Review (2)

COMP90007

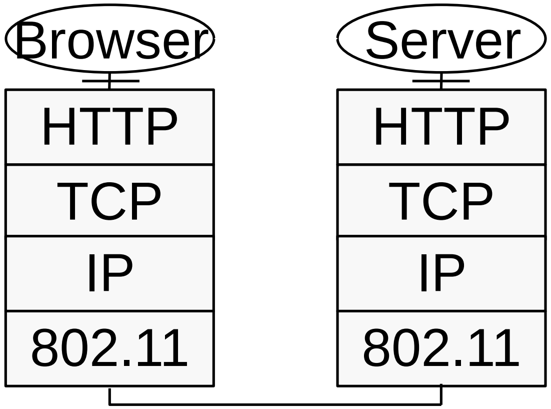
Internet Technologies

Hybrid Model

- The hybrid reference model used in this semester

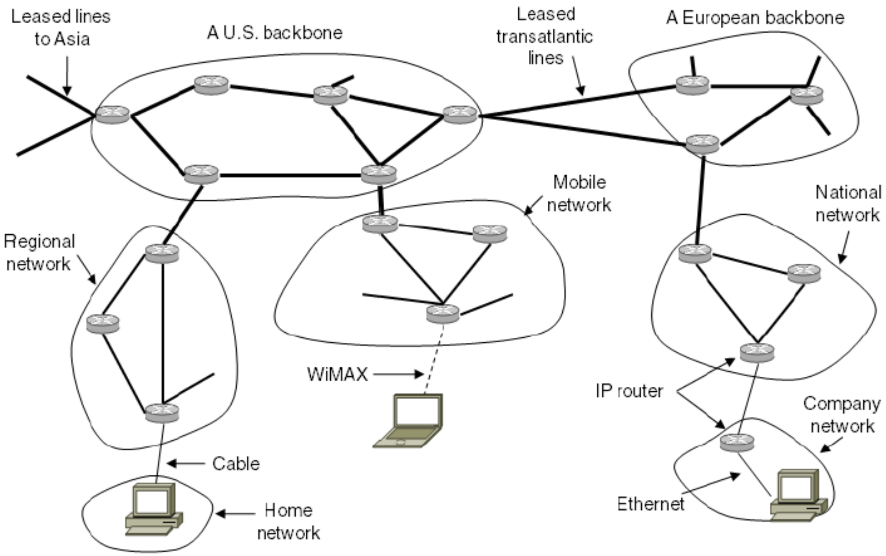
5	Application layer
4	Transport layer
3	Network layer
2	Data link layer
1	Physical layer

A typical network scenario



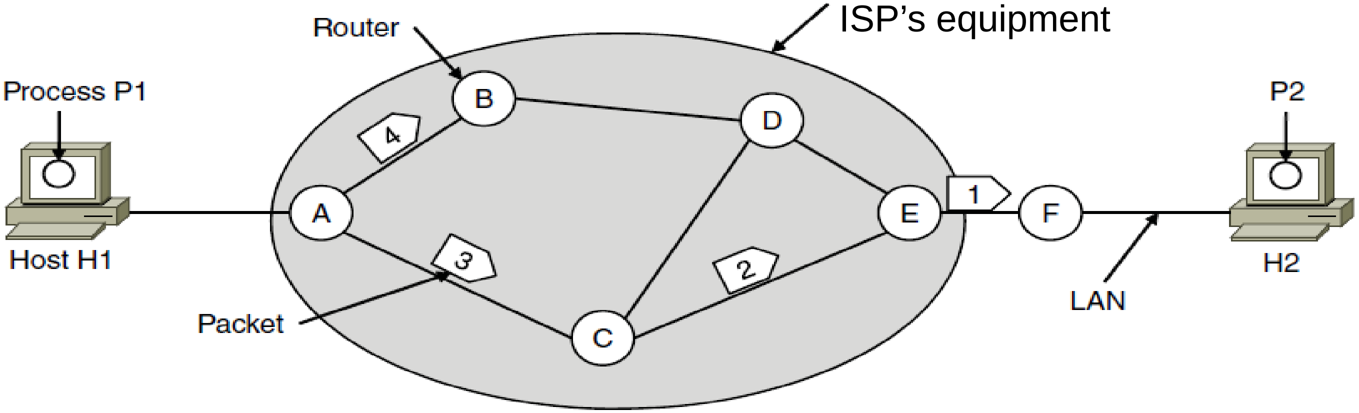
Network Layer: Internet Protocol (IP)

- Internet is an interconnected collection of many networks or Autonomous Systems that is held together by the IP protocol
- Provides a **best-effort** service to **route datagrams** from source host to destination host



Routing within a Datagram Subnet

- **Post office model**: packets are routed individually based on destination addresses in them
- Packets can take different paths
- E.g., P1 sends a long message to P2



A’s table (initially)

Dest.	Line
A	⊠
B	B
C	C
D	B
E	C
F	C

A’s table (later)

A	⊠
B	B
C	C
D	B
E	B
F	B

C’s Table

A	A
B	A
C	⊠
D	E
E	E
F	E

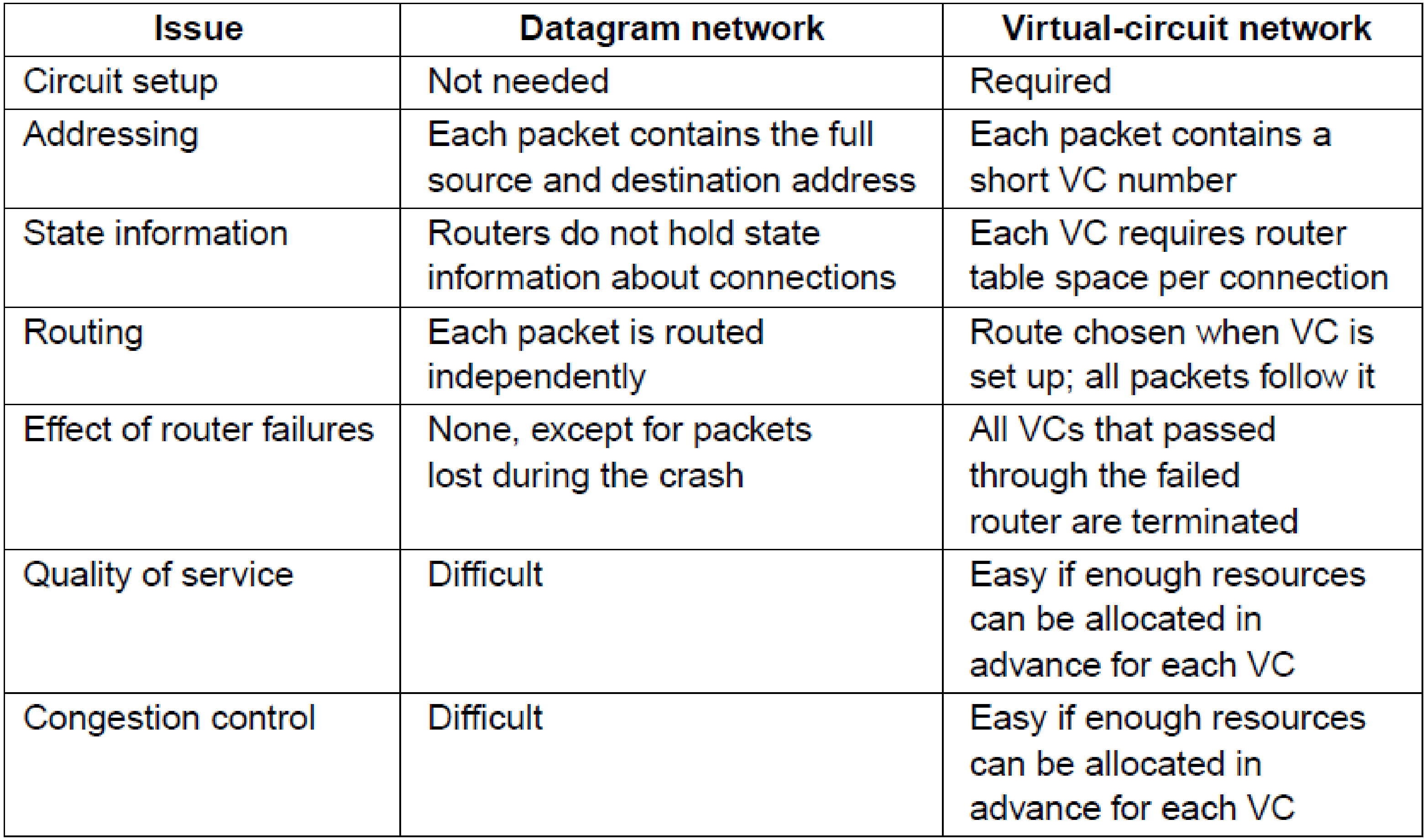
E’s Table

A	C
B	D
C	C
D	D
E	⊠
F	F

Routing table (can be fixed, can change over time)

Routing algorithm – manages the routing table

Differences in Virtual-Circuit and Datagram Subnets



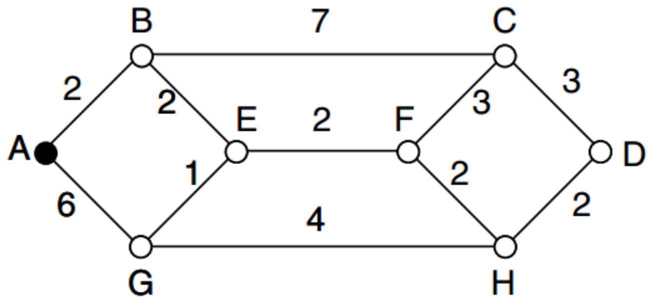
Issue	Datagram network	Virtual-circuit network
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Routing Algorithms

- Non-adaptive
  - Shortest path routing
  - Flooding
- Adaptive
  - Distance vector routing
  - Link state routing
- Hierarchical routing
- Broadcasting routing
- Multicasting routing

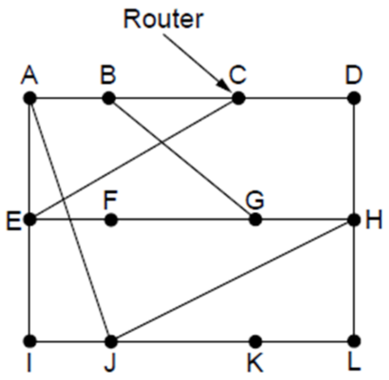
Shortest Path Routing

- A non-adaptive algorithm
- Shortest path can be determined by building a graph with each node representing a router, and each arc representing a communication link
- To choose a path between 2 routers, the algorithm finds the shortest path between them on the graph
- Metrics: number of hops, distance, delay etc.

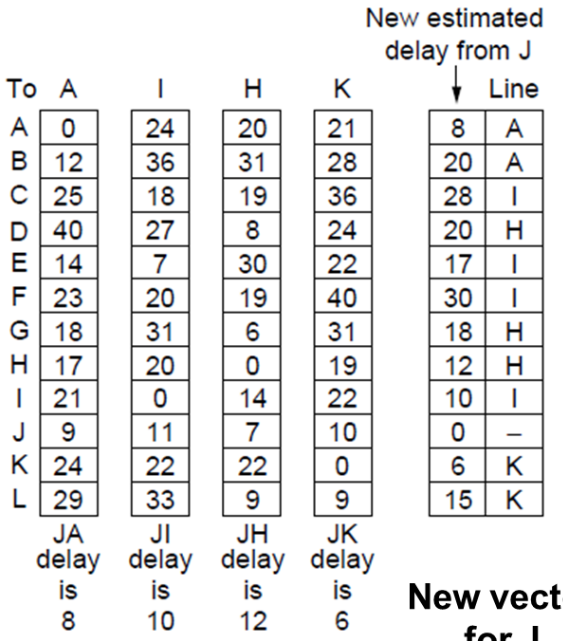


Distance Vector Routing

- Each router maintains a table which includes the best known distance to each destination and which line to use to get there.
- Global information shared locally.



Network



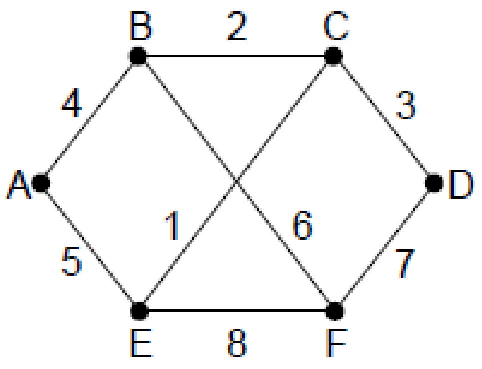
To	A	I	H	K	New estimated delay from J	Line
A	0	24	20	21	8	A
B	12	36	31	28	20	A
C	25	18	19	36	28	I
D	40	27	8	24	20	H
E	14	7	30	22	17	I
F	23	20	19	40	30	I
G	18	31	6	31	18	H
H	17	20	0	19	12	H
I	21	0	14	22	10	I
J	9	11	7	10	0	–
K	24	22	22	0	6	K
L	29	33	9	9	15	K
	JA delay is 8	JI delay is 10	JH delay is 12	JK delay is 6		

New vector for J

Vectors received at J from neighbors A, I, H and K

Link State Routing

- An alternative to distance vector: **too long to converge** after the network topology changed
- Widely used in the Internet, e.g. OSPF
- More computation but simpler dynamics
- Local information shared globally using flooding



Network

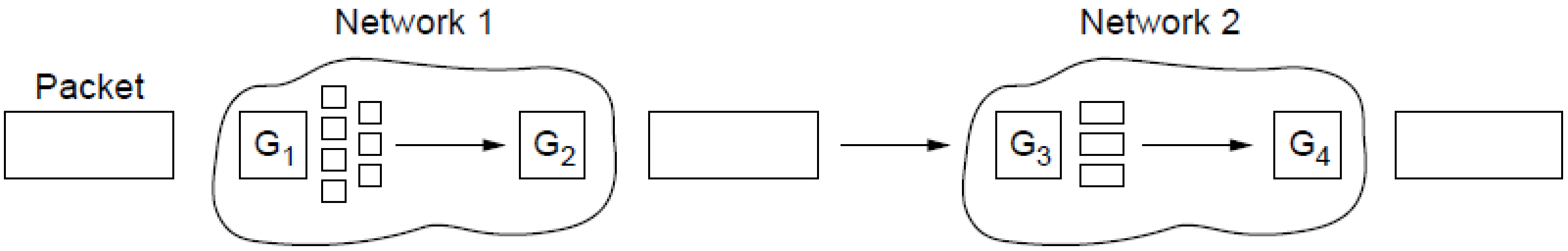
Link State Packets

A		B		C		D		E		F	
Seq.		Seq.		Seq.		Seq.		Seq.		Seq.	
Age		Age		Age		Age		Age		Age	
B	4	A	4	B	2	C	3	A	5	B	6
E	5	C	2	D	3	F	7	C	1	D	7
		F	6	E	1			F	8	E	8

LSP for each node

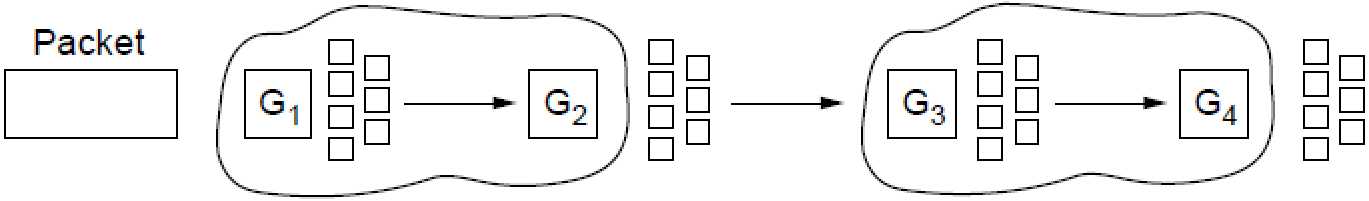
Types of Fragmentation

- Large packets need to be routed through a network whose maximum packet size is too small.
- **Solution: Fragmentation and Reassembly**.



G_1 fragments G_2 reassembles G_3 fragments G_4 reassembles

a) Transparent – packets fragmented / reassembled in each network.
Route constrained, more work



G_1 fragments

… destination
will reassemble

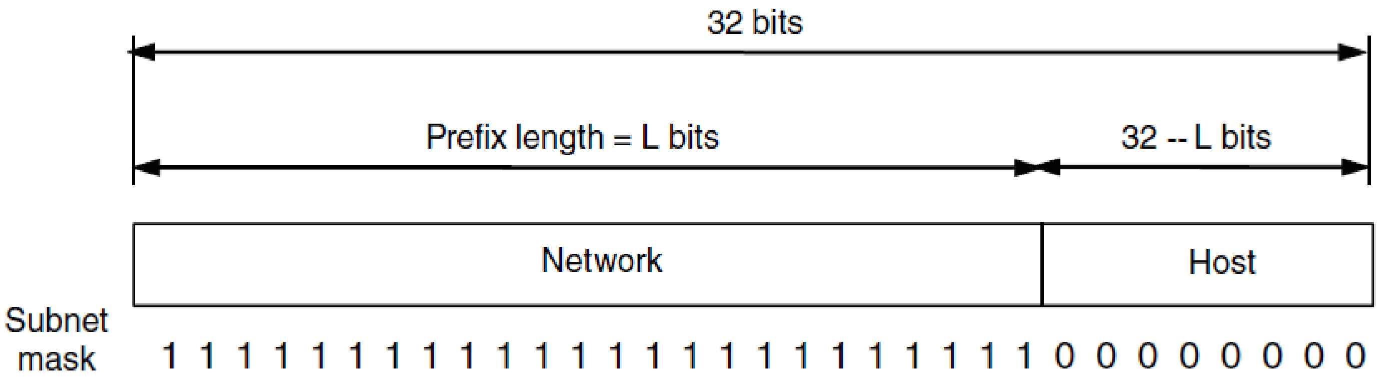
- **b) Non-transparent** – fragments are reassembled at destination.
Less work (IP works this way) – packet number, byte offset, end of packet flag

IP Addresses

- network portion + host portion
- **Prefix:** determined by the network portion, all hosts on a single network has the same network portion.

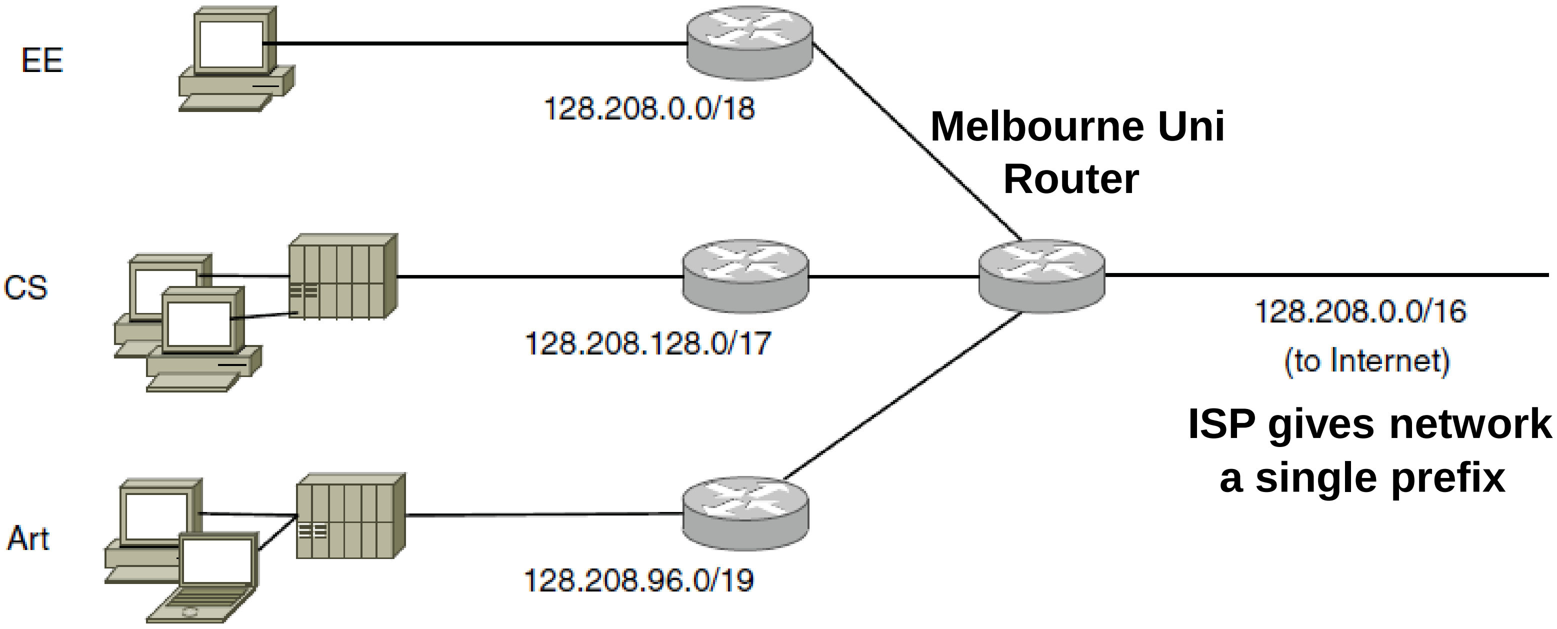
  prefix is written as: lowest address/bit-length

  18.2.31.0/24, 18.2.0.0/16
- **Subnet mask**: all 1s in the network portion
- **Extract** prefix: ANDed the IP address with the subnet mask



Subnets

- Subnetting allows networks to be split into several parts for internal uses whilst acting like a single network for external use
- Looks like a single prefix outside the network



Melbourne Uni Router

ISP gives network a single prefix

Network is divides into subnets internally

Data Link Layer

- Functions of the data link layer:
  1. Provide a well-defined service interface to network layer
  2. Handling transmission errors
  3. Data flow regulation
- Primary task:
  - Take **packets from network layer**, and encapsulate them **into frames** (containing a header, a payload, a trailer)

Framing Methods

- Framing methods:
  - Character (Byte) count
  - Flag bytes with byte stuffing
  - Start and end flags with bit stuffing
- Most data link protocols use a combination of character count and one other method

Error Control

- Ensuring that a garbled message by the physical layer is not considered as the original message by the receiver by adding check bits
- Error Control deals with
  - **Detecting** the error
  - **Correcting** the error
  - **Re-transmitting** lost frames
- Link layer deals with bit errors

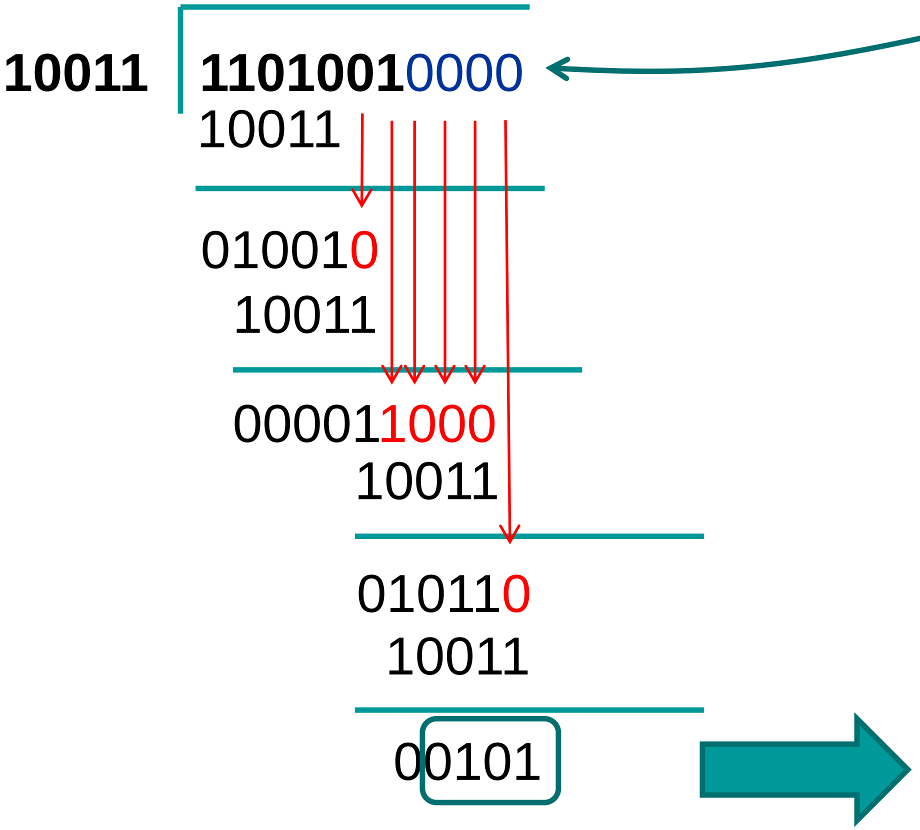
Error Detecting Codes

- More efficient in some transmission media – e.g. quality copper, where low error rates occur
- ***Parity*** (1 bit): XOR all the data bits and add the result as the check bit (Hamming distance=2)
- ***Checksum*** (16 bits): Add 16 bits of data and calculate 1's complement and add to the data as the check bits (Hamming distance=2)
- ***Cyclical Redundancy Check*** *(CRC)* – Use division by a k bits polynomial in base-2's representation (Standard 32-bit CRC: Hamming distance=4)

CRC Example

Data: **1101001** and G(x) = x^4+x+1 (**10011**)

5 bits polynomial add **4** bits as the checksum – so add 0000



```
10011 | 11010010000
        10011
        ------
        010010
          10011
          ------
          000011000
                10011
                ------
                010110
                  10011
                  ------
                  00101
```

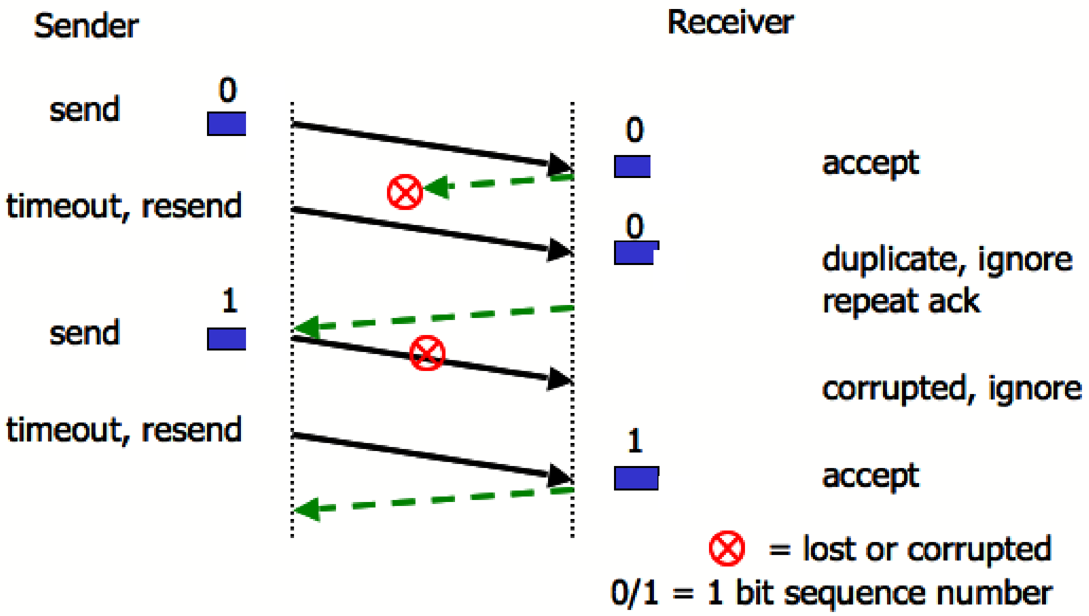
Data sent:
11010010101

Flow Control

- The **fast senders vs slow receivers problem requires a solution**
- Principles to control when sender can send next frame
  - **Feedback based flow control: ack**
    - **Stop and wait**
    - **Sliding window: go-back-N, selective repeat**

Stop and Wait Protocol

- Concept of ARQ (Automatic Repeat reQuest)
  - Ack and Timeout
- Stop and Wait
  - One bit Ack



Link Utilization in Stop and Wait Protocols

Principle of efficiency in communication is measured by **Link Utilization (U)**.

Let **B** be the **bit-rate** of the link and **L** the **length of the frame**,

T_f= Time needed to transmit a frame of length L,

T_p= Propagation delay of the channel,

T_a= Time for transmitting an Ack,

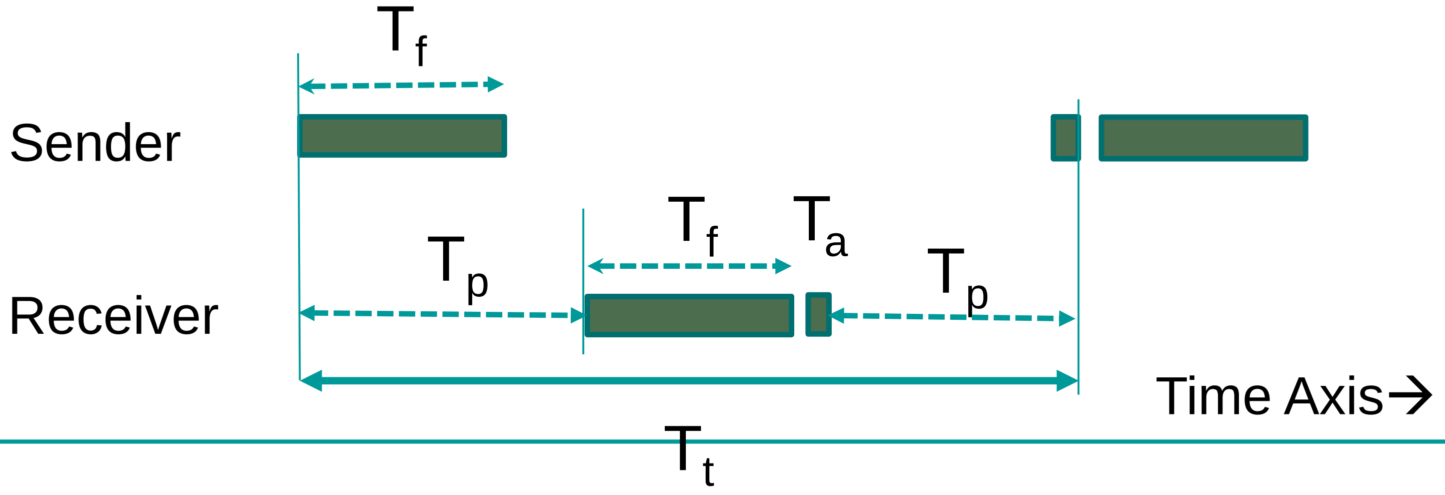
So we have $\mathbf{T_f = L/B}$. We can assume $\mathbf{T_a = 0}$. $\mathbf{T_t = T_f + 2T_p}$.

For example for a Link with B=1Mbps and T_p=50ms and frame size 10Kb:

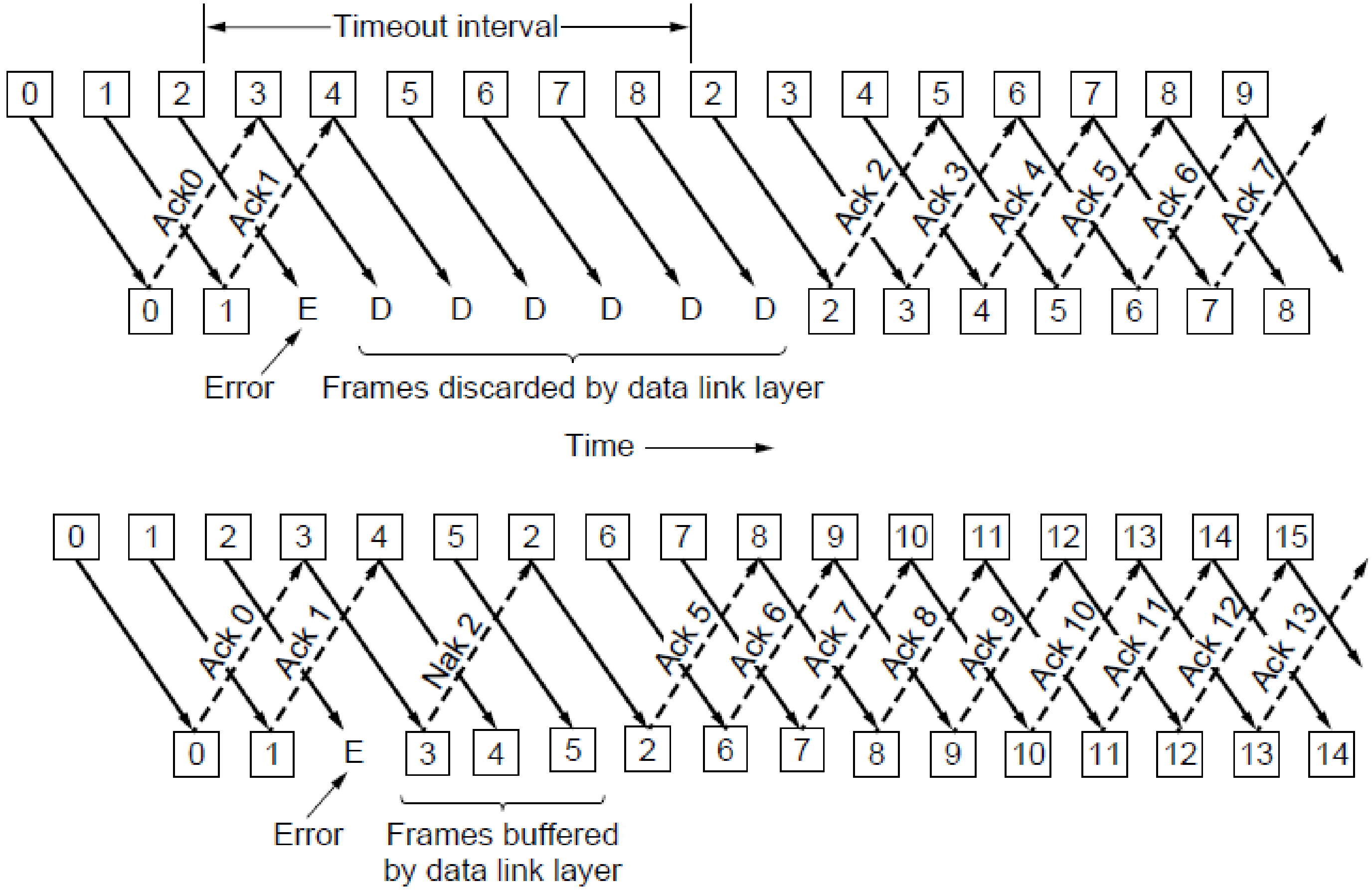
U= 10000/(10000+0.1* 10^6)=1/11;

U = (Time of transmitting a frame)/(Total time for the transfer) = T_f/T_t

We have $U = T_f / (T_f + 2T_p) = (L/B) / (L/B + 2T_p) = L/ (L+ 2T_p B)$.



Go-Back-N vs Selective Repeat



- Trade-off between efficient use of bandwidth and data link layer buffer space

Multiple Access Control

Medium Access Control (MAC) sub-layer is used to assist in resolving transmission conflicts

- Contention
  - ALOHA, Slotted ALOHA
  - Carrier Sense Multiple Access: 1-persistent, non-persistent, p-persistent, with collision detection
- Collision Free: bit map, binary countdown
- Limited Contention: adaptive tree walk
- MACA/MACAW (for Wireless LANs): RTS and CTS

Physical Layer

- Recall the layer hierarchy from network reference models
  - The physical layer is the lowest Layer in OSI model
  - The physical layer’s properties in TCP/IP model are in the “host-to-network” division.
- The physical layer is concerned with the mechanical, electrical and timing interfaces of the network
- Various physical media can be used to transmit data, but all of them are affected by a range of physical properties and hence have distinct differences
- How many different types of physical media can you think of?

Compare Transmission Medium

Wired: twisted pairs, coaxial cable, fibre optics …
Wireless: radio, microwave, infrared, satellite …

Comparison of the properties of wires and fibre:

Property	**Wires**	**Fibre**
Distance	Short (100s of m)	Long (tens of km)
Bandwidth	Moderate	Very High
Security	Easy to tap	Hard to tap
Cost	Inexpensive	More Expensive
Convenience	Easy to use	Harder to use

Data Communication using Signals

- Information is transmitted by varying a physical property e.g. voltage, current
- How to transform continuous signals into digital values? Sampling the amplitude values of the signal
- For a periodic function:

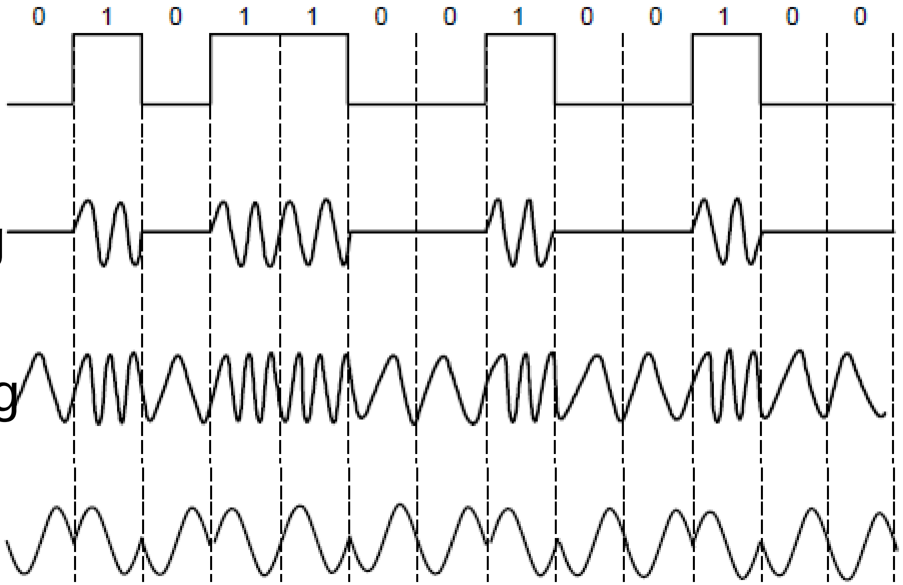
  e.g. Sine function: $c * \sin(a * t + b)$

  c: Amplitude, a/(2π):Frequency and b:Phase

  can change the behaviour of the function.

Modulation Types

- Modulating the amplitude, frequency/phase of a carrier signal sends bits in a (non-zero) frequency range



NRZ signal of bits

Amplitude shift keying

Frequency shift keying

Phase shift keying

Message Latency

- Latency is the time delay associated with sending a message over a link
- This is made of up two parts
    - Transmission delay
        - T-delay = Message in bits / Rate of transmission
        - = M/R seconds
    - Propagation delay
        - P-delay= length of the channel/ speed of signals
        - Length / Speed of signal (2/3 of speed of light for wire)
    - Latency = L = M/R + P-delay

Maximum Data Rate of a Channel

- Nyquist’s theorem relates the data rate to the bandwidth (B) and number of signal levels (V) (channel **without noise**):

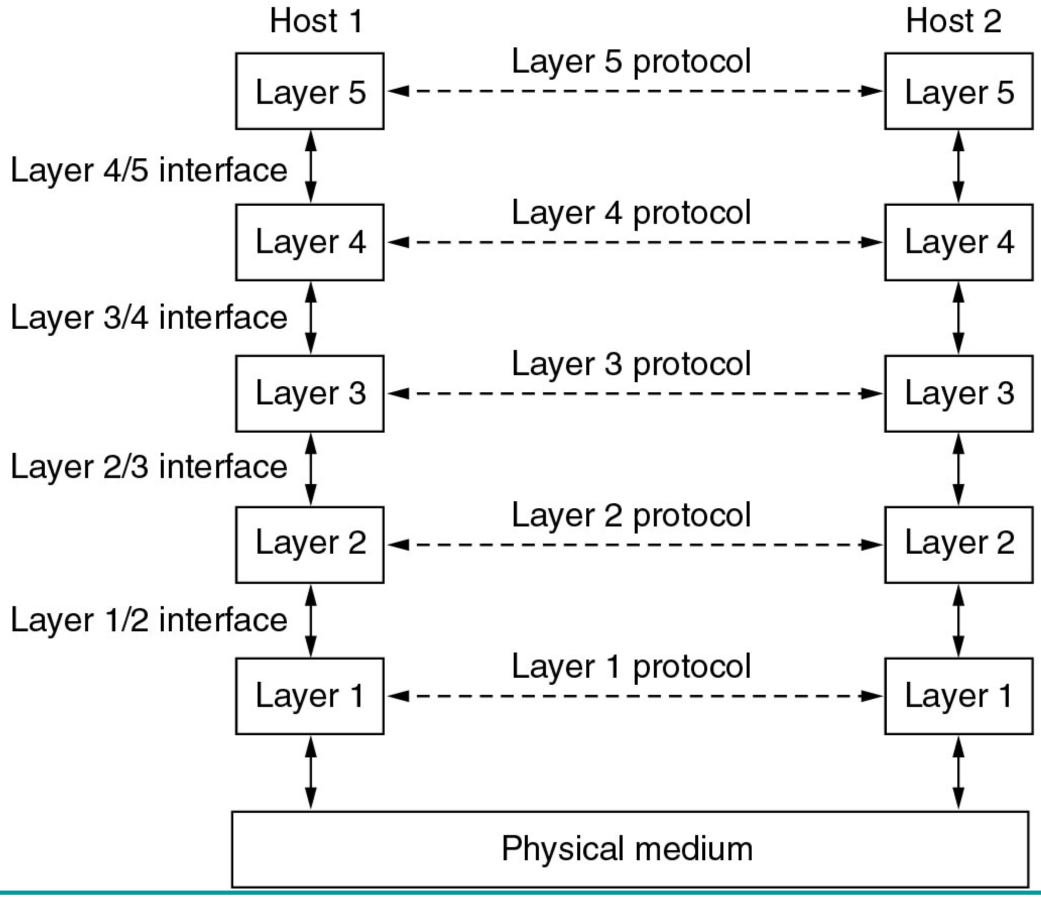
$$\boxed{\text{Max. data rate} = 2B\ \log_2 V \text{ bits/sec}}$$

- Shannon's theorem relates the data rate to the bandwidth (B) and signal strength (S) relative to the **noise** (N):

$$\boxed{\text{Max. data rate} = B\ \log_2(1 + S/N) \text{ bits/sec}}$$

Network Software: Protocol Hierarchies

- Layers, protocols and interfaces



Consider the network as a stack of **layers**

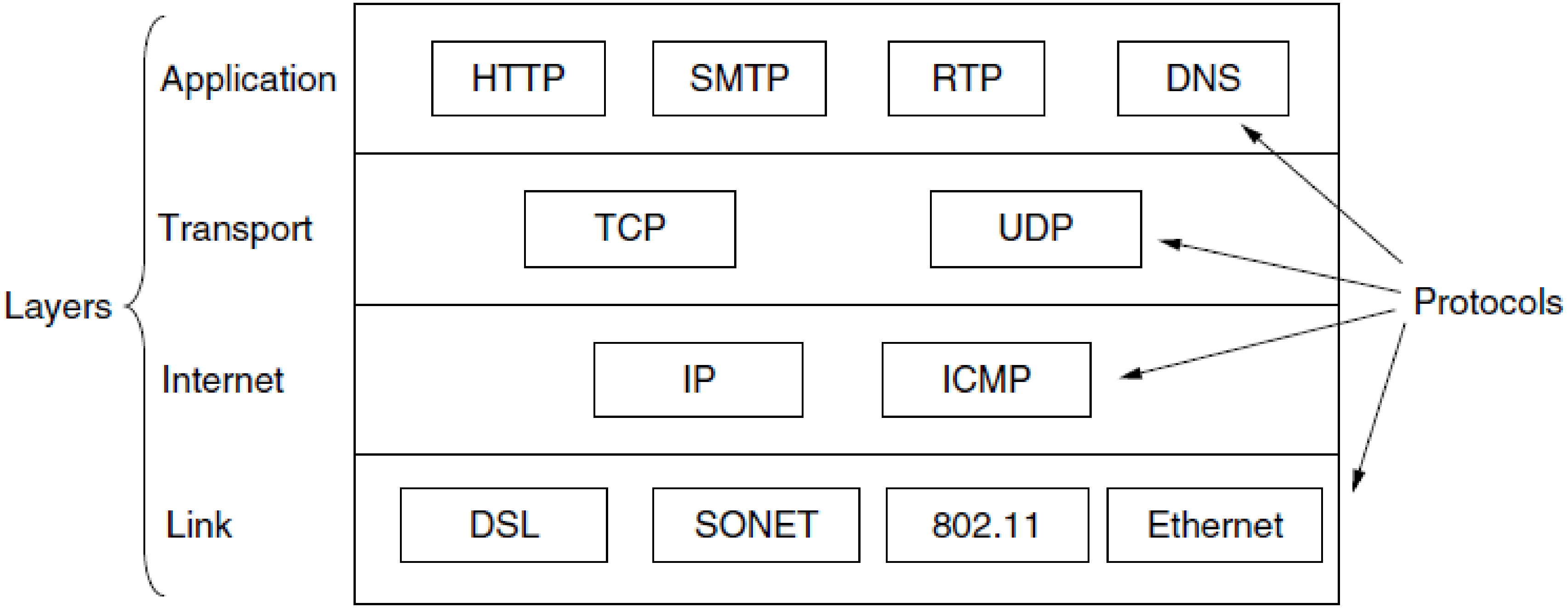
Each layer offers **services** to layers above it through **interface**

Protocol is an agreement between the communicating parties on how communication is to proceed

OSI: Layer Division Principles

1. A layer should be created where a different **abstraction** is needed
2. Each layer should **perform a well defined function**
3. The function of each layer should be chosen with a view toward defining **internationally standardised protocols**
4. The layer boundaries should be chosen to **minimise the information flow across the interfaces**
5. 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

TCP/IP: Protocols


Layers
Application
Transport
Internet
Link
HTTP
SMTP
RTP
DNS
TCP
UDP
IP
ICMP
DSL
SONET
802.11
Ethernet
Protocols