Introduction to Computer Networks

Syllabus

INTRODUCTION: Network goals - Applications of Networks - Design issues for the layers - OSI Reference Model - Types of Network - Network Topologies- Analog and Digital data transmission- Data encoding- Bandwidth and data rate- .Bit Rate, Baud Rate- Sampling Rate. (5)

DATA COMMUNICATION: Multiplexing - Synchronous and Asynchronous TDM – FDM –CDM - Switching, Circuit Switching, Packet Switching. (3)

TRANSMISSION OF DIGITAL DATA: Transmission Impairments - Single and Multiple bit error correction-Error Detection and Correction - Cyclic Redundancy Check Code -.Hamming Code. (4)

DATA LINK CONTROL AND PROTOCOLS: Line Discipline - Flow Control - Sliding Window Protocol - Error Control - Automatic Repeat Request – Stop and wait - ARQ - Go back by n ARQ - Selective Reject ARQ. (5)

LOCAL AREA NETWORKS: Random Access protocols- Ethernet – Fast Ethernet – Gigabit Ethernet – Wireless LANs- Internetworking- LAN -LAN Connections – Repeaters- Hubs - Bridge – Spanning tree-Switches – Routers (5)

IP: TCP/IP Protocol Structure - Internet Protocol – IP addressing-Subnetting-NAT- IPV6-ICMP-ARP-DHCP (9)

ROUTING: Distance vector routing _ Link state Routing – RIP – OSPF (4)

TRANSPORT LAYER: TCP concepts - Port number – Connection control – Flow control - Congestion Control (5)

APPLICATIONS: MTP - MIME Format, FTP, DNS, HTTP. (5)

COMPUTER NETWORKS LAB

1. Familiarize with GNS3 simulator.
2. Familiarize with wireshark tool.
3.Familiarize with IP addressing and subnetting concepts and building an interactive subnet calculator
4. Familiarising with virtualization,docker networking.
5. Implement client server programs using sockets which has multiple clients.
6. Network routing concepts in a Linux environment. These include use of the routecommand, defining a DNS server in the /etc/resolv.conf file, and using Network Address Translation(NAT).
7. Familiarize with pcaps and traffic analysis using Wireshark.
8. Network flow record analysis
9. Configure a DNS server , and then try various DNS Pharming attacks
10. Design a mail server and client
11. Implement a web proxy that passes requests and data between multiple web clients and web servers, concurrently.

Course Objectives

- To provide a solid conceptual understanding of the fundamentals of data communications and computer networks. More specifically,
  1. To learn the basic concepts of data communications.
  2. To learn the layered architecture of communication protocols.
  3. To learn digital signal transmission and encoding techiniques.
  4. To learn multiplexing techniques.
  5. To learn the concepts and techniques in error detection and correction.
  6. To learn data link control and its related protocols.
  7. To learn LAN architectures and systems.
  8. To learn switching techniques.
  9. To learn the main protocols and standards of the Internet.
  10. To learn basic concepts of internetworking, addressing, and routing.

Learning outcomes

- Describe the general principles of data communication.
- Describe how computer networks are organized with the concept of layered approach.
- Describe how signals are used to transfer data between nodes.
- Describe how packets in the Internet are delivered via TCP/IP protocol.
- Analyze the contents in a given data link layer packet and learn about the data link layer protocols
- Design logical sub-address blocks with a given address block.
- Decide routing entries given a simple example of network topology
- Describe what classless addressing scheme is.
- Describe how routing protocols work.
- Analyse all the application protocols

Why Study networking?

Networking is the "plumbing" of computing

Almost all areas of computing are network-based.

- Distributed computing
- Big Data
- Cloud Computing
- Internet of Things
- Smart Cities

Networking is the backbone of computing.

Networking is Fueling All Sectors of Economy

Networking companies are among the most valued companies: Apple, AT&T, Samsung, Verizon, Microsoft, China Mobile, Alphabet, Comcast, NTT, IBM, Intel, Cisco, Amazon, Facebook, …

All tech companies that are hiring currently are networking companies

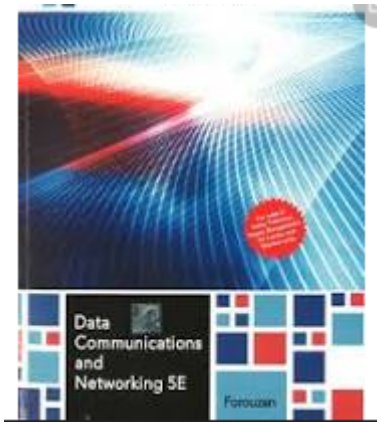
Note: Apple became highly valued only after it switched from computing to communications (iPhone)

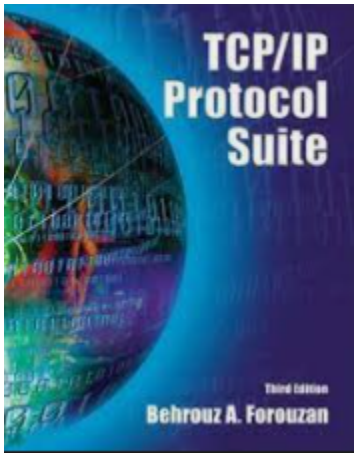
Networking = Economic Indicator

Text and Reference books

- **TEXT BOOKS:**
  1. Behrouz A Forouzan, “Data Communications and Networking”, Tata McGraw Hill, 2013
  . 2. Behrouz A Forouzan, “TCP/ IP Protocol Suite”, Tata McGraw Hill, 2017.
  3. Peterson, Larry L., and Bruce S. Davie. Computer networks: a systems approach. Elsevier, 2012.

  REFERENCES:
  1. Kevin Fall R and Richard Stevens W, "TCP/IP Illustrated, Volume 1: The Protocols”, Addison-Wesley, Ann Arbor, 2011.
  2. James F. Kurose, Keith Ross, “Computer Networking: A Top-Down Approach”, Addison-Wesley, 2017.
  3. Douglas Comer, “Internetworking with TCP/IP”, Prentice Hall, 2013.
  4. William Stallings, "Data and Computer Communications”, Prentice Hall, 2007.





History

On the Shoulders of Giants

- 1961: Leonard Kleinrock published a work on packet switching
- 1962: J. Licklider described a worldwide network of computers called Galactic Network
- 1965: Larry Roberts designed the ARPANET that communicated over long distance links
- 1971: Ray Tomilson invents email at BBN
- 1972: Bob Kahn and Vint Cerf invented TCP for reliable packet transport



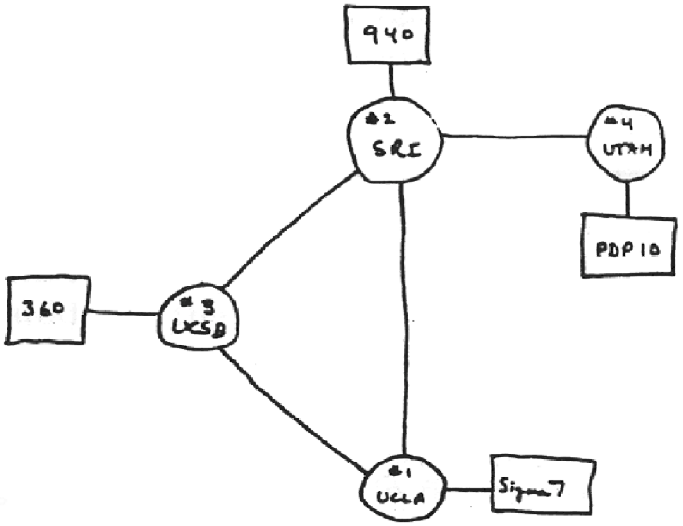


History

On the Shoulders of Giants ...

- 1973: David Clark, Bob Metcalfe implemented TCP and designed ethernet at Xerox PARC
- 1975: Paul Mockapetris developed DNS system for host lookup
- 1980: Radia Perlman invented spanning tree algorithm for bridging separate networks
- Things snowballed from there on ...

The World's Most Successful Computer Science Research Project



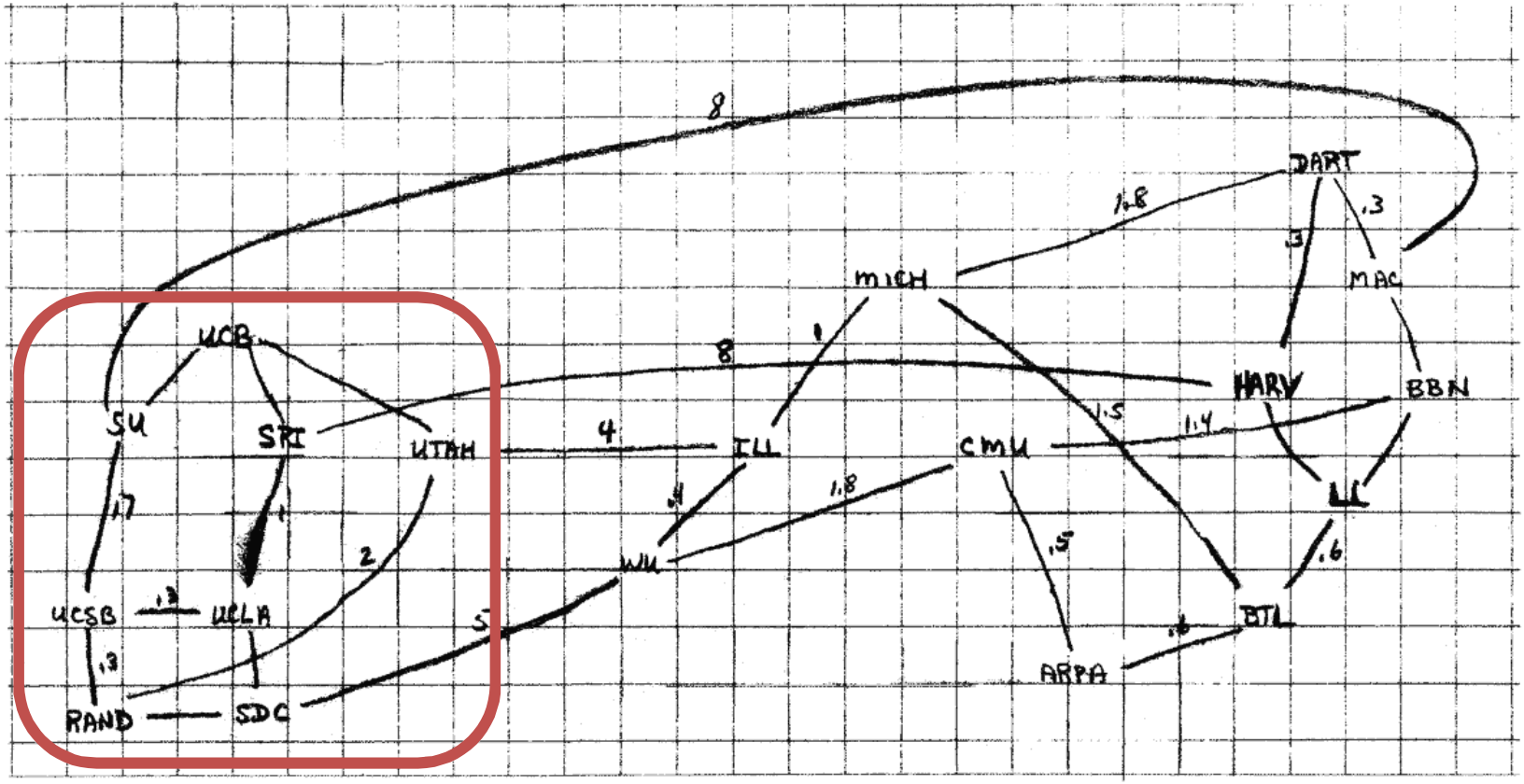
THE ARPA NETWORK

DEC 1969

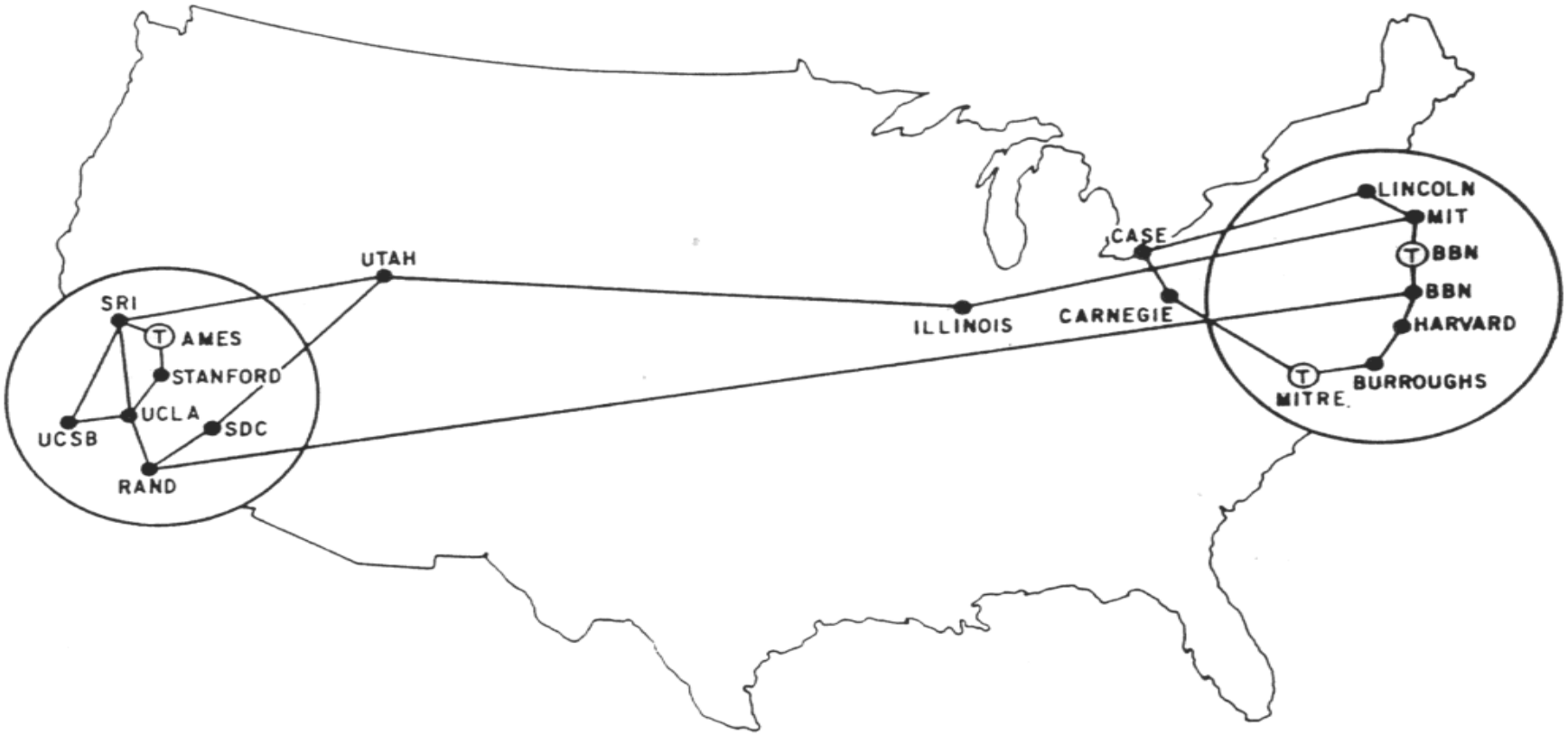
4 NODES

FIGURE 6.2 Drawing of 4 Node Network
(Courtesy of Alex McKenzie)

The 1960s

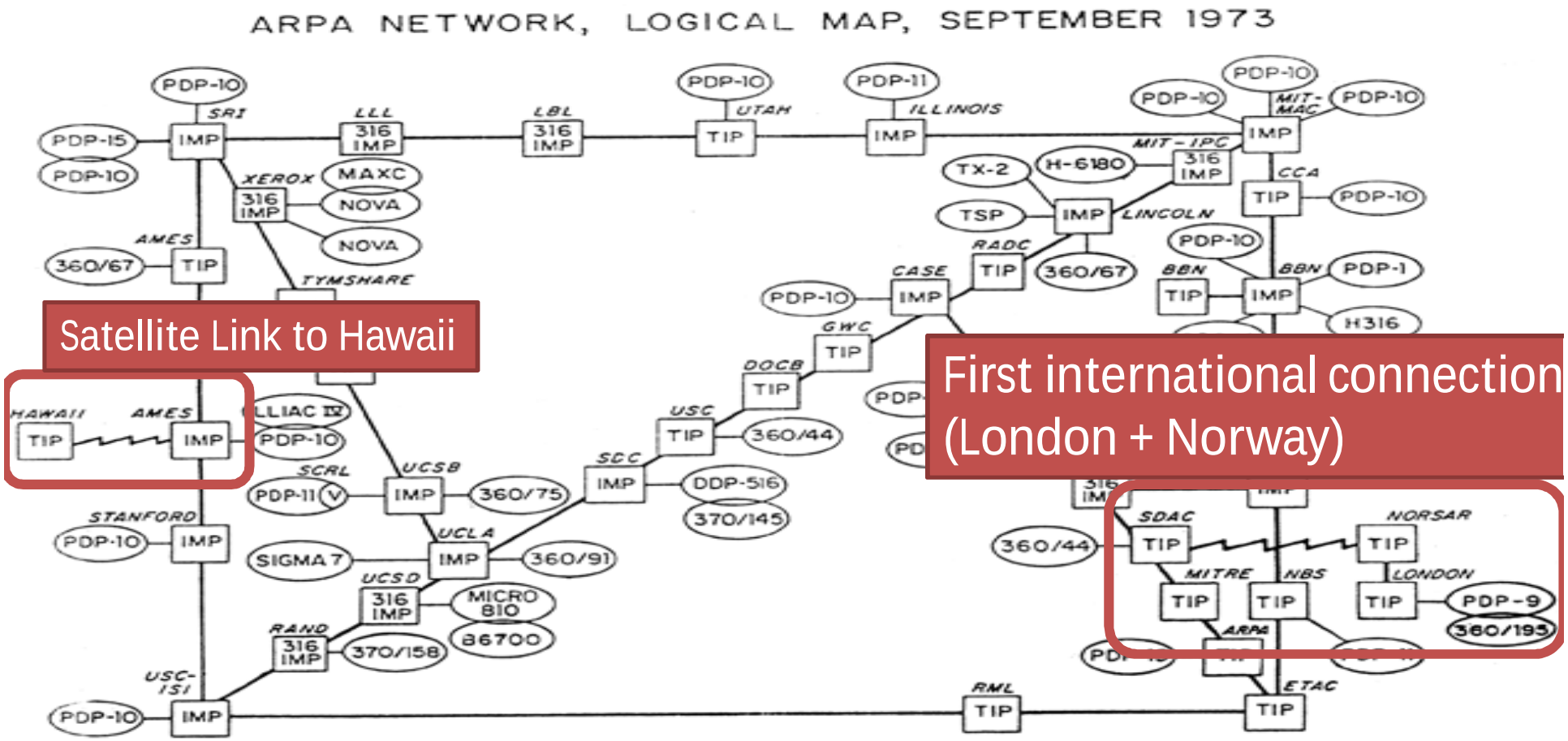

8
DART
1.8
.3
.3
MAC
MICH
UCB
8
1
HARV
BBN
SU
SRI
UTAH
4
ILL
CMU
1.5
1.4
LL
.4
1.8
WM
.5
.6
.2
2
UCSB
.3
UCLA
5
BTL
.3
ARPA
.6
RAND
SDC

1971



MAP 4 September 1971

1973

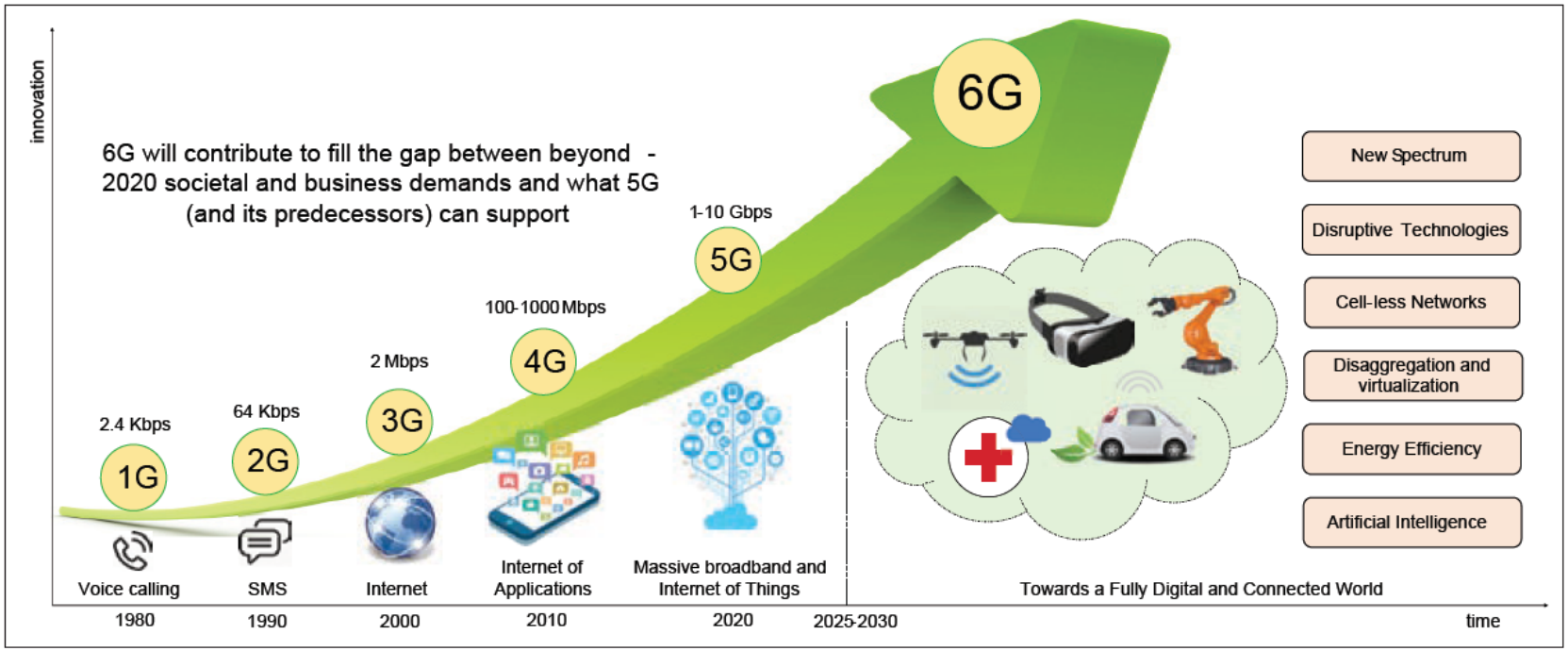

ARPA NETWORK, LOGICAL MAP, SEPTEMBER 1973
Satellite Link to Hawaii
First international connection (London + Norway)
SRI
LLL
LBL
UTAH
ILLINOIS
MIT-MAC
MIT-IPC
CCA
LINCOLN
BBN
RADC
CASE
GWC
OOCB
USC
SCC
UCSB
SCRL
UCLA
UCSD
RAND
USC-ISI
AMES
XEROX
TYMSHARE
HAWAII
STANFORD
SDAC
NORSAR
MITRE
NBS
LONDON
ARPA
ETAC
RML
IMP
TIP
316 IMP
PDP-10
PDP-11
PDP-15
PDP-9
360/67
360/44
360/75
360/91
370/158
370/145
86700
SIGMA 7
DDP-516
MICRO 810
MAXC
NOVA
TX-2
H-6180
TSP
H316

At Present

Network Trends

6G networking and connectivity

Historical and estimated 1G ..6G evolution



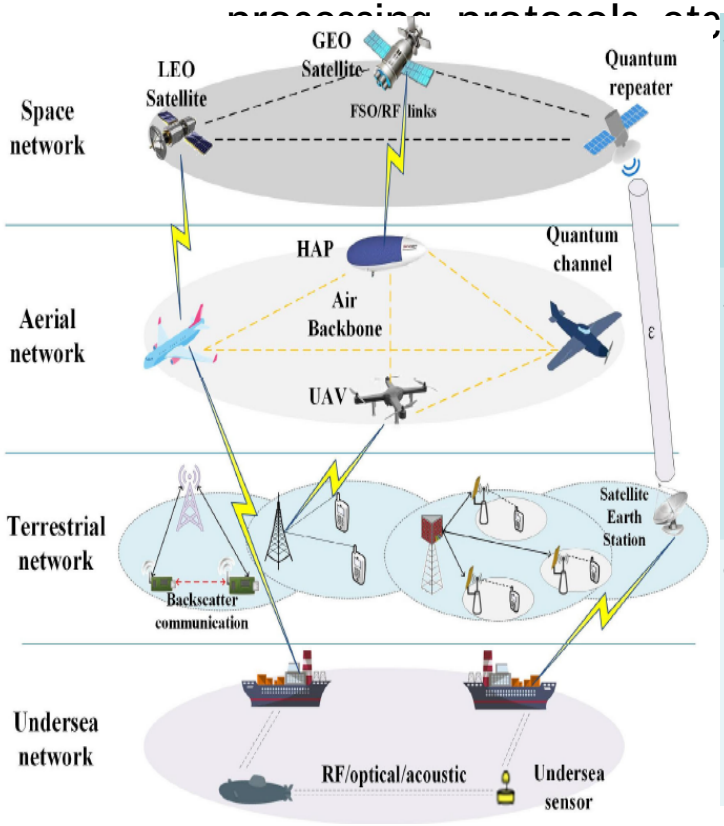
Source: M. Giordani, et al., "Toward 6G Networks:Use Cases and Technologies", IEEE Communications Magazine , March 2020

6G networking and connectivity

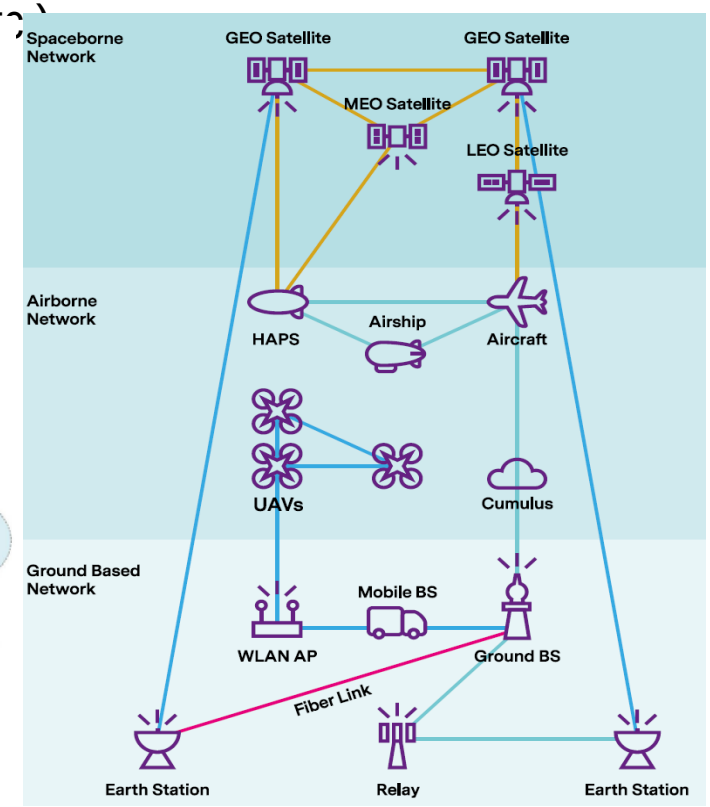
Integrated Space Aerial, Terrestrial and Undersea Network

Ubiquituous 3d coverage

LEO- Low Earth Orbit
MEO- Medium Earth Orbit
GEO- Geostationary Earth Orbit
HAP- High Altitude Platforms
UAV- Unmanned Aerial Vehicle



Source: T.Huang, et al., "A Survey on Green 6G Network: Architecture and Technologies", IEEE Access, VOLUME 7, 2019, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8922617



Source: 6G FlagShip, "WHITE PAPER ON BROADBAND CONNECTIVITY IN 6G", 6G Research Visions, No. 10 June 2020, Univ. of Oulu

Future of networking

#1: A collaborative, automated physical world
#2: Connected, intelligent machines
#3: The internet of senses
#4: Omnipresent and nonlimiting connectivity
#5: Pervasive network compute fabric
#6: Trustworthy infrastructure
#7: Cognitive network

Data Communication

Definitions

- **Data:** information presented in whatever form is agreed upon by the parties creating and using the data.
- **Data Communication:** exchange of data between two devices via transmission medium (wire cable / link).
- **Data Communication System:** Made up of a combination of **hardware** (physical equipment) and **software** (programs) to facilitate for effective communication of data.

Components of a Data Communication System

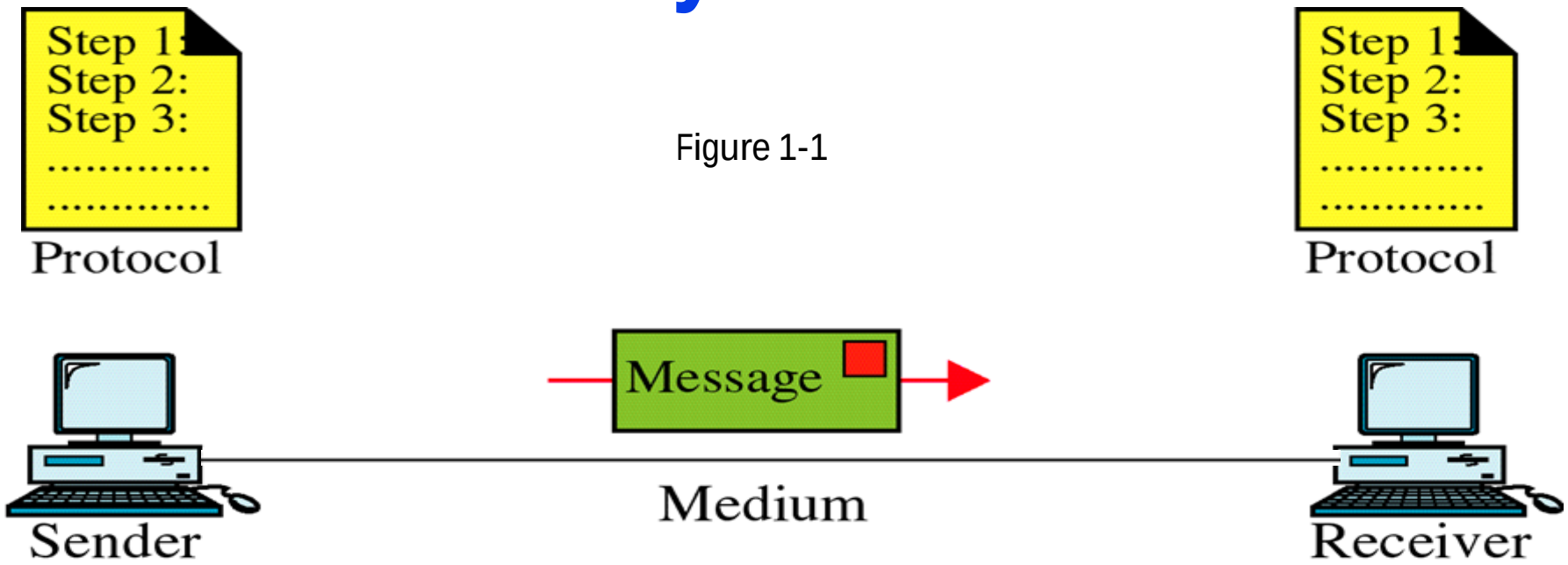


Figure 1-1

***Protocol*: is a set of rules that governs data communications. It represents an agreement between the communicating devices. Without a protocol two devices may be connected but not communicating.**

Characteristics of a Data Communication System

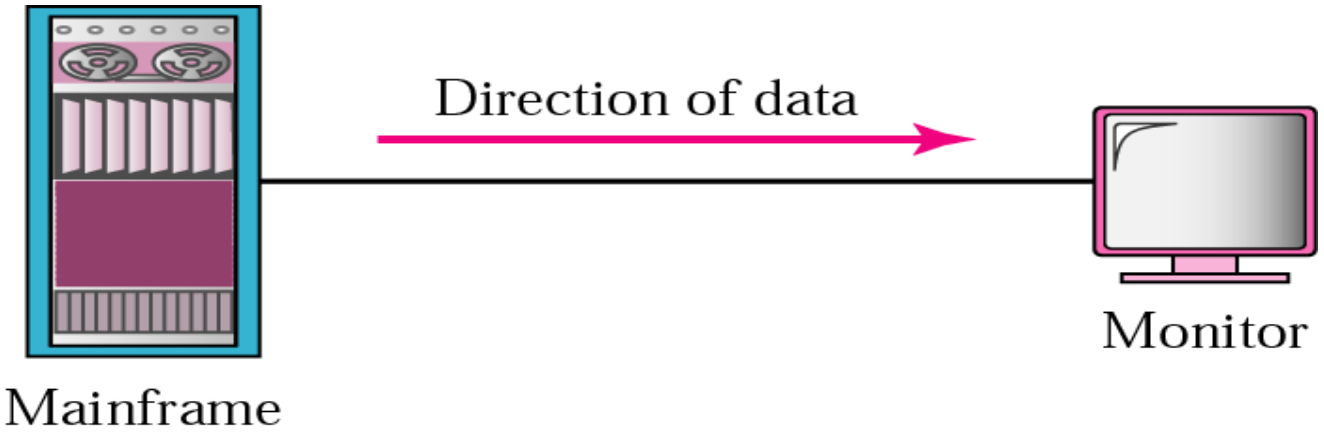
- ***Delivery*** : System must deliver data to correct destination. Data must be received by only intended device or user.
- ***Accuracy:*** The system must deliver data accurately
- ***Timeliness:*** the system must deliver data in a timely manner. Data delivered later are useless.
- ***Jitter:*** Variation in the packet arrival time. It is the uneven delay in the delivery of audio or video packets.

Data Flow

- Path taken by data within a device, network, or organization, as it moves from its source to its destination (a data repository or a data user).
- Categorized by direction of flow:
  - ❖Simplex
  - ❖Half-duplex
  - ❖Full-duplex

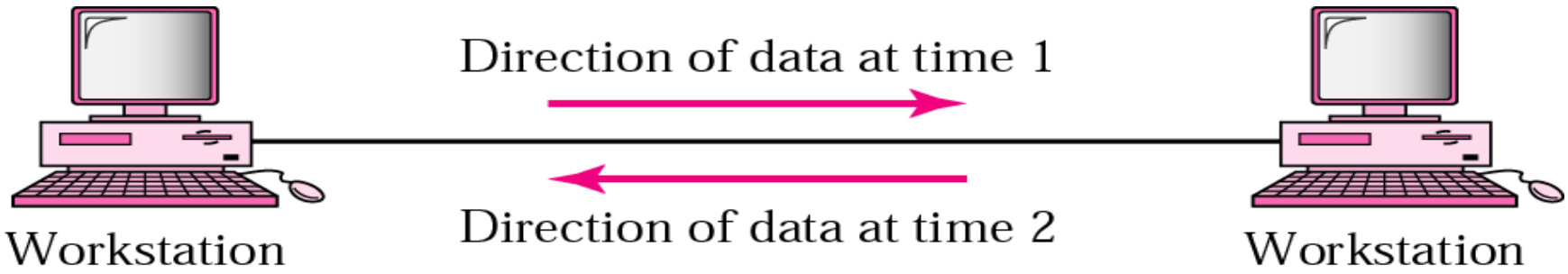
Simplex

- Communication is unidirectional, one of the two devices on a link can transmit; the other can only receive (one-way street).
- Ex: keyboard (input), monitors (output)



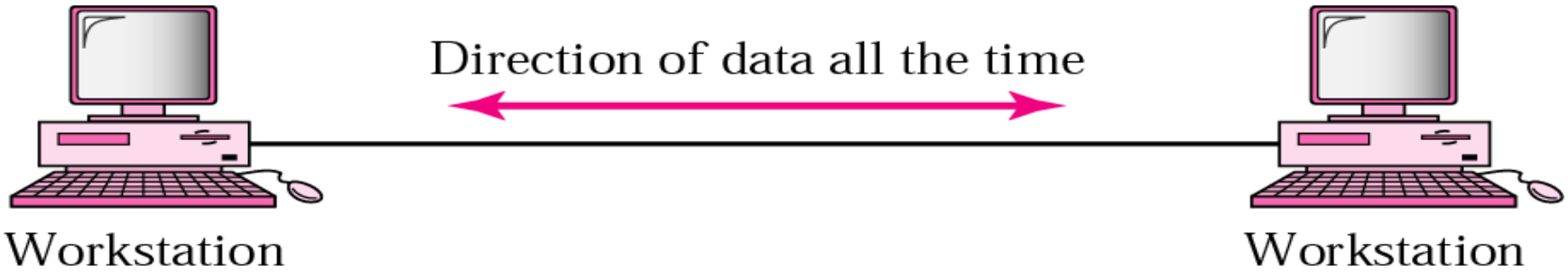
Half-duplex

Each station can both transmit and receive , ***but not at the same time***. When one device is sending the other can receive and vice versa. (one-lane road with two direction).



Full-duplex

- Both stations can transmit and receive simultaneously.
- Ex: telephone network.



Signals going in either direction share the capacity of the link in two ways:

➢Either the link must contain two physically separate transmission paths one for sending and other for receiving.

➢Capacity of the channel is divided between signals traveling in both direction

Networks

Definitions

- A *network* is a set of devices (often referred to as nodes) connected by communication links.
- A *node* can be a host (such as a computer, a laptop, a smart phone etc.) or a network device (such as a switch, a router, etc.).
- A *link* is a communication pathway that transfer data from one device to another.

Network Configuration

- There are a number of ways that computers can be connected together to form **networks**.
- Physical attributes of a network include:
  - ❖Type of connection
  - ❖Physical topology

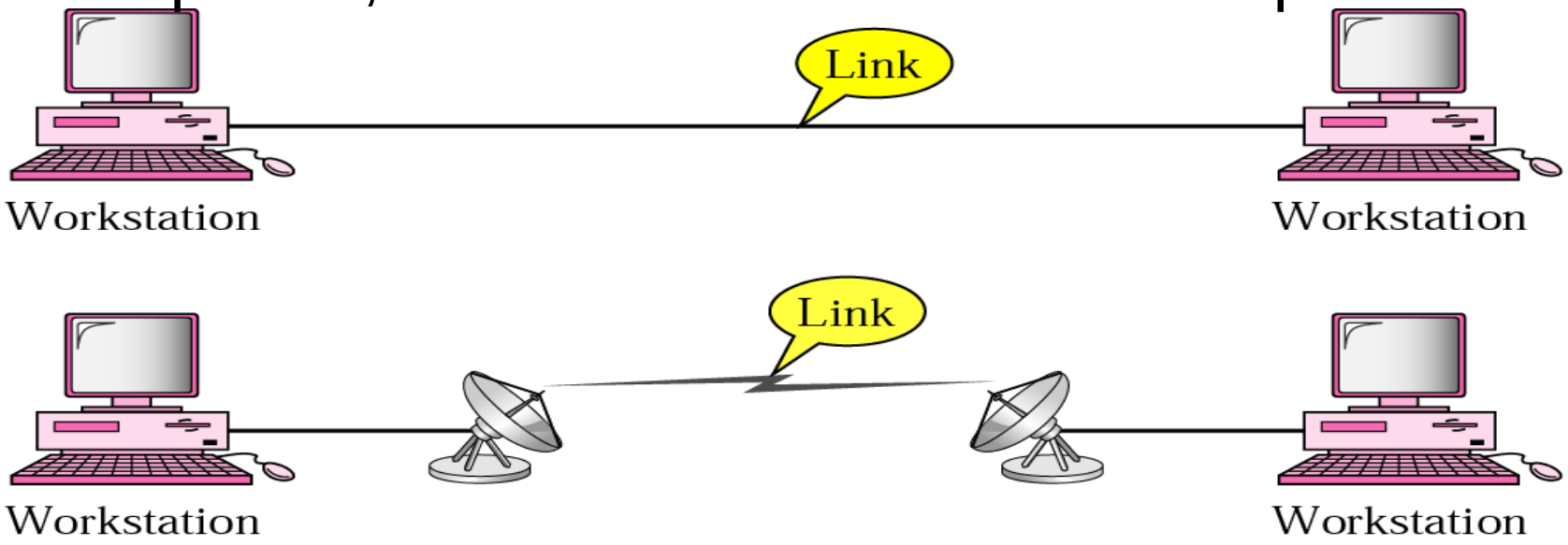
Type of Connection

- For communication to occur, two devices must be connected in someway to the same link at the same time.
- Two possible connections:
  - Point-to-point
  - Multipoint

Physical Structures: Type of connection

1. Point –to-point

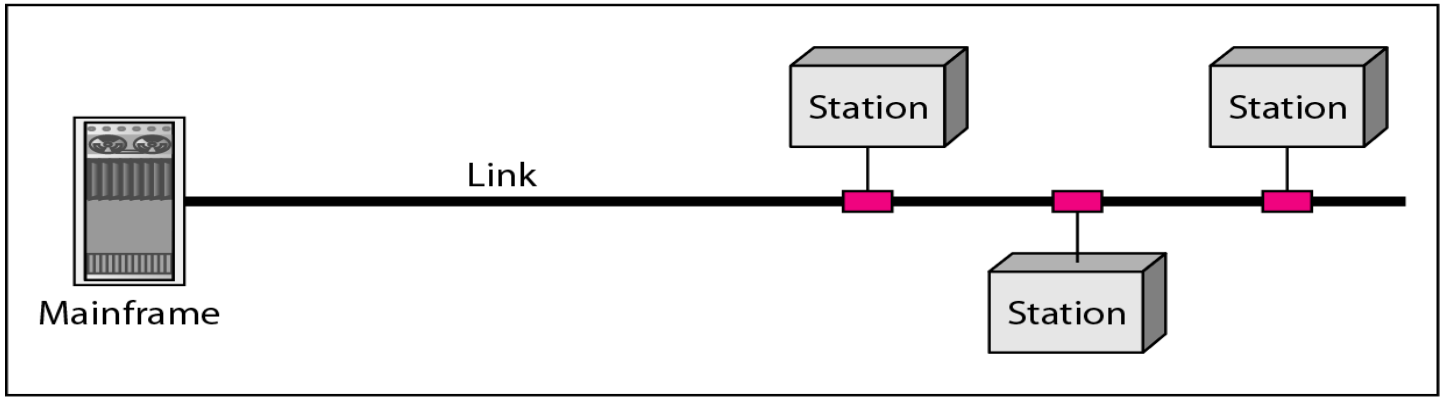
Dedicated link between two devices. Most of them uses an actual length of wire or cable to connect the two ends but other options ,such as microwave satellite are possible.



Physical Structures: Type of connection

2. Multipoint

Is one in which more than two specific devices share a single link



b. Multipoint

Network Configuration

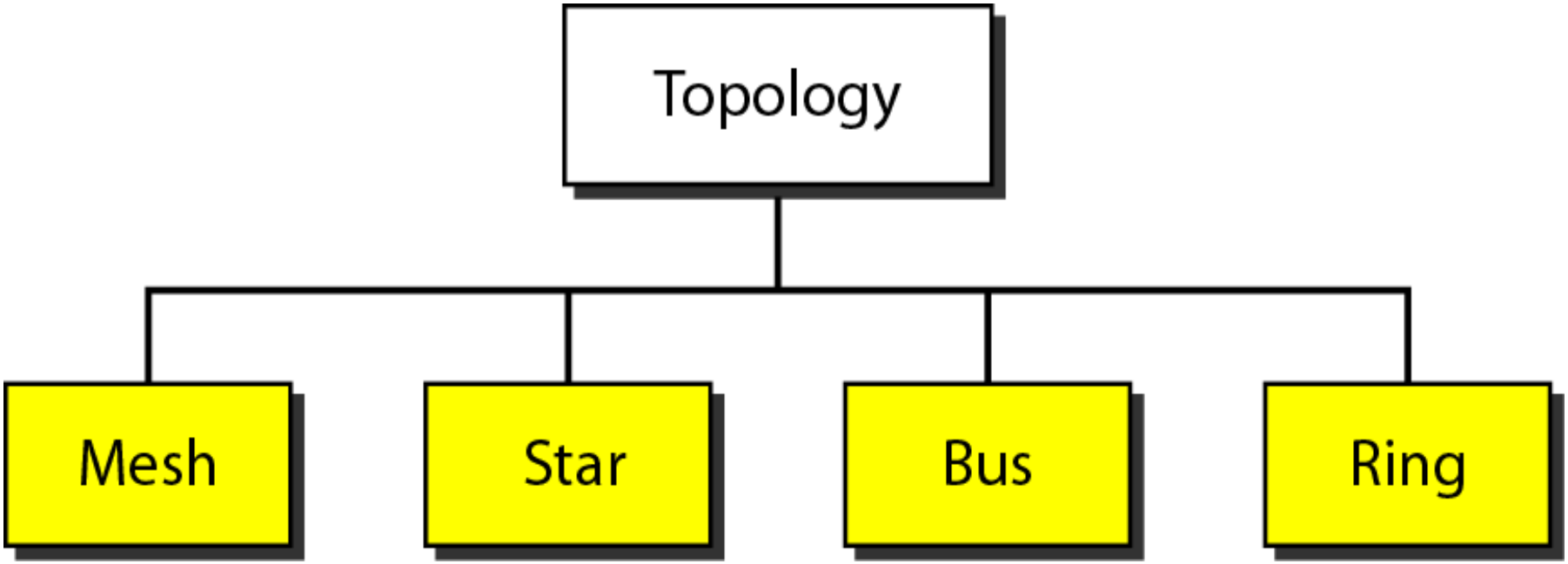
- Physical attributes of a network include:
  - ✓Type of connection
  - ❖Physical topology

Physical Topology

- Two or more links for a **topology**.
  - The ***topology*** **of a network refers to the geometric representation of the relationship of all the links and linking devices (nodes) to one another.**
- The term *physical topology* refers to the way in which a network is laid out physically.

Physical Topology

- The way in which a network is laid out physically.



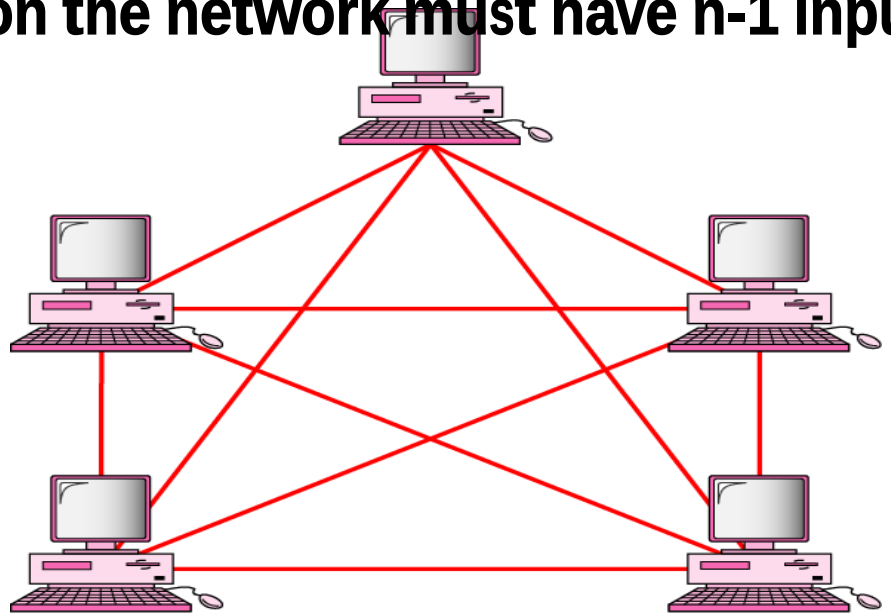
Mesh Topology

- Every device has a *dedicated* **point-to-point** link with every other device on the network.
- How many links do we need in a network with N nodes?
  - Half duplex
  - Full duplex

Mesh Topology

Fully connected mesh topology (for five devices)

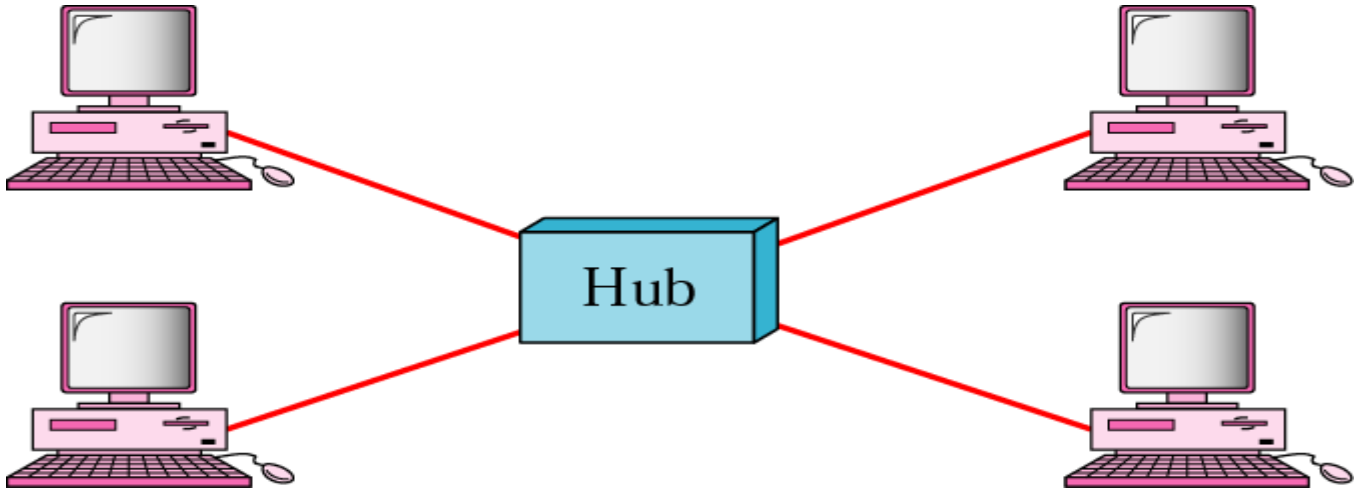
- **Every device has a dedicated point-to-point link to every other devices**
- **Fully connected mesh network has n(n-1)/2 physical connection to link n devices.**
- **Every device on the network must have n-1 input/output (I/O) ports**



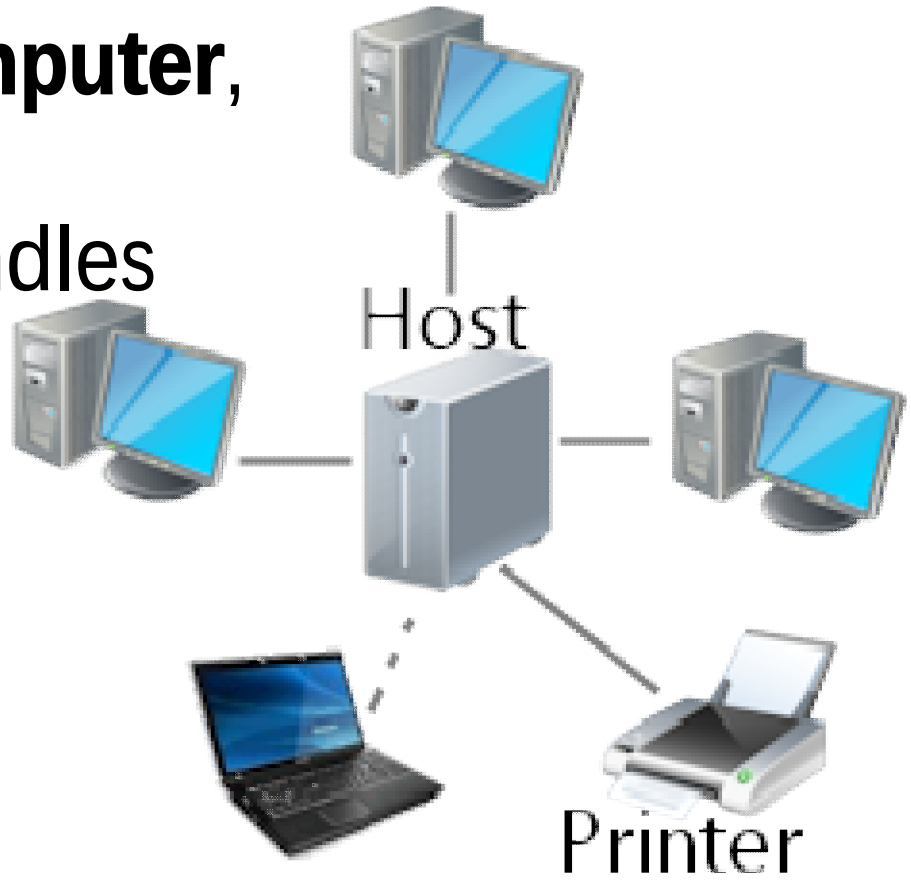
Star topology

Each device has a dedicated point-to-point link only to a central controller (hub)

Unlike a mesh , a star topology does not allow direct traffic between devices, if one device want to send data to another , it send it to the hub, which send it to other device

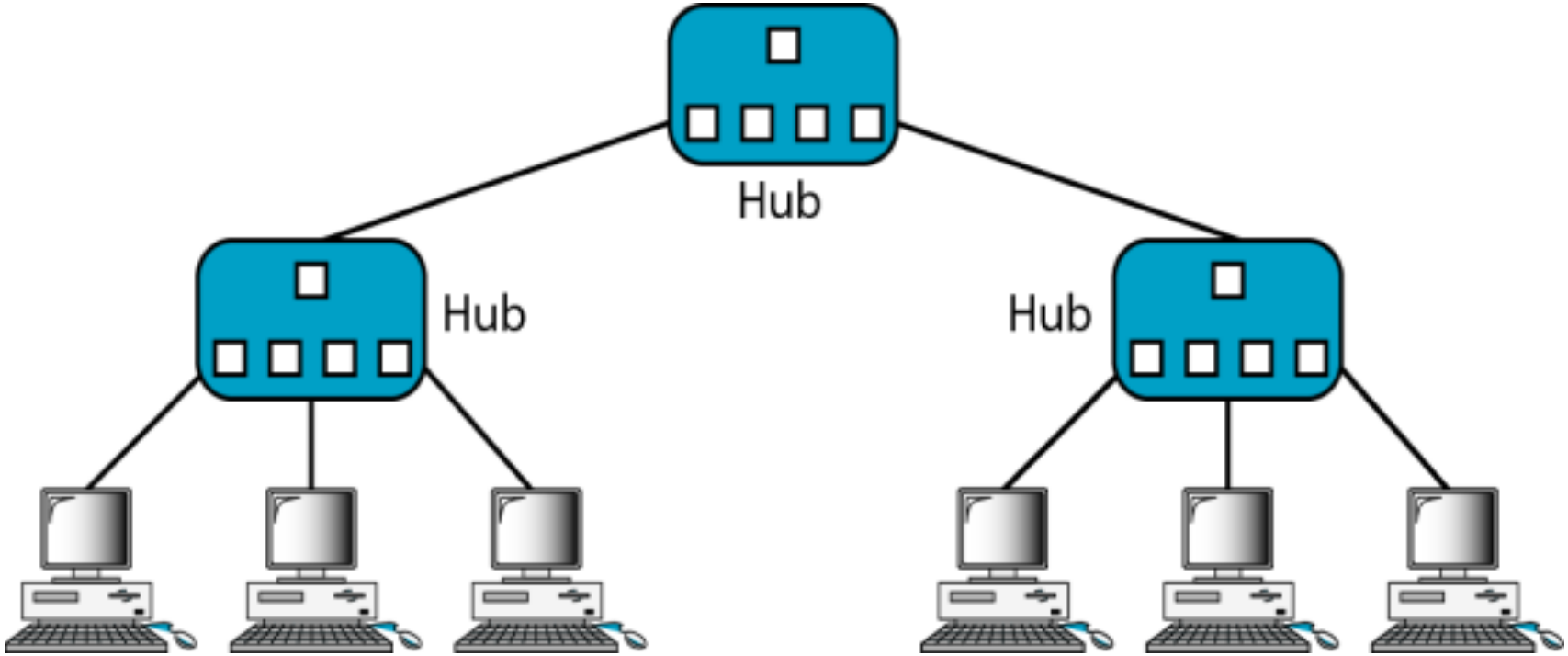


- The **star** pattern connects everything to a **host computer**, a **network switch,** or a **network hub**, which handles the network tasks.
- All communications between computers go through the host/switch/hub.



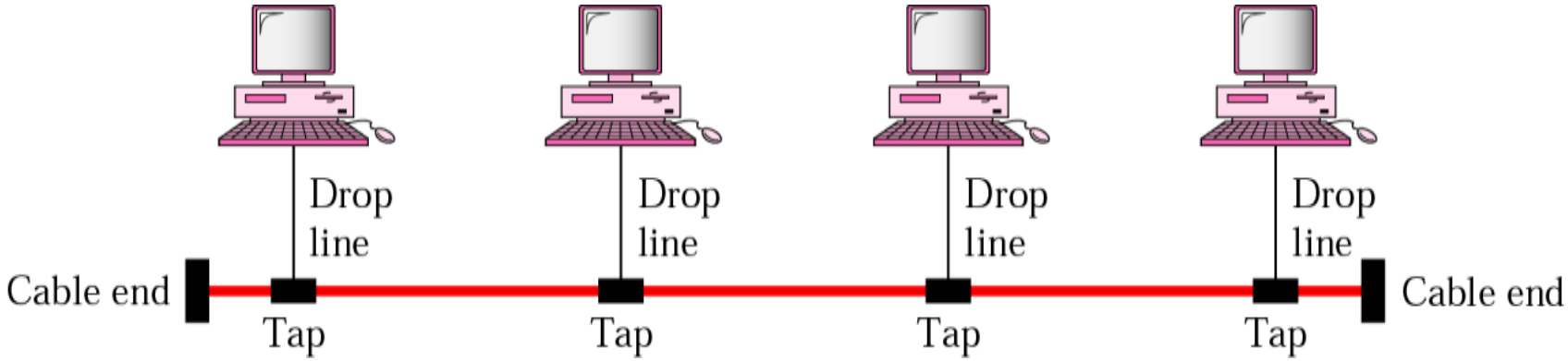
Tree topology : Is a variation of star

- Not every device plugs directly into the central hub. The majority of devices connect to secondary hub that in turn is connected to the central hub.



Bus topology

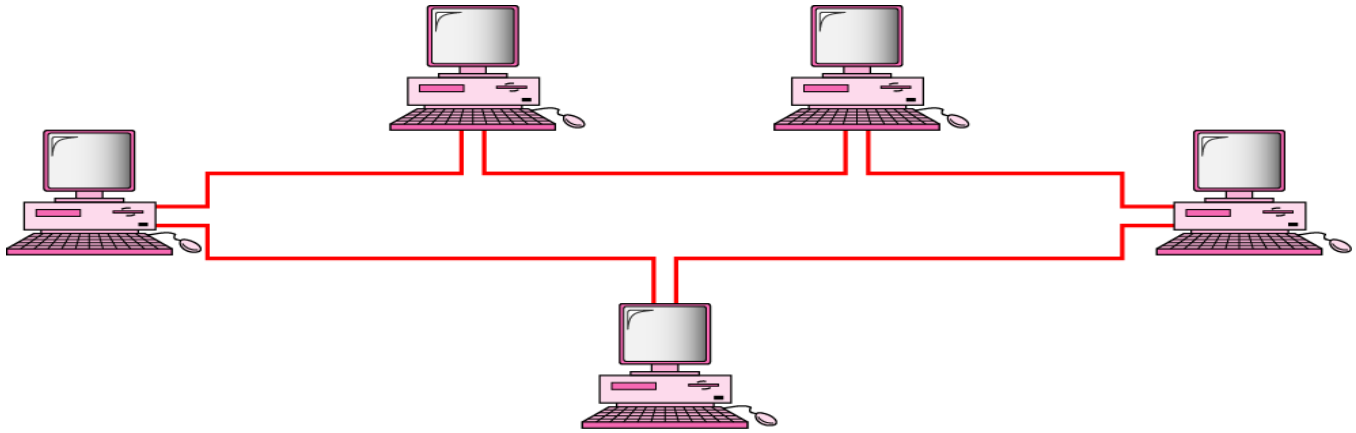
- Multipoint connection. Acts as a backbone to link all the devices in a network.



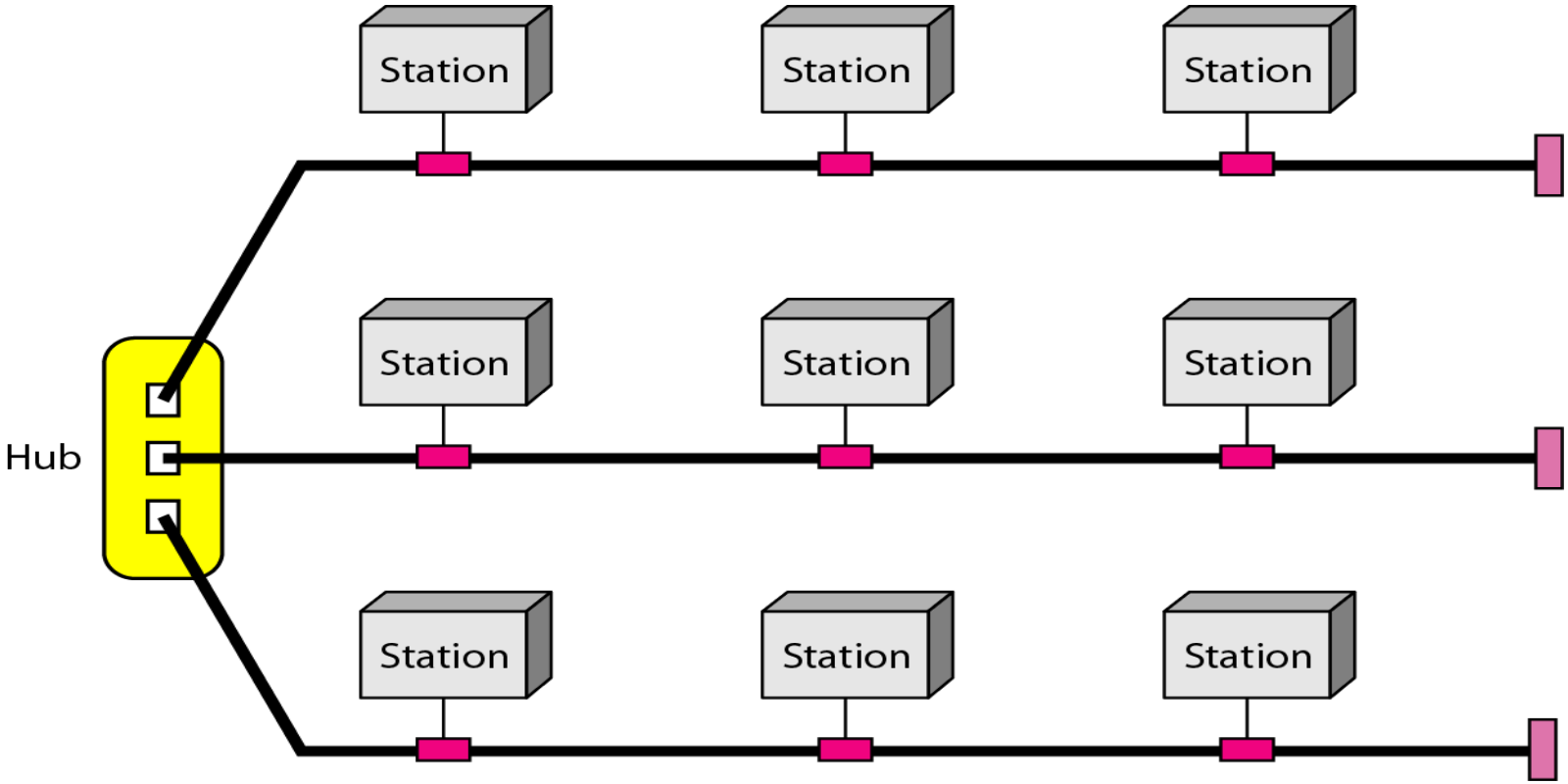
The **bus** pattern connects the computer to the same communications line. Communications goes both directions along the line. All the computers can communicate with each other without having to go through the server.

Ring Topology

- Each device has a *dedicated* point-to-point connection only with the two devices on either side of it
- A signal is passed along the ring in one direction from device until it reaches its destination.

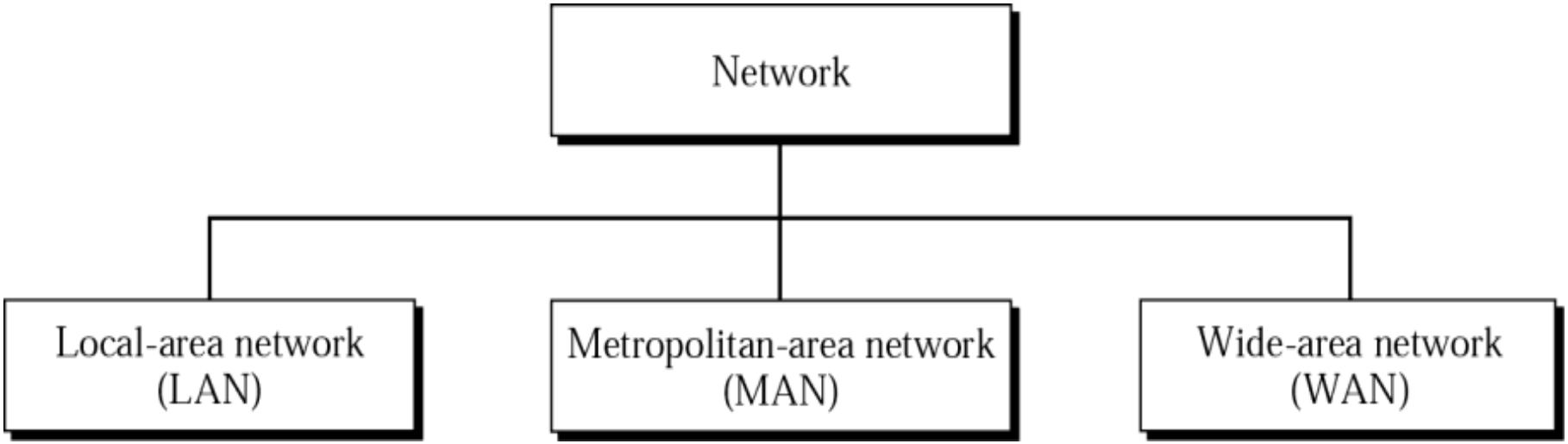


A hybrid topology: a star backbone with three bus networks



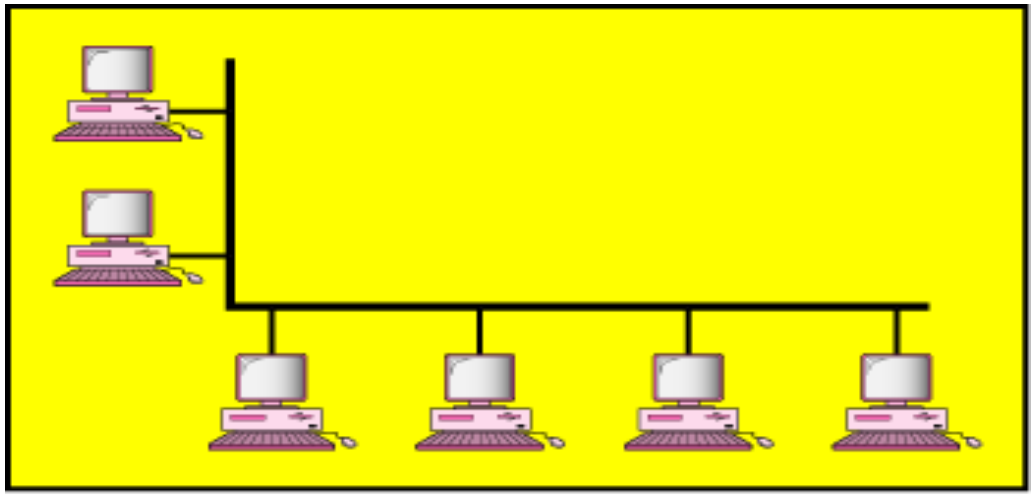
Network Categories

Network category is determined by its size, ownership, the distance it cover and its physical architecture.



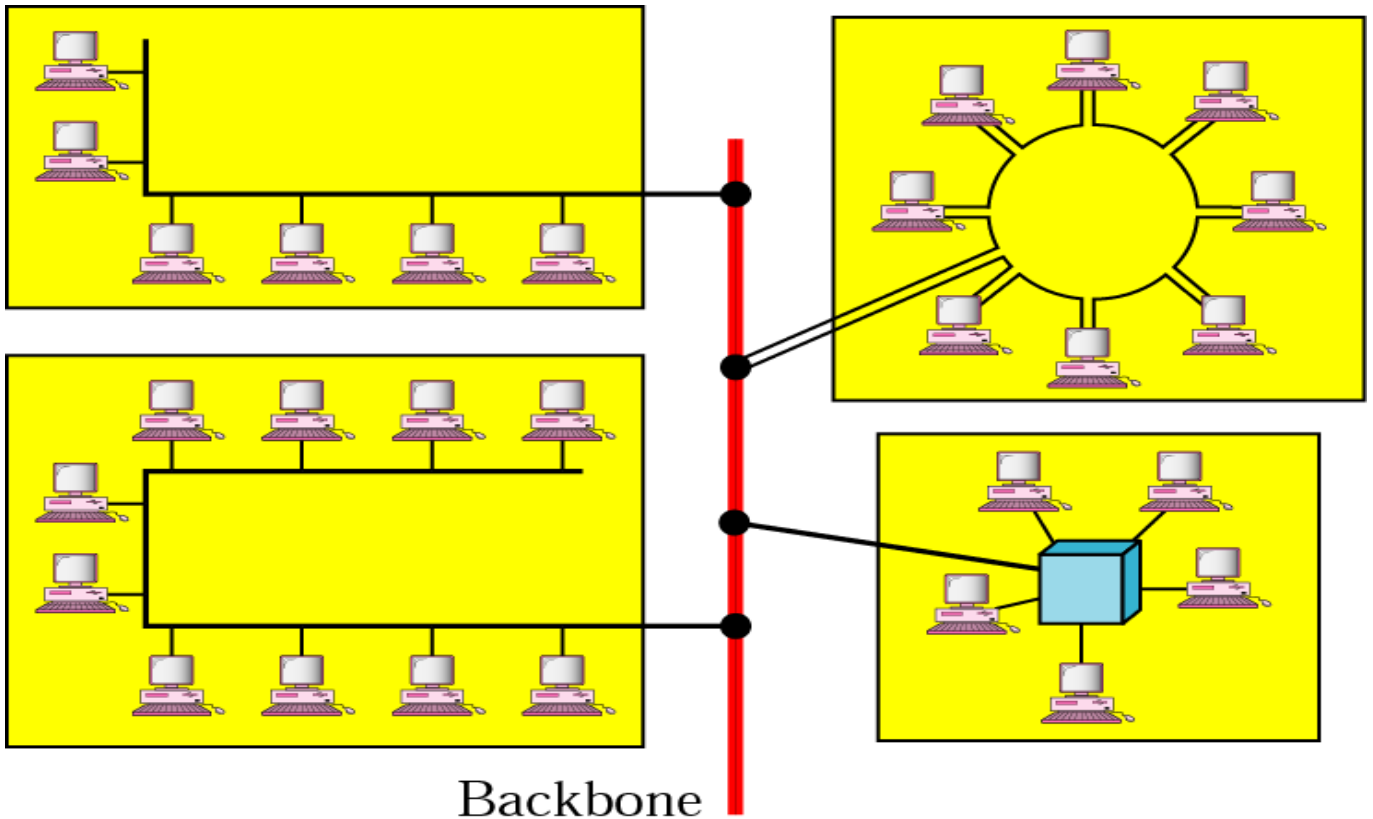
Single-Building LAN

Used in business environments, links a workgroup of task-related computer.



a. Single-building LAN

Multiple-building LAN



b. Multiple-building LAN

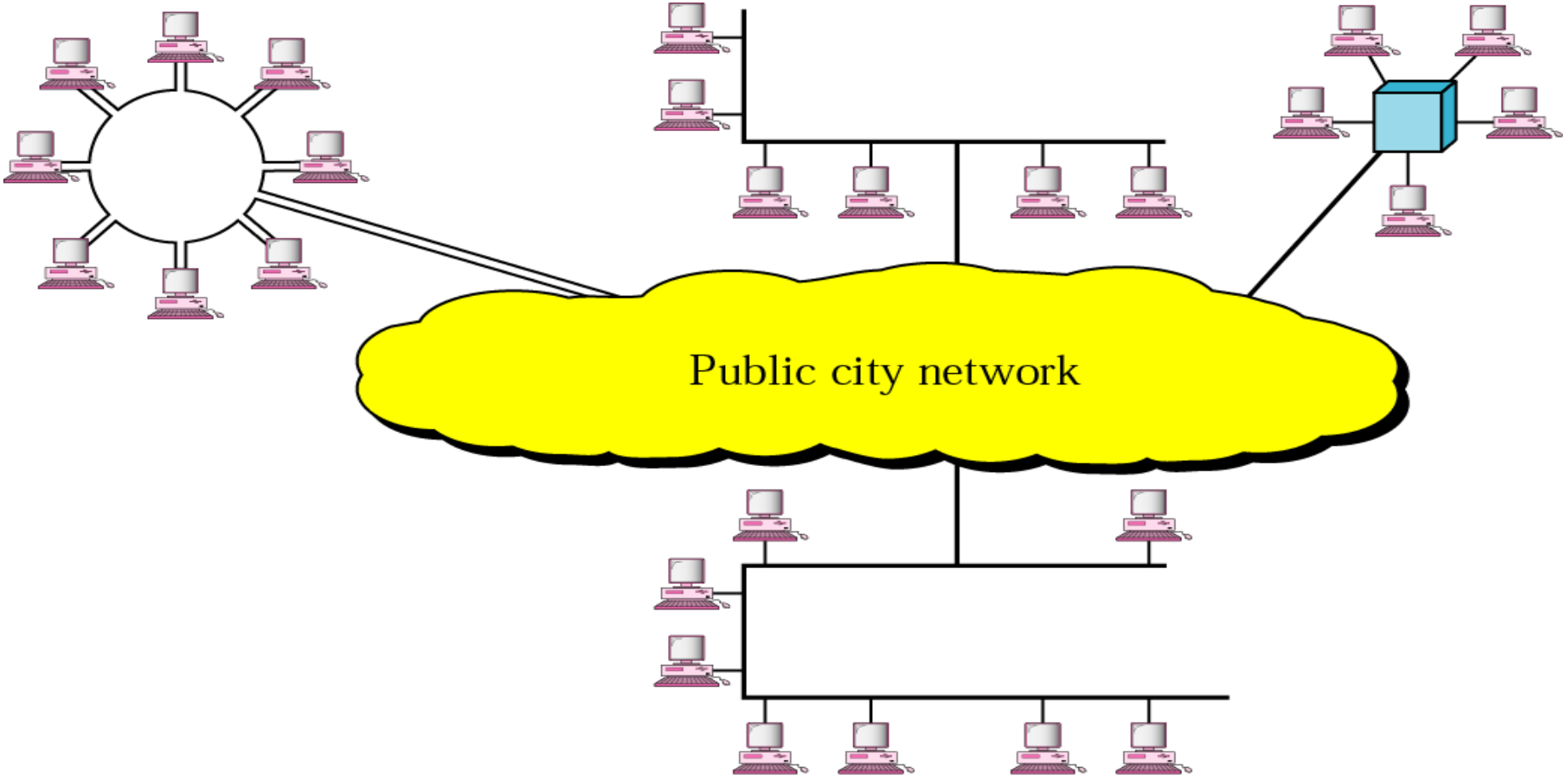
LAN (Local Area Network)

- Privately owned and links the devices in a single office, building or campus
- In LANs one of the computers has a large capacity drive and becomes a server to other clients.
- The most common LAN topologies are bus, ring and star.
- Traditionally LAN have data rates in the 4 to 16 Mbps. Today Speed can reach to 100Mbps or 1000MBps(1G).

MAN (Metropolitan Area Network)

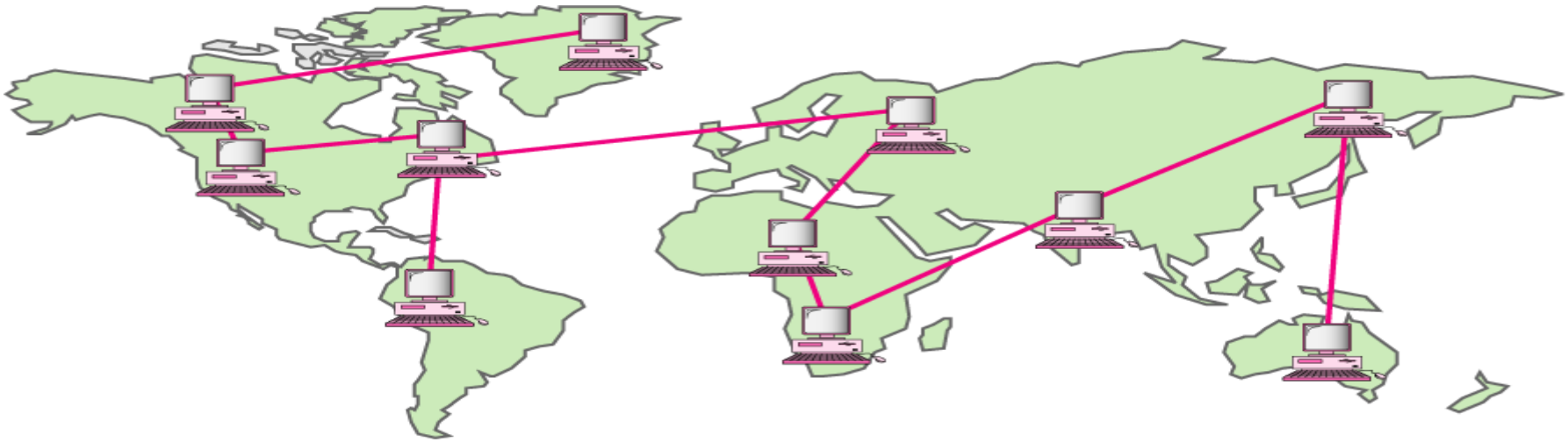
- Owned by private company or it may be a service provided by public company (such as local tel.-company)
- Extended over an entire city.
- May be single network such as a cable television network, or it may be connected number of LANs into a large network so that resources may be shared LAN-TO- LAN.

MAN



WAN (Wide Area Network)

- **Provides long distance transmission of data, voice , image and video information over large areas (country or whole world)**
- **In contrast to LAN, WAN may utilize public or private communication equipments or combination.**
- Ex:ATM,Internet



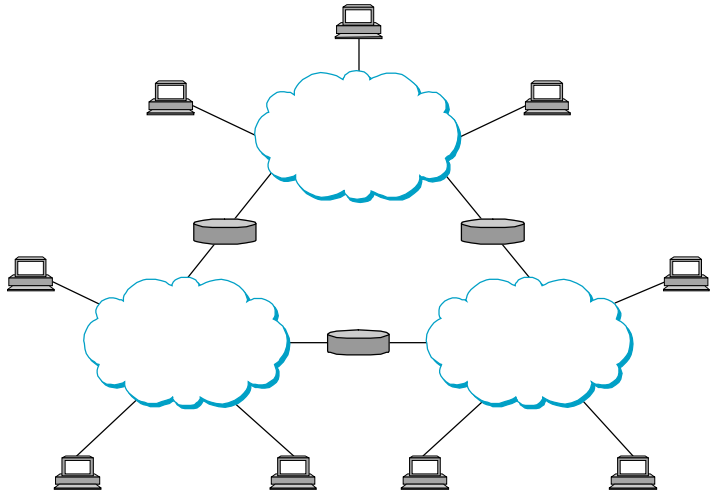
Hybrid Network Types

- Home Area Network (HAN)
  - Small scale network
  - Connects computers and entertainment appliances
  - Found mainly in the home
- Personal Area Network (PAN)
  - Very small scale network
  - Range is less than 2 meters
  - Cell phones, PDAs, MP3 players

Interconnection of Networks:
Internetwork

An internet (small i) is two or more networks that can communicate with each other.

To interconnect two or more networks, one needs a ***gateway*** or ***router***.



internet service providers (ISPs)

- Hierarchical organization of the Internet includes:
  - **International Internet Service Providers**
  - **National Internet Service Providers**
  - **Regional Internet Service Providers**
  - **Local Internet Service Providers**

KPI	5G	6G
Peak data rate	20 Gb/s	1 Tb/s
Experienced data rate	0.1 Gb/s	1 Gb/s
Peak spectral efficiency	30 b/s/Hz	60 b/s/Hz
Experienced spectral efficiency	0.3 b/s/Hz	3 b/s/Hz
Maximum bandwidth	1 GHz	100 GHz
Area traffic capacity	10 Mb/s/m^2	1 Gb/s/m^2
Connection density	10^6 devices/km^2	10^7 devices/km^2
Energy efficiency	not specified	1 Tb/J
Latency	1 ms	100 μs
Reliability	1-10^{-5}	1-10^{-9}
Jitter	not specified	1 μs
Mobility	500 km/h	1000 km/h