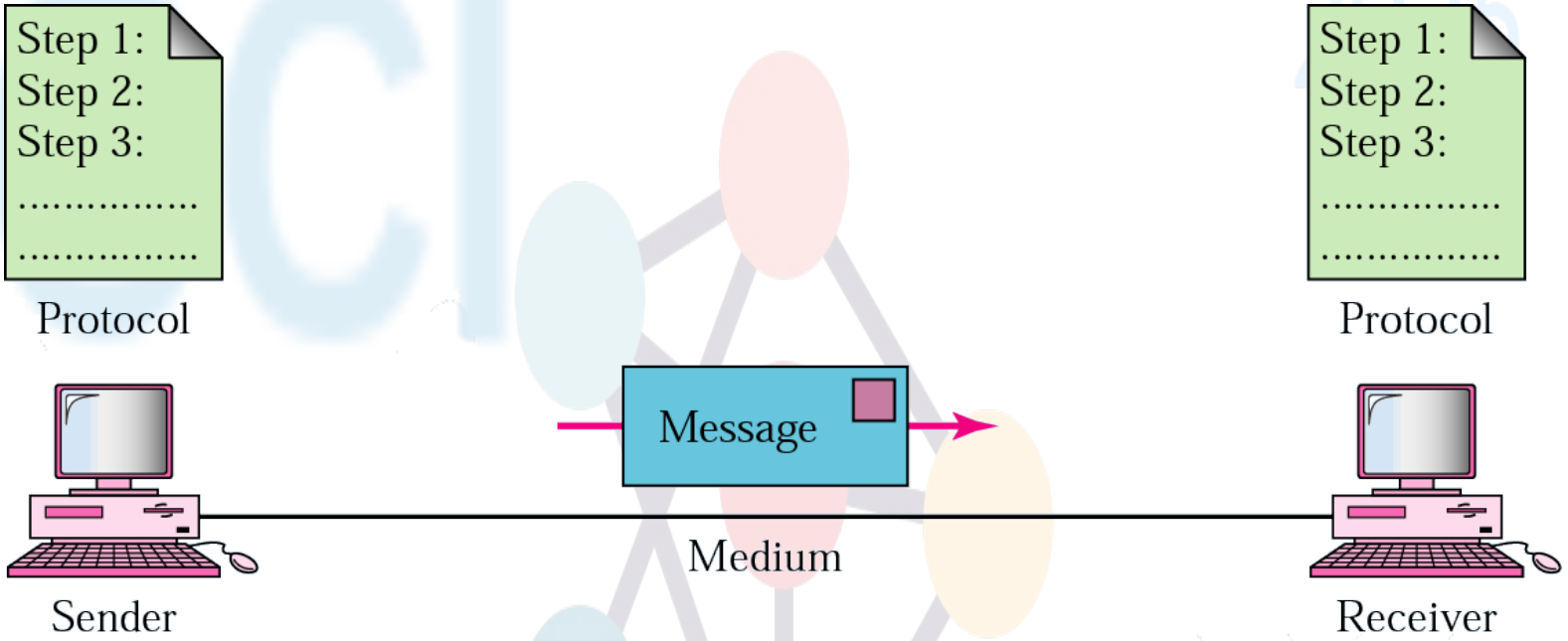
TU/e

CI0121 Computer Networks

Data communications and networks

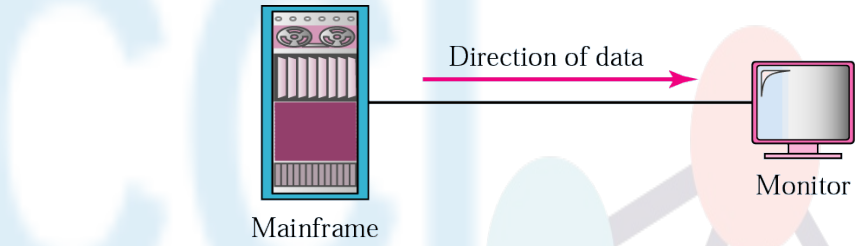
Profesores ECCI

Information interchange

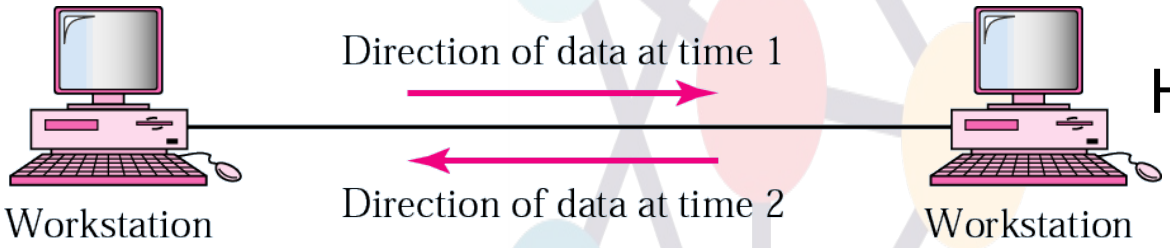


Message
Sender
Receiver
Medium
Protocol

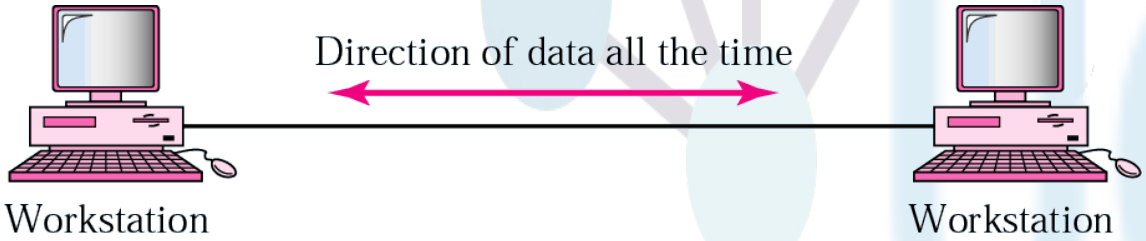
Direction of data flow



Simplex



Half Duplex



Full Duplex

Network key issues

Network criteria

- Performance
- Reliability
  - Data transmitted are identical to data received.
  - Boils down to error detection and correction & failure detection
- Security
  - Of data, media, equipment.
  - Making sure network resources are used by authorized persons only

Terminology

- ***Link:*** a physical medium for communication
  - bi-directional, uni-directional
- ***Circuit:*** sequence of links
- ***Channel:*** a means of communication (physical or logical)
- ***Path:*** sequence of channels
- The ***throughput*** or ***bandwidth*** of a channel is the number of bits it can transfer per second
- The ***latency*** or ***delay*** of a channel is the time that elapses between sending information and the earliest possible reception of it

Network architecture design

- Depends on the service it has to provide
  - Telegram (text; message), telephone, video, gaming
-
- Scalability
  - Design works for small and large networks
  - Extensions possible by adding new facilities
- Configurability
  - Automatic (stability), local configuration
  - Optimizable for certain conditions
- Determinism
- Migration & Evolution

Network architecture design

- Network complexity
  - Degree of how complex a network is
    - Gives an indication of scalability, i.e. when the number of processors increase, the network should not dominate the machine's cost, nor should it saturate and hamper the machine's capability

Network operational constraints

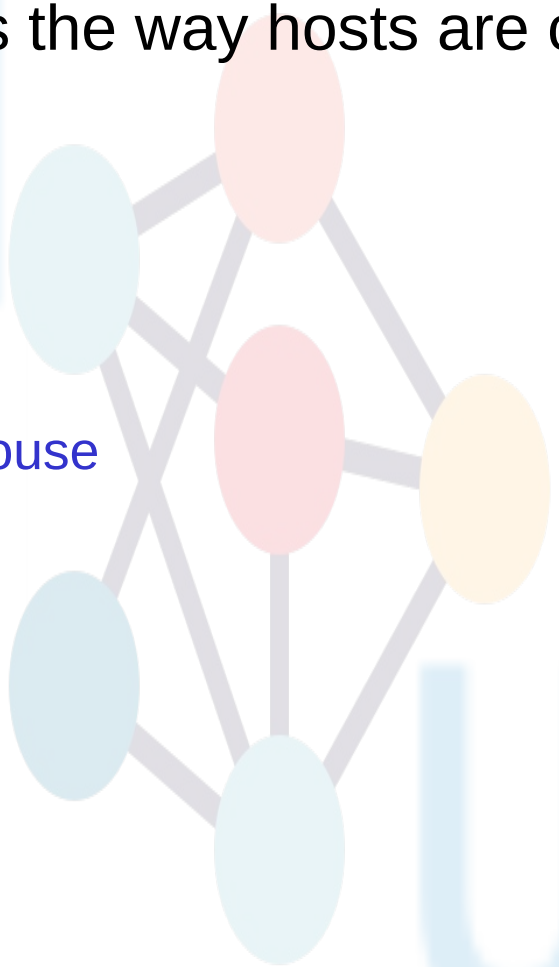
- Determining network topology
  - For a given set of requirements
- Operational constraints (vary in time)
  - Capacity
    - Maximum volume of traffic carried by a network
  - Routing
    - a means of discovering paths in computer network
  - Utilization
    - Ratio of carried traffic to network capacity
  - Efficiency
    - Ratio of carried traffic to capacity utilized for carrying that traffic

- Carried traffic: the total volume of traffic measured in bits/s (bps) entering or leaving network at its boundaries

Network topology

- *Topology* defines the way hosts are connected to the network

- Analogy:
  - Road map,
  - Blue-print of a house

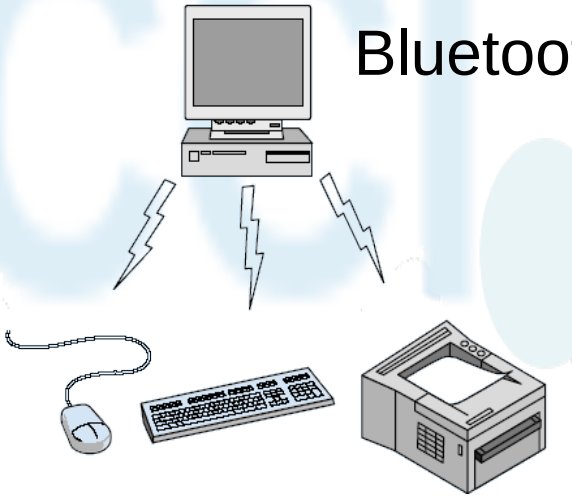


Type of connections

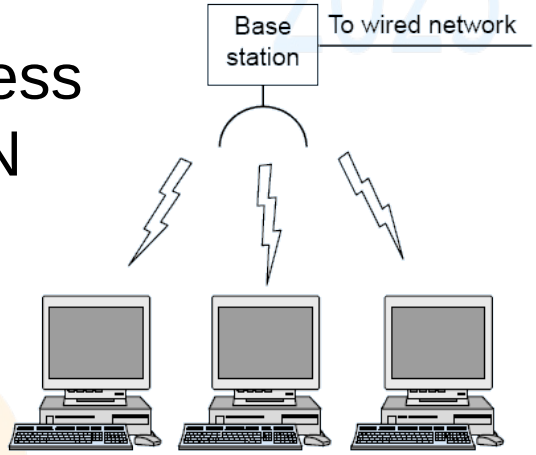
- Point-to-point
  - One-to-one communication
  - Unicasting
- Point-to-multipoint
  - Communication channel shared among nodes
  - One-to-many
  - Broadcasting
  - Multicasting
- Multipoint-to-point
  - Many-to-one

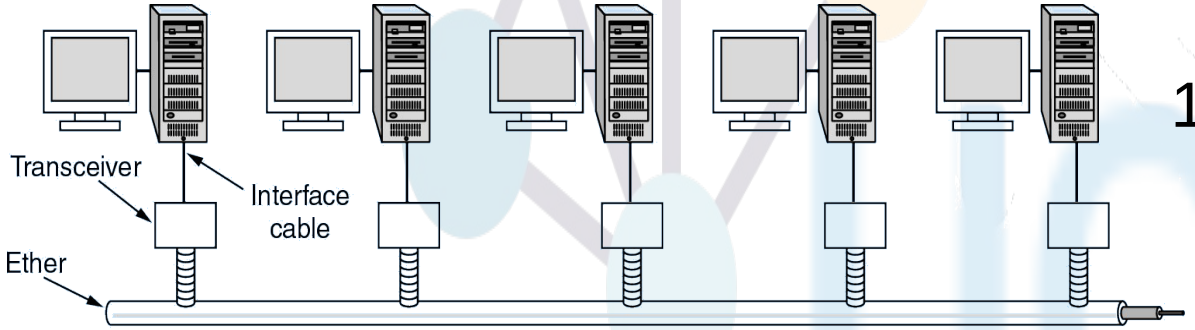
Broadcast networks

Bluetooth



Wireless LAN



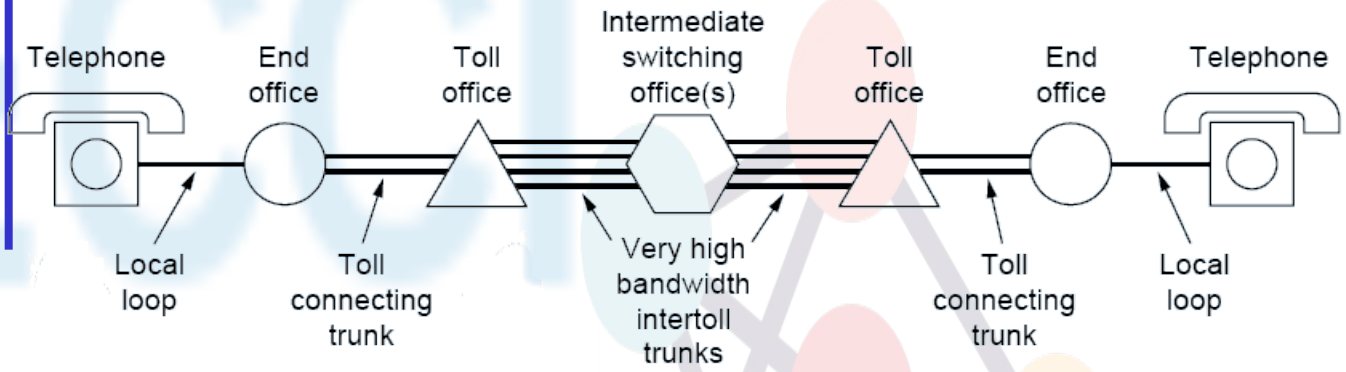


10BASE-2 Ethernet

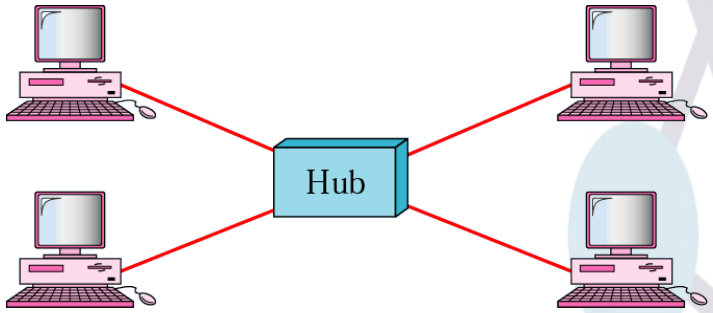
Limitations of broadcast networks

- Capacity shared by connected nodes
  - average and peak demands may vary
  - …hence, not too many nodes
- Propagation delays
  - For collision detection
    - Colliding parties need to be able to detect a collision *during* transmission; hence, propagation delay and speed of medium determine *minimum* packet size
  - Arbitration: just long negotiation delays
  - … hence limited physical distances
- Robustness
  - Network-wide physical effects of attach/detach/fail
  - … hence, decouple

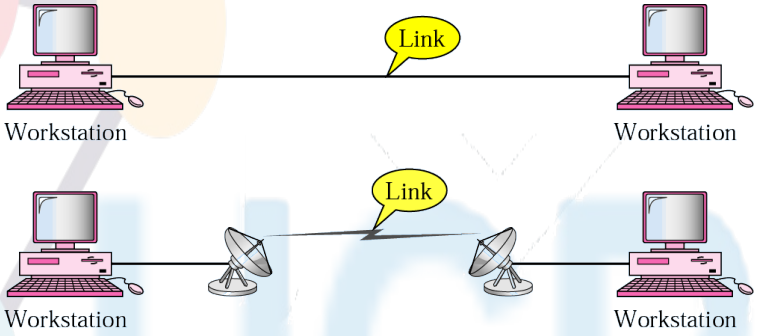
Point to point communications link



Telephone network



Switched Ethernet



Properties of point to point networks

- Advantages
  - Dedicated channels – more bandwidth
  - Dedicated bandwidths – guaranteed Quality of Service
  - Security

- Disadvantages
  - Larger resources – higher costs
  - Decreased reliability (multipoint-to-point?)

Network topology issues

- Diameter: maximum of the shortest distance between any two nodes
  - gives a measure of the time it takes to get a message through the network (or the number of links)
  - should be kept as small as possible
- Bisection bandwidth: minimum amount of traffic/wires that can go between any division in two equal halves
  - measure of the network capacity, in the worst case of one half of the machine communicating with the other
- Degree: Number of neighbors of a node
  - this should be kept a constant (modularity for scalable systems)

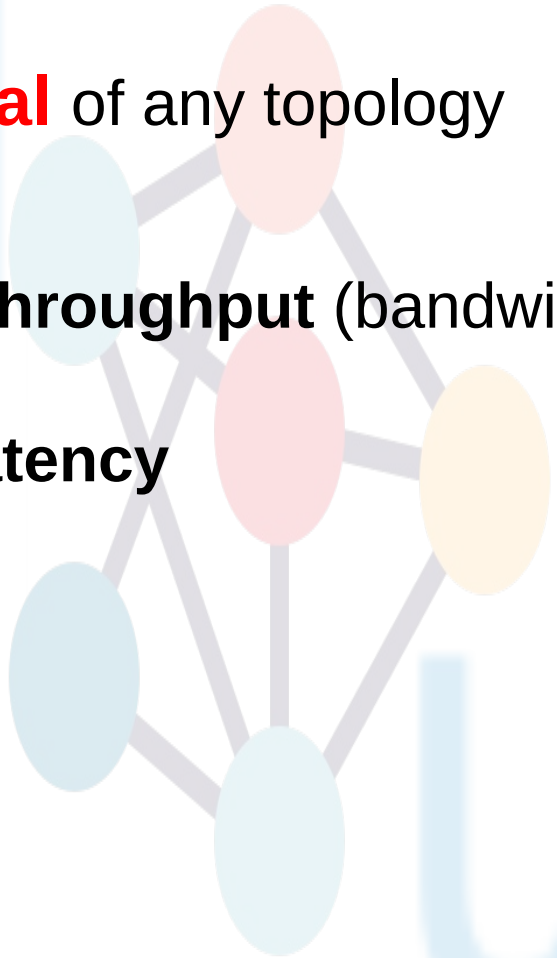
Network topology issues (cnt'd)

- Inter-dependence of degree, number of nodes and diameter
  - maximize number of nodes for given degree and diameter
  - Moore's upper bound
    - roughly logarithmic relation between number of nodes and diameter

Network topology issues (cnt'd)

a goal of any topology

1. high **throughput** (bandwidth)
2. low **latency**



Bandwidth and latency

Bandwidth

1. telecommunications: **range of radio frequencies:** a range of radio frequencies used in radio or telecommunications transmission and reception

2. computing: **communications capacity:** the capacity of a communications channel, for example, a connection to the Internet, often measured in bits per second

3. a data **transmission rate**; the maximum amount of information (bits/second) that can be transmitted along a channel

Latency

A synonym for *delay,* is an expression of how much time it takes for transmission from one designated point to another

Bandwidth and latency

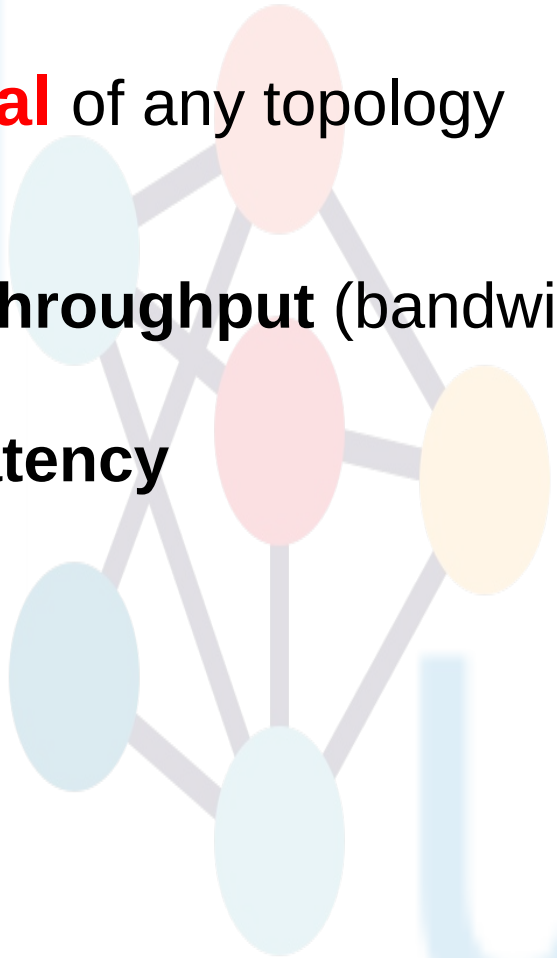
- The firefighter problem

- Fire in Venice!
- 12 firefighters have to be transported across the canal
- Only 1 gondola available with 1 gondolier and a place for 1 firefighter
- 1 min load man & equipment, 4 min transport time, 1 min to upload
  - 116 min to transport all the firefighters!!
- **Bandwidth:** 0.1 firefighter/min, **Latency:** 6 min
- The gondolier, the smart fellow, volunteers the services of 5 additional gondolas
- 16 min to transport all the firefighters!
- **Bandwidth:** 0.75 firefighters/min, **Latency:** 6 min
- A cat Cappelini stuck in the burning building!
- *Mayor:* “If you do not rescue him in 5 min you are fired!”
- The only solution to get there in time is not to bring the equipment!
- **It is usually more easy to increase bandwidth than to reduce latency!**

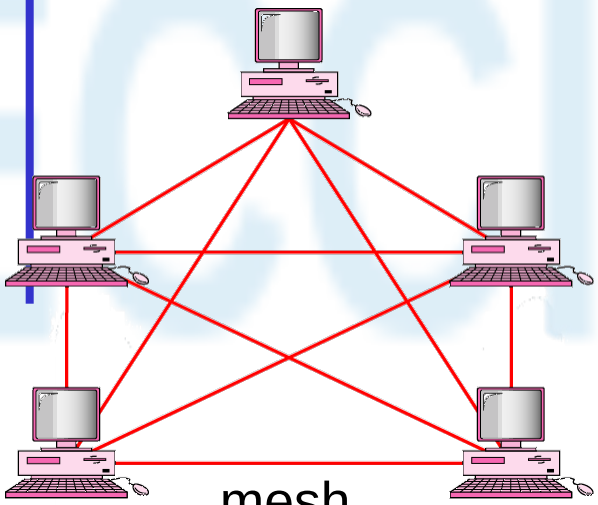
Network topology issues (cnt'd)

a goal of any topology

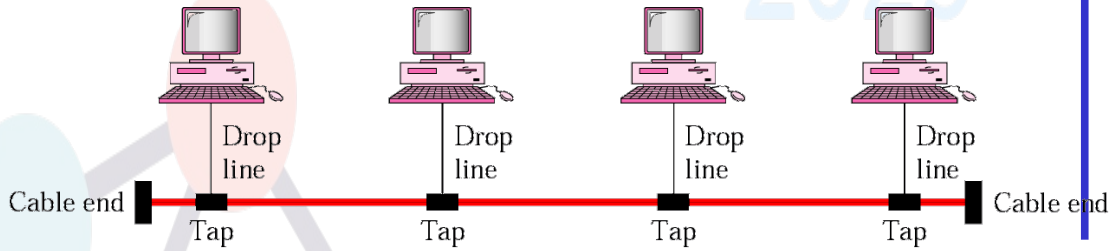
1. high **throughput** (bandwidth)
2. low **latency**



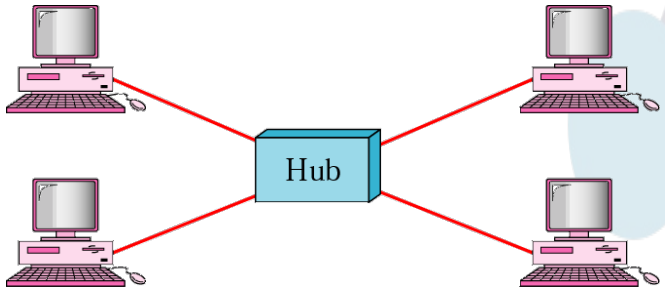
Most used network topologies



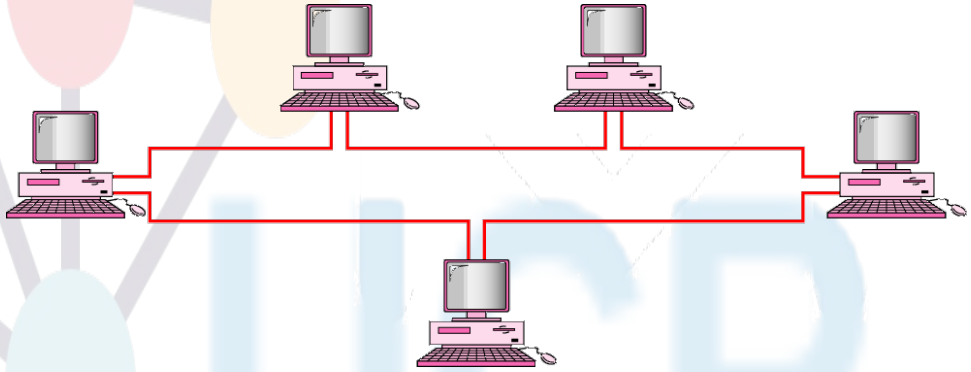
mesh



bus

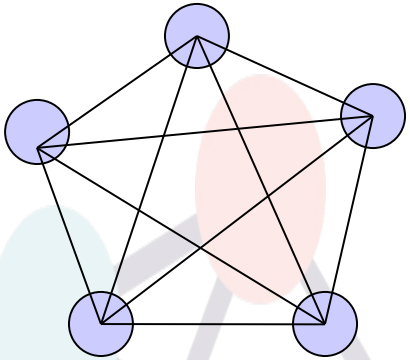


star



ring

Mesh topology



Number of links as function of number of nodes, N: $\frac{N \times (N-1)}{2}$

Number of connections per node *(degree)*: N-1 (constant)

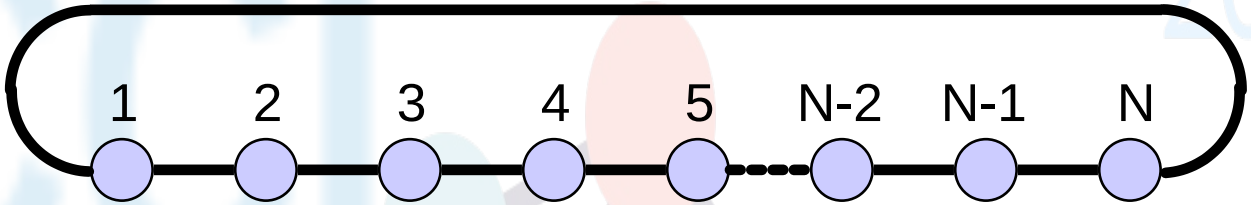
Link bandwidth: *r* (bandwidth of a single link)

Total bandwidth: $\frac{N \times (N-1)}{2} \times r$

Bisection bandwidth: $\frac{N^2}{4} \times r$

Diameter: 1

Ring topology



Number of links as a function of number of nodes, N: N (linear)

Number of connections per node *(degree)*: 2 (constant)

Link bandwidth: *r* (bandwidth of a single link)

Total bandwidth: $N \times r$

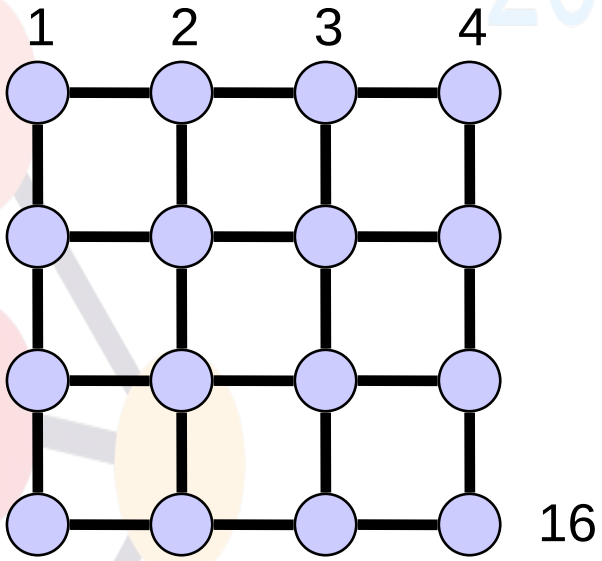
Bisection bandwidth: $2 \times r$

(to cut the network in half, you must cut two links)

Diameter: $\frac{N}{2}$

2-d grid topology

- Number of links as a function of number of nodes, N : ~4N (linear)
- Number of connections per node *(degree)*: 4 (constant)



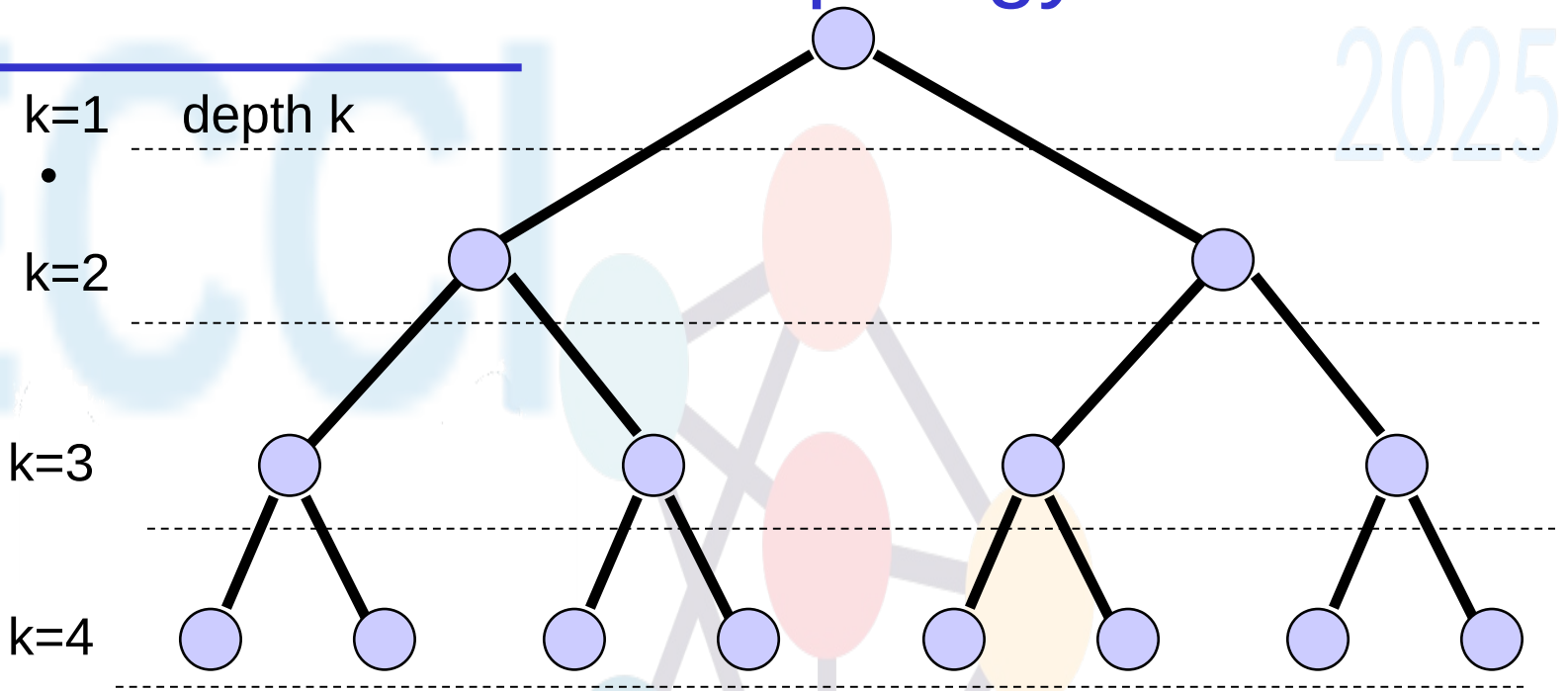
Link bandwidth: *r* (bandwidth of a single link)

Total bandwidth: $4 \times N \times r$

Bisection bandwidth: $\sqrt{N} \times r$

Diameter: $2 \times \sqrt{N} - 2$

Tree topology



Number of links as a function of number of nodes, N: 3* N-1

Number of connections per node (degree): 2

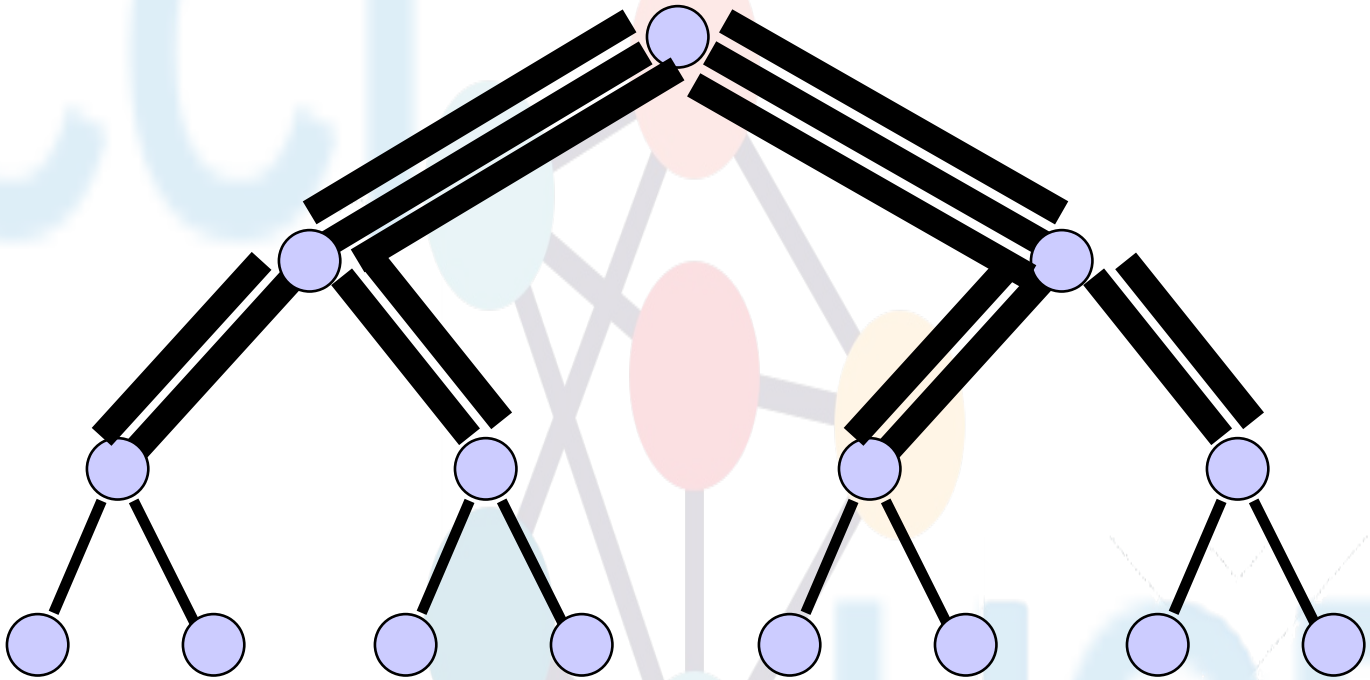
Link bandwidth - *r*

Total bandwidth: $(3\times N-1)\times r$

Bisection bandwidth: 1
(cut a link to the root)

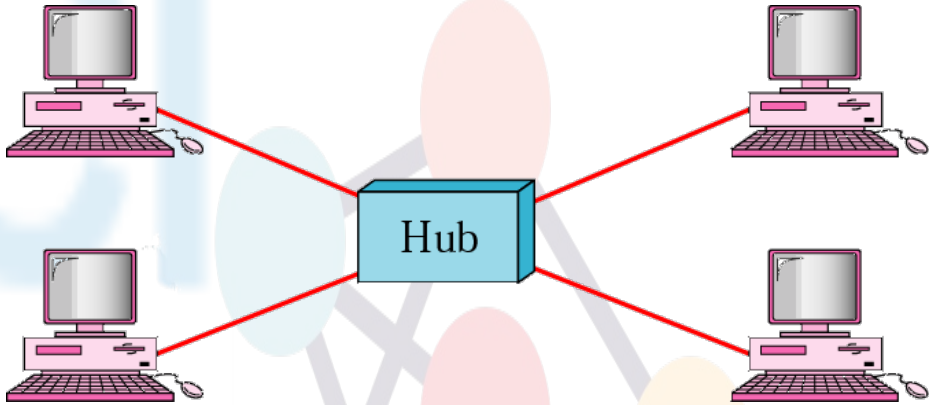
Diameter: $2\times k-2$ approx: $2\times\log(N)$

Fat tree topology



scale bandwidth per level

Star topology

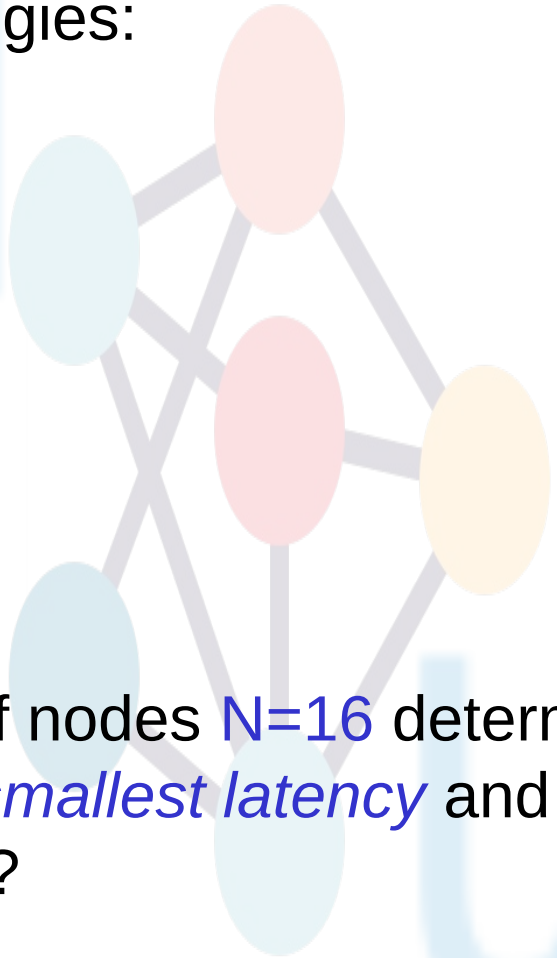


Degree: 1 or N-1,
Diameter: 2,
Bisectional bandwidth: N/2 or 1

Task

Given the 5 topologies:

1. bus
2. ring
3. 2-D grid
4. star
5. mesh



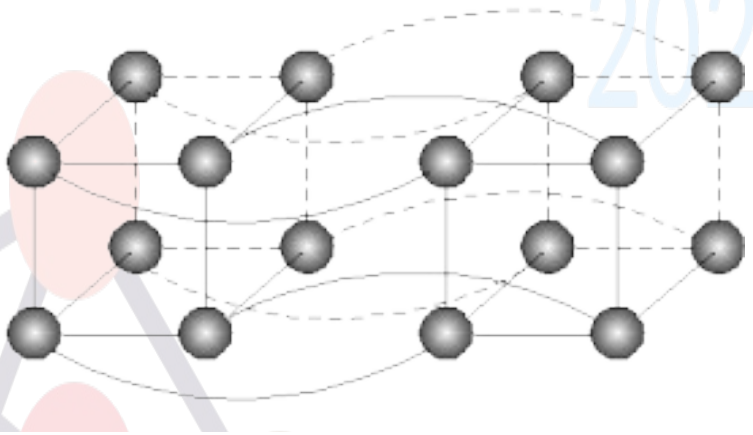
with the number of nodes N=16 determine which topology has the *smallest latency* and which one the *largest bandwidth*?

Hypercube

Degree: $\log(N)$

Diameter: $\log(N)$

Bisection Bandwidth: $\frac{N}{2}$



The best topology for a network changes with both

1. the number of nodes and
2. the length of the message.

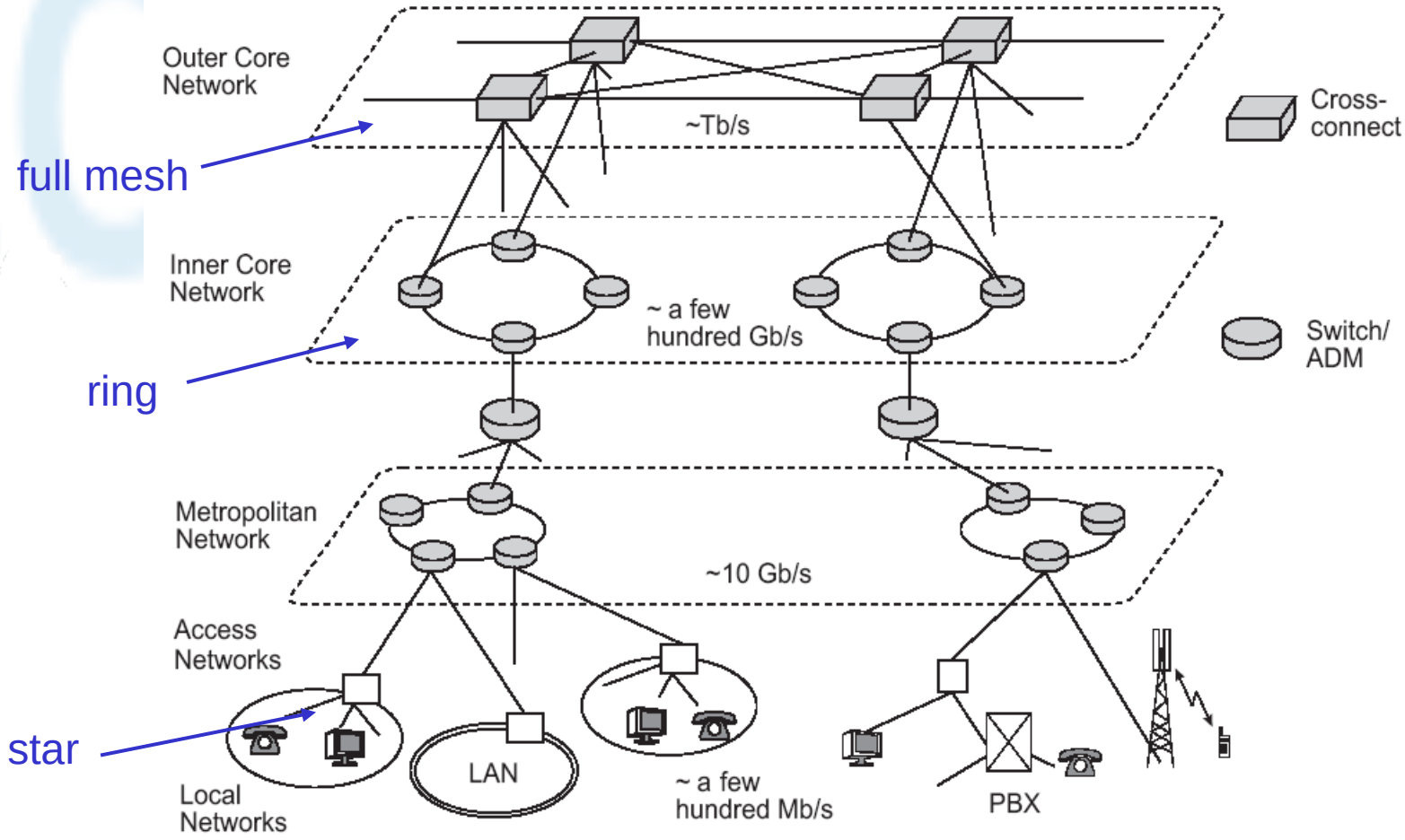
Short messages favor high-dimensional meshes, which have lower diameters.

Longer messages favor lower-dimensional meshes

An example

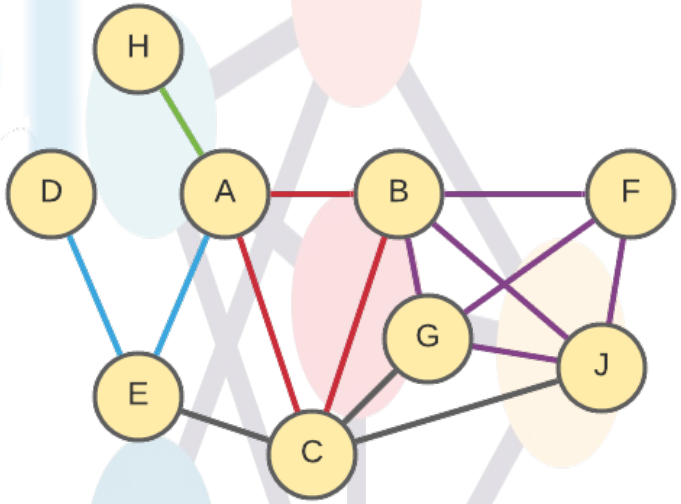
-lightwave infrastructure for public network-

$\frac{N}{2}$



Homework

- Determine the degree, diameter and the bisection bandwidth of the network below:



- Draw a hybrid topology with a mesh backbone connecting two ring backbones. Each ring backbone connects three star networks.