Computer Networks

Lecture on

Basic Terms and Network Reference Models

Plan of This Lecture

- Communication issues
- Network classifications
- Network **r**eference **m**odels
  - ISO OSI RM
    International **O**rganization for **S**tandardization, **O**pen **S**ystems **I**nterconnection
  - TCP/IP RM
    Transport **C**ontrol **P**rotocol/ **I**nternet **P**rotocol
  - IEEE LAN/MAN RM
    Institute of **E**lectrical and **E**lectronics **E**ngineers

Communication Issues

The communicating nodes have to know or agree on

- what they want to do
- what they can
- what information they are going to exchange
- what is the coding (representation) for transmission
- how to synchronise their activities

An item of information

- is something abstract
- has semantics and structure
- can have many representations –on different machines, on storage, on transmission channel
- can have metadata

Communication between nodes has to

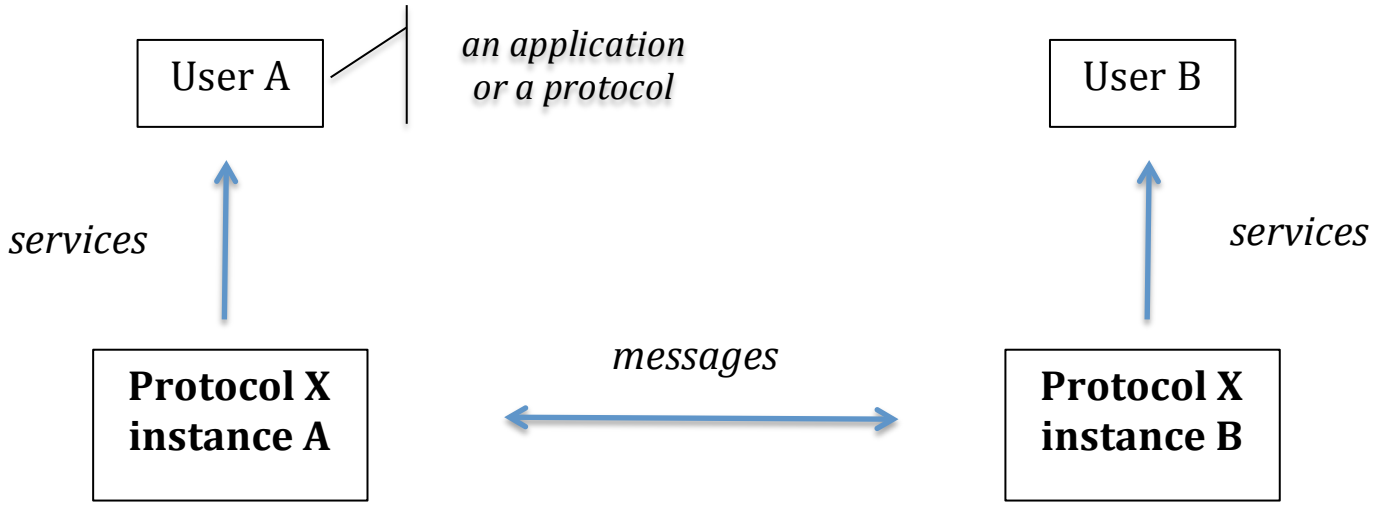
- tolerate transmission errors
- recover from node's failures
- adapt to network capabilities (speed, delay, jitter, availability, error rate)

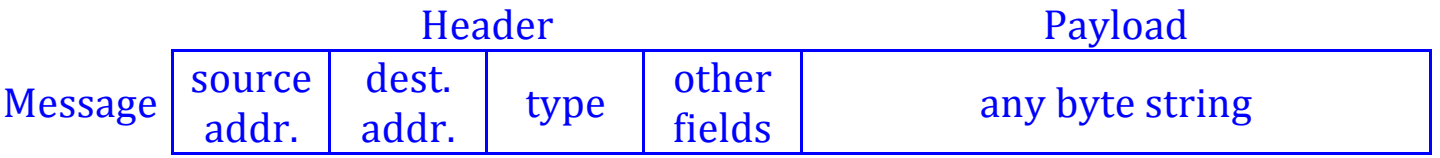
To enable communication – standard rules must be defined

A communication protocol

A **communication protocol** is a system that realizes a set of rules,
which governs cooperation between autonomous entities

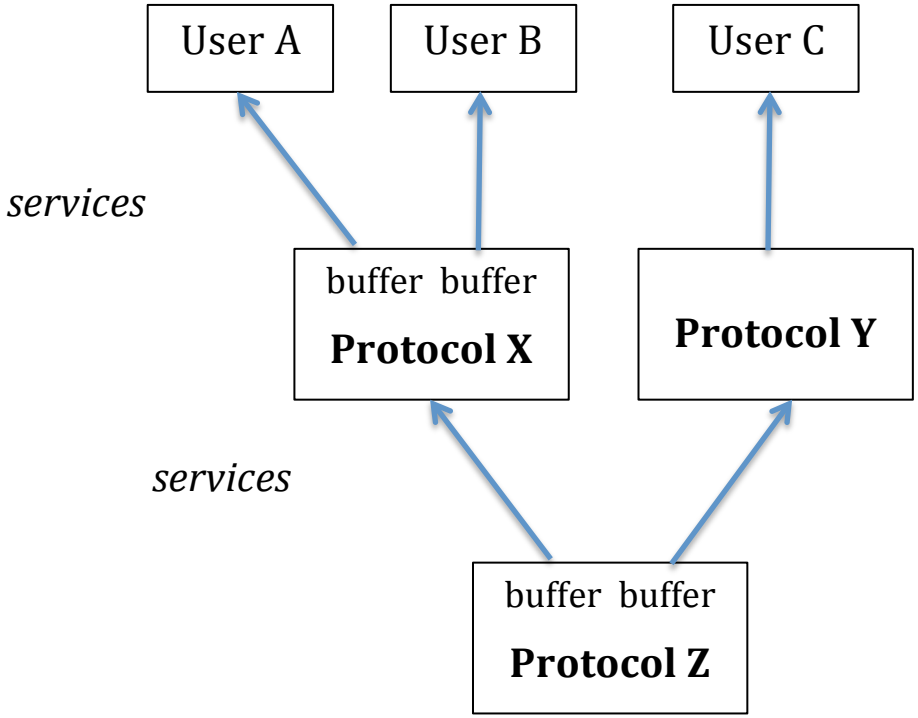
To deal with complex problem – we split it to sub-problems – here to different protocols





Protocol service multiplexing

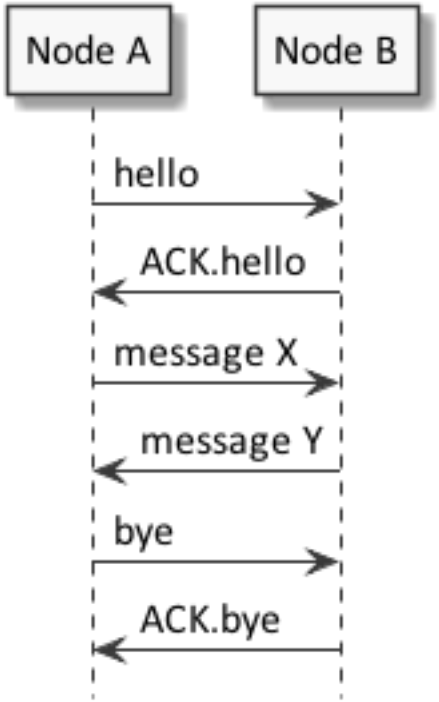
Provided by **X** and **Z** on this example:



Connection-Full & Connectionless Communication

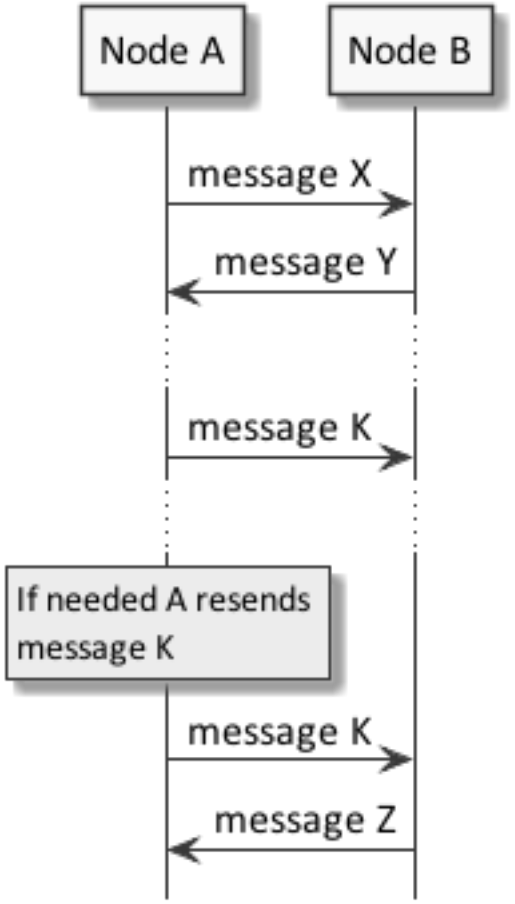
- Connection full, can be:
  - reliable
  - unreliable

  Provided by X.25, Frame Relay, ATM

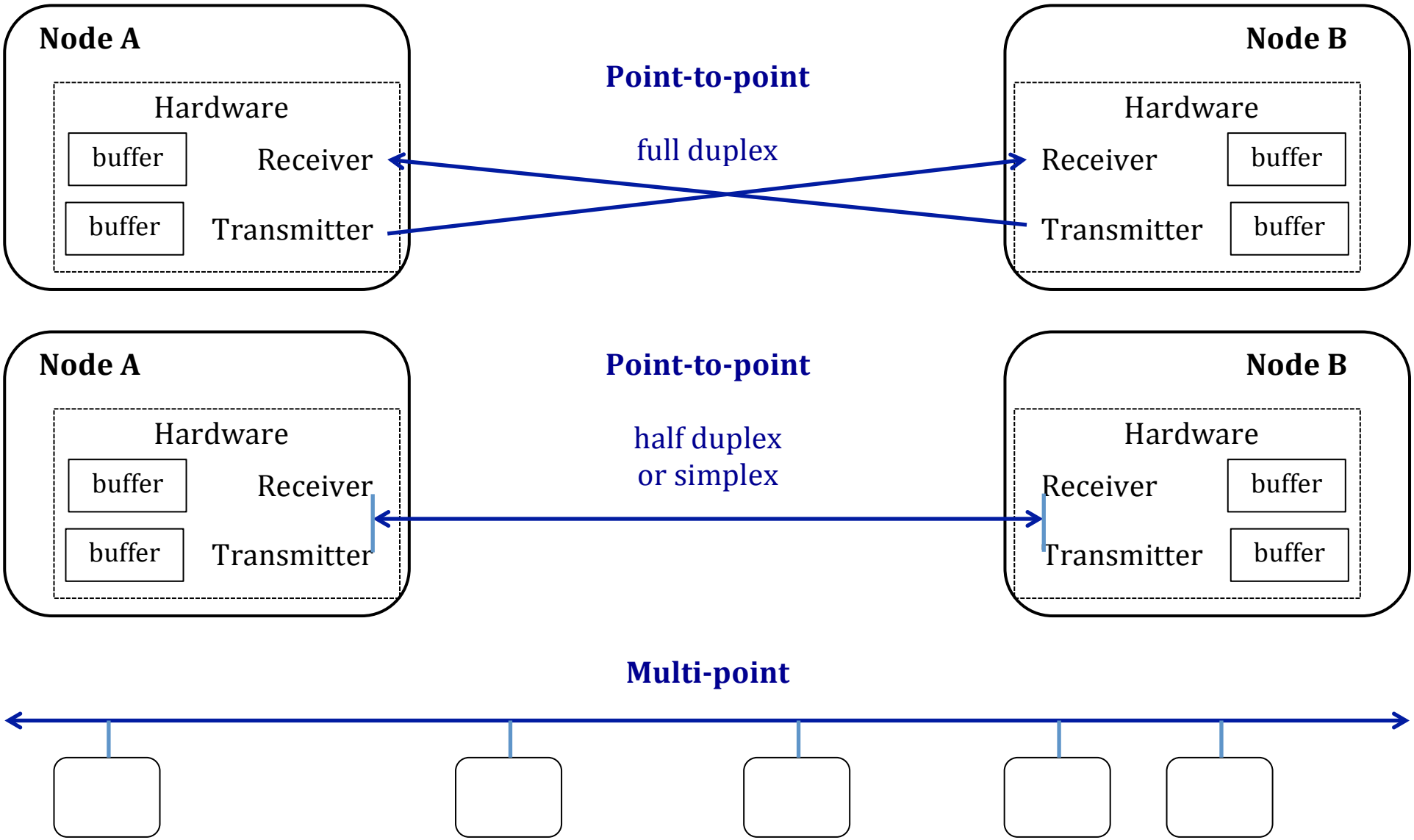


- Connectionless, can be:
  - reliable
  - unreliable

  E.g. Internet protocol



Simplex & Duplex Links



Link Rate, Bandwidth, Throughput and Goodput

Link Rate ≡ Data Rate

– the rate at which bits are transmitted

Throughput

– the overall effective transmission rate,
taking into account things like transmission overhead & protocol inefficiencies

- usually in kilo (10^3), mega (10^6) or giga (10^9) bits per second – kb/s, Mb/s, Gb/s

Bandwidth

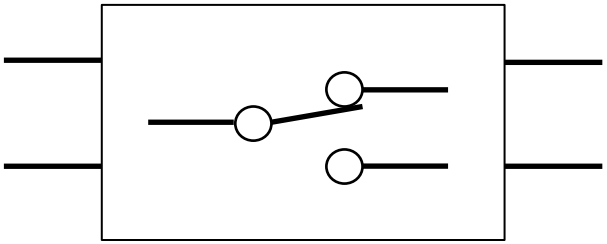
– depending on author or context, can be link rate or throughput

Goodput

– the amount of usable data delivered to the receiving application

- usually in Kilo (2^{10}) or Mega (2^{20}) bytes per second – kB/s, MB/s
- rarely in kilo (10^3) or mega (10^6) bytes per second – kB/s, MB/s

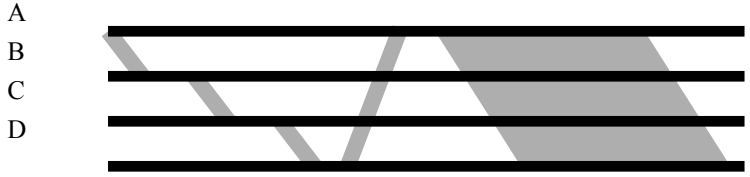
Switching



Switch types

- direct connection (galvanic, capacitive or inductive coupling, mirrors for light beams)
- TDMA – Time Division Multiple Access
- FDMA – Frequency Division Multiple Access
- packet switching

Circuit Switching



e.g. traditional telephone communication

Efficient for:

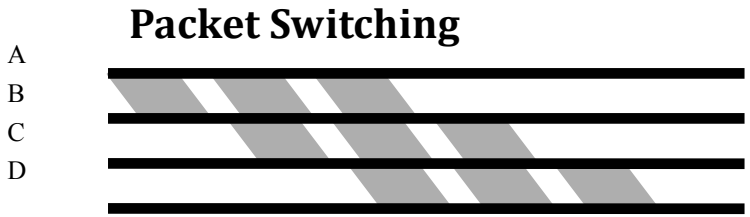
- real time applications
- large chunk data transfer

Message Switching

e.g. email

- short messages transfer

Packet Switching



e.g. IP

- any kind of messages

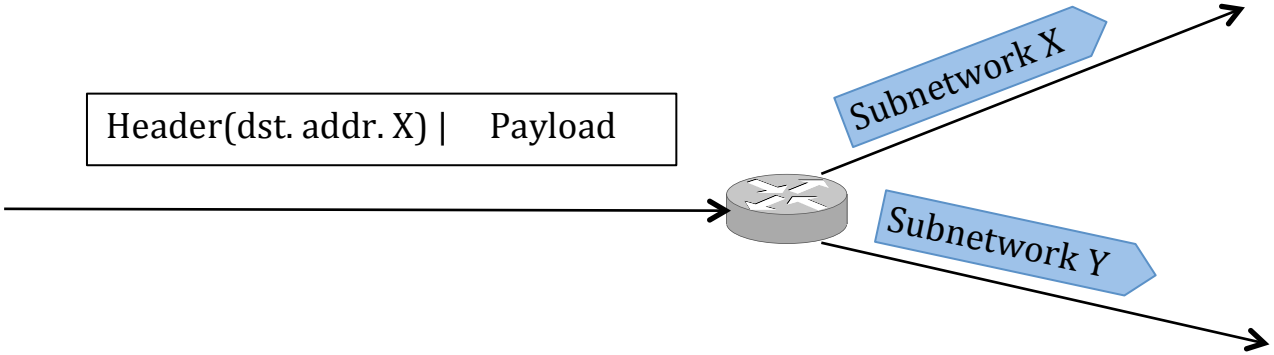
Efficient usage of network links!

Permanent Virtual Circuits
– predefined path in a packet network

e.g. X.25, Frame Relay, ATM

- for real time applications e.g. live video streams

Datagram Packet Switching



Every sent packet contains a destination address

Advantages

- simple implementation
- efficient for short data exchanges

Disadvantages

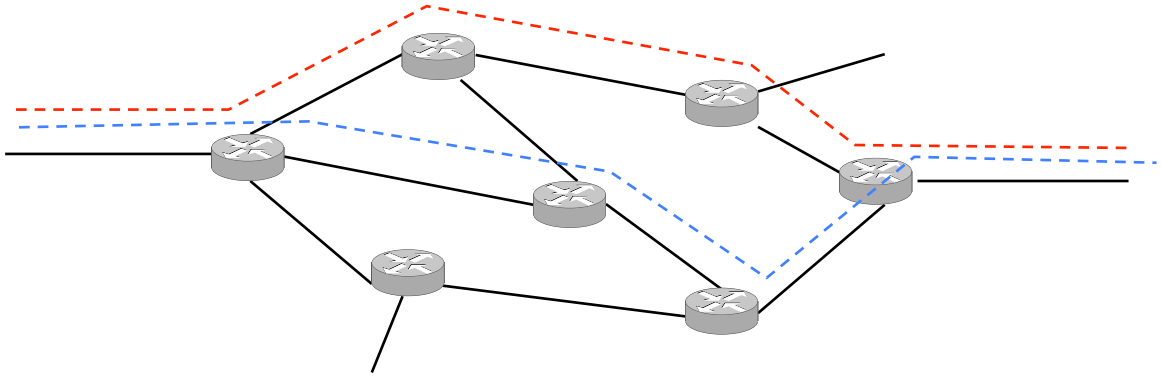
- destination addresses are long due to the number of possible destinations
- switch should process the address to find output queue for every packet !

IP routers apply this method

Virtual Circuit Packet Switching

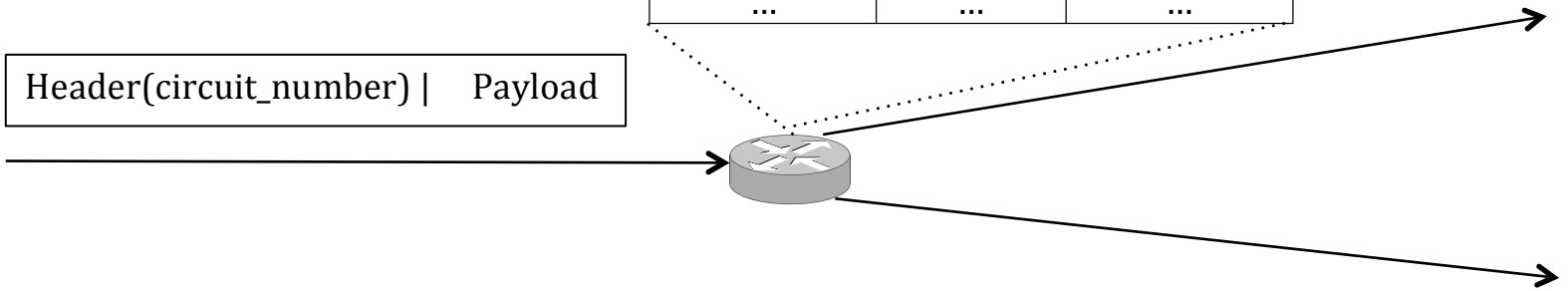
Every data packet contains a circuit number

The circuits are set before transmission of data packets



Index of attributed bandwidth on the output port

Input Circuit_Num	Output port	Output Circuit_Num
1	1	5
2	1	3
3	2	1
...	...	...



The circuit can be set

- When a terminal starts the communication session
  - Connect_request message creates the circuit
  - Connect_confirmation message confirms it
- Permanently by network admin

Advantages

- circuit number are short – due to limited number of circuits over one interface
  - the number points information in circuit table – fast forwarding
  - packet header is short – efficient payload / packet length ratio
- efficient for long data exchanges
- possible to guarantee bandwidth and delays for connections

Disadvantages

- complex implementation

X.25, Frame Relay, ATM switches apply this method

Addressing

Unicast

- only one destination node

Multicast

- group of destination nodes
- all of them should obtain the messages

Anycast

- group of destination nodes
- one of them should obtain the messages

Broadcast

- every node in the network should obtain the messages

The sender is always distinguished by its unicast address

Fragmentation & Grouping

Fragmentation

- Every network and link limits max. message size
- Too big message must be fragmented
- Recipient defragments the message

Grouping

- Messages can be grouped to optimise communication cost or time
  - e.g. telephone dial-up connections
  - e.g. satellite links between ground stations
- Sender groups the messages
- Recipient regroups them

Network Classifications

By coverage

- WAN – Wide Area Network
- MAN – Metropolitan Area Network
- LAN – Local Area Network
- PAN – Personal Area Network

By types of communication medium

- wireless – radio, optical, acoustic
- wired – optical, electrical

By mobility

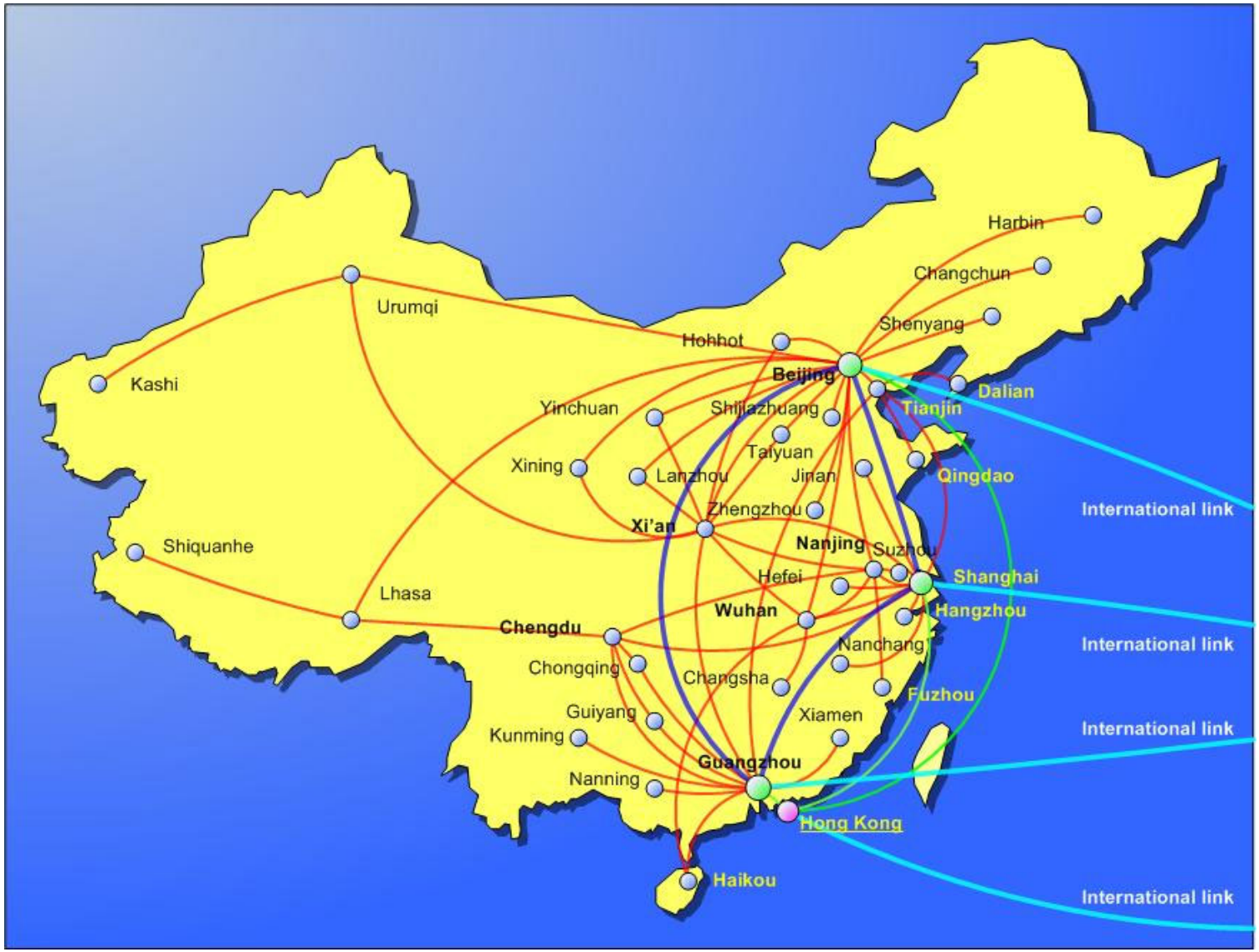
- fixed
- mobile

By topology

- star
- bus
- ring
- mesh
- tree

- Nanoscale
- NFC – Near-field
- BAN – Body
- PAN – Personal
- NAN – Near-me
- LAN – Local
  - HAN – Home
  - SAN – Storage
  - WLAN – Wireless
- CAN – Campus
- Backbone
- MAN – Metropolitan
- WAN – Wide
- IAN – Cloud (Internet area network)
- Internet
- Interplanetary Internet

WAN example: ChinaNet



Source: www.ctamericas.com/resource/chinanet-network-map/chinanet-network-map-2

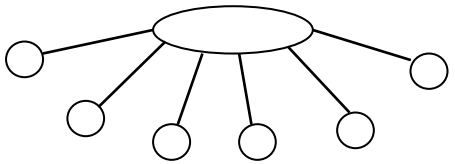
Topology

Distinguish!

- Physical (tubes) topologies
- **Signal topologies**
- Logical topologies

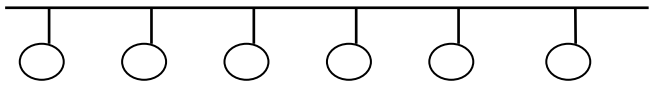
Star

- Size limited by efficiency of the main node
- Easy implementation and management
- Reliability of the main node!
- Time consuming broadcast



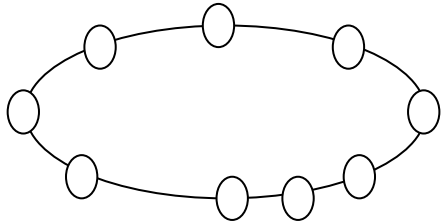
Bus

- Network size limited by the bus throughput
- Broadcast is very fast



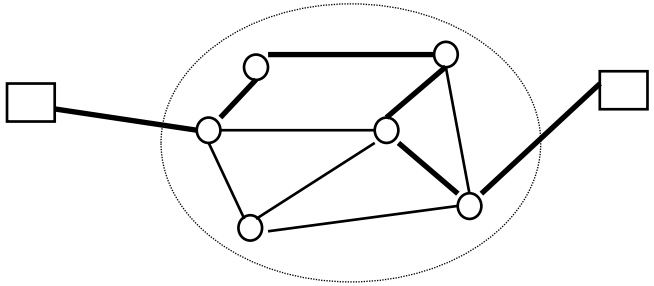
Ring – Nodes retransmit a received stream of bits

- Congestion resistant
- Easy management
- Sensible for a node failure



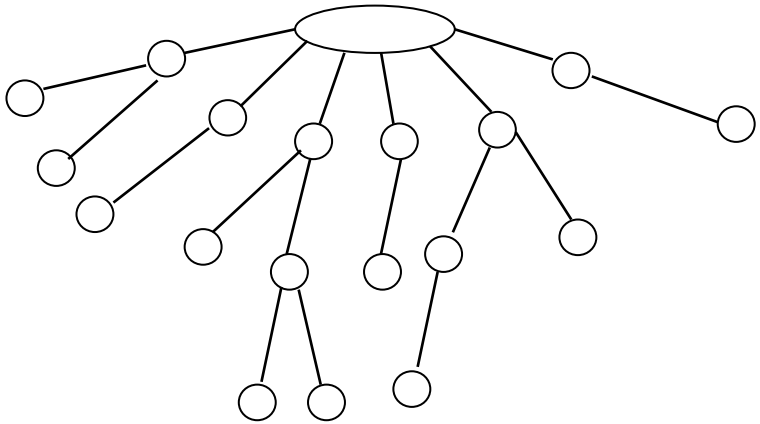
Mesh

- Good reliability
- Possibility of load balancing – for congestion reduction
- Routing problems



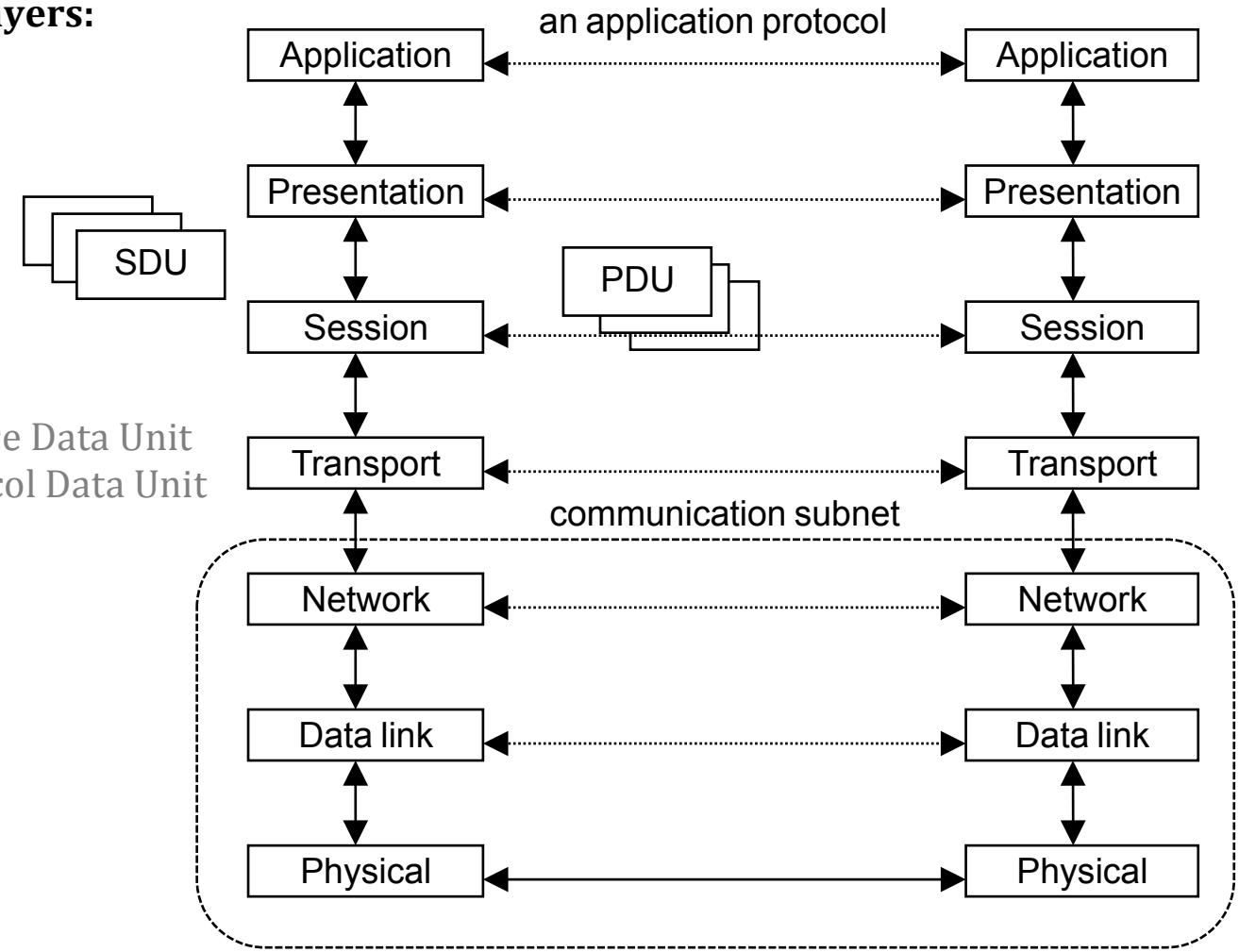
Tree – Hierarchical distribution of transmission control

- Relatively easy management
- Risk of root node congestion



ISO 7498, Open Systems Interconnection Reference Model

7 protocol layers:



SDU – Service Data Unit
PDU –Protocol Data Unit

L4-7 messages
L3 packets
L2 frames
L1 signals

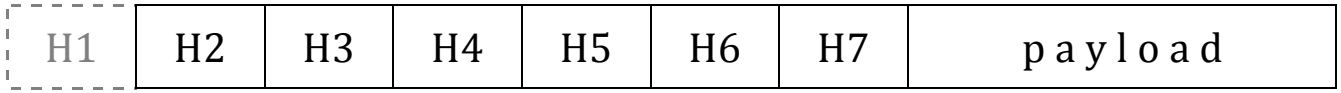
OSI defines:

- Functionality of communication protocols for every layer
- Rules of naming, description and co-operation between layers

OSI does not define:

- Any implementation aspects

Headers encapsulation:



Examples of ISO protocols and not ISO:

L7 FTAM, DTP, X.400, X.500, Virtual Terminal
L6 ISO Presentation Protocol
L5 ISO Session Protocol
L4 ISO TP4, TCP, UDP
L3 ISO Network Protocol, IPX, IP
L2 HDLC, Ethernet, Wi-Fi
L1 RS-232, RS-485

Protocol Functionalities

1. Physical Layer

- mechanical, electrical details
- coding, signals

2. Data link Layer

- bit, frame synchronization
- bit error detection/correction
- control of data flow

3. Network Layer

- node addressing
- multiplexing of higher layer data streams
- fragmentation, defragmentation
- grouping, regrouping
- network and users administration
- error detection/correction
- control flow

4. Transport Layer

- transport addressing
- connection quality negotiation
- fragmentation, defragmentation
- grouping, regrouping
- error detection/correction, control flow

5. Session Layer

- synchronization points
- activity management

6. Presentation Layer

- data context negotiation
- data translation: host-network representation
- compression, ciphering

7. Application Layer

- email, file transfer
- distributed transactions
- directory services
- …

TCP/IP Reference Model

<table>
<tr><th>TCP/IP model</th><th>ISO model</th><th colspan="2">Example protocols</th><th></th></tr>
<tr><td rowspan="3">Application</td><td>L7</td><td>NFS</td><td rowspan="3">Telnet, FTP, SMTP, DNS, …</td><td rowspan="3">user processes</td></tr>
<tr><td>L6</td><td>XDR</td></tr>
<tr><td>L5</td><td>RTP</td></tr>
<tr><td>Transport</td><td>L4</td><td colspan="2">TCP, UDP, …</td><td rowspan="2">kernel modules</td></tr>
<tr><td>Internet</td><td>L3</td><td colspan="2">IP, ICMP, RIP, …</td></tr>
<tr><td>Network Interface</td><td>L1, L2</td><td colspan="2">Ethernet, PPP, Wi-Fi, …</td><td>hardware drivers</td></tr>
</table>

TCP/IP is a shortcut for a bunch of related protocols

Network devices

L1 ÷ L7	gateway	
L1 ÷ L3	router	(intermediate system – in ISO standards) (gateway – in many IETF documents)
L1, L2	bridge	– can translate a frames of different L2 protocols
L1	hub	_ can be passive or active
L1	signal amplifier	
L1	cross-panel	
?	switch:	

- layer 2 switch
- layer 3 switch
- layer 4 switch
- layer 7 switch

– layer X address determines the output

Layer 2 switch – process and forward data at the data link layer

Layer 3 switch

- can be a hardware switching router (CISCO definition)
- can by just a router
- can combine switching in layer 2 and 3

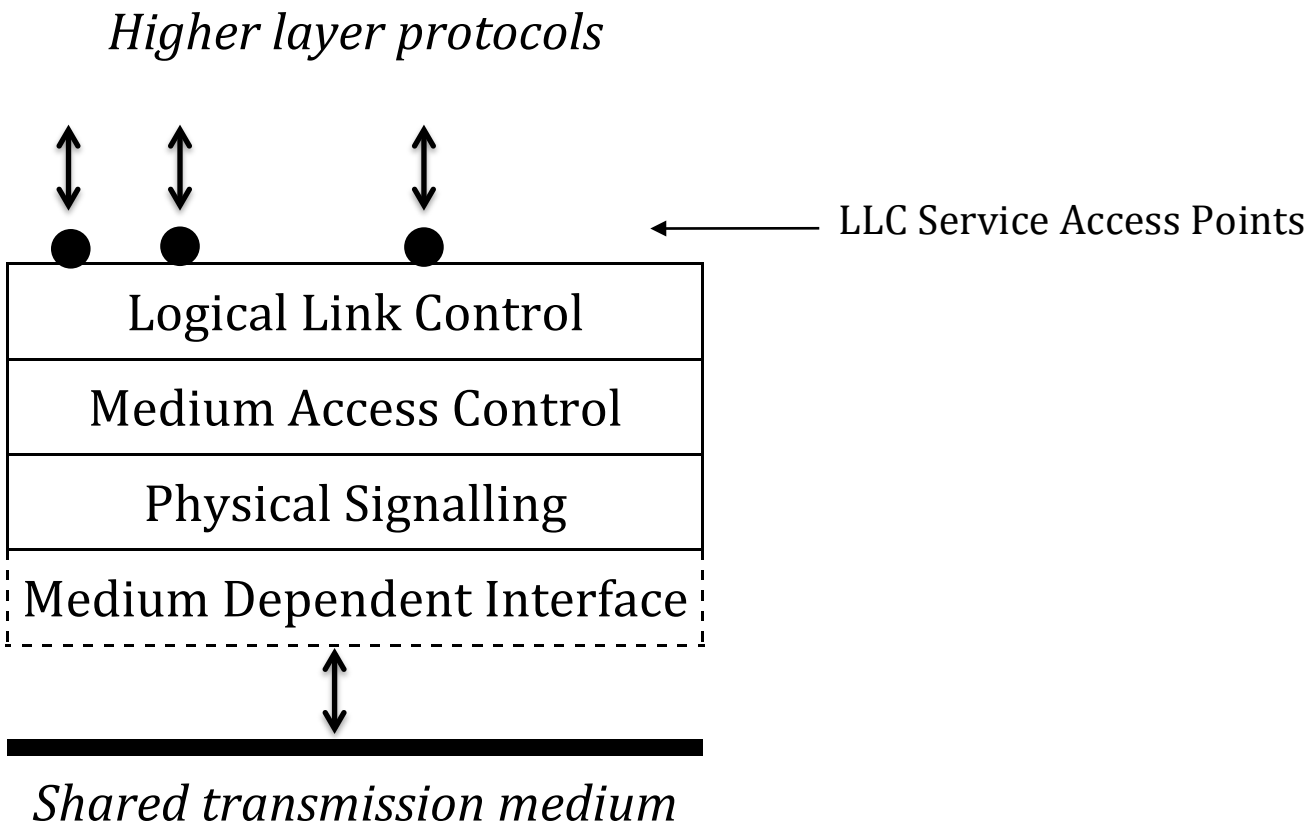
Layer 4 switch can

- perform network address translation
- perform load distribution – depending on layer 4 address
- combine a firewall
- support VPNs

Layer 7 switch can

- perform load distribution – depending on layer 7 address
  based on uniform resource locators (URLs)
- support WWW caching
- support content delivery network

IEEE 802.1, LAN/MAN Reference Model

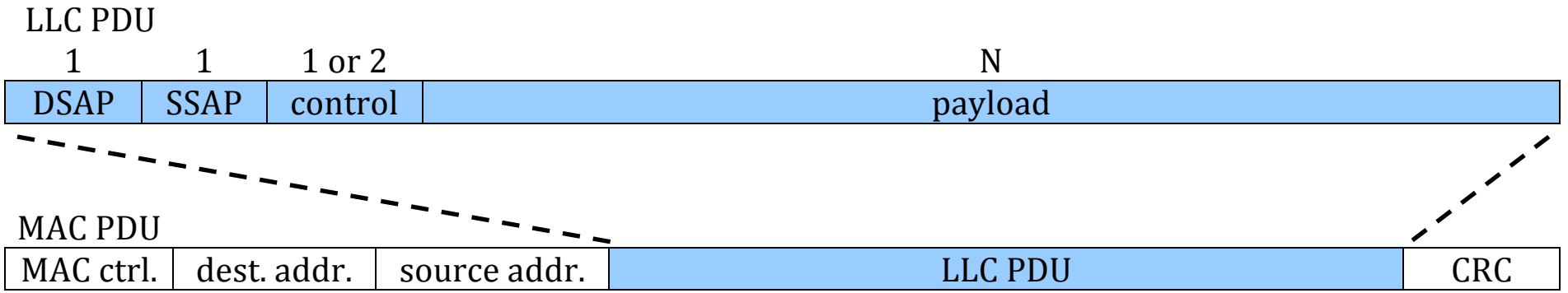


Logical Link Control Protocol

- Common interface independent from different MAC protocols

  Medium Access Control

- Data streams multiplexing
- Control flow for every SAP *Service Access Points*
- Duplicated and lost frames treatment



Summary

- Communication issues
  - Communication protocol
  - Connection-full & connectionless communication
  - Simplex, half-duplex, full-duplex links
  - Link rate, bandwidth, throughput and goodput
  - Switching
    - Datagram packet switching
    - Virtual circuit packet switching
  - Types of addresses
  - Message fragmentation & grouping
- Network classifications
  - by coverage area
  - by topology
- Network **r**eference **m**odels
  - ISO OSI RM
  - TCP/IP RM
  - IEEE LAN/MAN RM

Questions

1. What is a communication protocol?
2. Why throughput can be lower than link rate of the same communication channel?
3. Can we set a full duplex communication over a multi-point link?
4. What means circuit switching?
5. What means packet switching?
6. In which case packet switching is more efficient than message switching?
7. What are virtual circuits in packet networks?
8. What is the meaning of unicast, mulicast, anycast and broadcast?
9. What is the reason for packet fragmentation?
10. What is the reason for packet grouping?
11. Characterize different network topologies.
12. What is the topology of a simple broadcasting radio network?
13. List the principal functions of all OSI ISO protocol layers.
14. Characterize the layers defined by the TCP/IP protocol stack model.
15. What is the difference between the 2nd layer switch and the 3rd layer switch?
16. In which ISO OSI layers do the devices: hub, bridge, router, switch, gateway, firewall work?
17. Characterize Local & Metropolitan Area Network Reference Model defined by IEEE.
18. What are the functions of Logical Link Control layer?
19. What are the functions of Medium Access Control layer?