Introduction

- Computation and Communication
- How do the computers inter-communicate
- Need for communication protocols
- OSI Model and communication protocols

Computation

Abacus

Calculator

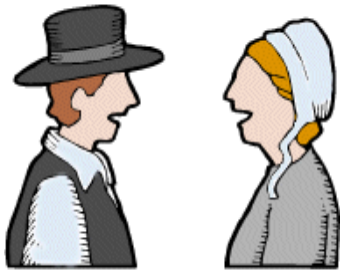
Computer

Timeline

Adding machine

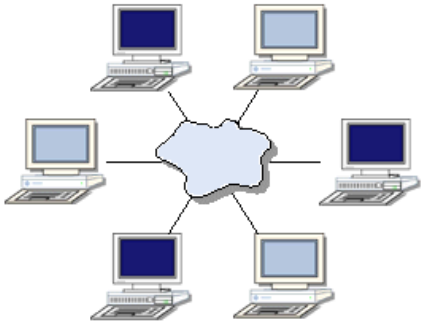
Mainframe

Communication



Conversation

Telephone

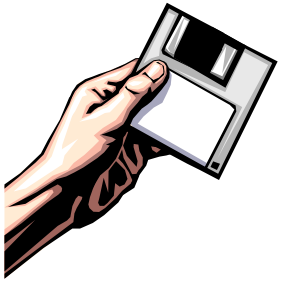


Network

Timeline

Mail

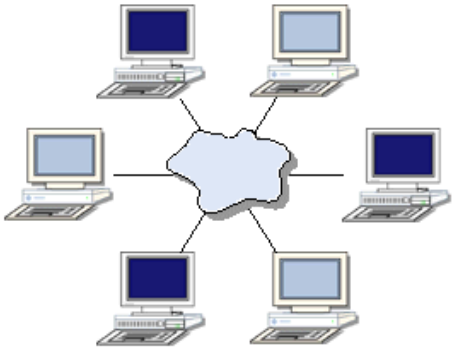
Data Transfer



Computation and Communication

Mainframe

PCs

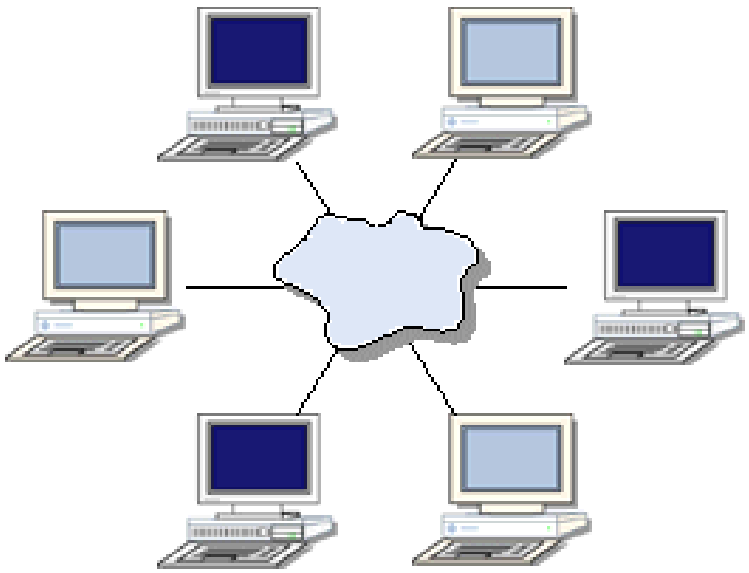


Network

Timeline

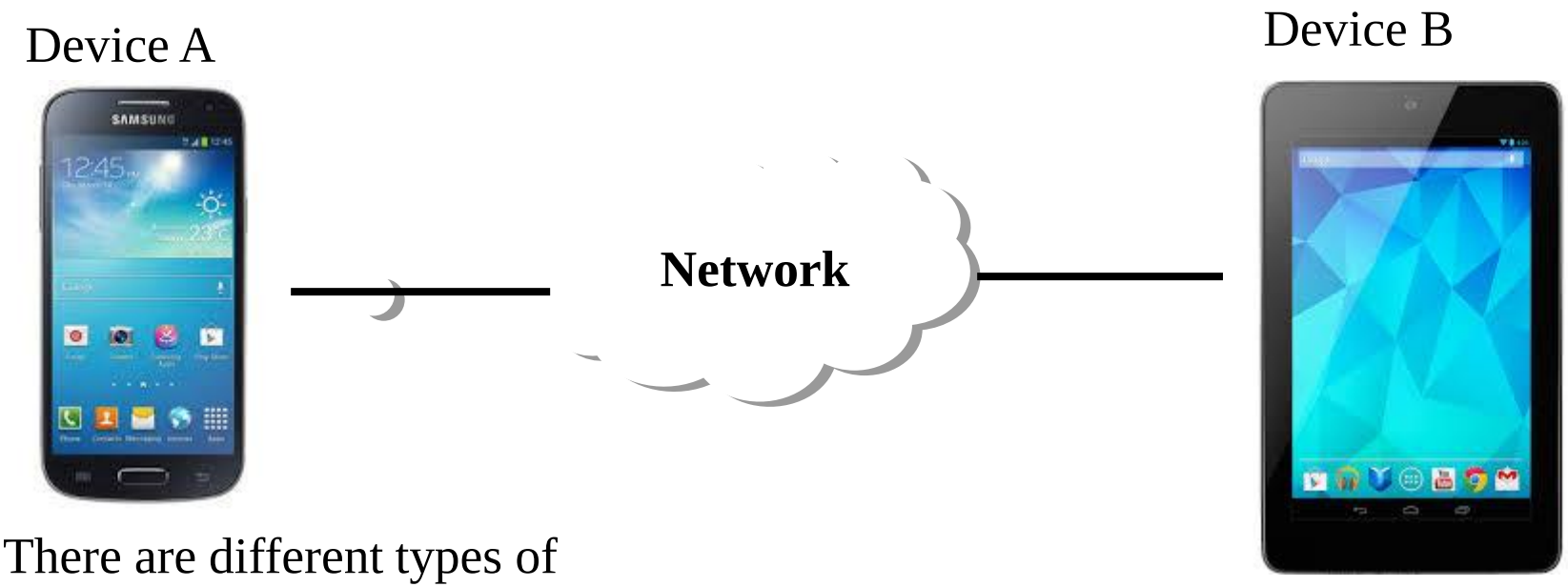
- Resource Sharing (equipment, programs, data)
- Increased Reliability (alternative sources of supply)
- Parallelism (distribution of tasks)
- Cost Savings (better price/performance ratio)

Inter-networked Devices



- Data exchange (main factor)
- Access to remote services (news, banking, etc.)
- Inter-personal communication (e-mail, messaging, etc.)
- Interactive entertaintment (radio, TV, etc.)

Computer communications



- There are different types of
  - networks
  - operating systems
  - applications
- Some incompatible with others

Need for a set of rules used when exchanging messages

Communication Protocols

(agreement about the format and meaning of the messages exchanged)

- Communication is performed:
  - in diverse forms, and
  - requires significant support
- In order to reduce the complexity, a layered structure was proposed
- Each layer:
  - offers a set of services to the layer above, and
  - uses those services provided by the layer underneath

- Who does the standardisation?
- Legal Standards: ITU, International Telecommunications Union, ISO, International Standards Organisation, FCC, Federal Communications Commission, and loads more
- Informal Standards: IEEE, IBM, Google, Web Services…

Closed & Open Systems – OSI Model

- The original implementations were not based on any globally accepted standards and the manufacturers produced their own standards.
- Such systems are known as “Closed Systems” since only computers from the same manufacturer can exchange information.
- To overcome this a wide range of network and protocol standards was produced where equipment complying to a particular standard can be used interchangeably. This is an Open System Interconnection Environment (OSIE).
- The International Standardisation Organisation (ISO) described a layered model for network protocol architectures called the Reference Model for Open Systems Interconnection (OSI model).
- It is not an implementation standard, but partitions the communication functions into layers so they can be individually standardised.
- International Standards Organization has proposed the Open Systems Interconnection (OSI) Reference Model
- 7-Layer model, network and application layers

Network Introduction

- what is a computer network?
- components of a computer network
- network hardware
- spectrum and wireless
- network software

What is a computer network ?

- "an interconnected collection of autonomous computers"
  interconnected = able to exchange information

- "a set of nodes connected by media links"
  node = any device capable of sending &/or receiving data to &/or from other nodes in the network

- "a connected collection of hardware and software that permits information exchange and resource sharing"
  information = data, text, audio, video, images, ...
  resources = printers, memory, link bandwidth, ...

Computer networks vary

- ***type:*** Ethernet, Cable TV, telephone, Internet, cellular, personal…
- ***size:*** from a few computers close together, to a world-wide network of networks containing millions or billions of devices
- ***technology:*** copper wire, coaxial cable, wireless, fibre optics…
- ***technical issues:*** services offered, rules for inter-computer communications, how users are charged for network use...

Why all these variations ?

Due to a combination of factors, including:

- different target applications
- different operating environments
- historical reasons
- lack of (sensible) standards
- difficult problems $\Rightarrow$ no “optimal” solutions

Computer networks use digital transmission

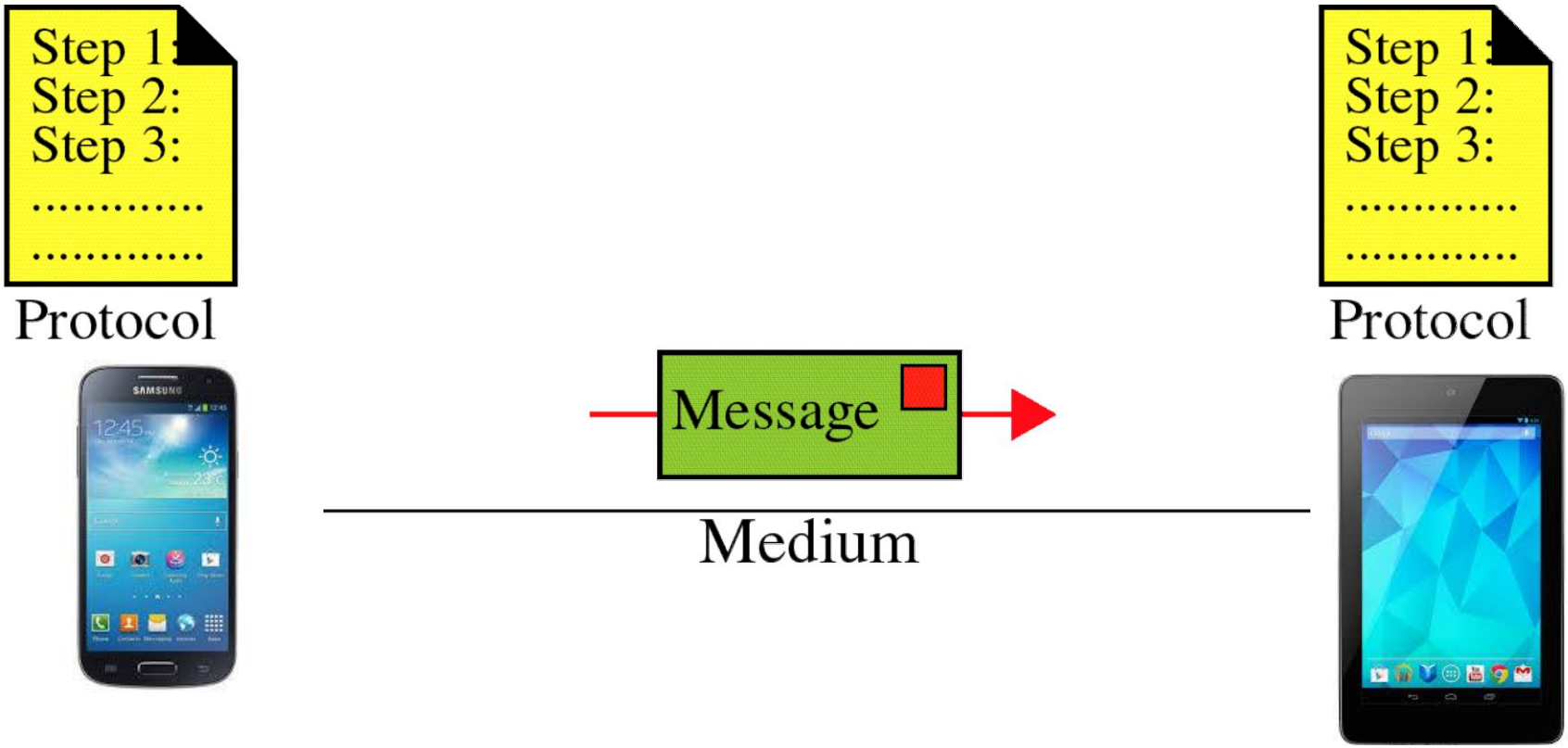
(as opposed to (older) analogue systems)

- all information represented by *bits* (only values are 0 and 1)
- more resistant to *noise*, which unpredictably changes transmitted values
    - basic idea: transmit two **very different** signals for 0 and 1
    - even if these signals are corrupted during transmission, they should still be **distinguishable** – and as long as the destination can distinguish 0 and 1, who cares about noise ?!
    - in addition, extra bits (not part of the information to be transmitted) can be added in order to reduce noise effects
        - e.g. automatically correct bit errors

- may require analogue-to-digital &/or digital-to-analogue conversions (e.g. if input/output information is in analogue form)

Components of a computer network

- ***message:*** information to be communicated
- ***sender:*** device that sends the message
- ***receiver:*** device that receives the message
- ***medium:*** physical path from sender to receiver
- ***protocol:*** set of rules that govern data communications



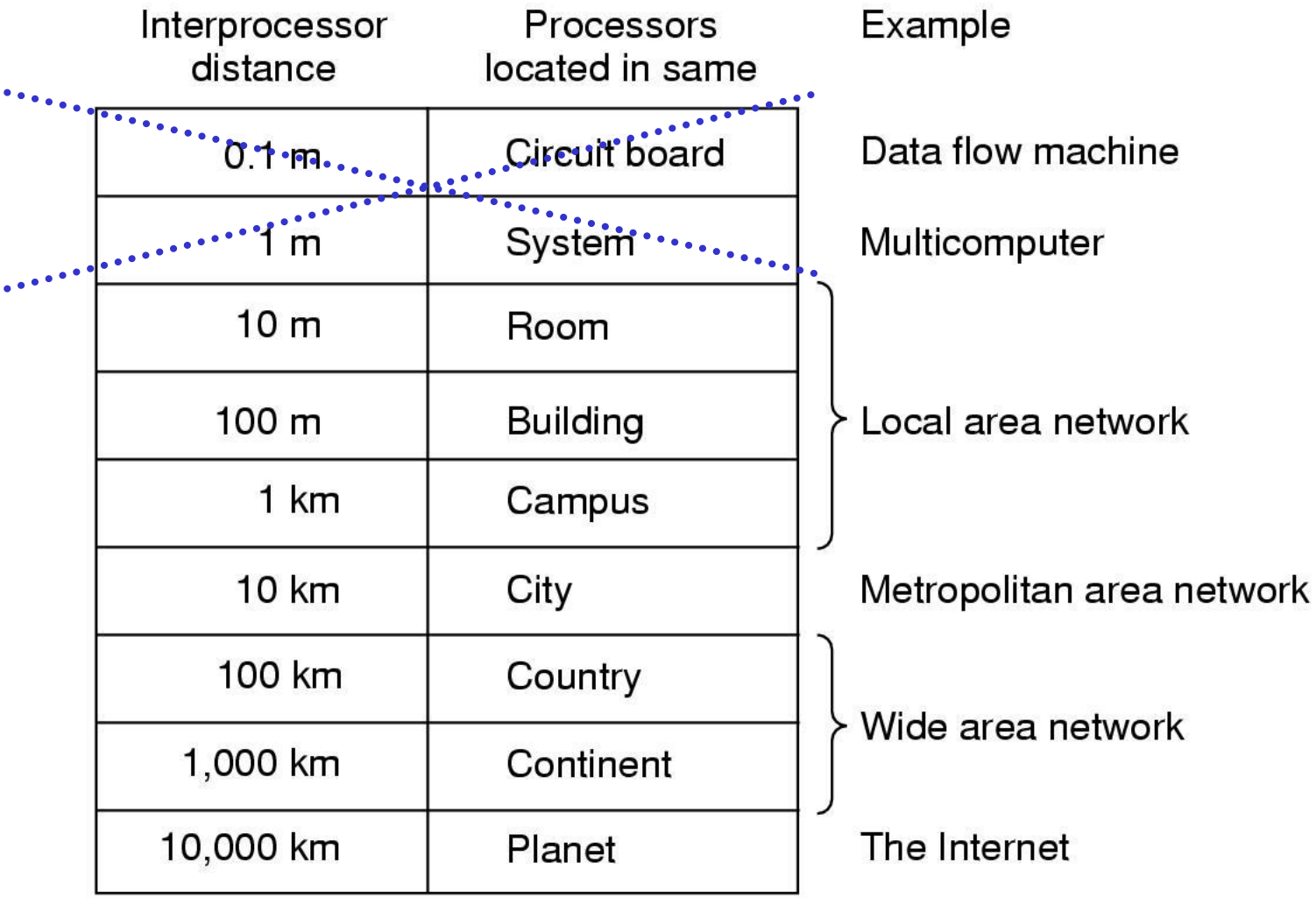
Computer network hardware

- *transmission technology*
  - broadcast networks: single communication channel **shared** by all network nodes
    - can send to: one node, all nodes, (maybe) group of nodes
    - address field in message specifies receiver(s)

  - point-to-point networks: many possible connection paths between any pair of nodes
    - message may have to pass through intermediate nodes on the way from sender to receiver
    - usually, need a **routing algorithm** to decide ***if*** a path exists from sender to receiver, and -- if multiple such paths exist -- ***which one(s)*** to use

Computer network size

• *network scale:* different techniques are used at different scales

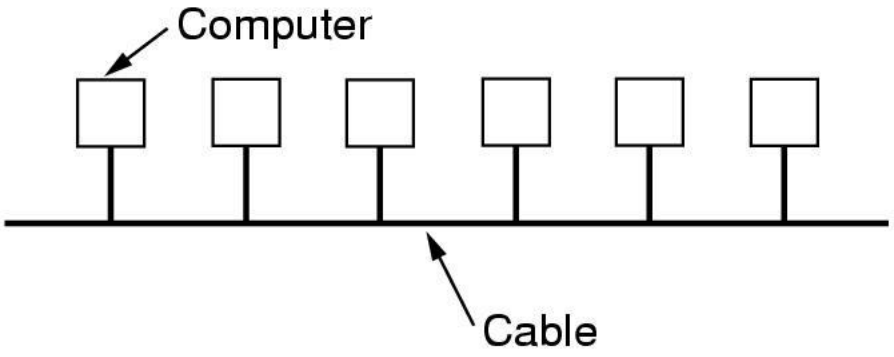


Interprocessor distance	Processors located in same	Example
0.1 m	Circuit board	Data flow machine
1 m	System	Multicomputer
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1,000 km	Continent	
10,000 km	Planet	The Internet

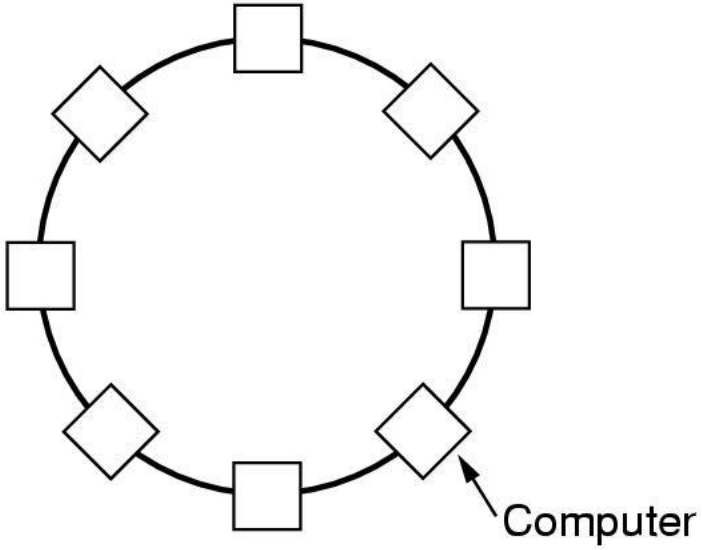
Wired Local Area Networks (LANs)

- *restricted size* ⇒ worst-case communication delay is bounded
- *low propagation delay* (e.g. small fractions of a second)
- *high speed* (e.g. 100 Mbps up to >Gbps and beyond)
- *low error rate*

- *different possible topologies for broadcast LANs*

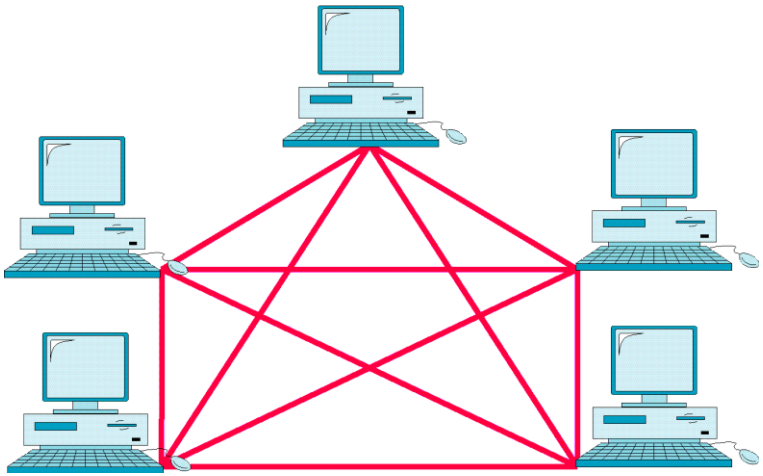


(a) bus

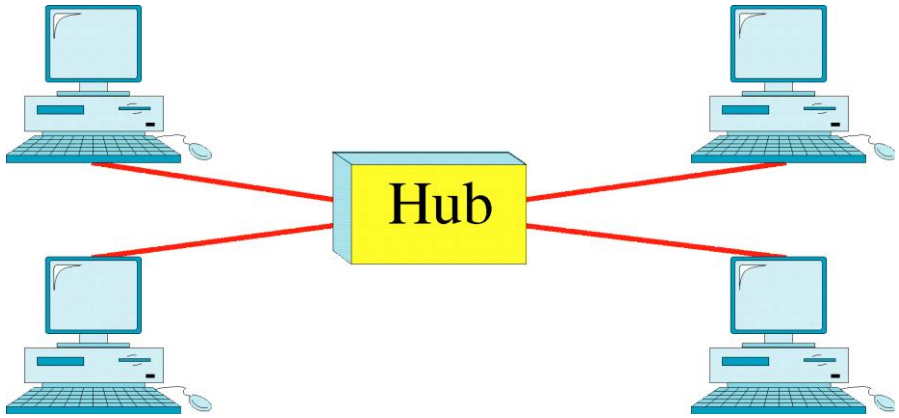


(b) ring

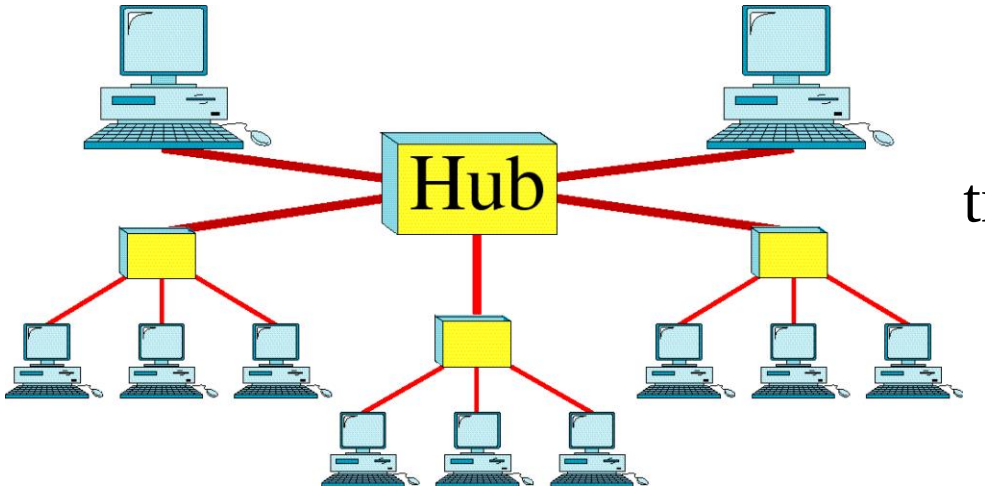
Other possible LAN topologies



mesh



star

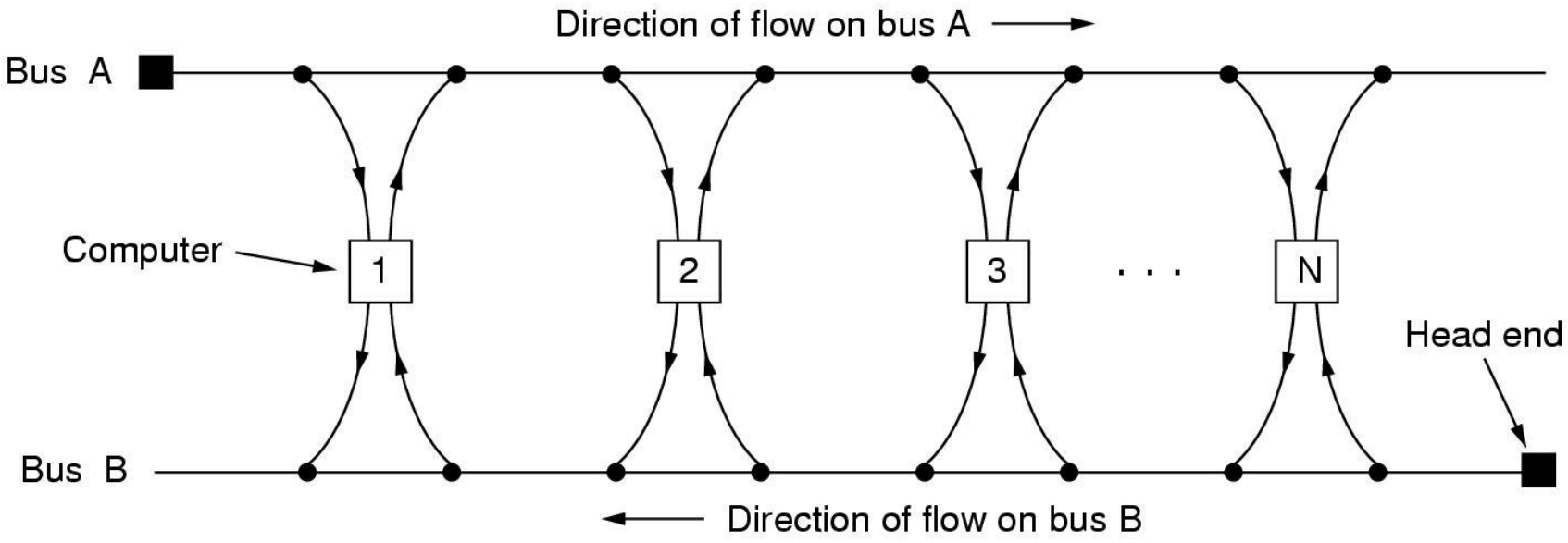


tree

Metropolitan Area Networks (MANs)

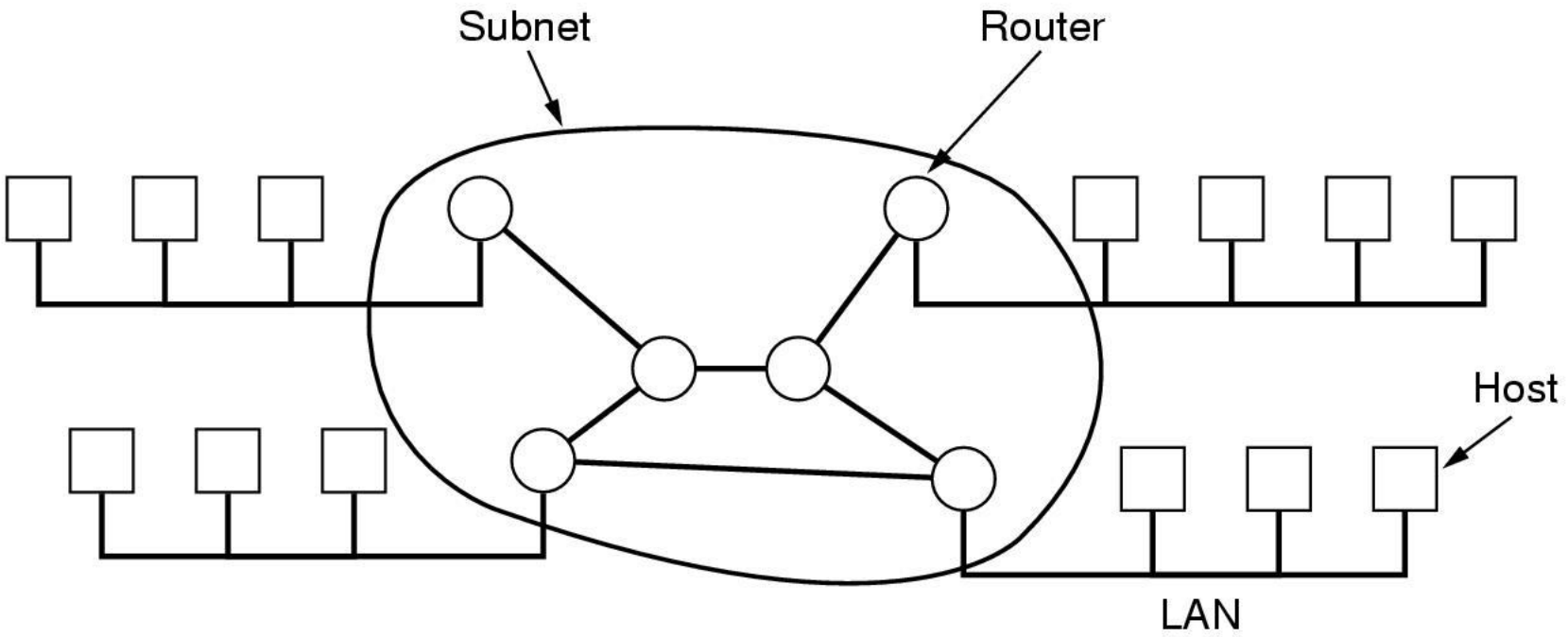
- bigger version of wired broadcast LANs
- may be a means of connecting multiple LANs ("backbone")

Example of a MAN: Distributed Queue Dual Bus (DQDB)



Wide Area Networks (WANs)

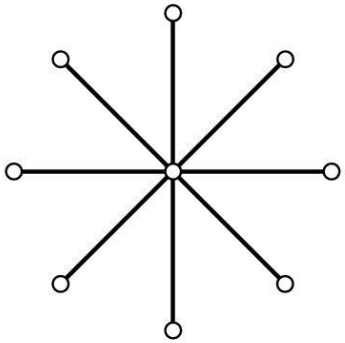
- nodes which run user applications: **hosts** (or end-systems)
- **subnet** connects the hosts
- nodes within the subnet: **routers**, switches, intermediate systems...
- links within the subnet: **links**, circuits, channels, trunks...



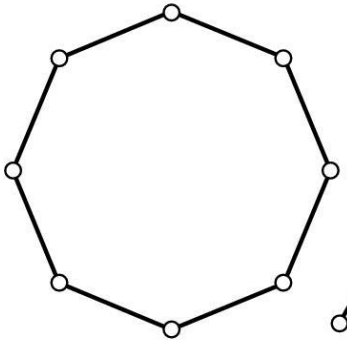
Beware: "subnet" has another (specific) meaning in IP networks!

WANs (cont.)

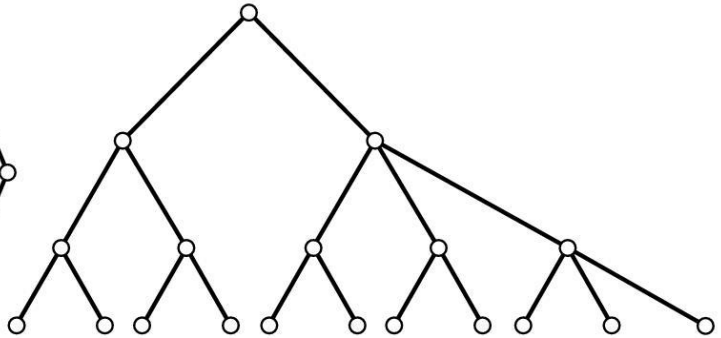
- **point-to-point subnet:** most common type of WAN



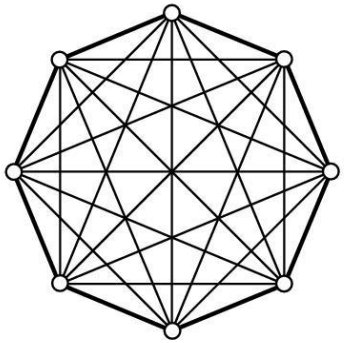
(a) star



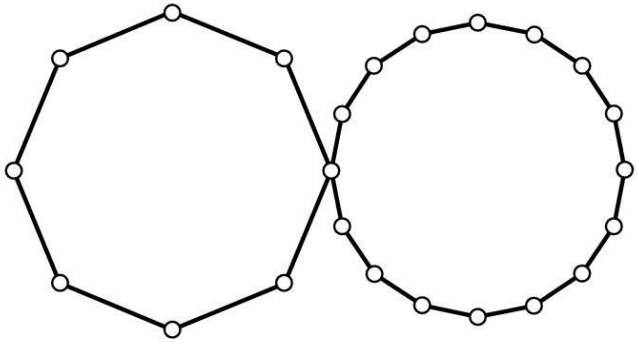
(b) ring



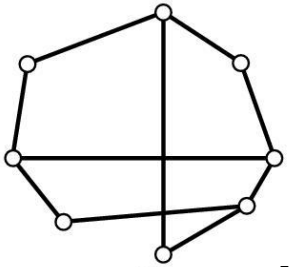
(c) tree



(d) mesh



(e) intersecting rings

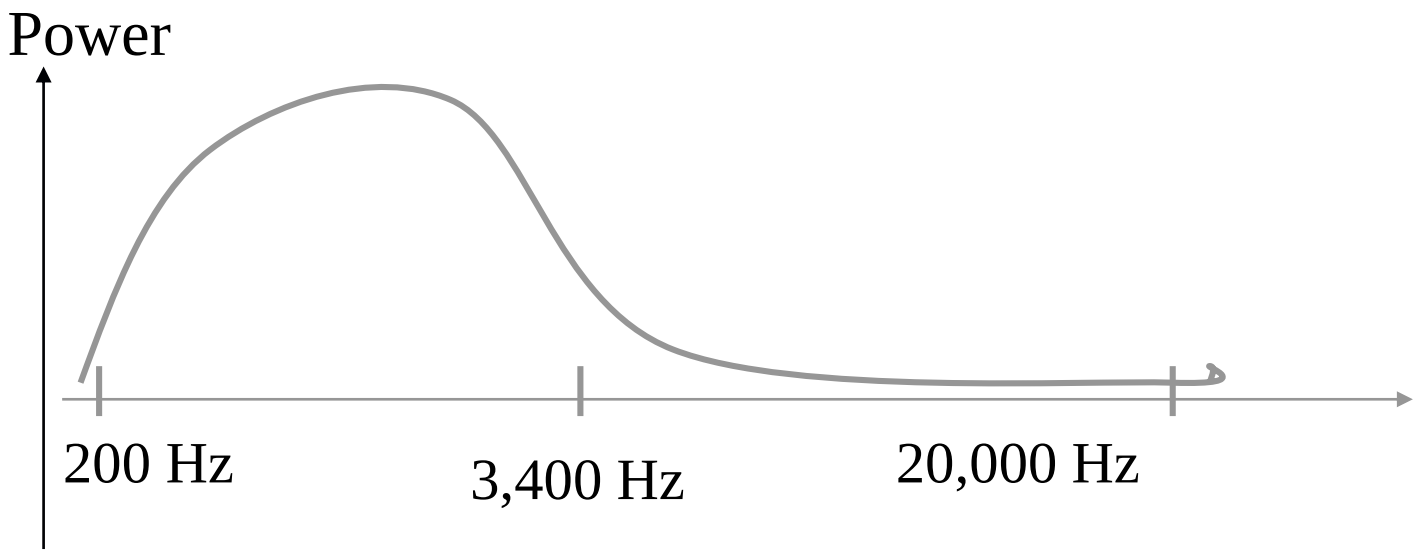


(f) irregular

Blue Whales have an exceptional way of speaking to one another travelling thousands of miles across the sea. They have a deep voice at frequencies as low as 14 Hz and a volume greater than 180 decibels (loudest animal on the planet).

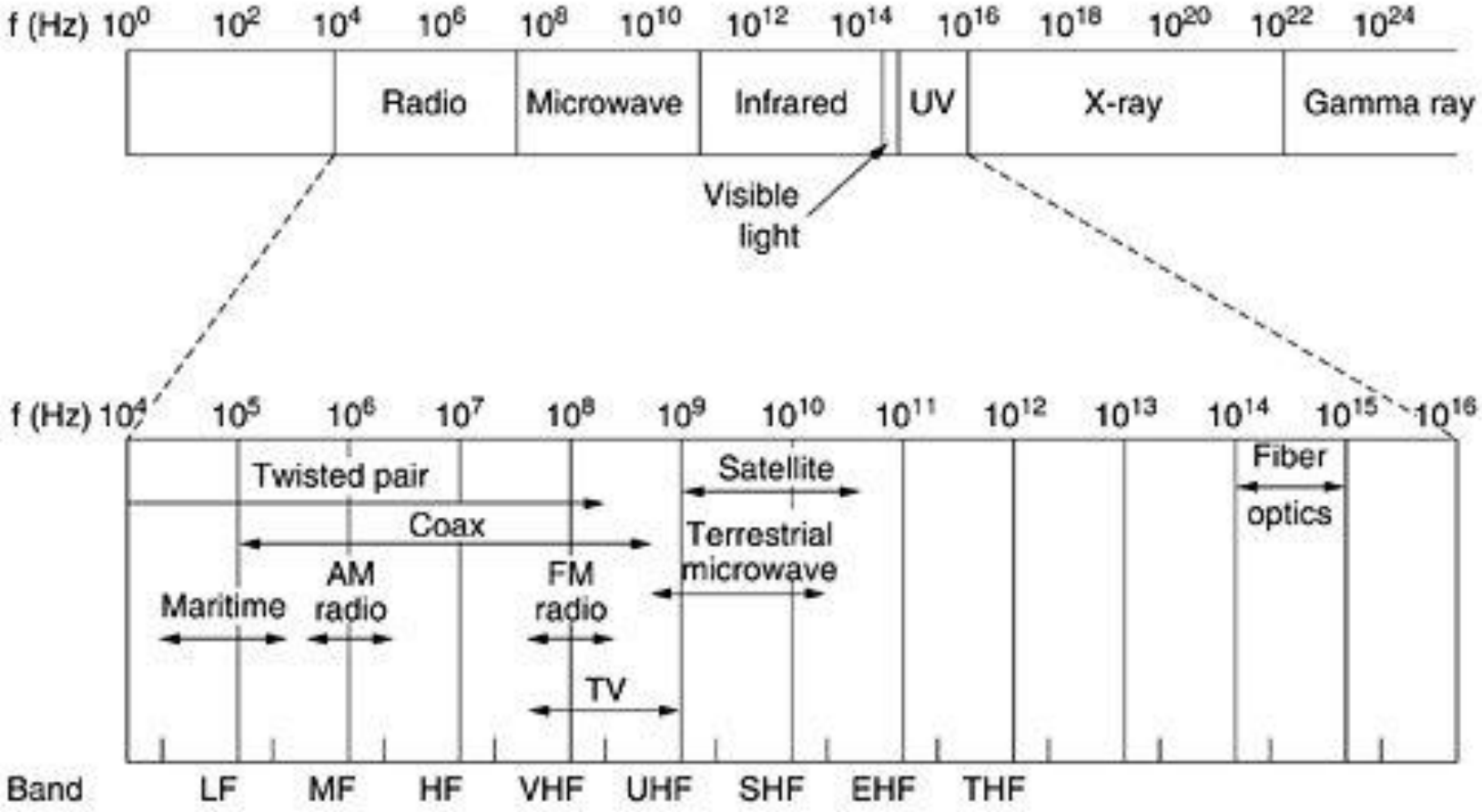
Tarsiers are one of the smallest primates, large fixed eyes (one of the biggest), and high frequency hearing (90 KHz)

Human Voice Spectrum



Voice Spectrum

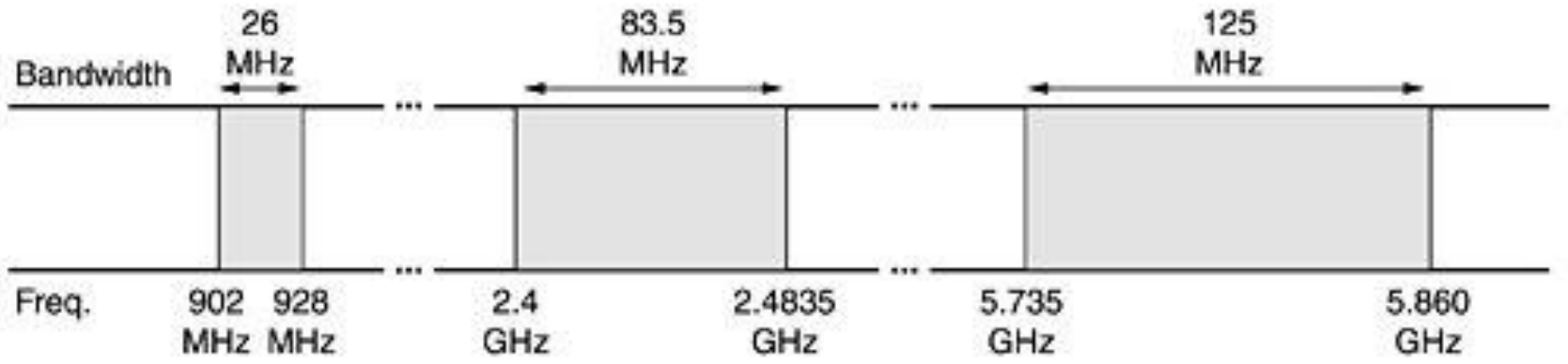
Wireless Networks - Spectrum



ISM Band – WiFi

IEEE802.11 – WiFi

802.11b	-	2.4Ghz	-	11Mbps
802.11a	-	5Ghz	-	54Mbps
802.11g	-	2.4Ghz	-	54Mbps
802.11n	-	5 or 2.4Ghz	-	140Mbp



Wireless and Mobile Networks

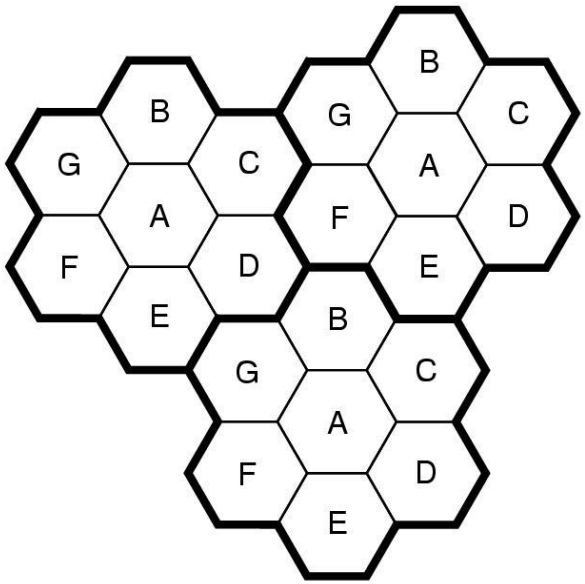
- wireless LANs (as compared to wired LANs):
  - lower speed, higher error rates

- distinction between wireless network and mobile computing:

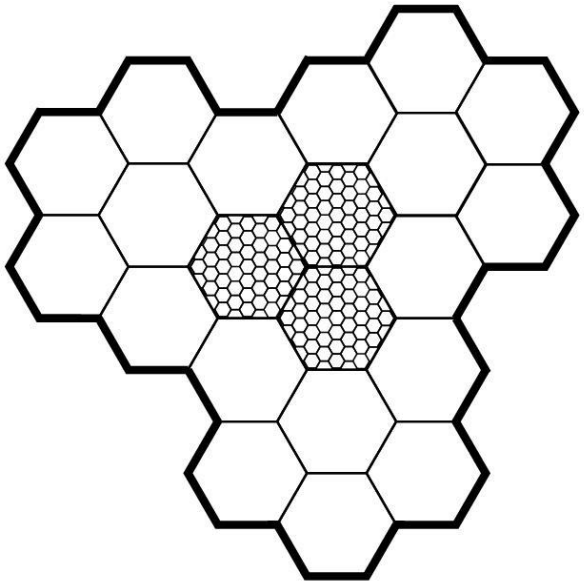
Wireless	Mobile	Example Application
no	no	stationary wired computers
no	yes	using a (non-wireless) laptop PC
yes	no	wireless LAN in unwired office
yes	yes	rental car return handheld computer

Wireless and Mobile Networks (cont.)

- mobile telephony uses **cellular** technology
  - coverage area divided into smaller regions called *cells*
  - simultaneous transmissions from neighbouring cells (ideally) don't interfere with each other
  - important issue: *handoff* at cell boundaries
  - *originally:* analogue system; *now:* digital (e.g. GSM)



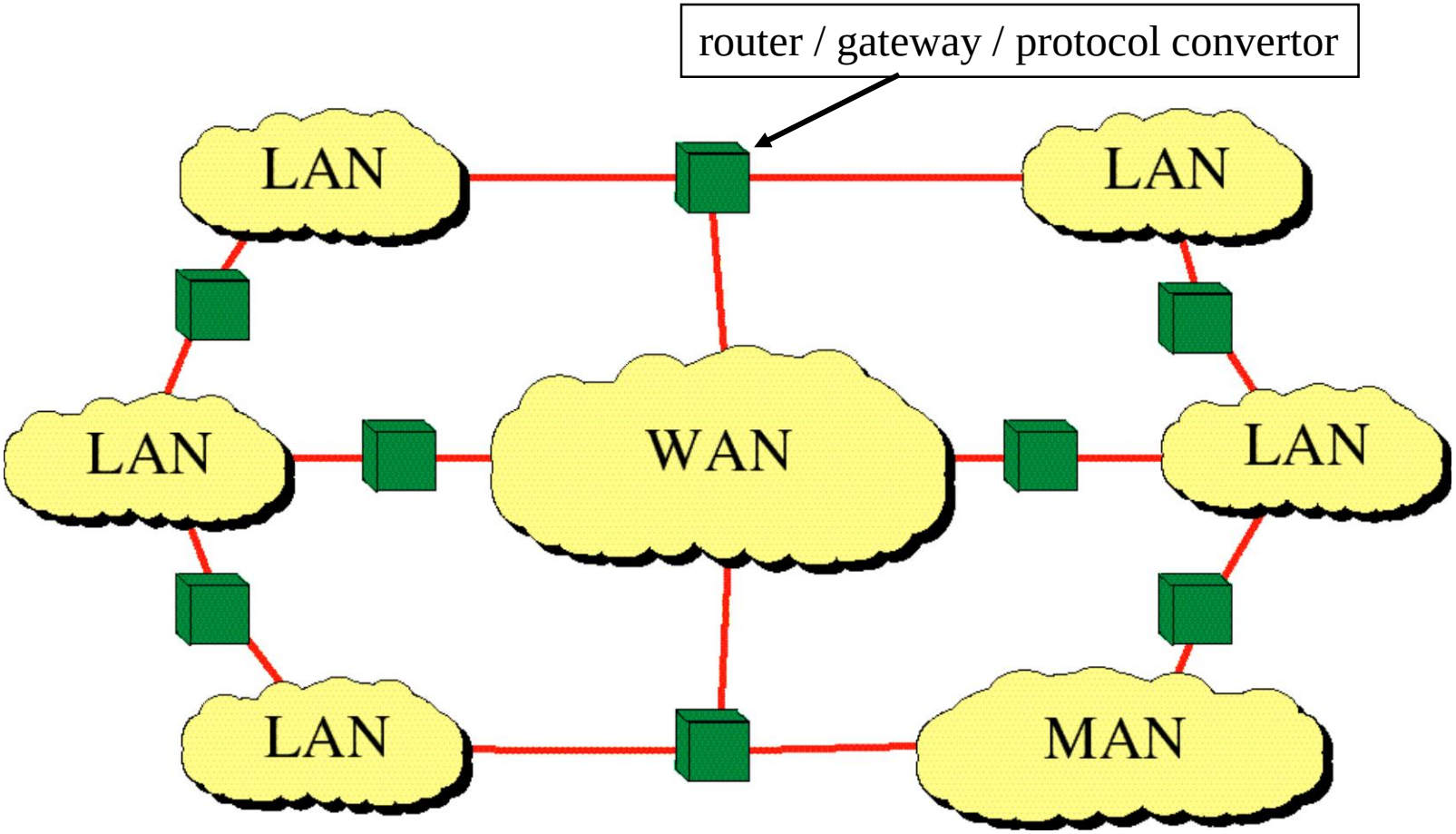
(a) frequency re-use



(b) smaller cells in overloaded areas

Internetwork

- collection of connected networks

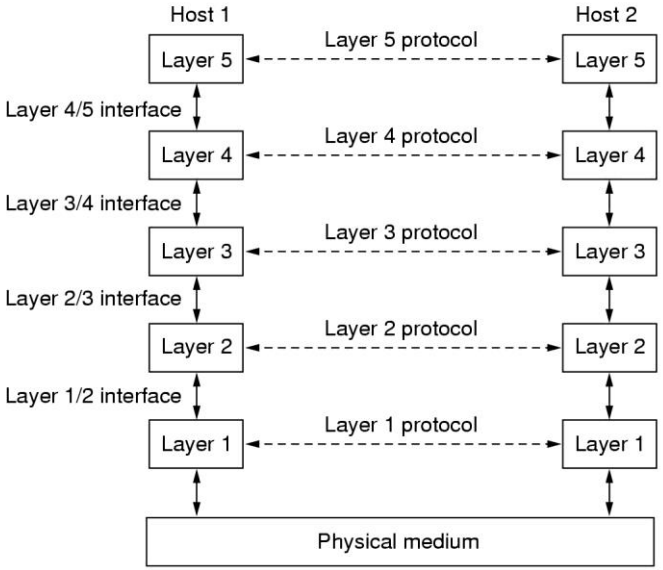


- “an internet” vs. “the Internet”
  - the Internet = connected set of networks which all use IP

Computer network software

- structured as a hierarchy of **layers**
  - each layer offers certain *services* to the higher layers, while hiding from the higher layers the *details* of how those services are implemented: **hierarchical modularity**
- a particular layer in one network node communicates with the corresponding layer in another network node by using an agreed **protocol** for that layer
  - this communication may be *actual* or *virtual*

Example:



Note: the lower layers are often implemented (at least partly) in hardware

Computer network software (cont.)

- actual communication is “vertical” except in the physical medium
- peer entities are programmed as if data transmission were “horizontal”
    - together, these peer entities execute *distributed scripts*

- **interfaces** between adjacent layers define which operations and services the lower layer offers to the higher layer
    - *minimise* amount of information passed between layers
    - allow different *equivalent* implementations of a layer

- **encapsulation:**
    - at the sender, layer N may add control information to the data it receives from layer N+1 before passing the (increased) data to layer N-1; at the receiver, layer N-1 passes data to layer N, which can read, act upon, & remove this control information before passing the (reduced) data up to layer N+1
    - layer N should not need to know which portion of layer N+1’s data is control information, or its meaning

Computer network software layers

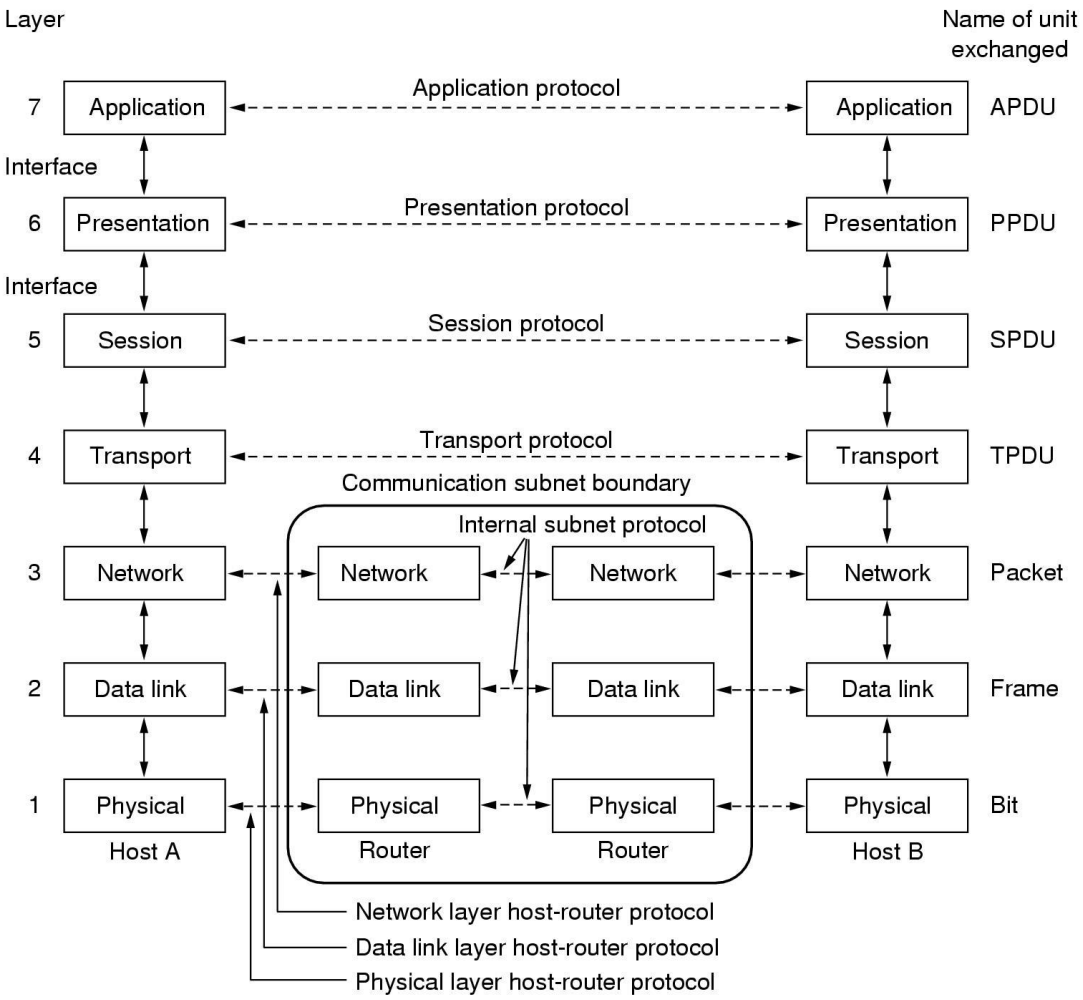
- **network architecture** = set of layers & protocols
  - doesn't contain implementation details or interface specifications
- basic principle: each layer should perform a specific set of well-defined functions
-
- basic question: how many layers are needed ?
  - we'll see that different network architectures have different numbers of layers and/or different functions within their layers

  - minimum of 2: one focused on (user) application issues, and one focused on network issues

  - more realistically, the following general issues must be addressed:
    - ➢ physical signal transmission between directly connected nodes
    - ➢ digital transmission of a message between neighbouring entities
    - ➢ end-to-end communication between a source and a destination
    - ➢ communications needed to run a distributed (user) application

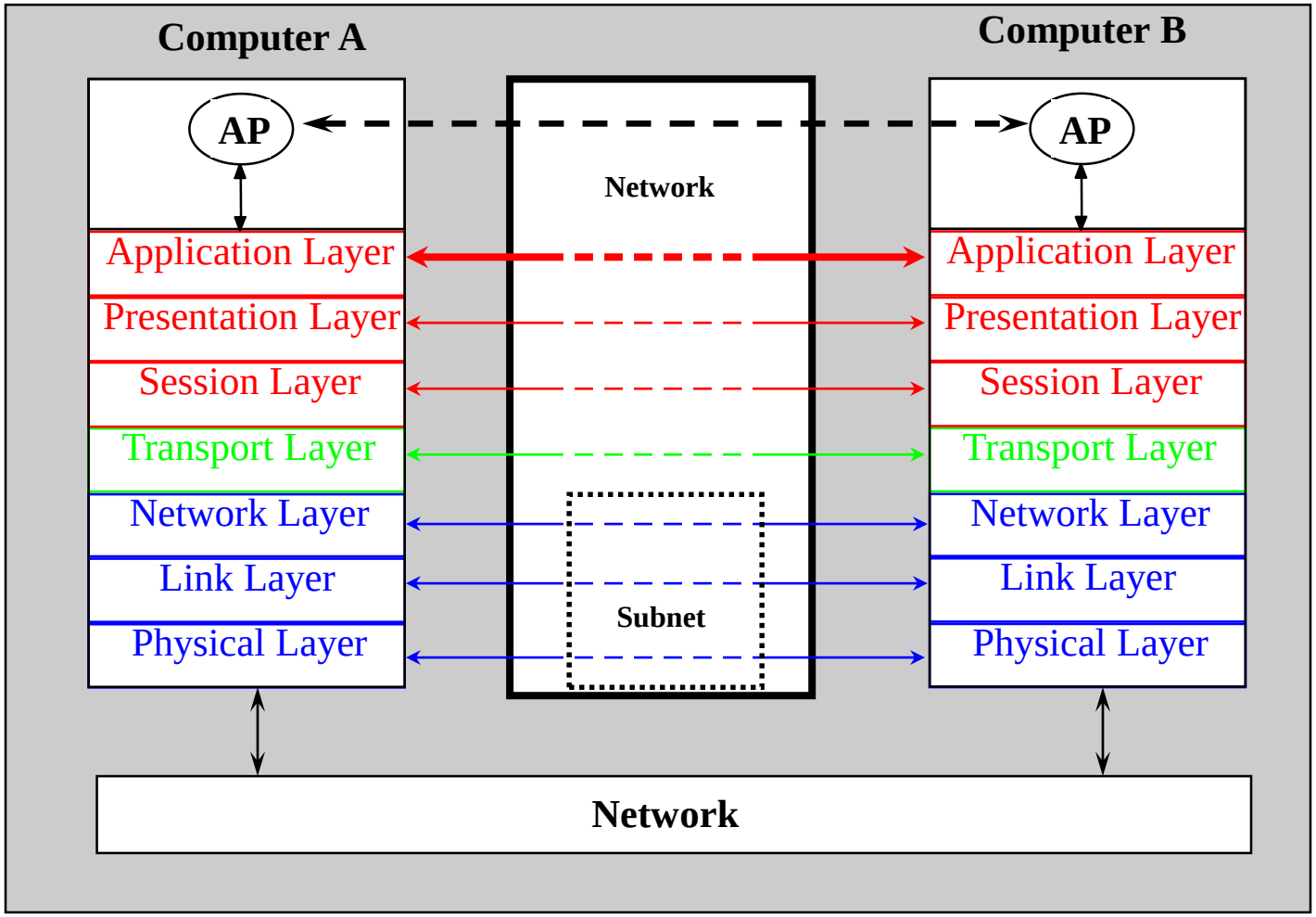
ISO Reference Model for Open System Interconnection (OSI)

- late 70's: a framework for the structure of open communication systems, not a network architecture (not intended to have a single standard protocol at each layer)



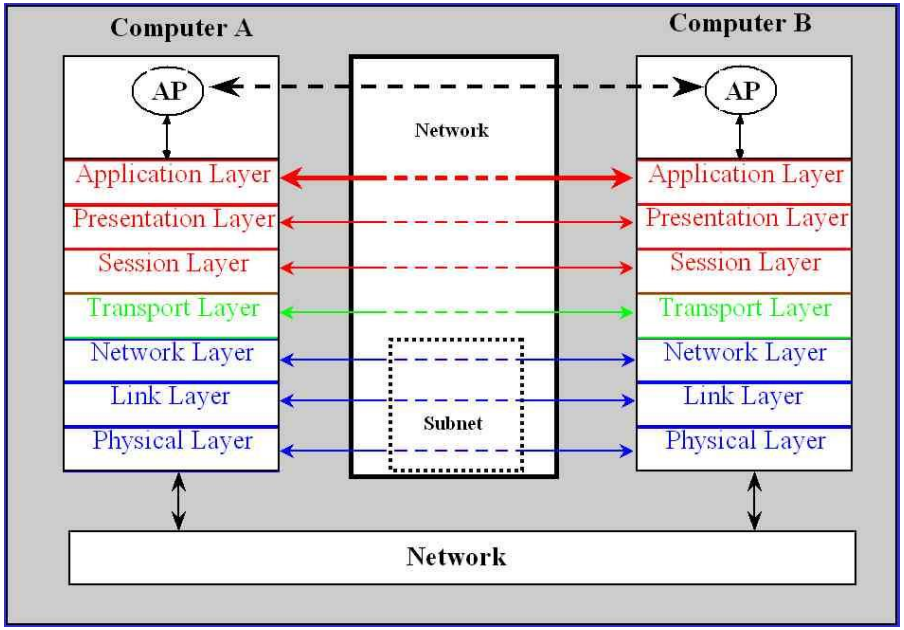
PDU = Protocol Data Unit

OSI Model - Principle



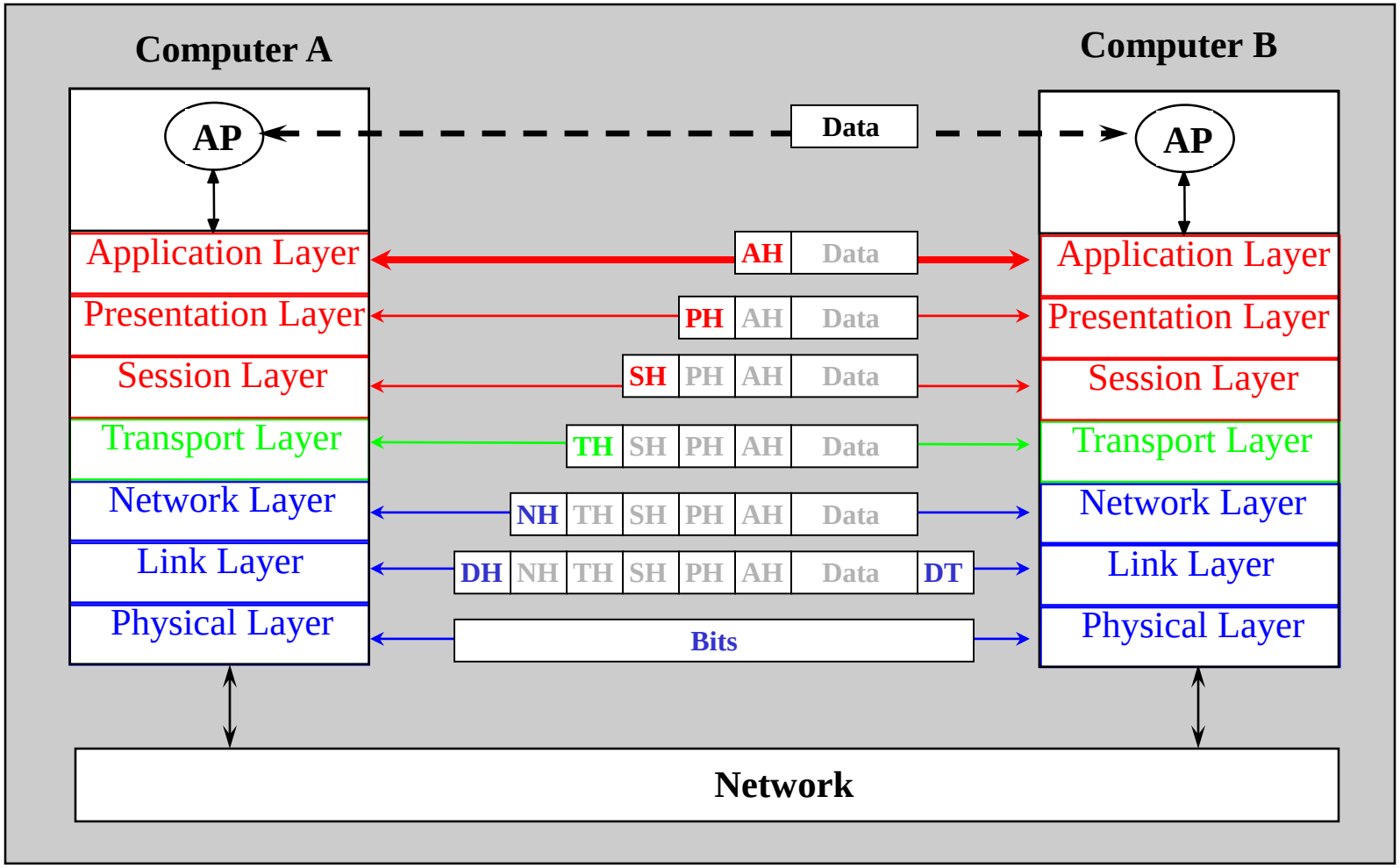
OSI Model - Details

- Physical Layer – concerned with the transmission of data bits between two directly inter-connected devices
- Link Layer – concerned with ensuring data transmission is free of errors
- Network Layer – ensures successful transmission of packets between two nodes of the network
- Transport Layer – provides end-to-end sender-destination communication, including correct packetization
- Session Layer – supports sessions and synchronization during data exchange



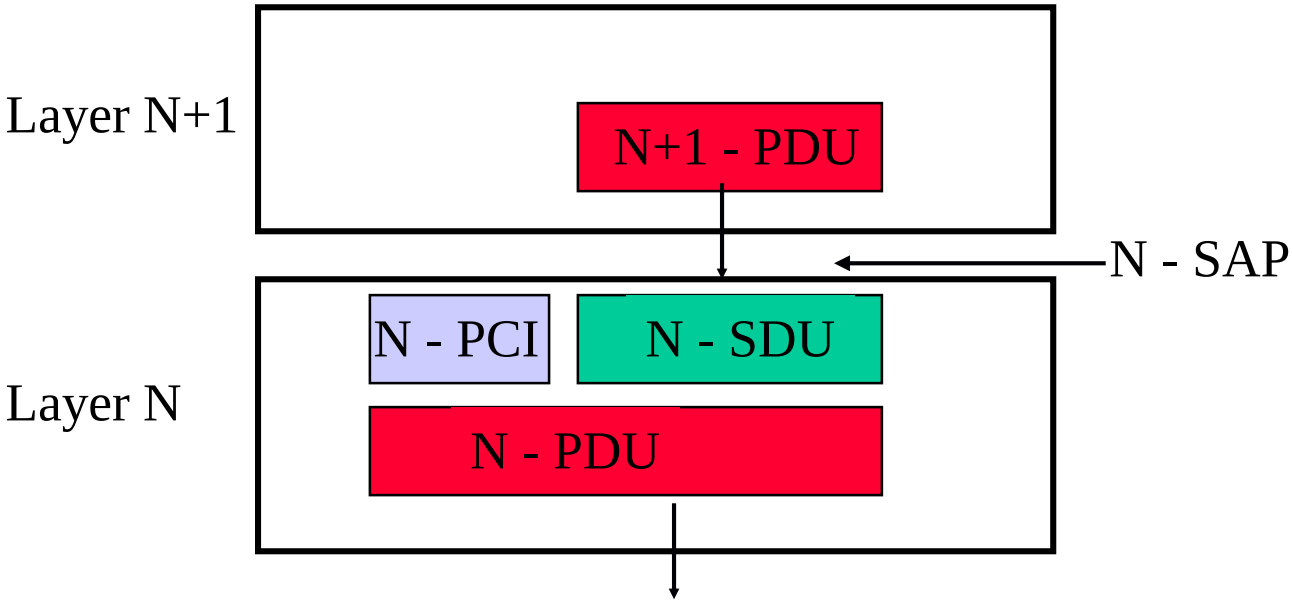
- Presentation Layer – concerned with syntax and coding when exchanging data
- Application Layer – provides access to extensive network-related services (file transfer, message exchange, etc.)

Data Exchange

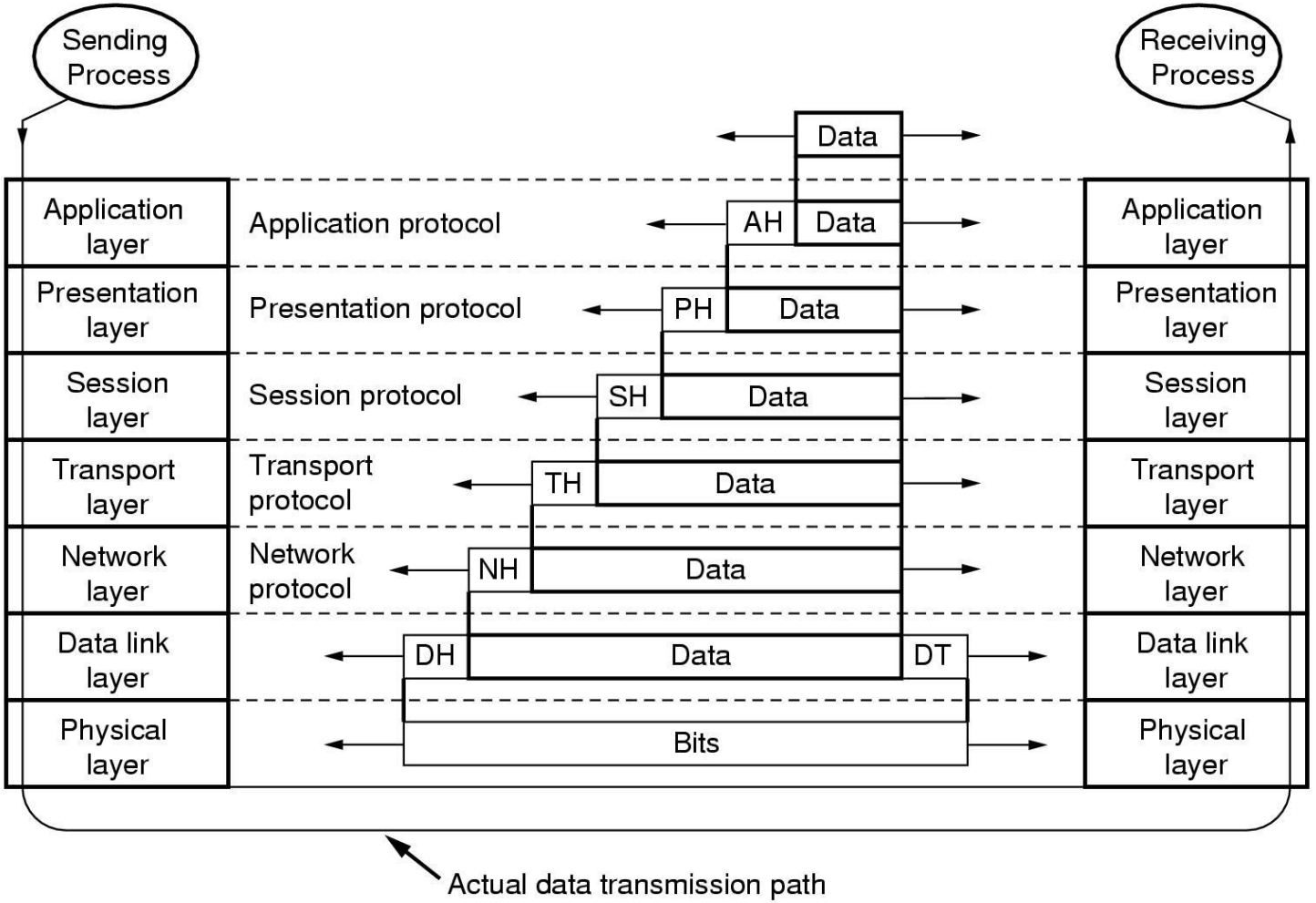


OSI Terminology

- Service Access Point (SAP) is the point between a layer and the next higher one
- Service Data Unit (SDU) is the block of data coming down from the higher layer
- Protocol Control Information (PCI) is the header that is added on to the SDU to make the relevant data block at this layer
- Protocol Data Unit (PDU) is the block of data that is given to the next layer underneath the current layer

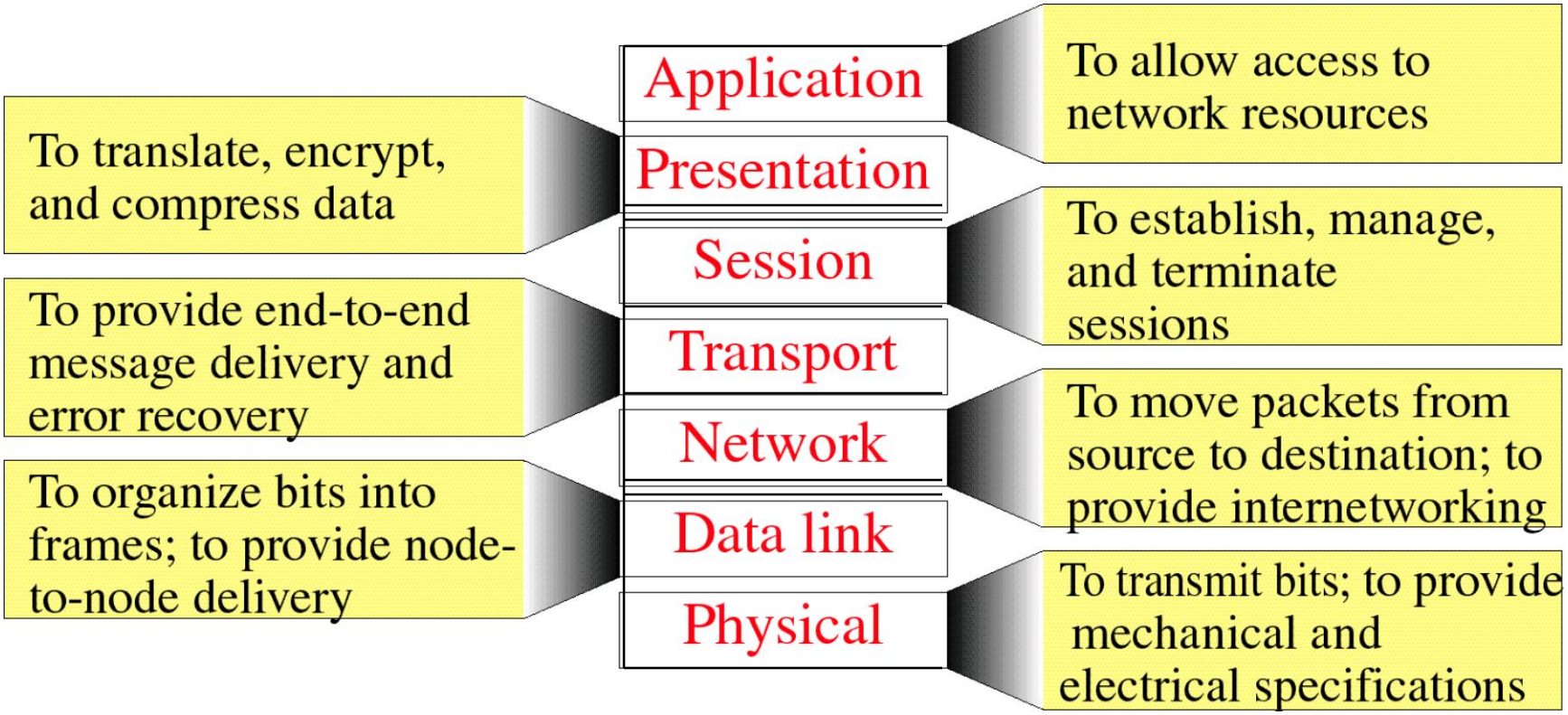


Data Transmission in the OSI model



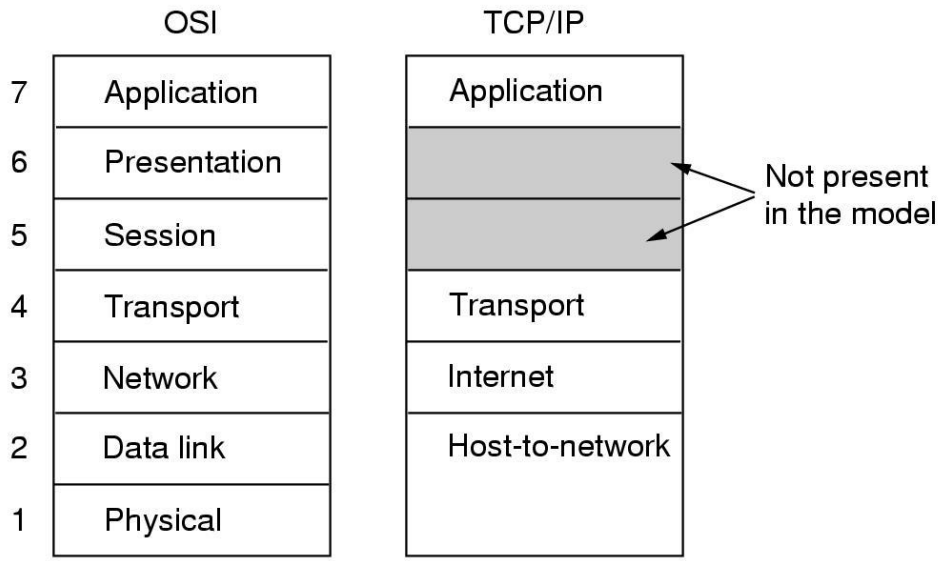
Ideally, each layer is independent of the other layers and interacts with AT MOST 2 other layers

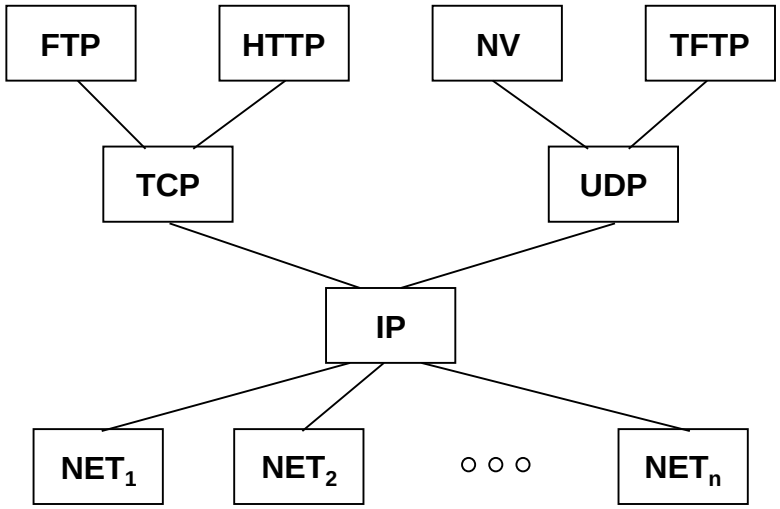
Summary of layer functions in the OSI model

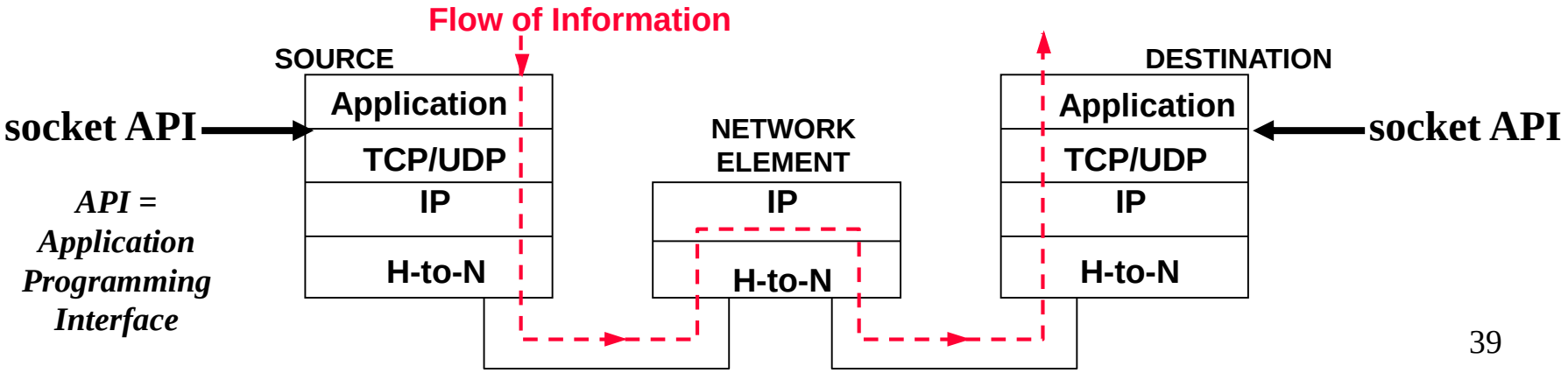


The TCP/IP Reference Model (or "Internet Protocols")

- OSI model dominated by a telecommunications mentality
- mid 70's onwards: data communications protocols implemented
  - widespread use, public domain specs, computer industry support



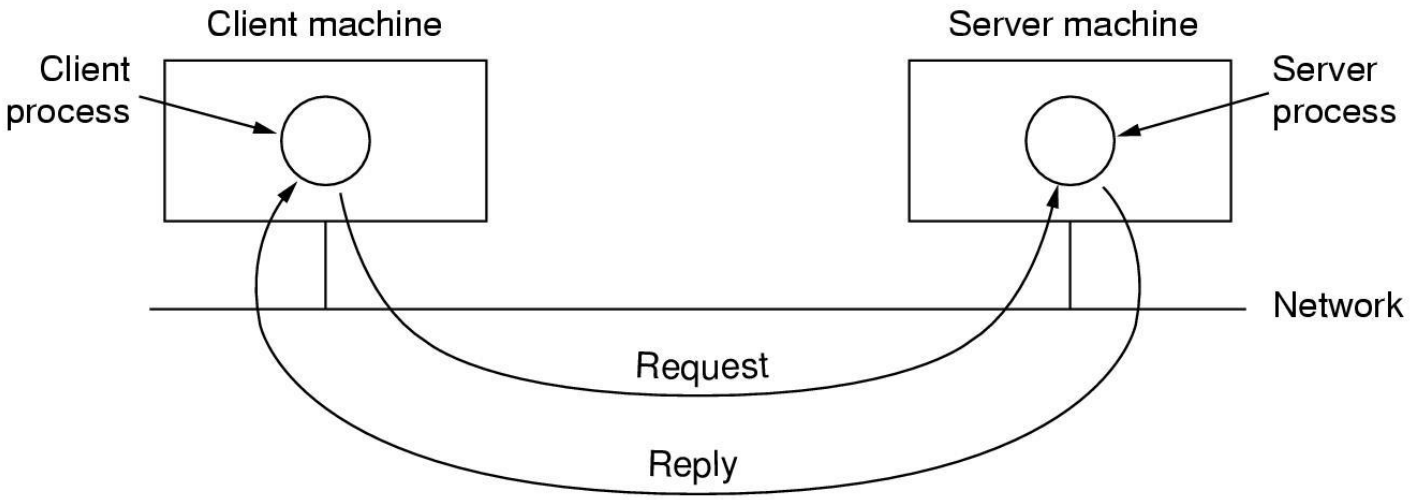




The TCP/IP Reference Model (cont.)

- based on the **client-server** model of communications
  - server = a process which provides a service when requested
  - client = a process which requests a service

- in general, a client program is run only when it is needed, and is *finite* (started by the user/application, terminates when service received)
- a server program should run all the time, and is *infinite* (when started, it runs infinitely, waiting for incoming requests and responding to them)



Why is the OSI model not the dominant one ?

- unclear what layers 5,6, & 7 should do
- layers 1, 2, & 3 have had to be split into sublayers, so the original layering was unrealistic
- several functions (e.g. error control, flow control) can occur in more than one layer
- with 7 layers, long processing delays are possible
- de facto standards (such as the Internet protocols, which were already widely used) don't fit very well with the OSI model
- the OSI model was devised before the protocols were invented
- associated OSI service definitions and protocols are complex, difficult to implement, and relatively inefficient in operation

- **However:** unlike the Internet protocols, the OSI model distinguishes between *services*, *interfaces*, and *protocols*, and has proved to be a useful "textbook" introduction to layered networking
    - OSI terminology is widely used in describing other models