CSC 524

Computer Networks
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Lecture 6
11-12/03/2013

Agenda

1. Introduction
2. Design Issues
3. Routing Algorithms
4. Congestion Control
5. Internet Protocol
6. Summary & Discussion

Introduction

- Lowest layer for end-to-end
- concerned with getting packets from the source all the way to the destination
- may require making many hops at intermediate routers along the way
- choose routes to avoid overloading some of the communication lines and routers while leaving others idle

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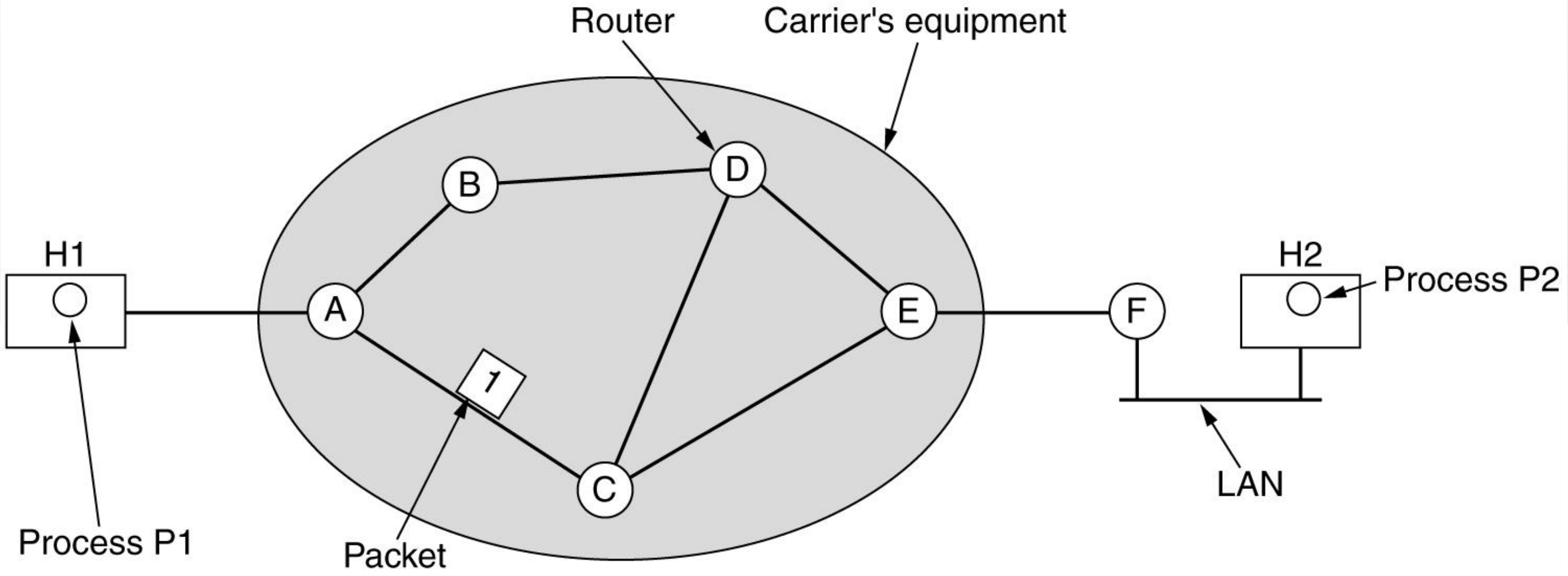
Design Issues

- Store-and-Forward Packet Switching

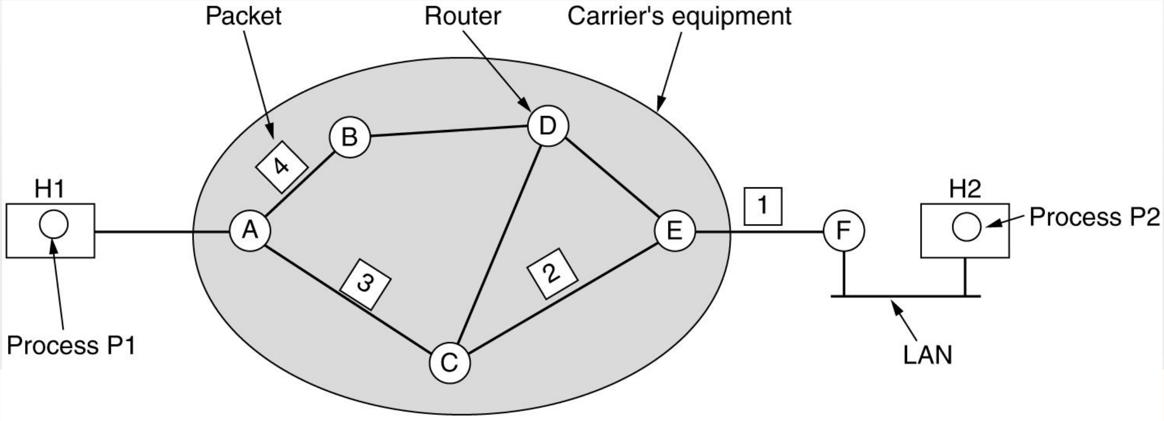


Design Issues

- Services to Transport Layer
  - The services should be independent of the router technology.
  - The transport layer should be shielded from the number, type, and topology of the routers present.
  - The network addresses made available to the transport layer should use a uniform numbering plan, even across LANs and WANs.
- Connectionless vs. Connection-oriented

Design Issues

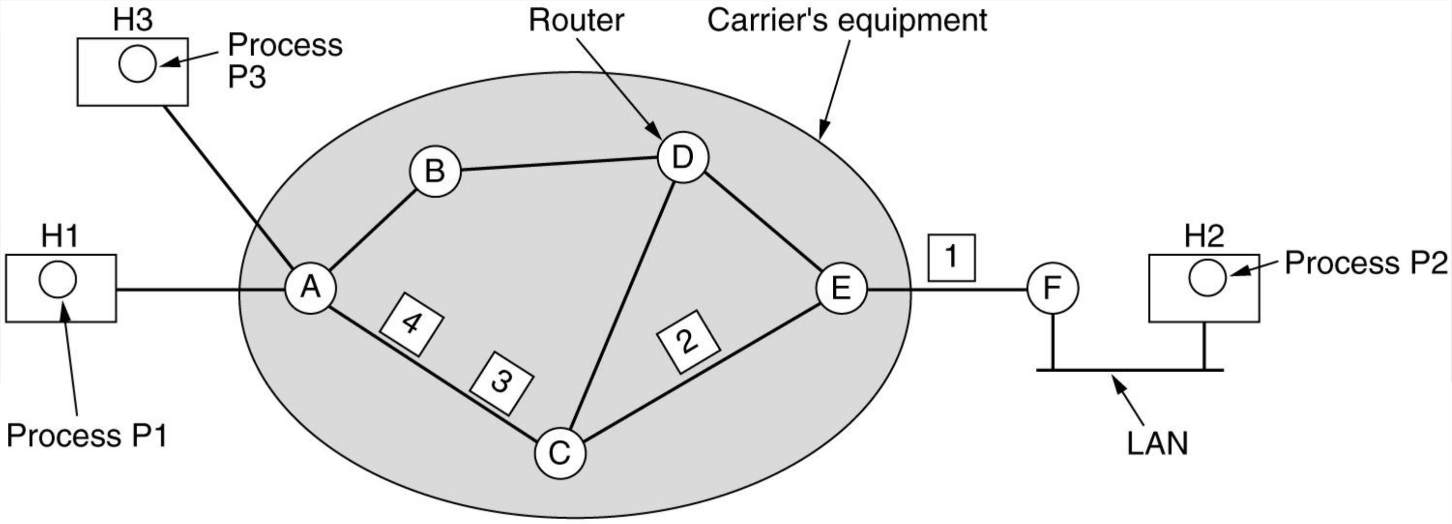
- Connectionless
  - Datagrams: each packet is sent independently



Dest.	A's table initially (Line)	A's table later (Line)	C's table (Line)	E's table (Line)
A	–	–	A	C
B	B	B	A	D
C	C	C	–	C
D	B	B	D	D
E	C	B	E	–
F	C	B	E	F

Design Issues

- Connection-oriented
  - Virtual Circuit (VC) with connection identifier !



A's table In		A's table Out		C's table				E's table			
H1	1	C	1	A	1	E	1	C	1	F	1
H3	1	C	2	A	2	E	2	C	2	F	2

Design Issues

Issue	Datagram subnet	Virtual-circuit subnet
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

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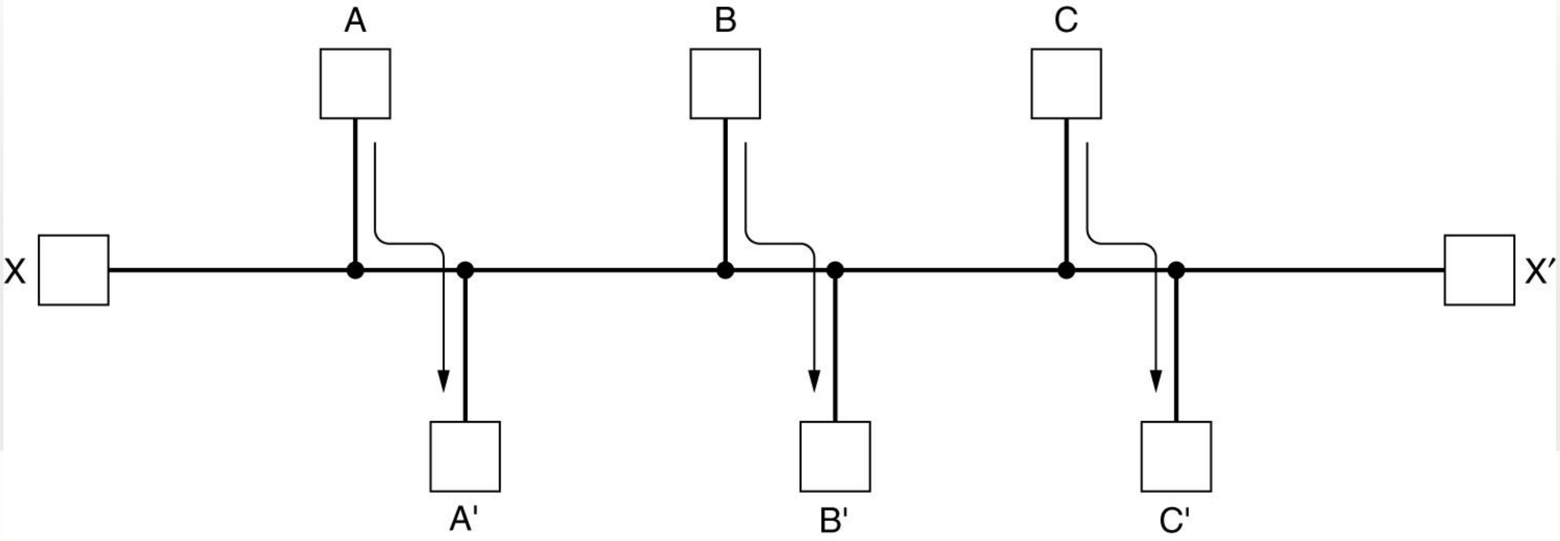
Routing algorithms

- A packet comes in.. The router has multiple output lines.. Which one to choose?
  - Datagrams: decision is made for every packet
  - VCs: decision is made once (session routing)
- correctness, simplicity, robustness, stability, fairness, and optimality.

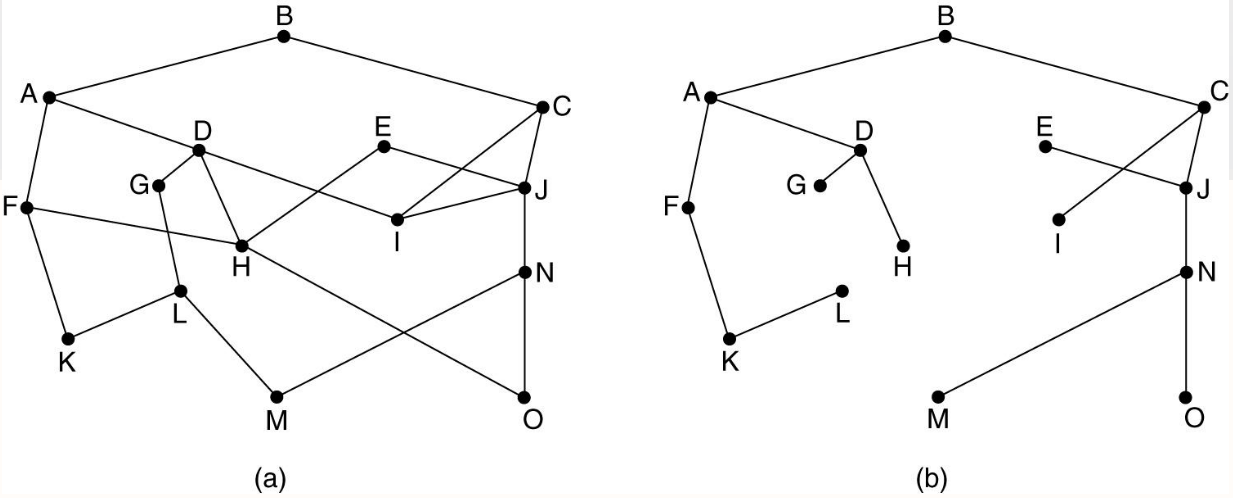
Routing algorithms

- Optimality vs. fairness



- Static vs. dynamic (adaptive)

- Optimality Principle
  - if router J is on the optimal path from router I to router K, then the optimal path from J to K also falls along the same route

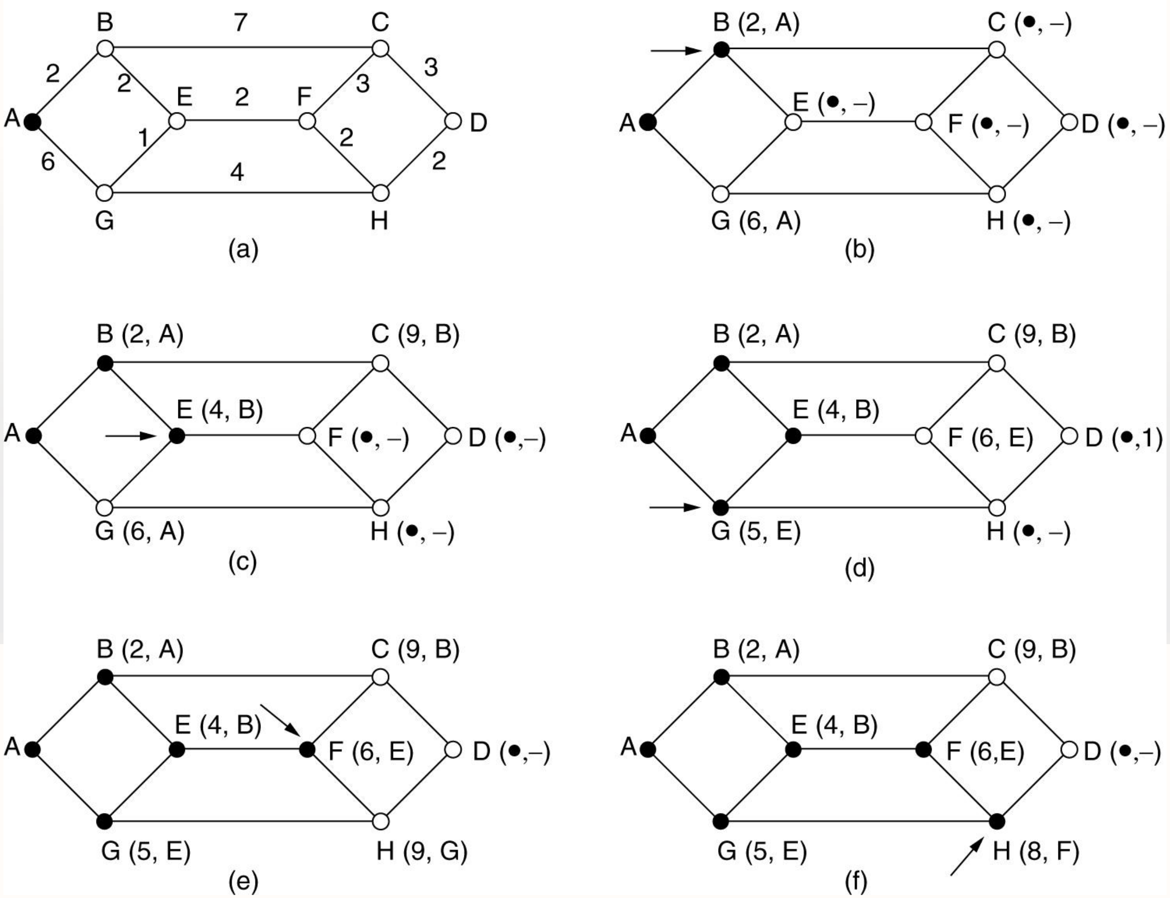


(a) A subnet. (b) A sink tree for router B.

Routing algorithms

- Shortest Path Routing (STATIC)
  - build a graph of the subnet, with each node of the graph representing a router and each arc of the graph representing a communication line
- From one node to another, choose the shortest path !
- Shortest ? # of hops, distance, queuing delay..etc
- labels on the arcs could be computed as a function of the distance, bandwidth, average traffic, communication cost, mean queue length, measured delay, and other factors

Routing algorithms



The first 5 steps used in computing the shortest path from A to D.
The arrows indicate the working node.

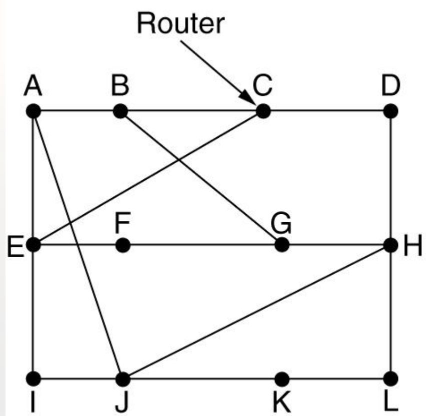
Routing algorithms

- Flooding
  - in which every incoming packet is sent out on every outgoing line except the one it arrived on.
  - vast numbers of duplicate packets
    - hop counter contained in the header of each packet, which is decremented at each hop
      - Zero ? Drop the packet
    - Keep track of flooded packets ! (seq. #)

Routing algorithms

- Distance Vector Routing (DYNAMIC)
  - operate by having each router maintain a table (i.e, a vector) giving the best known distance to each destination and which line to use to get there. These tables are updated by exchanging information with the neighbors
  - It has a problem !! It converges slowely

Routing algorithms



(a)

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 routing table for J	

Vectors received from J's four neighbors

(b)

Routing algorithms

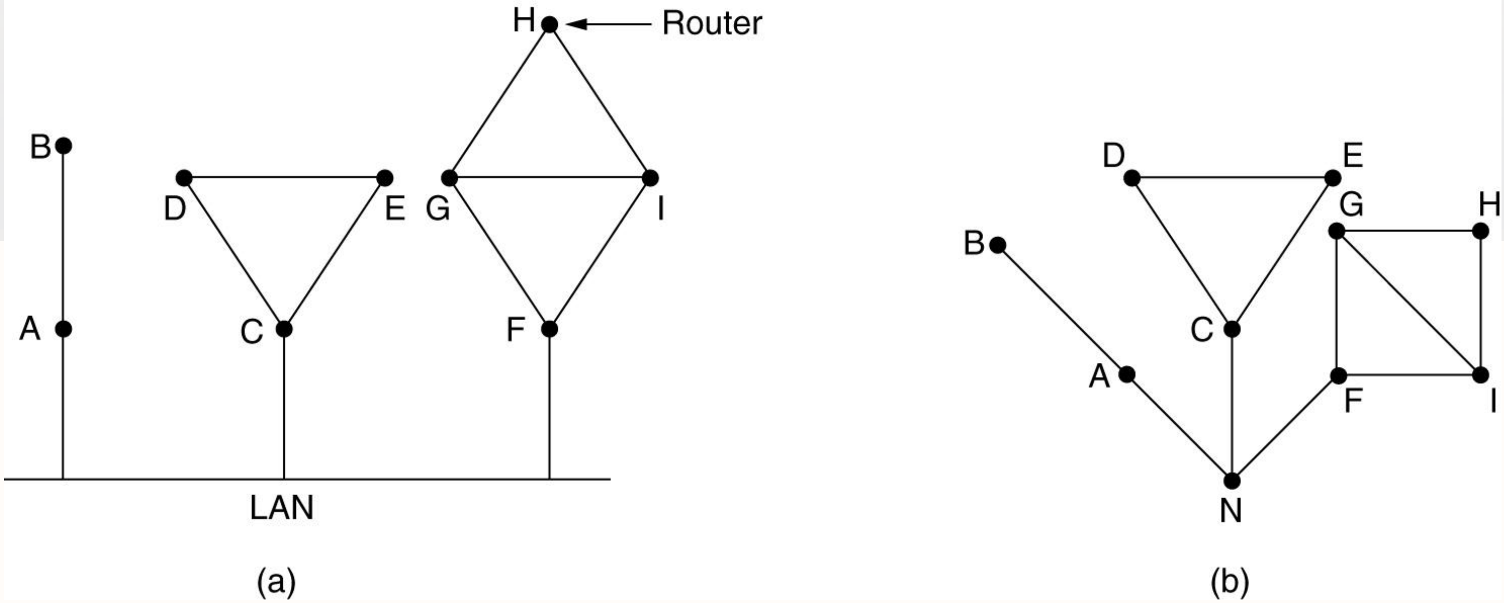
- Link State Routing (DYNAMIC)
  - Distance vector routing was used in the ARPANET until 1979
    - Then replaced by Link State Routing
    - Why ? Delay metric only ! Also too slow convergance

Routing algorithms

- Each router must do the following:
  - Discover its neighbors and learn their network addresses.
  - Measure the delay or cost to each of its neighbors.
  - Construct a packet telling all it has just learned.
  - Send this packet to all other routers.
  - Compute the shortest path to every other router.

Routing algorithms

- Learning about neighbors ?
  - HELLO msg.. Others reply !
  - LAN is considered as node

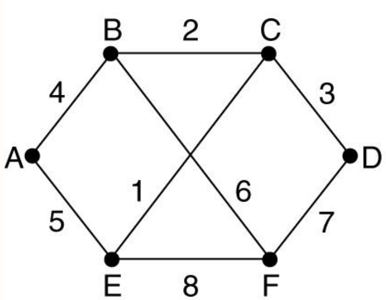


Routing algorithms

- Estimating cost ?
  - Send a packet
  - Other routers replay ASAP
  - Measure the time/2
- Load ?
- Other factors ?

Routing algorithms

- Distributing state packets
  - Flooding .. Seq # for control
  - Age is set and decremented



(a)

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

(b)

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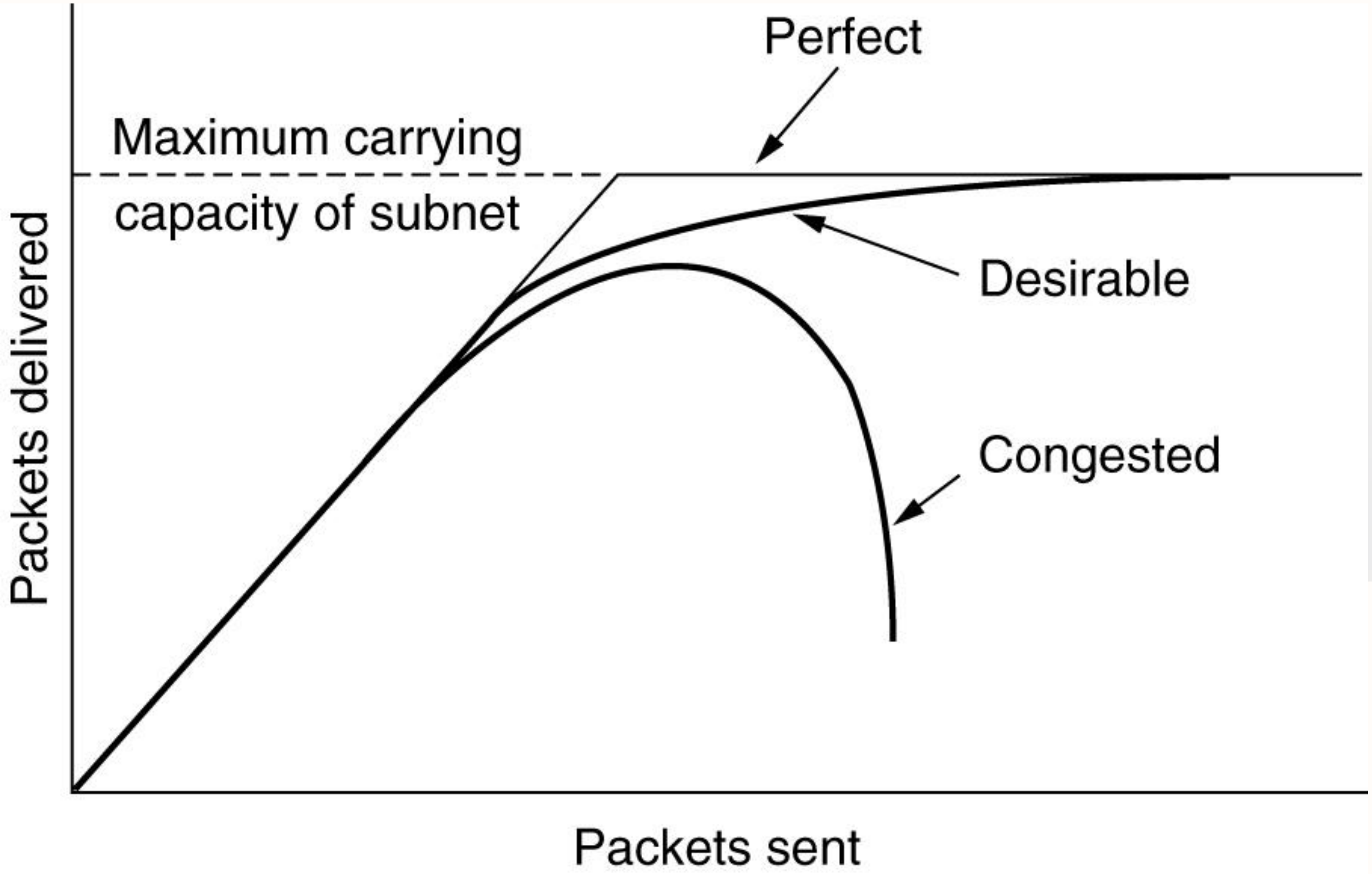
Congestion Control



Congestion Control

- Congestion control vs. flow control
  - Flow between 2 hosts
    - Imagine fiber 1000GB
    - 1 host has 1GB, the other 1MB.. !!
    - No congestion but flow problem
  - Congestion is related to the link itslef
    - E.g. 1MB bandwidth
    - 1000 hosts with
    - 500 hosts trying to send 100K to the others

Congestion Control

- Congestion Control
  - Monitor the system to detect when and where congestion occurs.
  - Pass this information to places where action can be taken.
  - Adjust system operation to correct the problem.

Quality of Service

- QoS
- How ?
  - Overprovisioning: expensive !
  - Buffering !

Application	Reliability	Delay	Jitter	Bandwidth
E-mail	High	Low	Low	Low
File transfer	High	Low	Low	Medium
Web access	High	Medium	Low	Medium
Remote login	High	Medium	Medium	Low
Audio on demand	Low	Low	High	Medium
Video on demand	Low	Low	High	High
Telephony	Low	High	High	Low
Videoconferencing	Low	High	High	High

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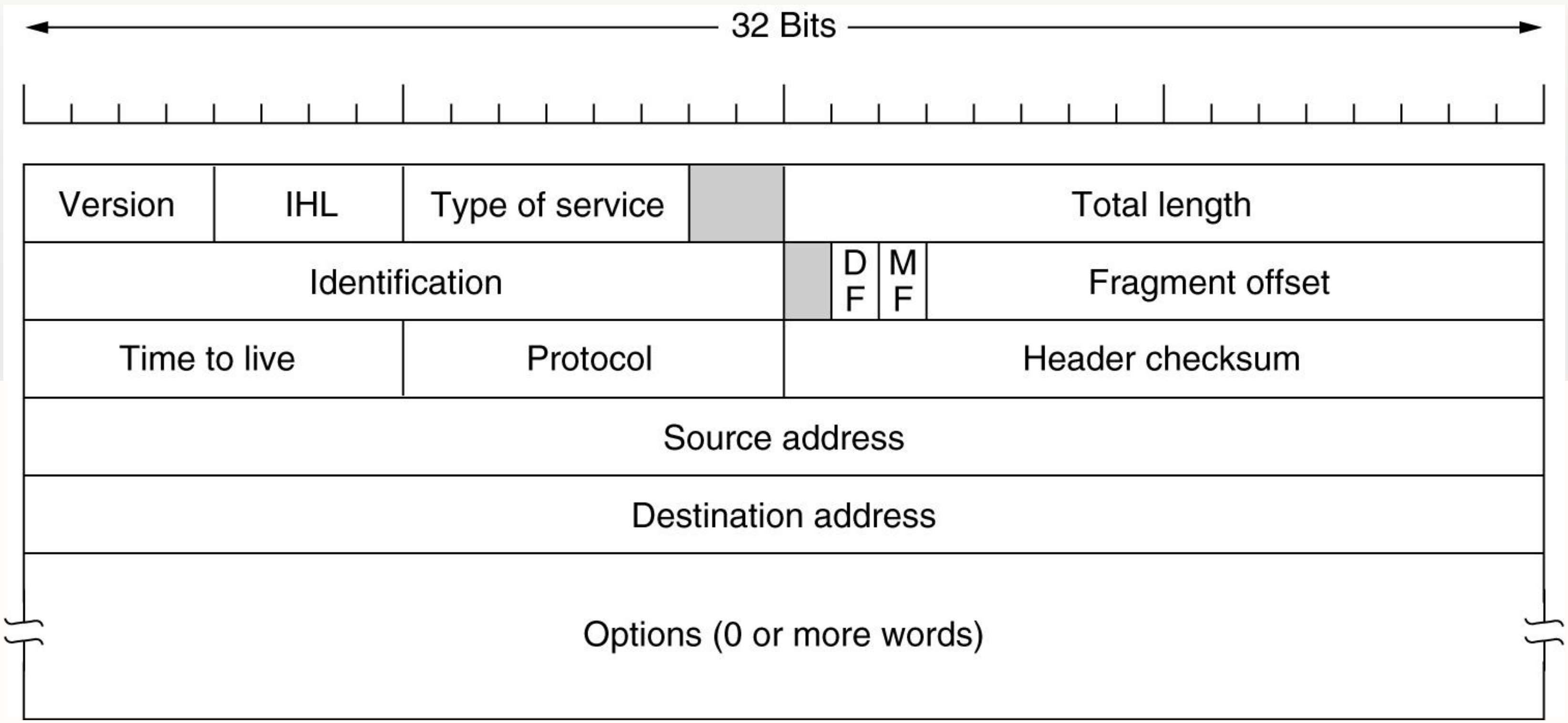
Internet Protocol

- 20 byte fixed .. Variable optional!

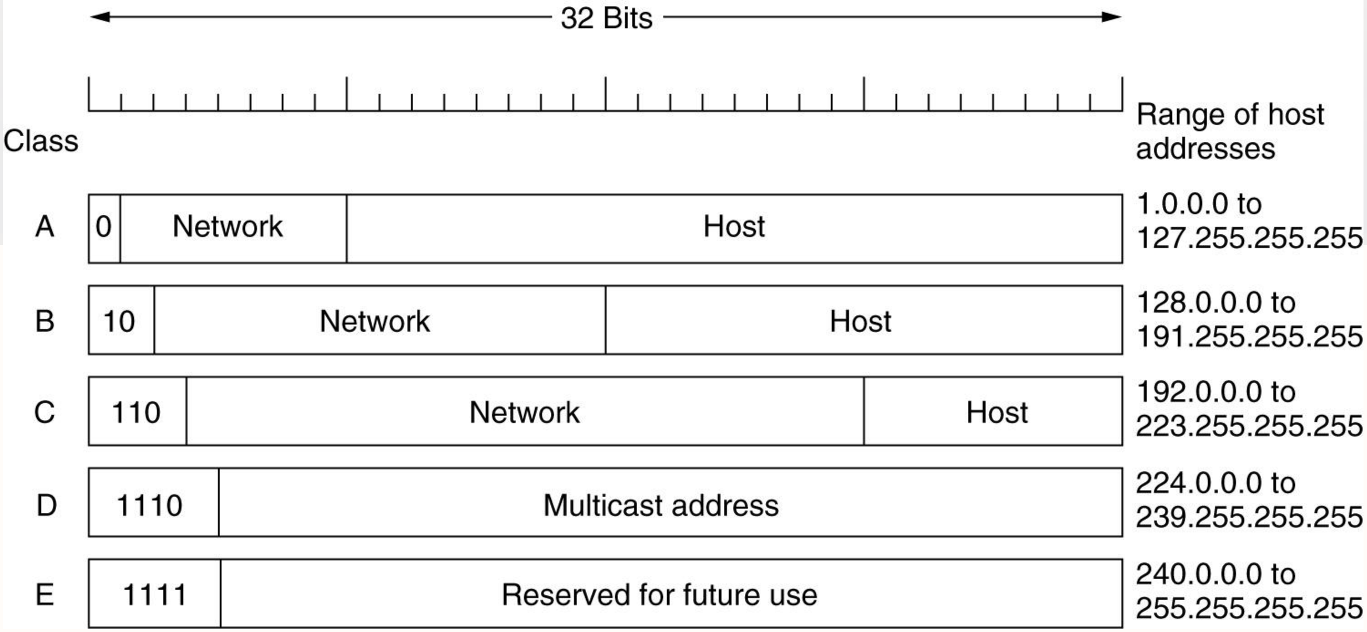


Internet Protocol

- Version: expansion v4, v5, v6
- IHL, is provided to tell how long the header is, in 32-bit words
- The Type of service field is one of the few fields that has changed its meaning
- Total length includes everything in the datagram-both header and data
- Etc. (please review the book)

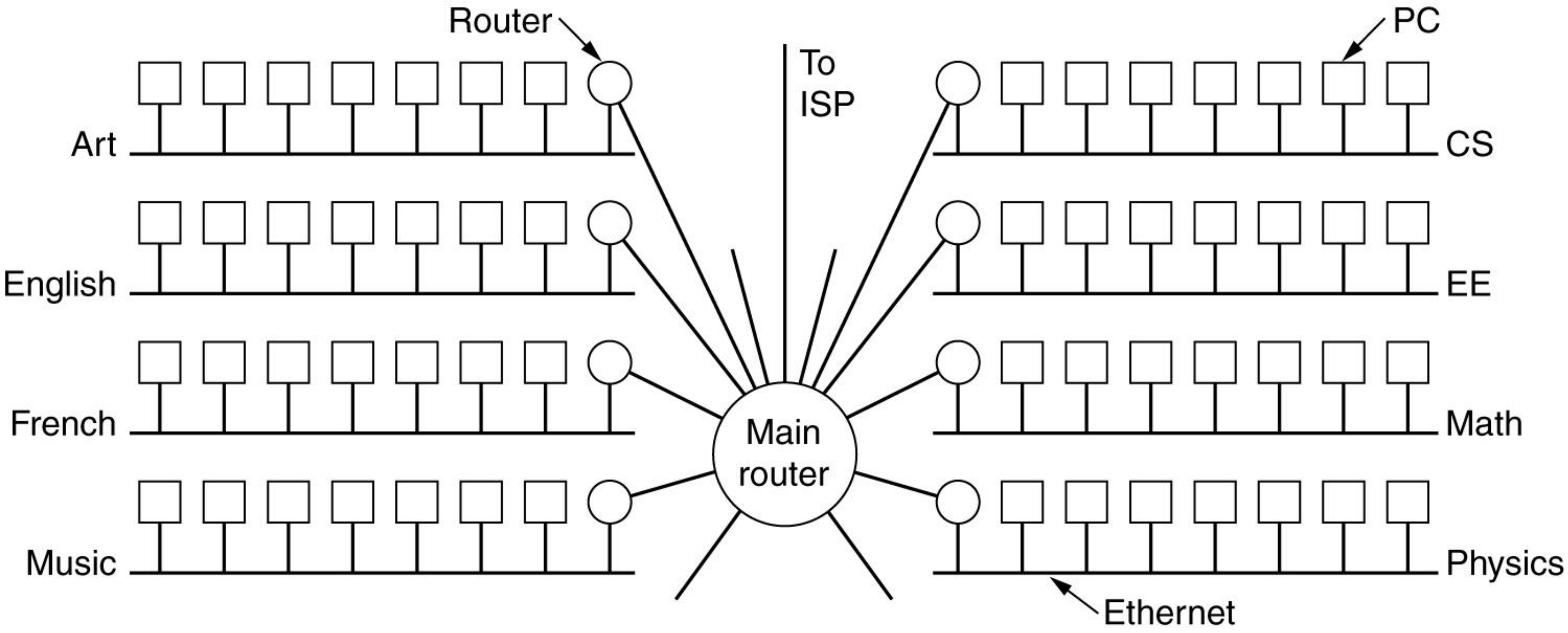
Internet Protocol

- Class A = 128 networks (16million each)
- Class B = 16K networks (64K each)
- Class C = 2 million networks (256 each)



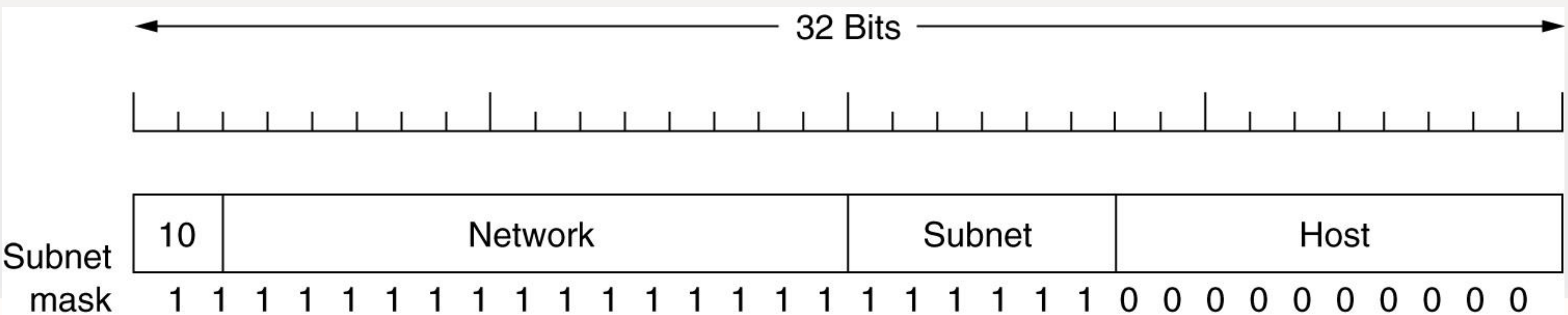
Internet Protocol

- subnets



Internet Protocol

- Subnet mask
- 255.255.252.0



THANK YOU!

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