The University of Melbourne
School of Computing and Information Systems

COMP30023
Computer Systems

Semester 1, 2017

Network Fundamentals

Resources / Acknowledgement

- Tanenbaum, A.S. (2003). *Computer networks (Fourth Edition)*. Pearson Education International / Prentice Hall
- Tanenbaum, A.S. and Wetherall, D. (2011). *Computer networks (Fifth Edition)*. Pearson Education International / Prentice Hall
- Kurose, J.F and Ross, K.W. (2010). *Computer Networking: A Top-Down Approach Featuring the Internet (Fifth Edition)*. Addison Wesley.

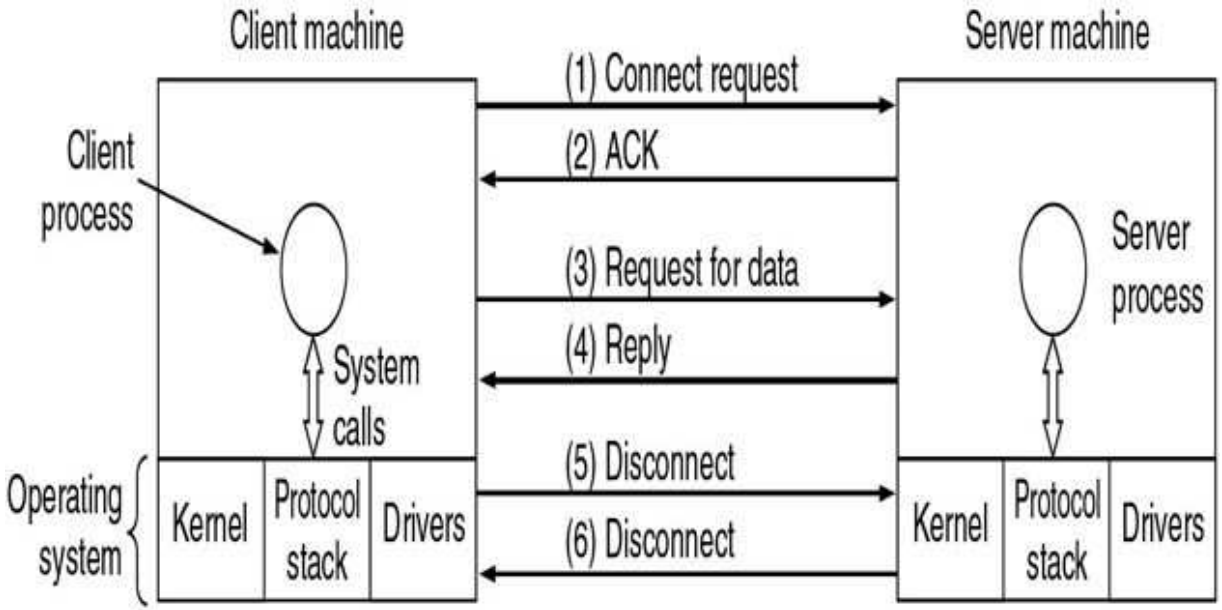
The slides for the Network Services component of the course were prepared by Michael Kirley. Some of the images included in the notes were supplied as part of the teaching resources accompanying the text books listed above.

Note: Many textbooks are available from the library (on reserve). There are numerous online resources available.

Network definitions

- Network
  - An intricately connected system of things or people.
  - An interconnected or intersecting configuration or system of components.
- Computer Network:
  - A data network with computers at one or more of the nodes. [Oxford Dictionary of Computing]
  - A collection of autonomous computers interconnected by a single technology.
- Internet:
  - The internet is not a single network but a network of networks
  - The WWW is a distributed system that runs on top of the internet

Michael's favourite slide



Network categories

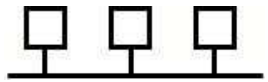
In this subject, we will briefly discuss the following network types:

- Local Area Networks
- Wide Area Networks
- Wireless Networks
- Internetworks

However, the emphasis will be on **networks services** rather than "physical" implementation issues.

Differentiating factors of networks

Transmission Type – Broadcast links



Broadcast networks have a single communication channel shared by all machines on a network. Packets sent by any machine are received by all others, an address field in the packet specifies the intended recipient. Intended recipients process the packet contents, others simply ignore it.

Broadcasting is a mode of operation which allows a packet to be transmitted that every machine must process.

Multicasting is a mode of operation which allows a subset of machines to process a given packet.

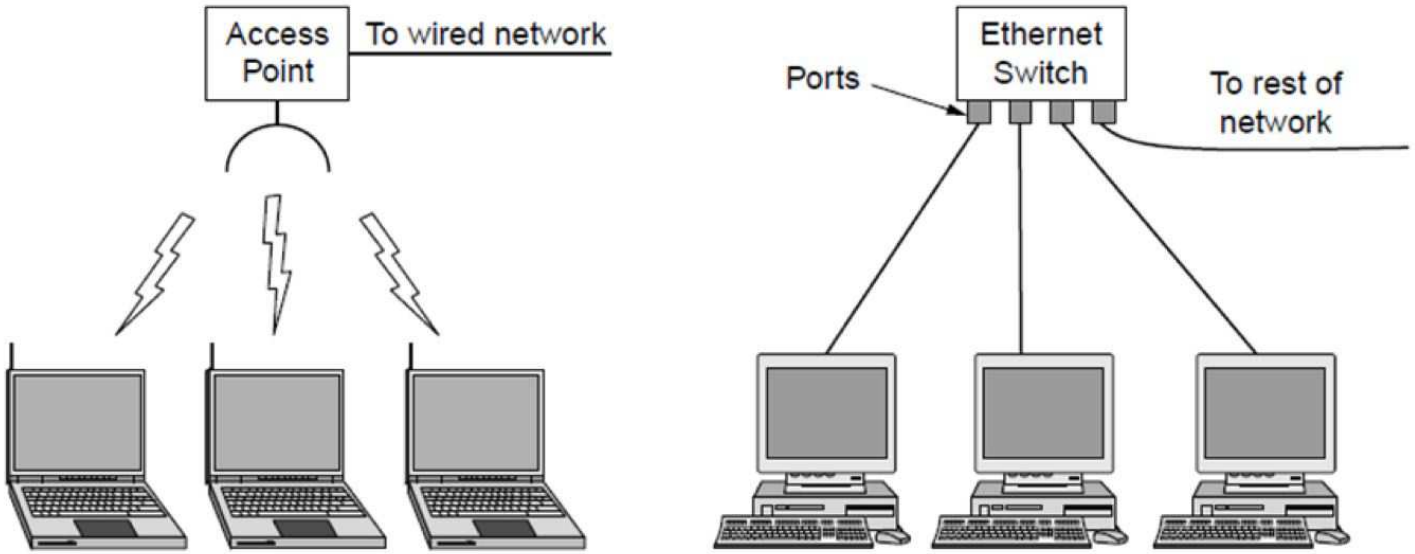
Differentiating factors of networks

Transmission Type – Point-to-point links

Point to point networks consist of many connections between individual pairs of machines. Packets traveling from source to destination must visit intermediate machines to determine a route - often multiple routes of variant efficiencies are available and optimisation is an important principle.

Unicasting is the term used where point-to-point networks with a single sender and receiver pair can exchange data.

Local area networks



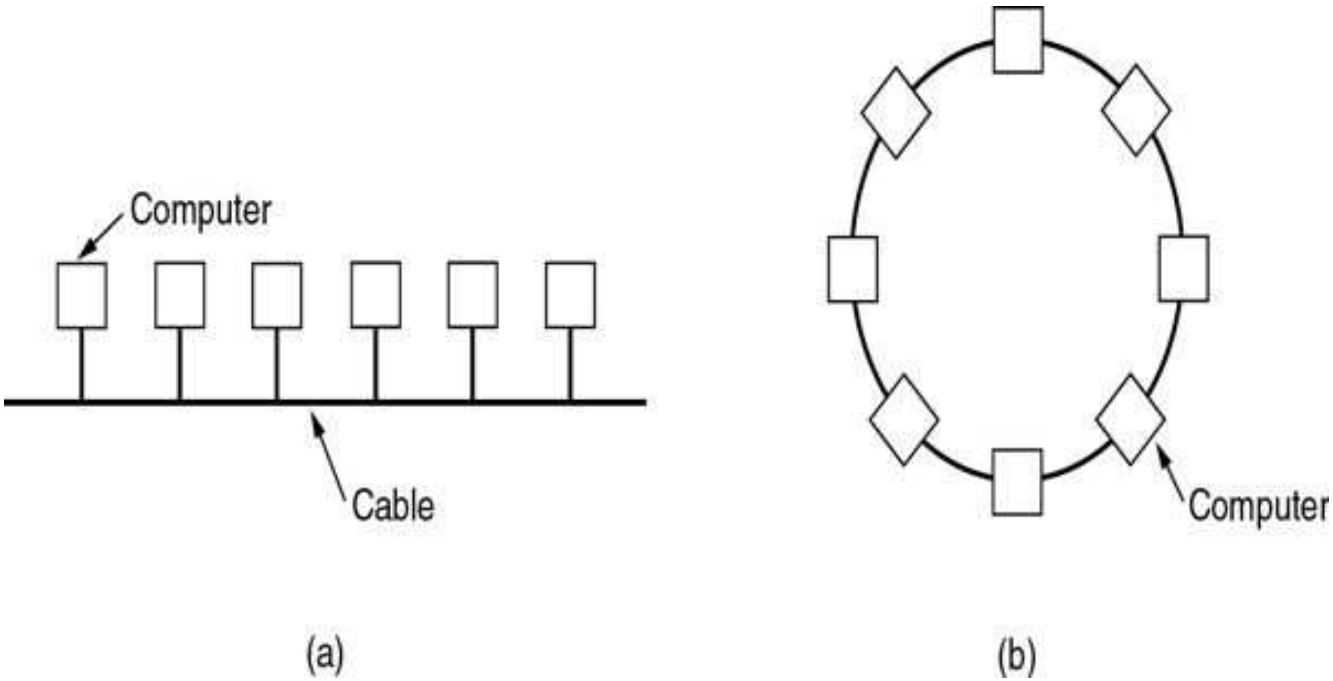
Wireless and wired LANs. (a) 802.11. (b) Switched Ethernet.

Local area networks

Distinguished by 3 factors

- **Size**
  - Worst-case transmission time can be predicted in advance
- **Transmission Technology**
  - physically wired network; wireless
- **Topology**
  - Bus
    - only a single machine on the network can transmit at any point in time
    - requires a negotation mechanism to resolve transmission conflicts
    - Ethernet (IEEE 802.3) is the most common bus network
  - Ring
    - Each transmission bit is propagated individually
    - Requires access control to resolve propagation queuing
    - Token Ring (outdated), FDDI is the most common ring network type

Local area networks – Bus vs Ring topology

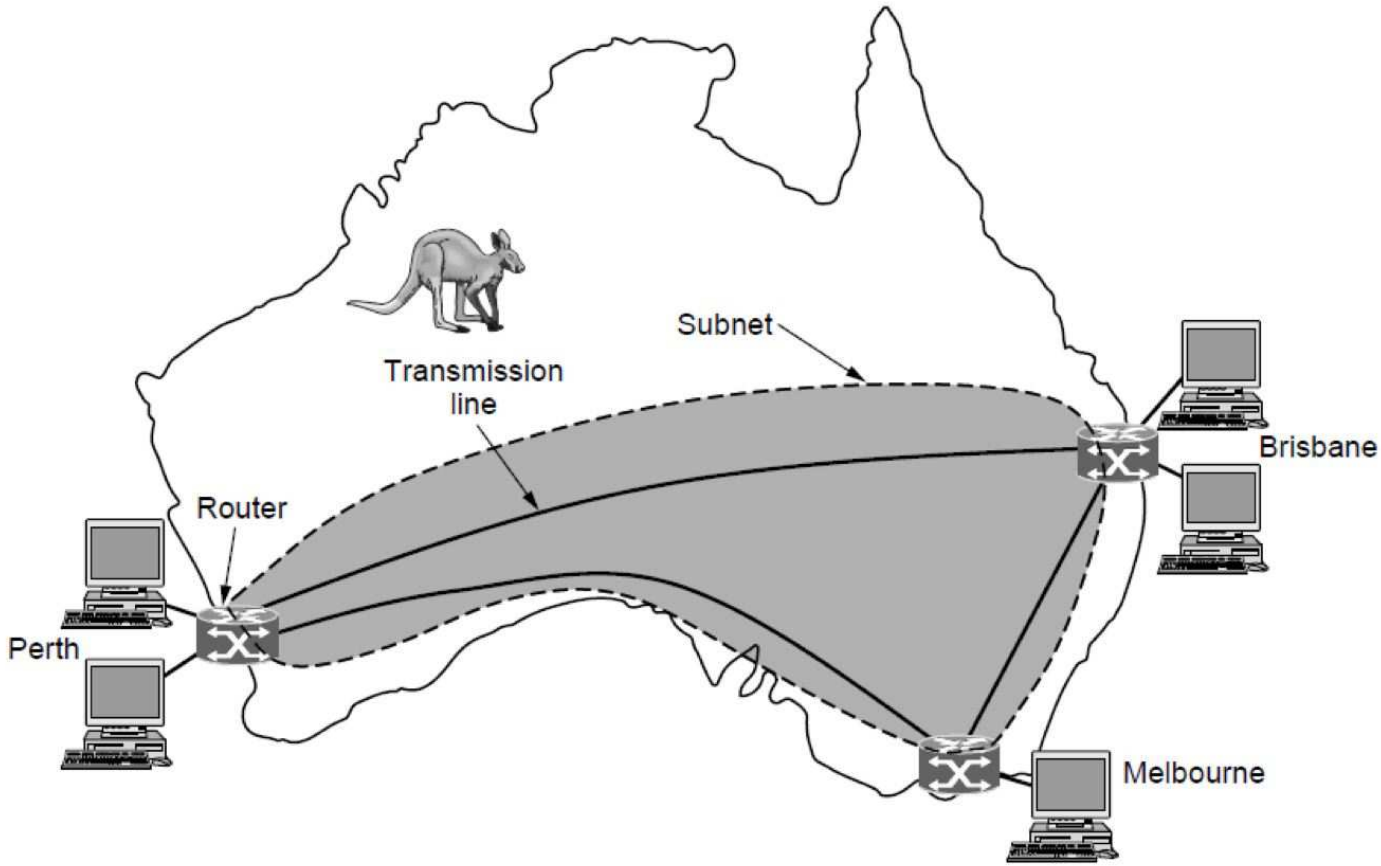


Two broadcast networks (a) Bus; and (b) Ring

Wide area networks

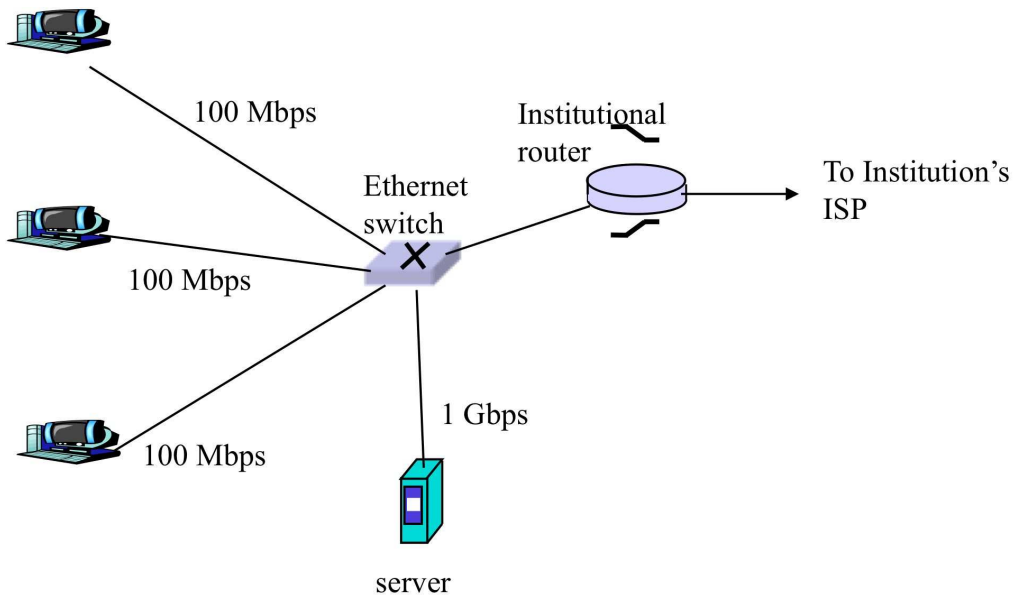
- Large scale geographical coverage - cities, states, countries
- Typically a single network provider is used across the WAN, although aggregation models are increasingly common
- WANs feature multiple hosts, typically owned by non-network providers
- WANs also feature multiple subnetworks, including different transmission types and a range of *routing* and *switching* infrastructure

WAN example



WAN that connects three branch offices in Australia

Ethernet access



Typically used in companies, universities, etc. (10 Mbs, 100Mbps, 1Gbps, 10Gbps Ethernet).

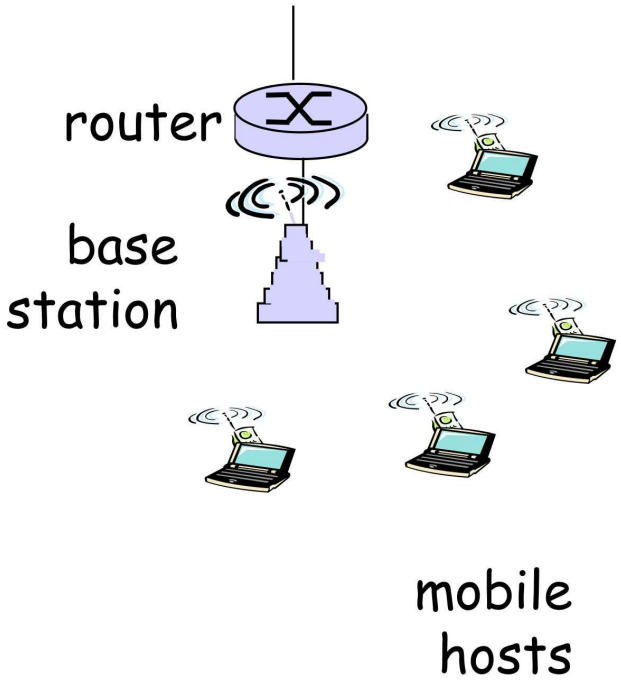
Today, end systems typically connect into Ethernet switch.

Types of wireless networks

- System Interconnection
  - Short range radio ($<$ 10m)
  - Low bandwidth (-100Kbps)
  - Numerous technologies including Infrared (IR), Bluetooth ...
- Wireless LAN
  - Longer range radio (typically 100-200m, but up to 3-4km with the right equipment)
  - Moderate bandwidth (1-54Mbps)
  - Requires transmission and reception devices
  - 802.11 family is the most common

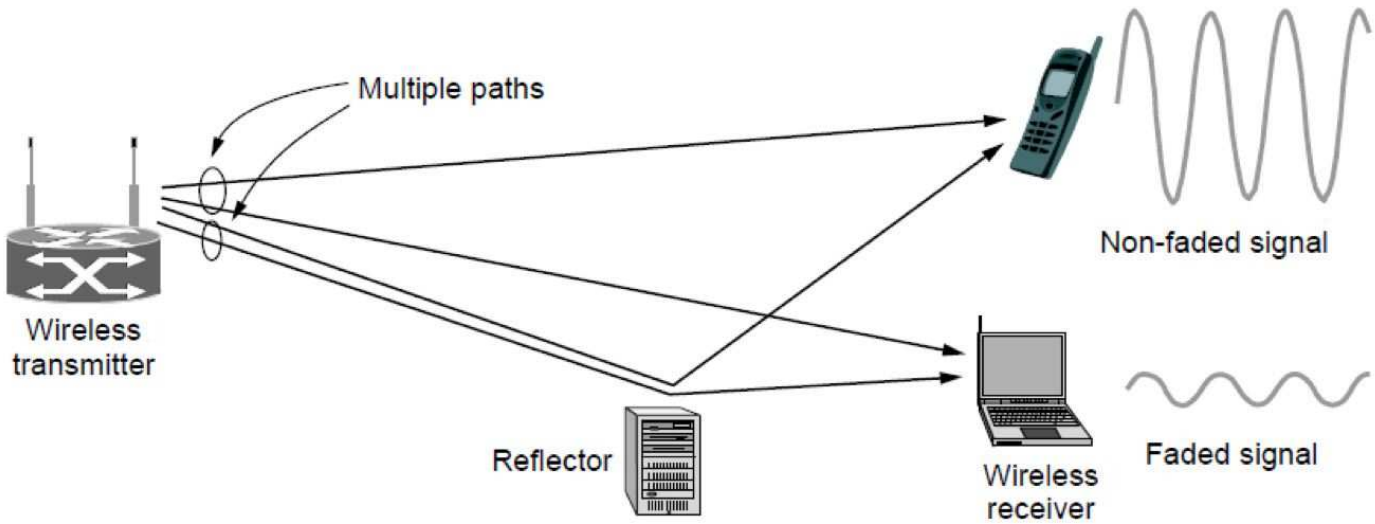
NOTE: *The aim here is to simply list types rather than providing comprehensive details. Please consult the recommended text for details.*

Wireless access



Shared wireless access network connects end system to router via base station aka “access point” (NAP).

Wireless LANs: 802.11



802.11b/g (WiFi): 11 or 54 Mbps

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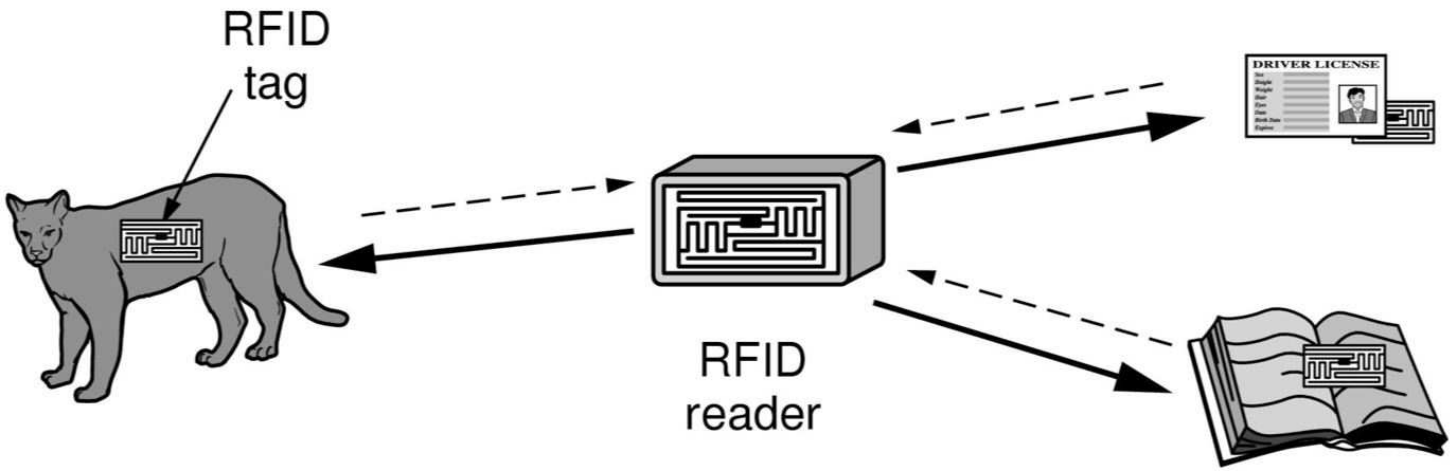
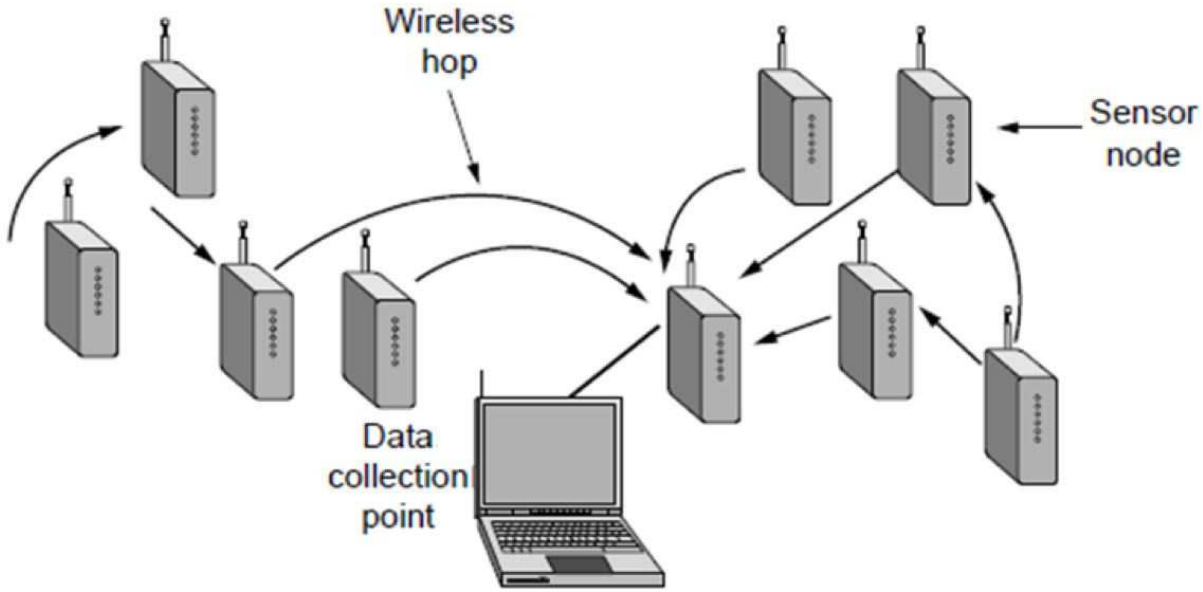
RFID and Sensor Networks



RFID and Sensor Networks



Multihop topology of a sensor network

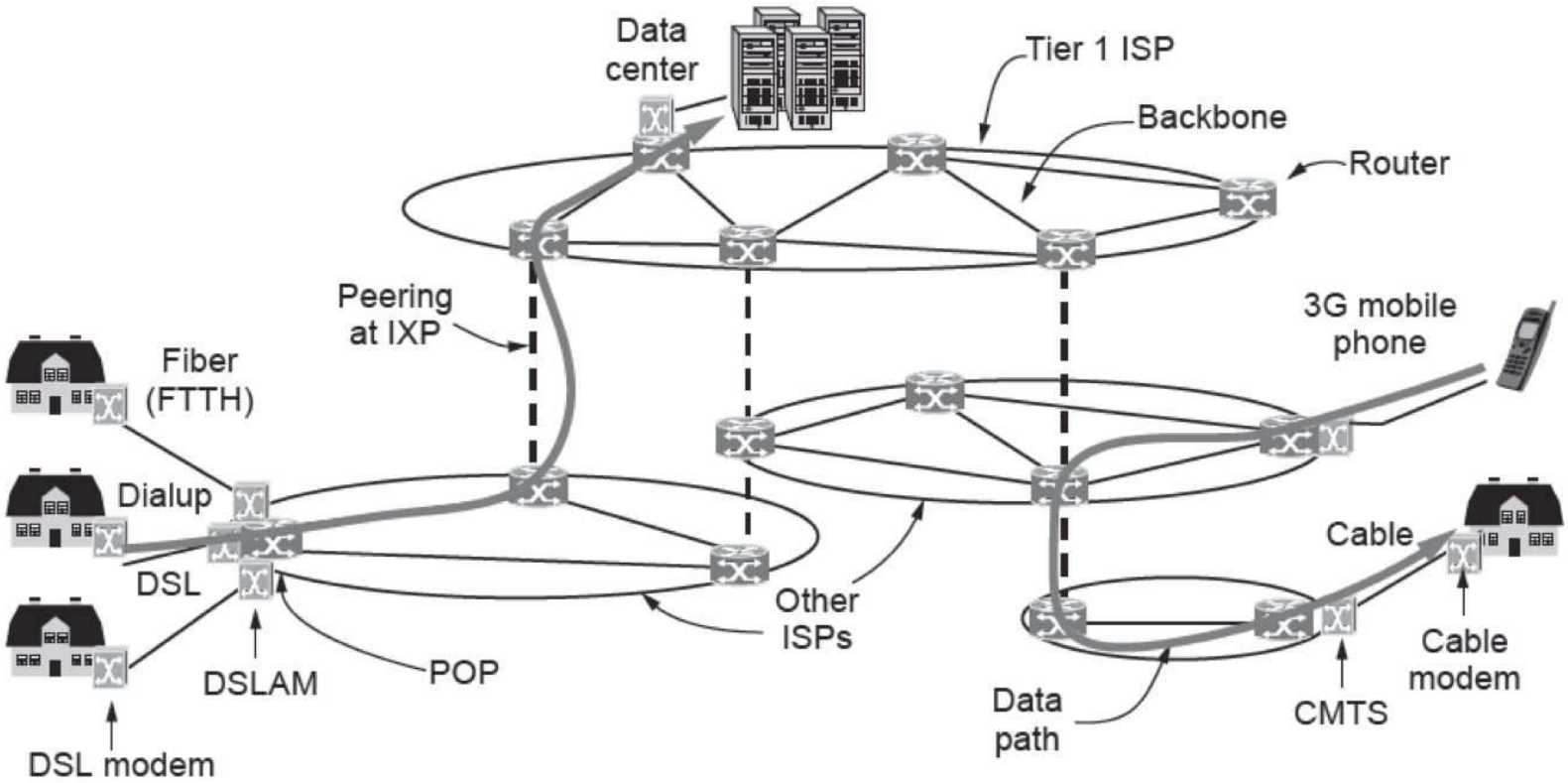
The Internet

The Internet is composed of the aggregation of many smaller networks – not a single network or under a single point of control.

Historically, the Internet developed in 3 distinct phases

- ARPANET (1960's - early 1970's)
- NSFNET (1970's - early 1980's)
- Internet (1980's - present)
- ... *the rise and rise of social media, Web 2.0+* (present)

High level architecture of the Internet



Further details in come . . .

Communication links

Link: A connection between two devices in the network.

Bandwidth: The maximum speed in which data can be transmitted on a link.

Data is transferred from end-to-end using several links. Different links have different bandwidths.

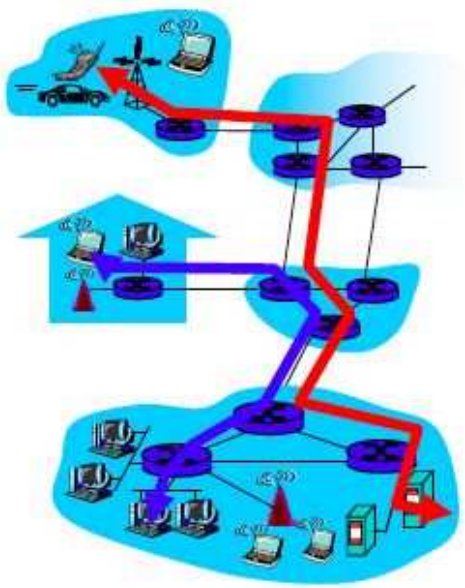
How is data transferred through the Internet?

- circuit-switching
- packet-switching

Circuit switching

Circuit switching: End-to-end resources reserved for the session. Requires initial setup to reserve the resources.

Dedicated resources with reserved bandwidth; no sharing

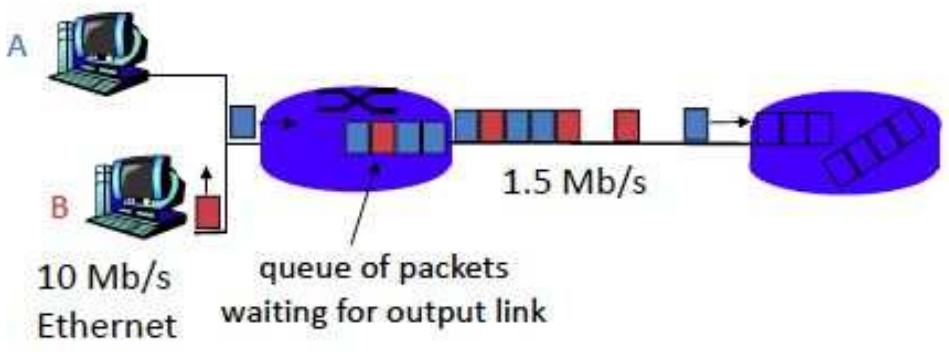


Packet switching

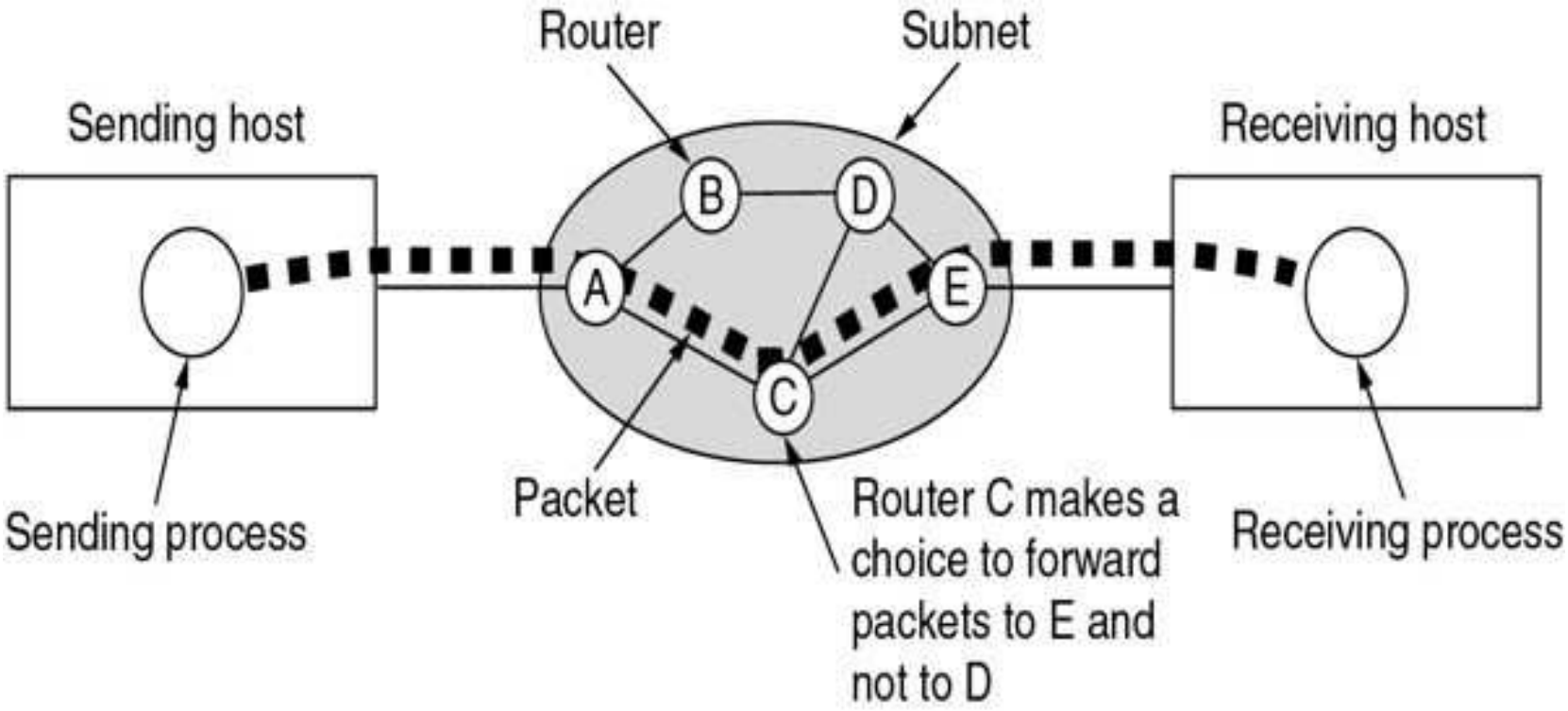
Packet switching: Data stream divided into packets. Packets from different users share network resources .

No resource reservation or dedicated allocation.

+ different packets can take different routes ; resource sharing
+ better utilisation of network resources
- no performance guarantees
- congestion; packets may be lost



Packet switching on a network



A stream of packets travels from the *sender* to the *receiver*. A key questions – what route did the packets follow?

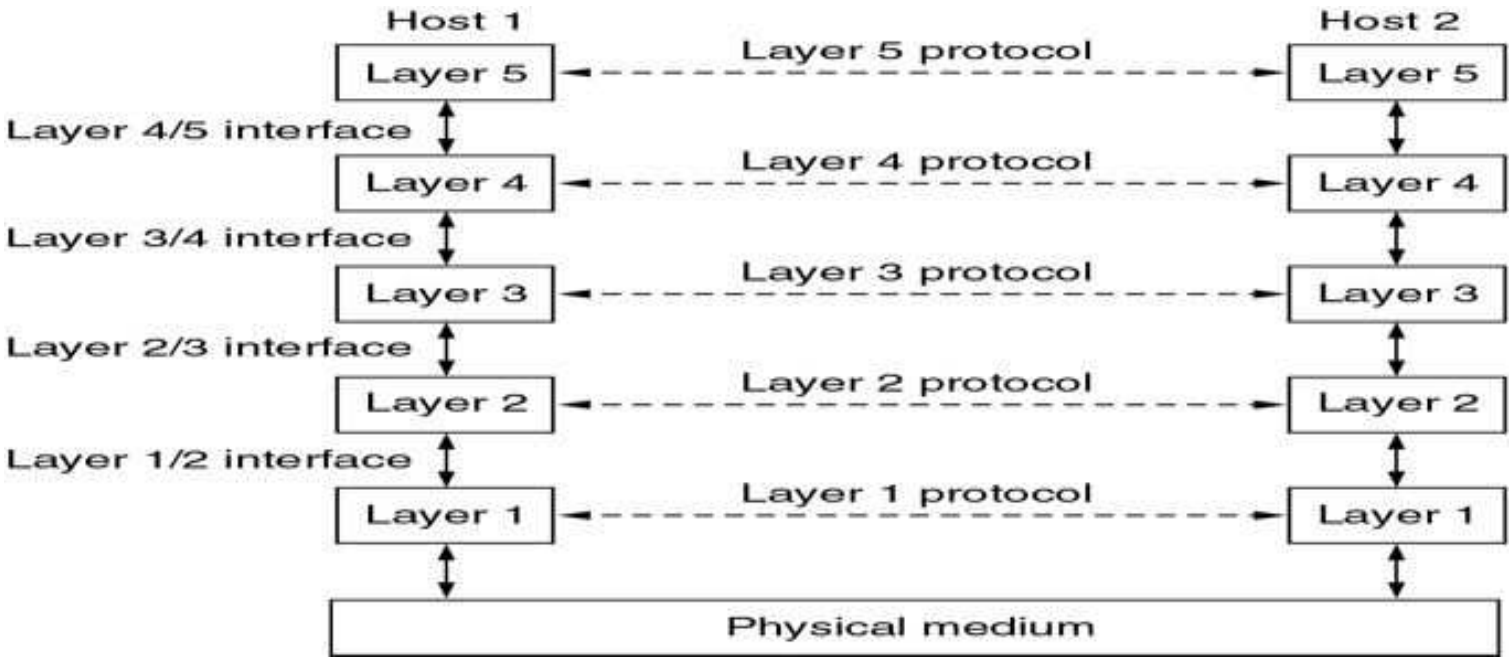
Protocols, Layers and Services

Topics to be covered:

- Protocol hierarchies
- Design issues for the layers
- *Connection-oriented* vs *Connectionless* services
- Service primitives
- The relationship of *services* to *protocols*

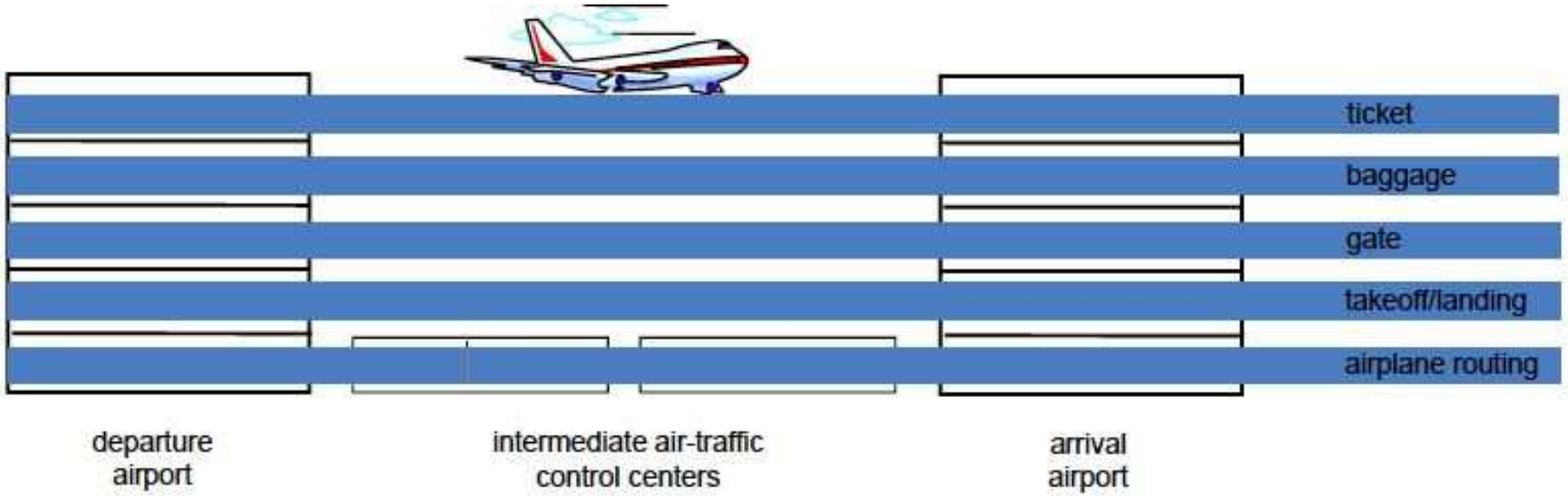
Network protocol hierarchies

Consider the network as a stack of layers. Each layer offers services to layers above it. Inter-layer exchanges are conducted according to a protocol.

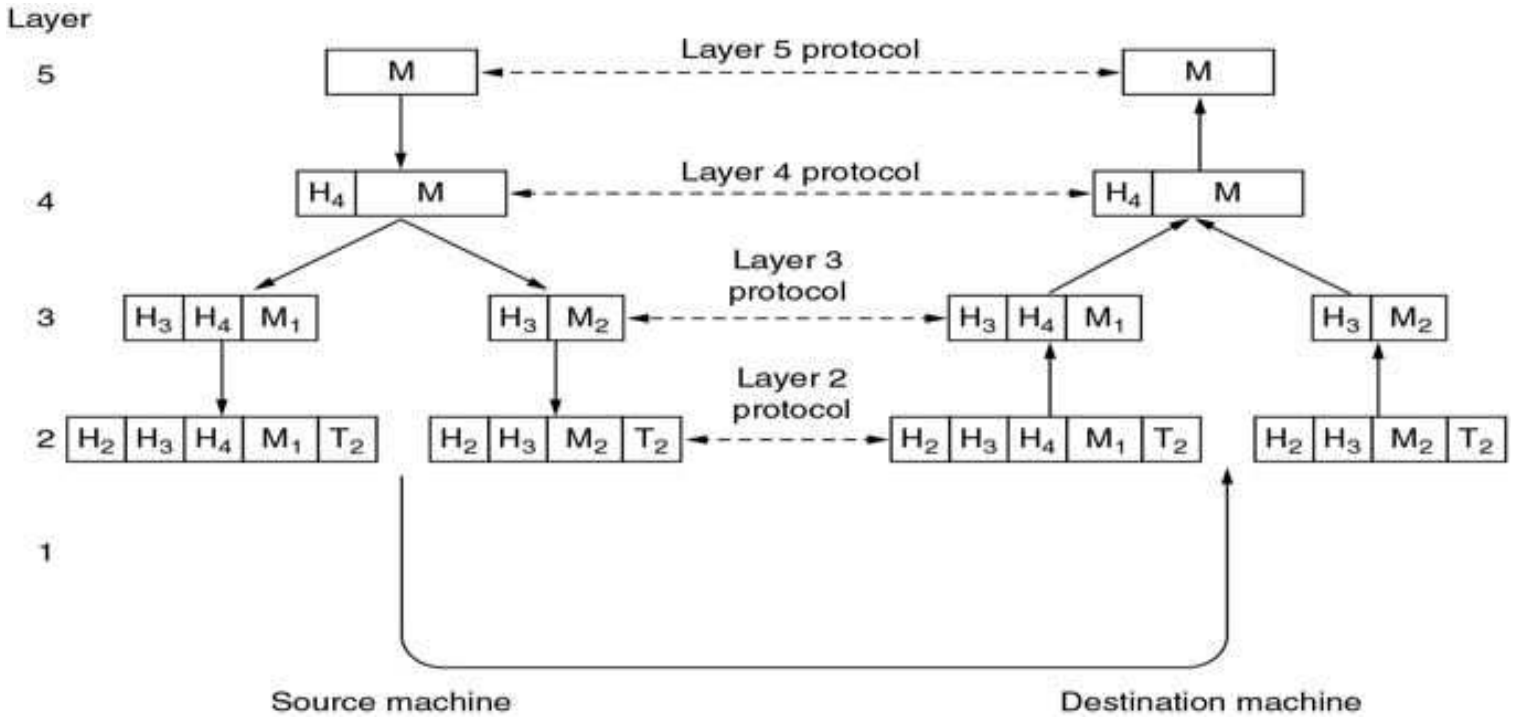


Network protocol hierarchies

A simple analogy:



Network protocol hierarchies



Connection-oriented and Connectionless services

Connection Oriented:

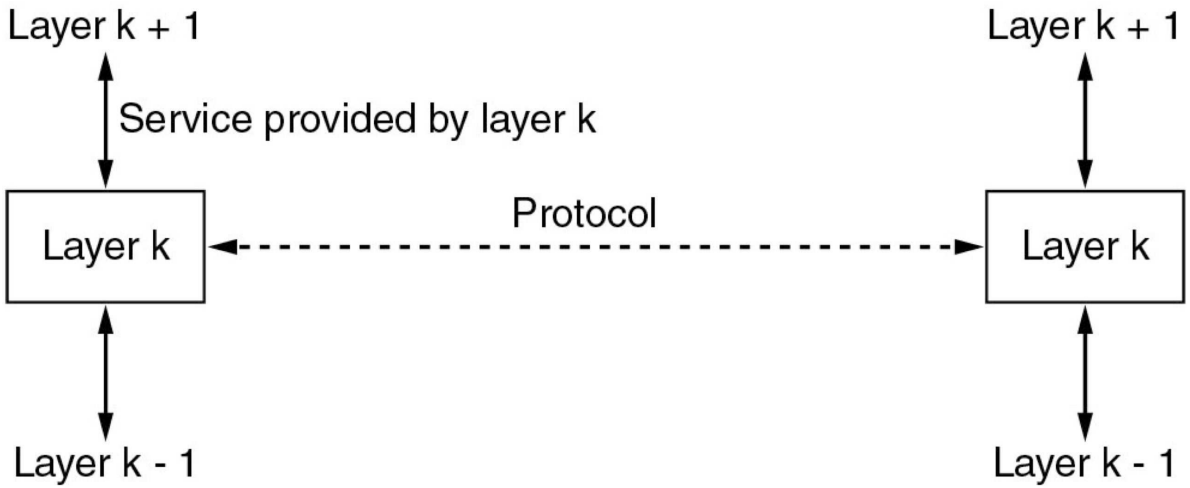
- **connect, use, disconnect**
- negotiation inherent in connection setup
- *similar to telephone service*

Connectionless:

- **use**
- message routed through intermediate nodes
- *similar to postal service*

The choice of service type has a corresponding impact on the reliability and quality of the service itself.

Services to protocols relationship



Service = set of primitives that a layer provides to a layer above it

* interfaces between layers

Protocol = rules which govern the format and meaning of packets that are exchanged by peers within a layer

* packets sent between peer entities

Why do we need a network reference model?

A reference model provides a common baseline for the development of many services and protocols by independent parties.

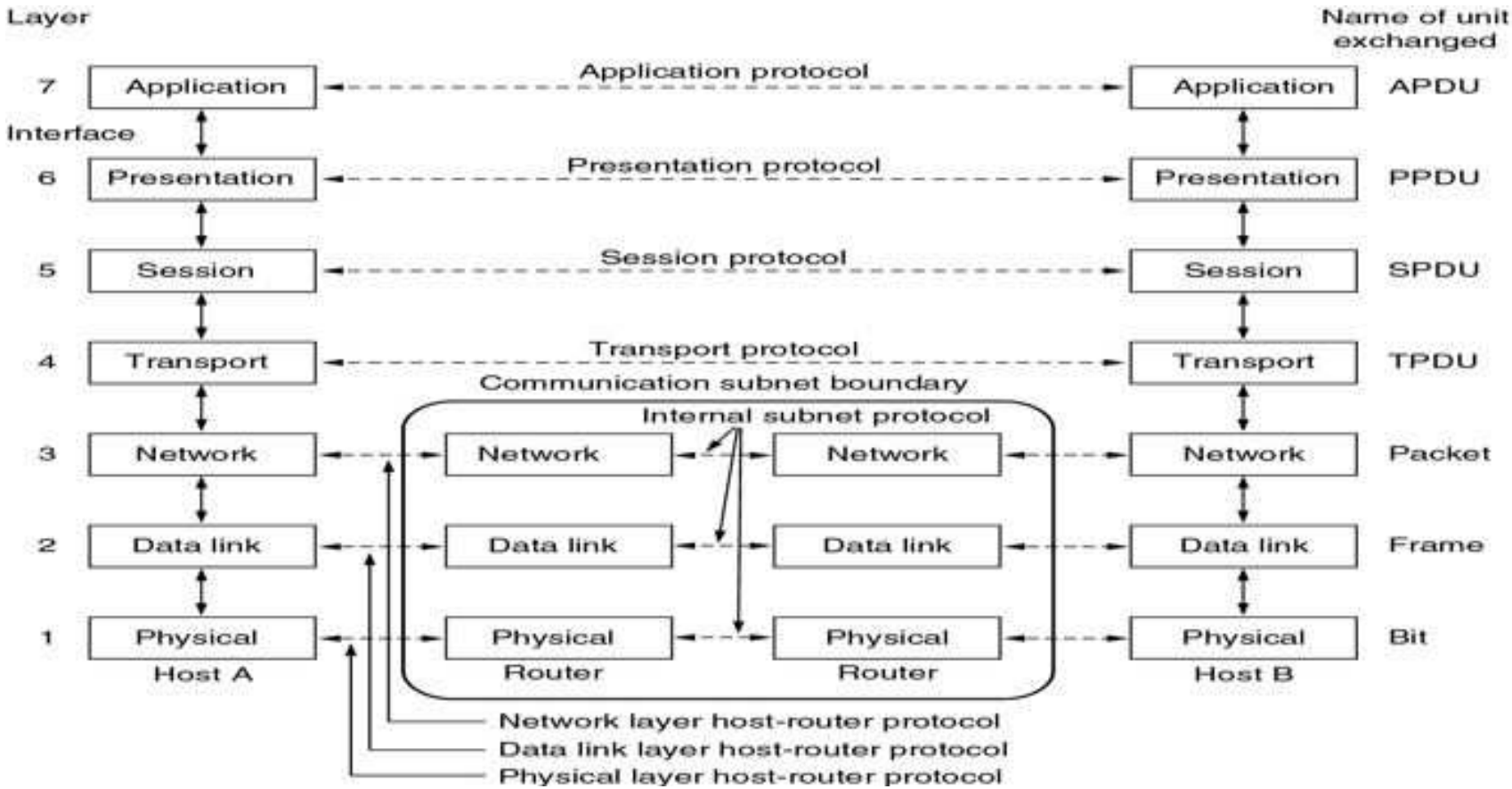
Since networks are multi-dimensional, a reference model can serve to simplify the design process.

It's engineering best practice to have an abstract reference model, and a reference model and corresponding implementations are always required for validation purposes.

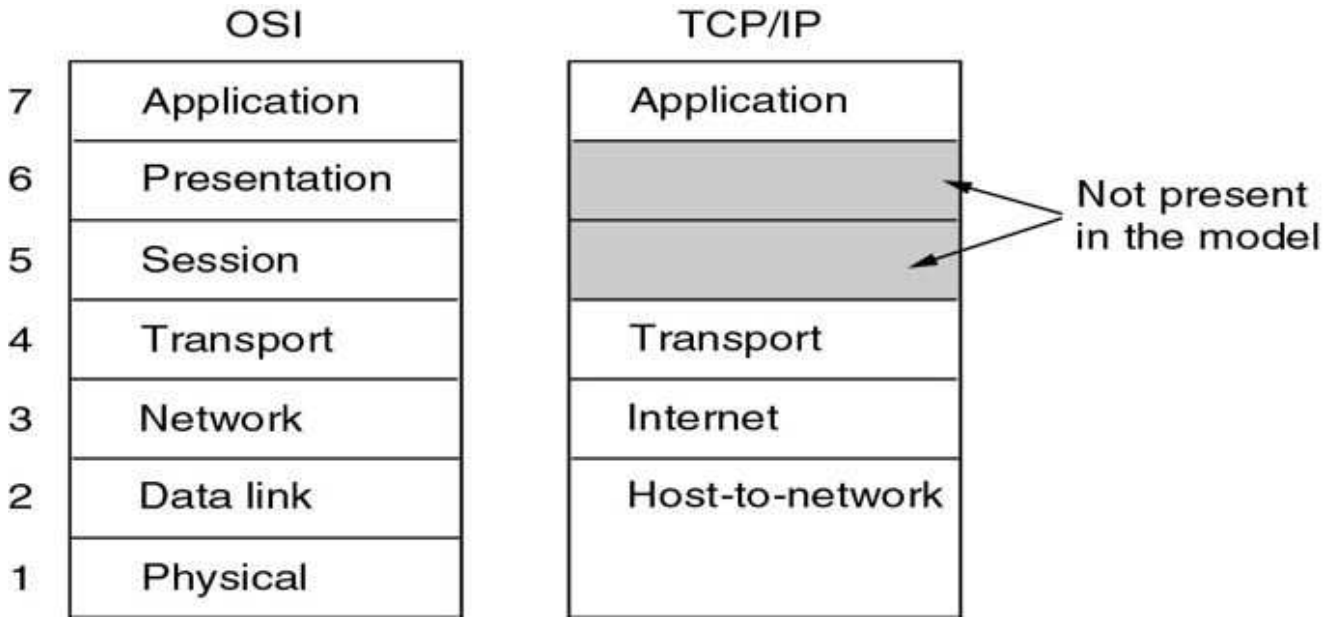
Open Systems Interconnection (OSI) reference model

- A layer should be created where a different abstraction is needed.
- Each layer should perform a well defined function.
- The function of each layer should be chosen with a view toward defining internationally standardised protocols.
- The layer boundaries should be chosen to minimise the information flow across the interfaces.
- The number of layers should be large enough that distinct functions need not to be thrown together in the same layer out of necessity, and small enough that the architecture does not become unwieldy.

OSI model

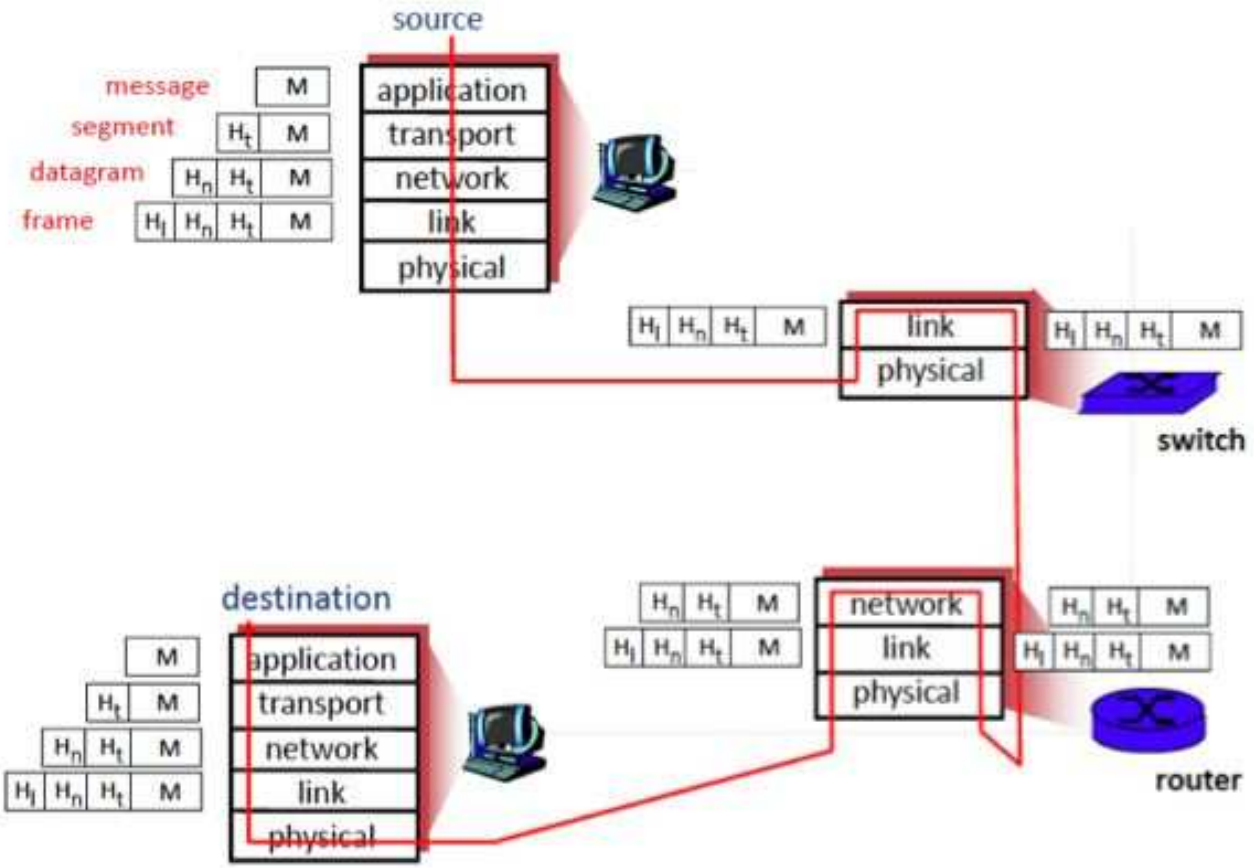

Layer
Name of unit exchanged
7
Application
Application protocol
Application
APDU
Interface
6
Presentation
Presentation protocol
Presentation
PPDU
5
Session
Session protocol
Session
SPDU
4
Transport
Transport protocol
Transport
TPDU
Communication subnet boundary
Internal subnet protocol
3
Network
Network
Network
Network
Packet
2
Data link
Data link
Data link
Data link
Frame
1
Physical
Physical
Physical
Physical
Bit
Host A
Router
Router
Host B
Network layer host-router protocol
Data link layer host-router protocol
Physical layer host-router protocol

TCP/IP model

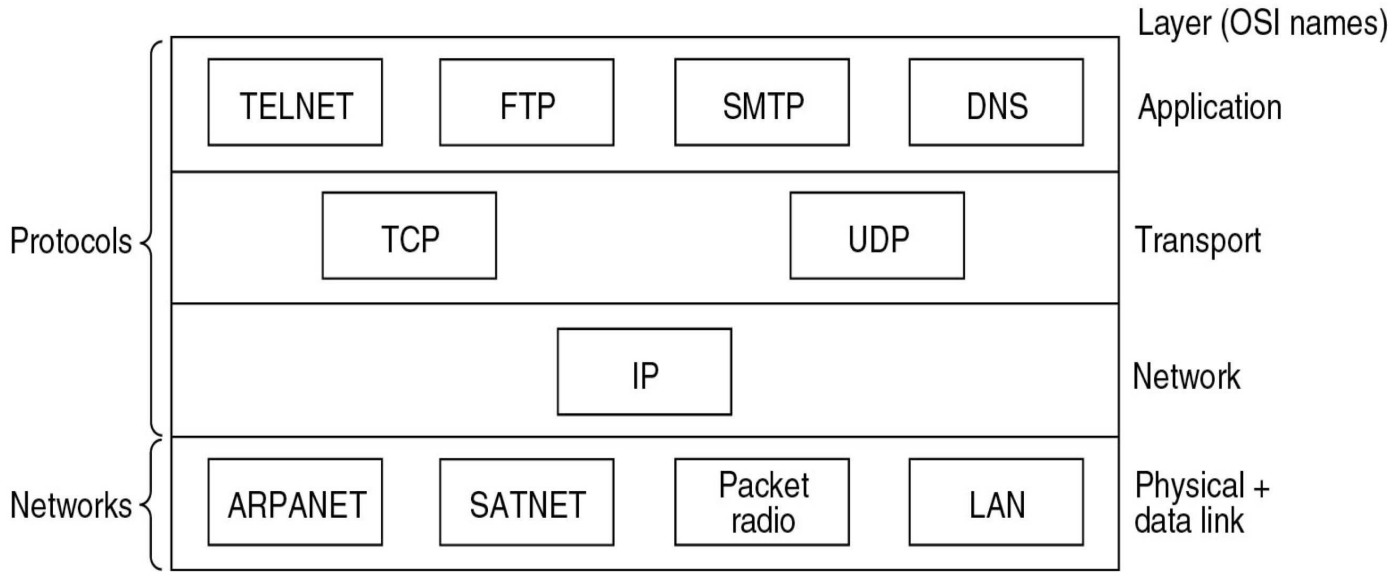


TCP/IP – Transmission Control Protocol/Internet Protocol – is infrastructure independent (Cerf & Kahn, 1974)

Using the protocols



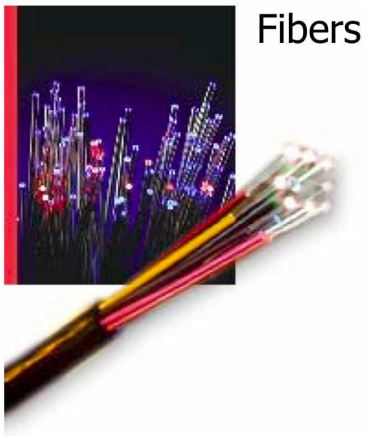
The protocol stack – where to from here?



We will be concentrating on the **Protocols** section – the application level and a high-level overview of TCP, UDP and IP.

Network components (... an overview)

Links



Fibers

Coaxial Cable

Interfaces

Ethernet card

Wireless card

Switches/routers

Large router

Telephone switch

4

Host-to-network layers

Physical layer:

- corresponds to signaling technology – all done in hardware.

Data link layer:

- frame management
  - take packets from network layer, and encapsulate them into frames (containing a header, a payload, a trailer)
- Ethernet device address or Media Access Control (MAC) address
  - **48-bit unique address** usually represented as six colon-separated pairs of hex digits, e.g., `8:0:20:11:ac:85`
  - the data link layer's protocol-specific header specifies the MAC address of the packet's source and destination.

Network layer

The primary purpose of the network layer is to provide the necessary functionality to "combine networks" and route data through the network.

- creates an internet address space: each host has a **32-bit IP address**
- runs IP routing software
- implements packet routing across networks; defines a standard transfer unit – or **packet** – consisting of:
  - header: contains info such as packet size, source & destination addresses.
  - payload: contains data bits sent from source host.
- routers are used to forward data among computer networks (beyond directly connected devices)
- intermediate hosts are typically called gateways

Addresses

MAC address allocation administered by IEEE – manufacturer buys portion of MAC address space (to assure uniqueness)

MAC addresses: flat, portable – can move LAN card from one LAN to another

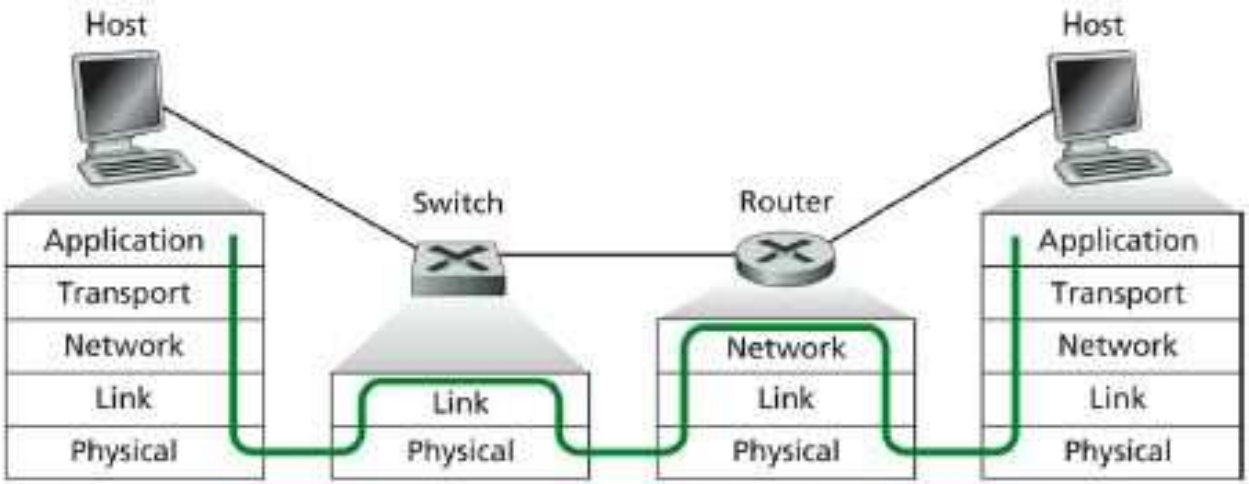
IP addresses: hierarchical, not portable – depends on IP subnet to which node is attached

Analogy:

MAC address: like Social Security Number

IP address: like postal address

Switches and Routers



Switches:

- link layer device
- maintain switch table
- implement filtering algorithms
- plug-and-play
  - self-learning

Routers:

- network layer device
- maintain forwarding table
- implement routing algorithms
- must be configured by administrator

Transport layer

Two primary protocols:

- Transmission Control Protocol (TCP)
  - connection oriented, reliable delivery
  - provides a stream-oriented interface to the network
- User Datagram Protocol (UDP)
  - connectionless – no guarantee that packets will be delivered
  - more efficient relative to TCP

The transport layer provides yet another address extension. While the IP only references networks and hosts, the transport layer uses a port number – a **16-bit number (or address)** – as an interface for applications.

Application layer

Application layer:

- examples include: HTTP, FTP, SMTP, DNS (+ client-server apps)
- treats the transport layer (and lower) protocols as "black boxes".

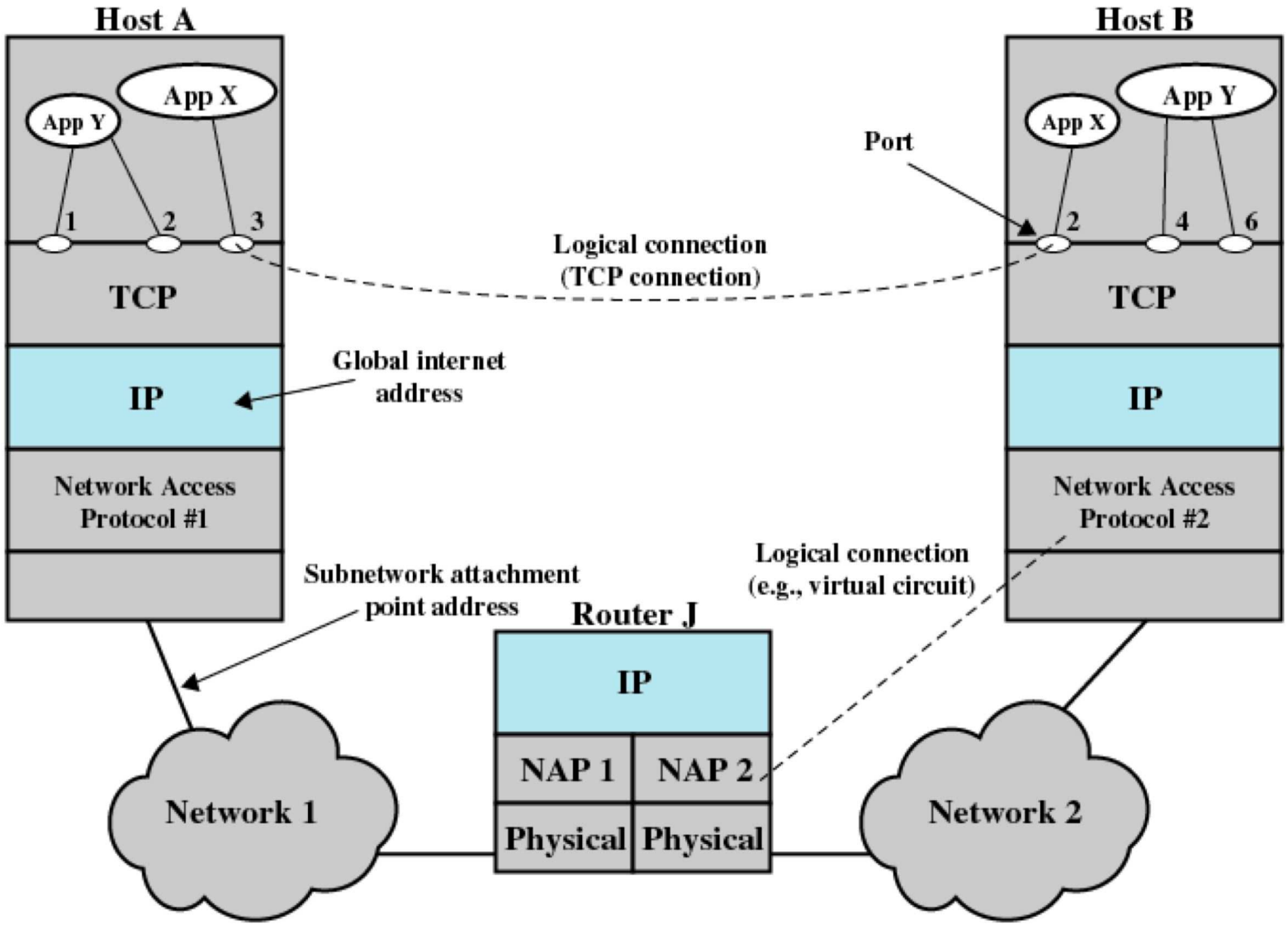
Transport layer:

- provides services for the application layer
  - relies on network layer to help provide a service for the application layer
  - service is between processes (e.g., via sockets)

Network layer:

- provides services for the transport layer
  - between nodes (e.g., routers and hosts)
  - hides details of the link technology e.g., IP

TCP/IP "in action"



Internet standards (reference material)

Standards provide an important common core, allowing a wide range of implementations which are interoperable.

- Internet Engineering Taskforce (IETF)
  - Open consortium
  - Mainly protocol level standards
  - RFC's
  - http://www.ietf.org/rfc
- World Wide Web Consortium (W3)
  - Membership based organisation
  - Mainly applications level standards
  - http://www.w3.org