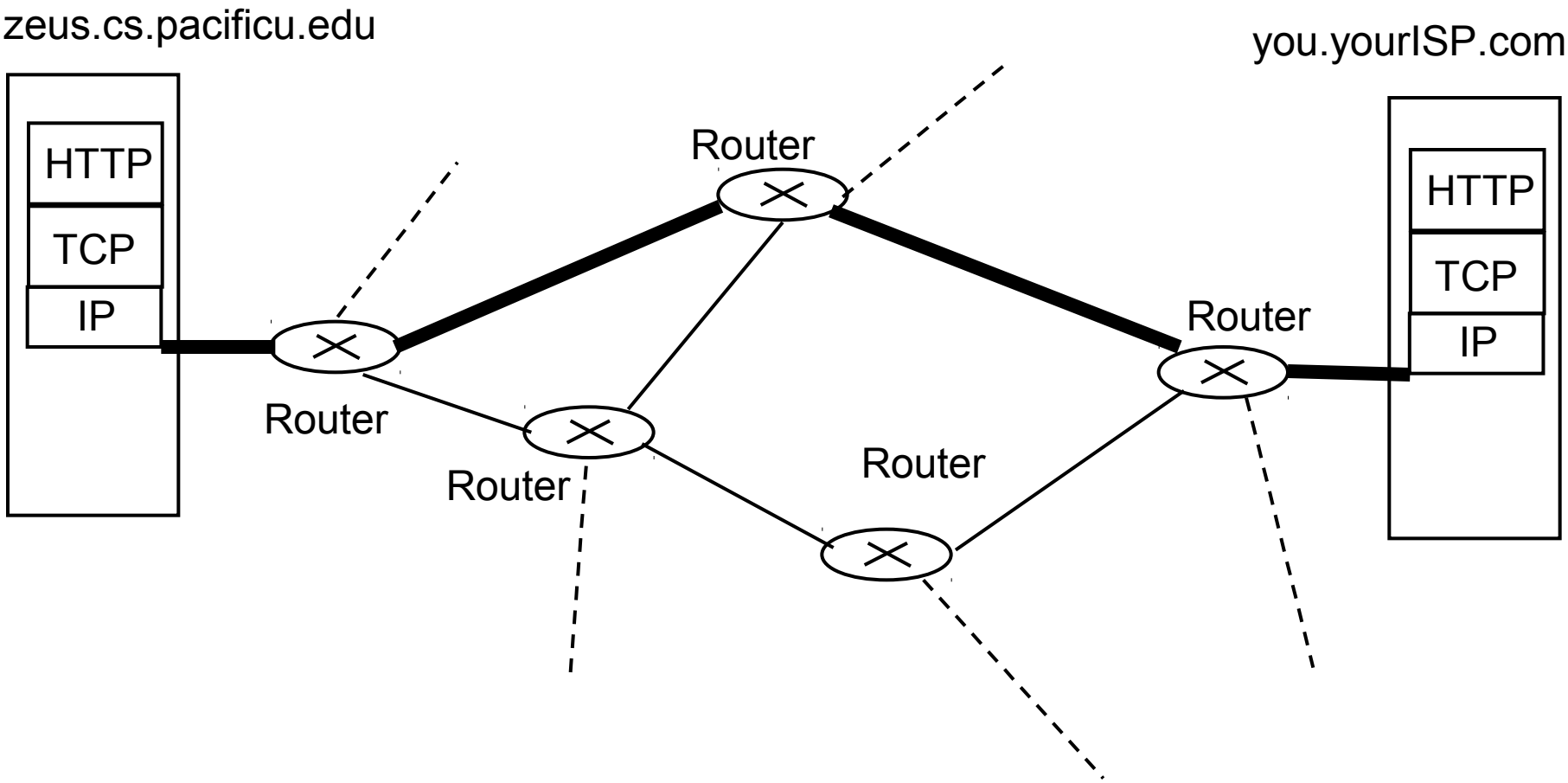
Network Layer

Chapter 5

Section 5.1, 5.3, 5.5, 5.6

Network with Routers



Network Layer

- Goal:
- Routing
- Routers may be standard computers running routing software
- Routers may be specialized hardware

Connection vs Datagram

- Just like TCP/UDP, some network layers are connection based, some are datagram based
  - for connection based networks each router keeps track of every connection running through it
  - for datagram based networks, no state for the connection is kept at the router
    - the Internet is datagram based (which is why implementing TCP is so much work!)
  - mainly concerned with datagram based networks in this class

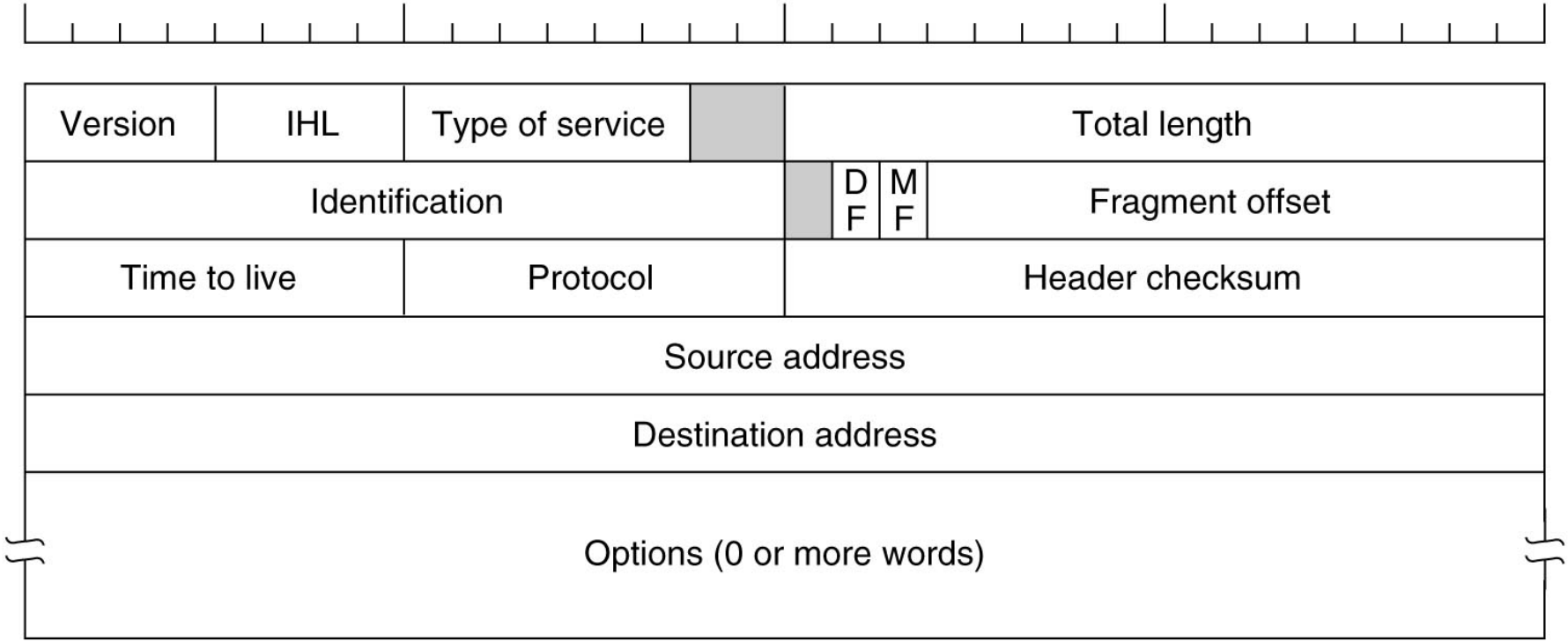
Network Service Models

- The network layer **may** provide different levels of service
  - guaranteed delivery
  - guaranteed delivery with bounded delay
  - in order packet delivery
  - guaranteed minimal bandwidth
  - guaranteed maximum jitter

- The Internet (IP) provides
  - best effort service
  - "Sure, I'll try to get it there, but I'm not making any promises."
  - why?
  - layers: provide only what you need
    - you can build anything on top of it

Internet Protocol (v4) (RFC 791)

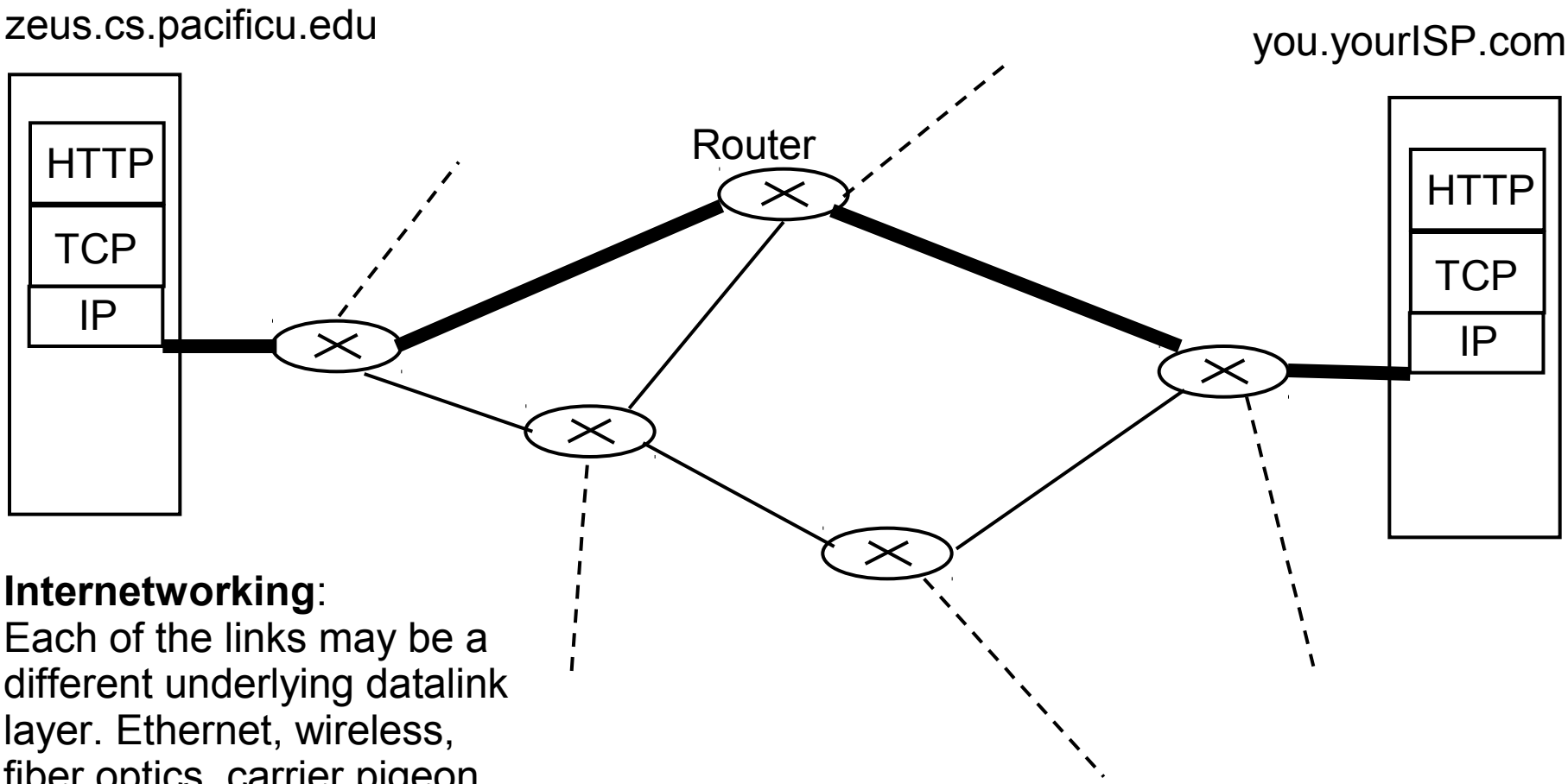
- Network layer for the Internet
- Designed with *internetworking* in mind
  - many underlying datalink layers may be used
  - the IP header is what the router looks at to route the data



Tanenbaum, Fig 5-46, p439

Not identical to the pseudo header in the UDP RFC

Network with Routers



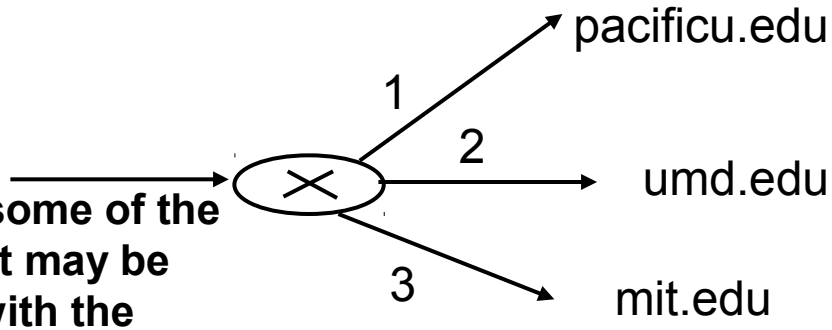
Internetworking:
Each of the links may be a different underlying datalink layer. Ethernet, wireless, fiber optics, carrier pigeon, smoke signal, token ring, PPP, SLIP

Router Operations

- Forwarding

Forwarding Table

Interface	Destination Address
1	pacificu.edu
2	umd.edu
3	mit.edu



What are some of the issues that may be involved with the design/implementation of the forwarding table?

Routers really use IP addresses rather than DNS addresses

Router Operations

- Routing
  –

Message type	Description
Destination unreachable	Packet could not be delivered
Time exceeded	Time to live field hit 0
Parameter problem	Invalid header field
Source quench	Choke packet
Redirect	Teach a router about geography
Echo	Ask a machine if it is alive
Echo reply	Yes, I am alive
Timestamp request	Same as Echo request, but with timestamp
Timestamp reply	Same as Echo reply, but with timestamp

Tanenbaum, Figure 5-60, p 466

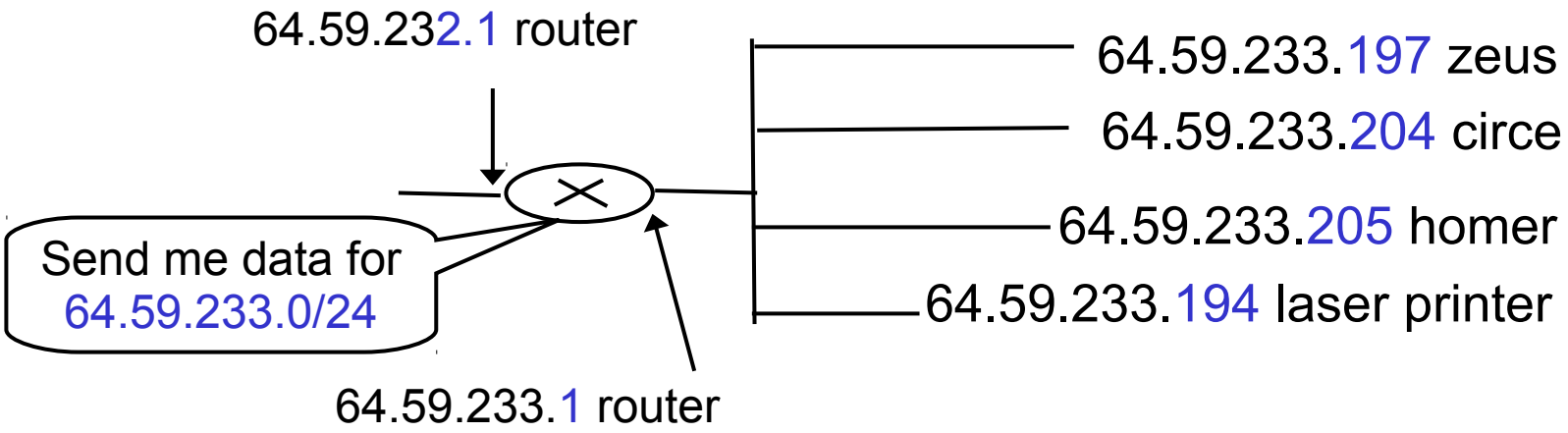
IPv4 Address

- 32 bit addresses: 64.59.233.197

- Previously on The Internet...
  - *Classful* addresses were given out
  - a.b.c.d
  - Class A: a.x.x.x
  - Class B: a.b.x.x
  - Class C: a.b.c.x
    - first octet (a) denoted which class of address
    - U of Maryland: 128.8.x.x -- Class B
    - MIT: 18.x.x.x -- Class A
  - how many addresses does each class of address contain?
  - why might this be a problem?

IPv4 Addressing

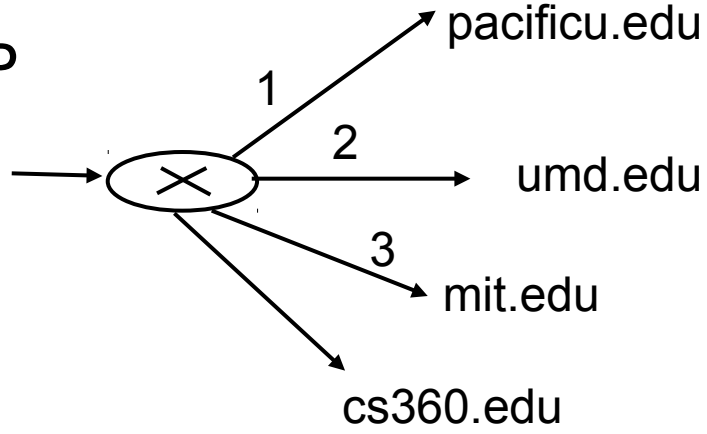
- Classless InterDomain Routing (CIDR)
  - 64.59.233.0/24



  - 255.255.255.0 ***subnet*** mask
  - clever way of organizing addresses helps in routing
  - we don't need an entry in the forward table for each machine
    - just one for the subnet

Forwarding tables

- Forwarding table works on the IP addresses
- Only concerned with the significant bits
- Look for longest prefix match



Interface	Destination Address	
1	64.59.192.0/18	(0100 0000 0011 1011 11)
2	128.8.0.0/16	(1000 0000 0000 1000)
3	18.0.0.0/8	(0001 0010)
4	64.59.224.0/19	(0100 0000 0011 1011 111)

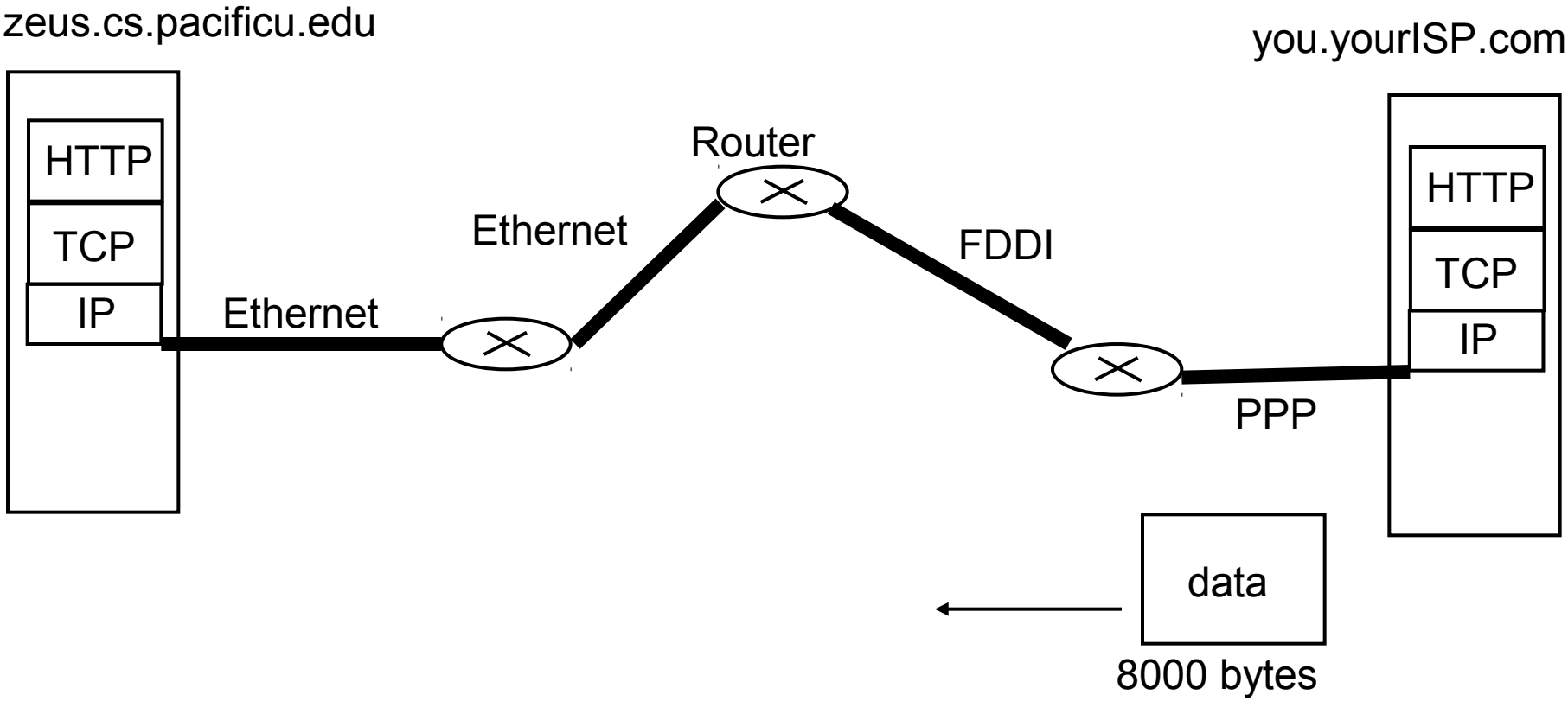
Input Packet	Output Interface
64.59.192.1	
64.59.193.2	
64.59.223.2	

Internet Protocol

- Designed with internetworking in mind

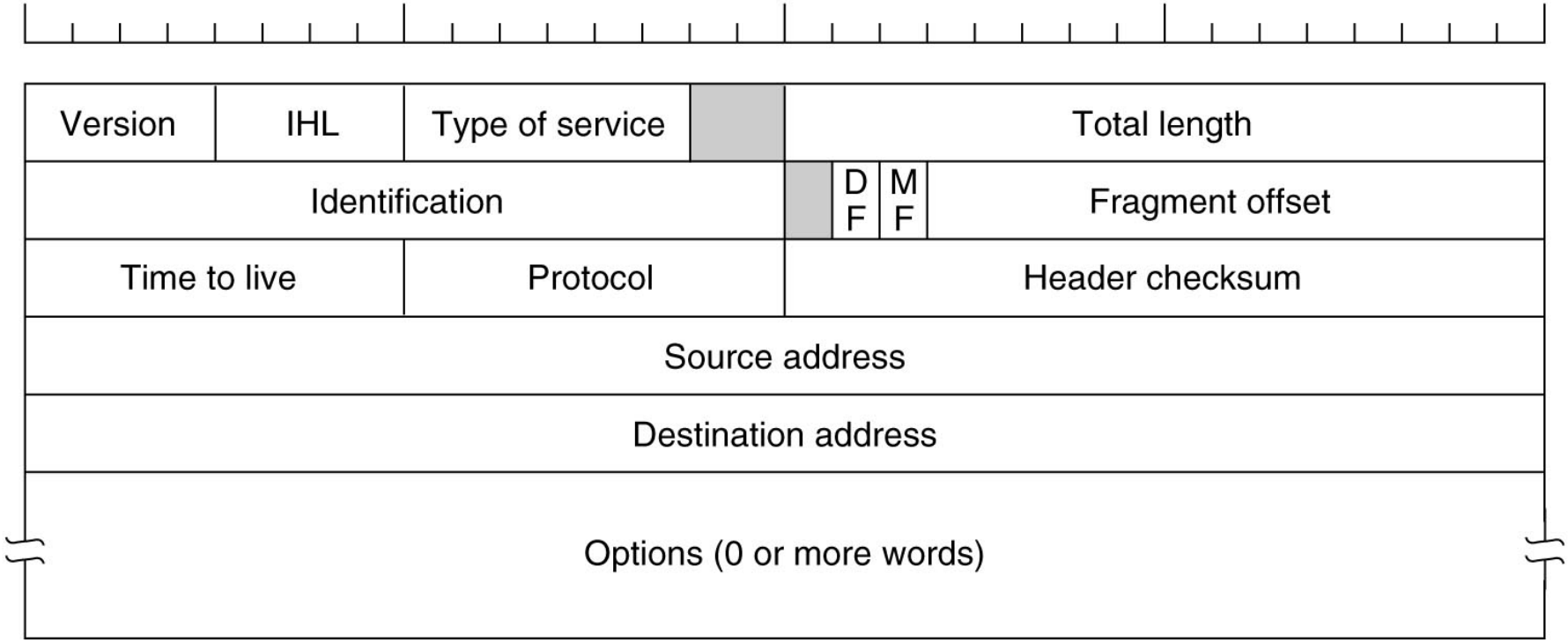
- Fragmentation
  - maximum transfer unit (max frame size)
    - Ethernet: 1500 bytes
    - FDDI: 4500 bytes

Network with Routers



Fragmentation

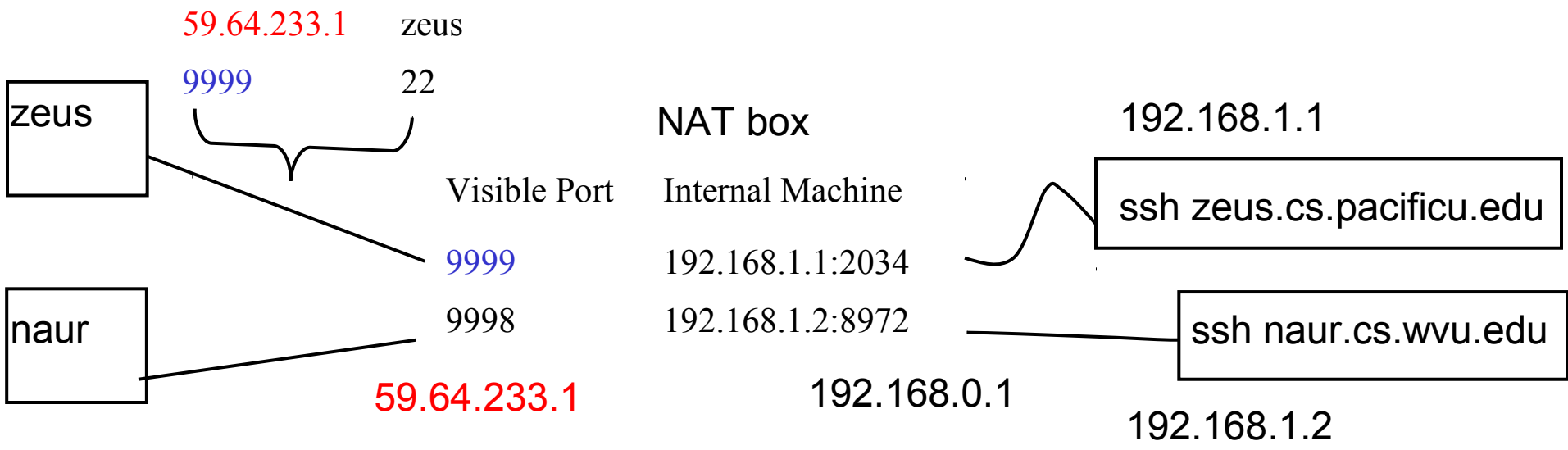
- Set the MF bit for each fragment but the last one
- Copy Identification number to each fragment
- Set the Fragment Offset
- If the destination does not receive one of the fragments, what should it do?
- DF bit means ‘Don’t Fragment Me!’



Tanenbaum, Fig 5-46, p439

Network Address Translation

- IP addresses are scarce ♦
- present one IP address to the rest of the world via a firewall/router
- assign your own IP addresses in your local network
  - these IP addresses are NOT visible to the rest of the world
  - map internal address:port to ISP assignedAddress:port
  - this mapping is not permanent
- this is how the wireless router your ISP sends you works
- some purists object to this. Why? When might this cause problems?

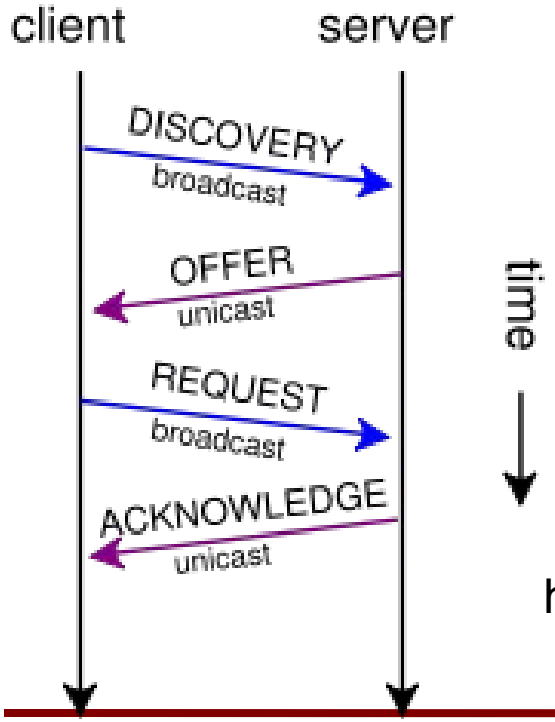


ARP

- Address Resolution Protocol
- Mapping IP address to Ethernet addresses

DHCP

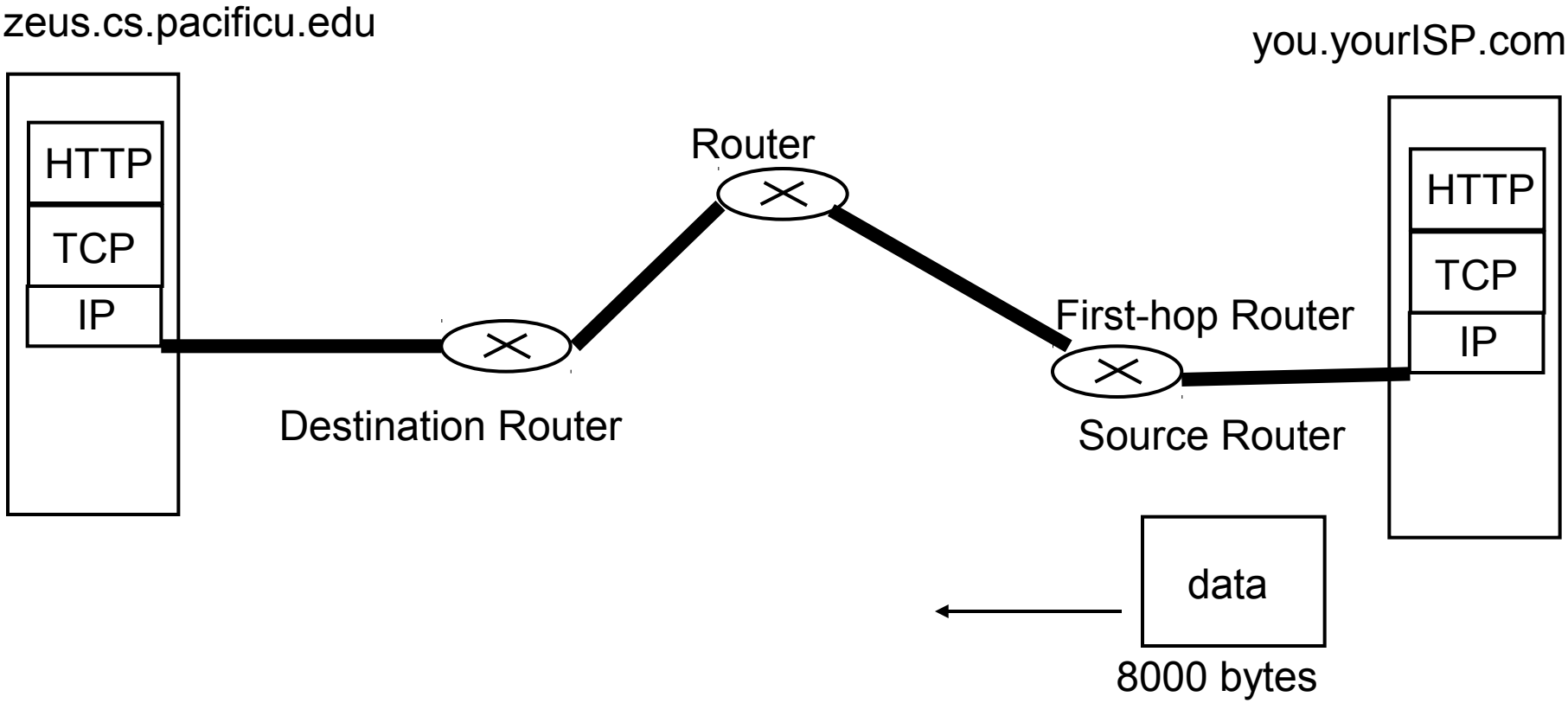
- How do you get an IP address when you plug into the wall?
- Dynamic Host Configuration Protocol (RFC 2131/2132)
  - formerly BOOTP
  - formerly RARP
- Your wireless router at home does this as well



http://en.wikipedia.org/wiki/Image:DHCP_session_en.svg

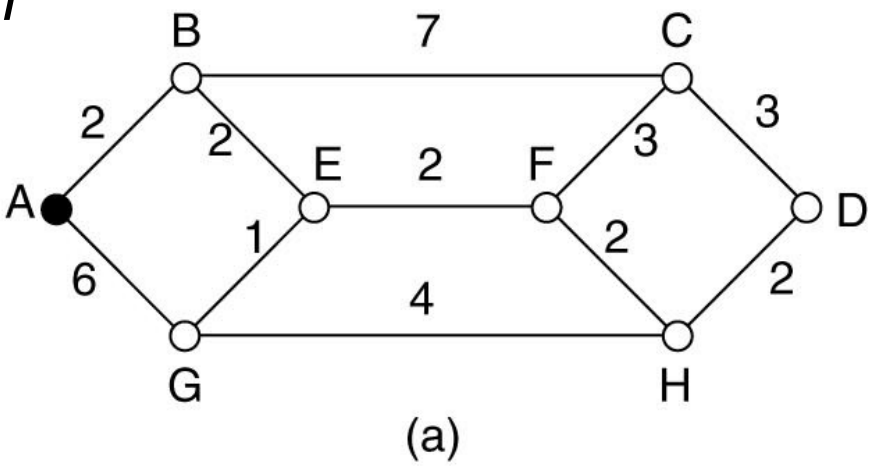
Routing Algorithms

Read section 5.2 - 5.2.6
And 5.6 - 5.6.6



Routing Algorithms

- View the network as a *graph*
  - routers are nodes
  - links are edges
  - what may weights indicate?



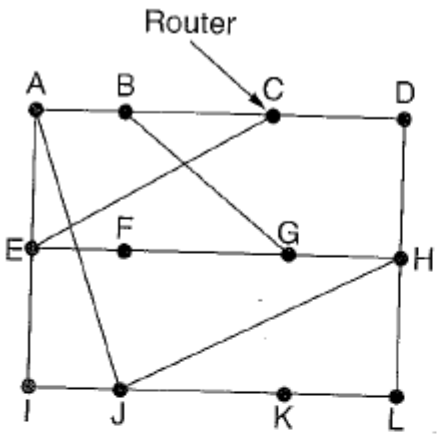
- Two types:

Tanenbaum, Figure 5-7a, p 366

Routing Algorithms

- Link State Routing
  - global (complete) information
  - based on Dijkstra's algorithm (read section 5.2.2)
  - some use Prim's algorithm
  - both algorithms compute the least cost path from node X to all other nodes in the graph (one to all)
  - Example!

Link State Routing



(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)

Figure 5-9. (a) A network. (b) Input from *A*, *I*, *H*, *K*, and the new routing table for *J*.

Link State Routing

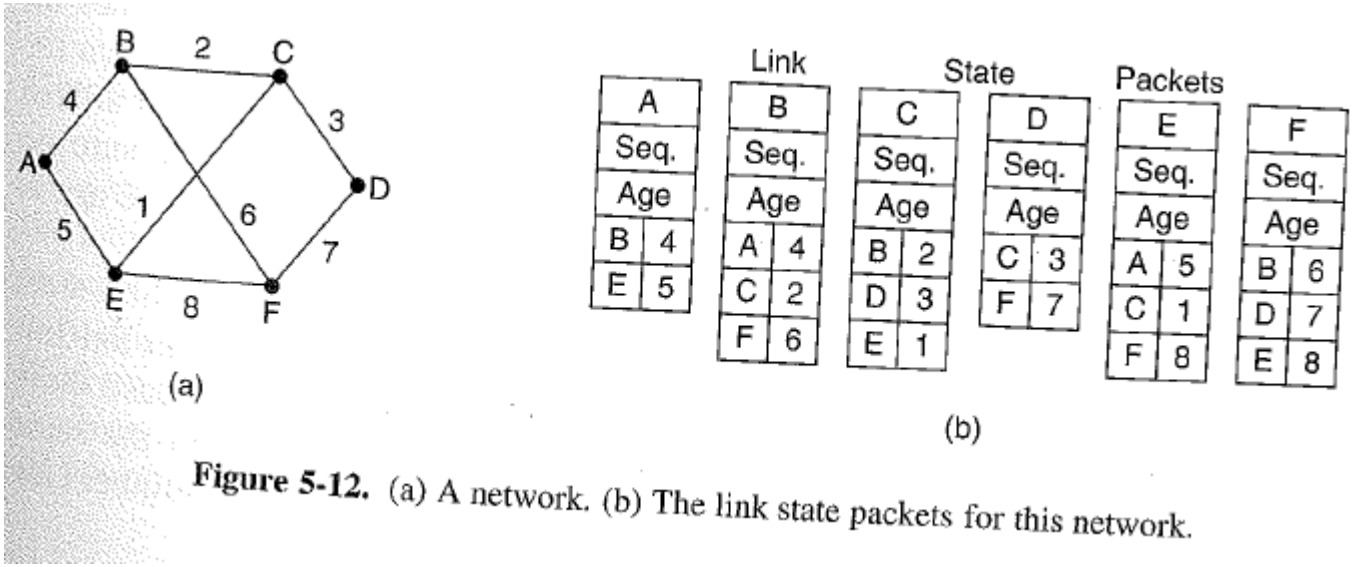


Figure 5-12. (a) A network. (b) The link state packets for this network.

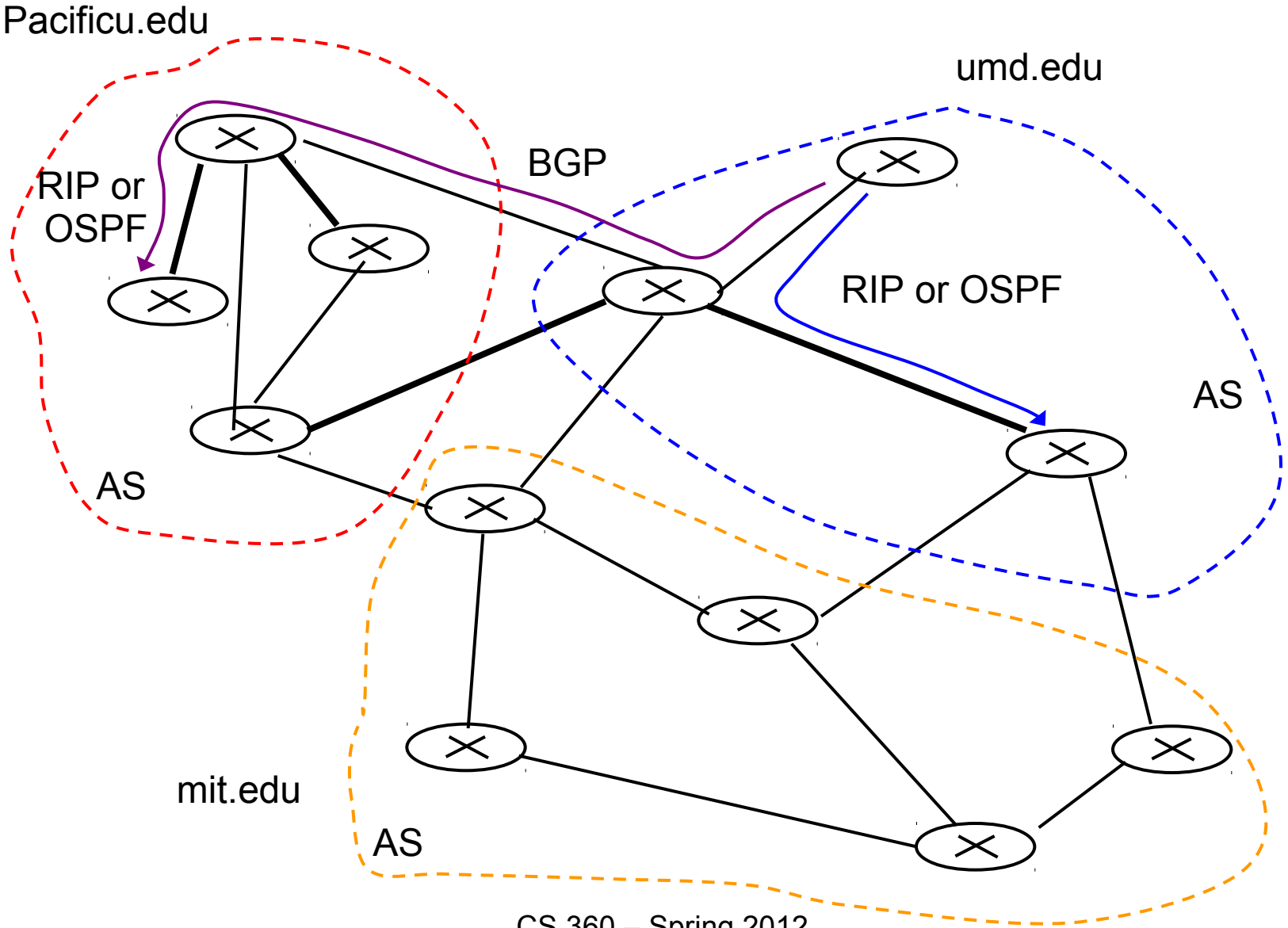
Routing Algorithms

- Distance Vector Routing
  -

Routing on the Internet

- Hierarchical Routing:
  - break the network up into regions so the router's forward table does not get too large
  - you know detailed information about your subnet
  - where to send data for other subnets
- AS: Autonomous Systems
  - the regions mentioned above!
- Intra-AS: RIP (not in your book) RFC 1058
- Intra-AS: OSPF RFC 2328
- Inter-AS: BGP RFC 1771

Network with Routers



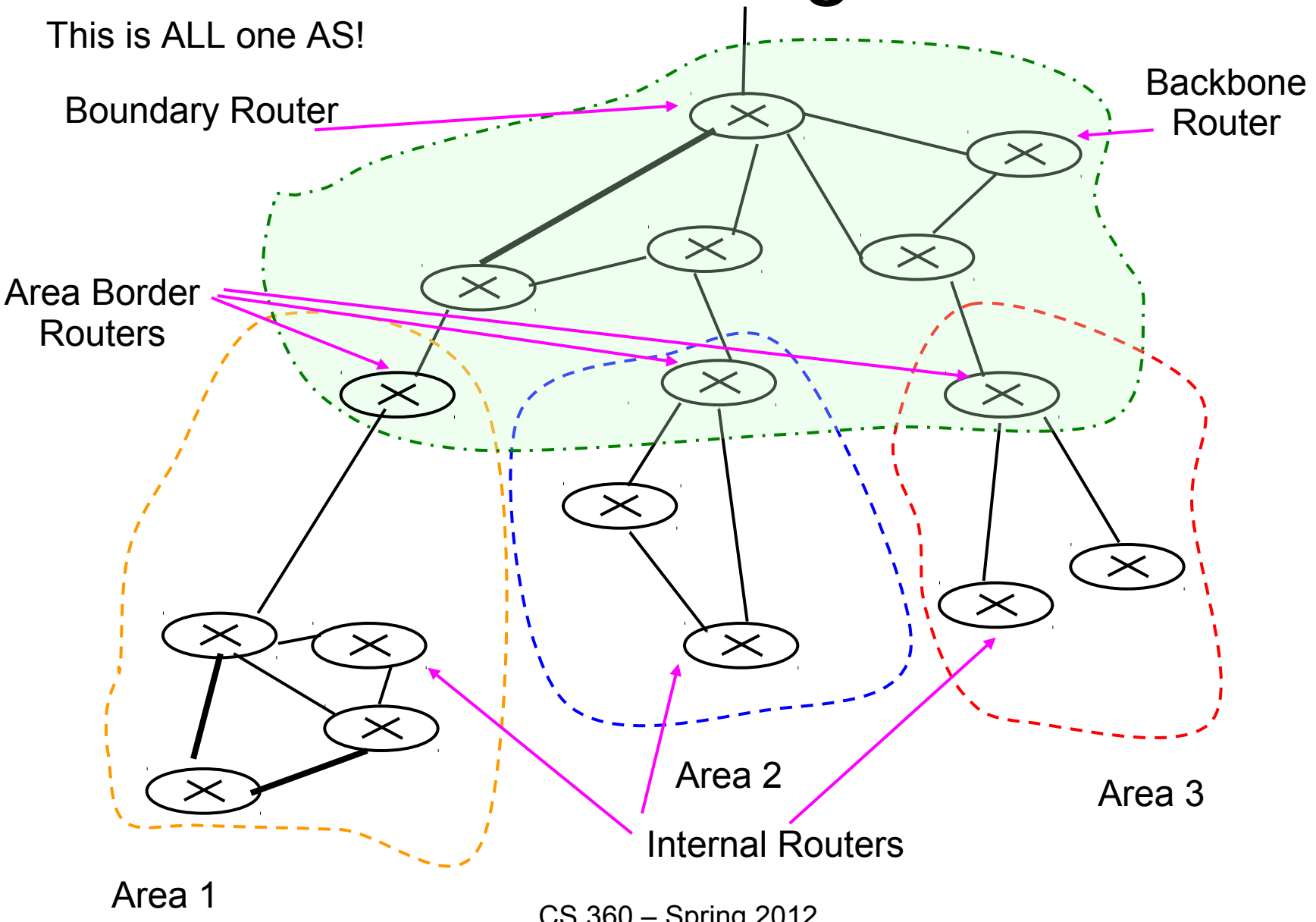
Routing Information Protocol

- Intra-AS: RIP (not in your book!) RFC 1058
  -

Open Shortest Path First

- Intra-AS: OSPF RFC 2328
  –

Hierarchical Routing with OSPF



OSPF

- Protocol
  -

OSPF

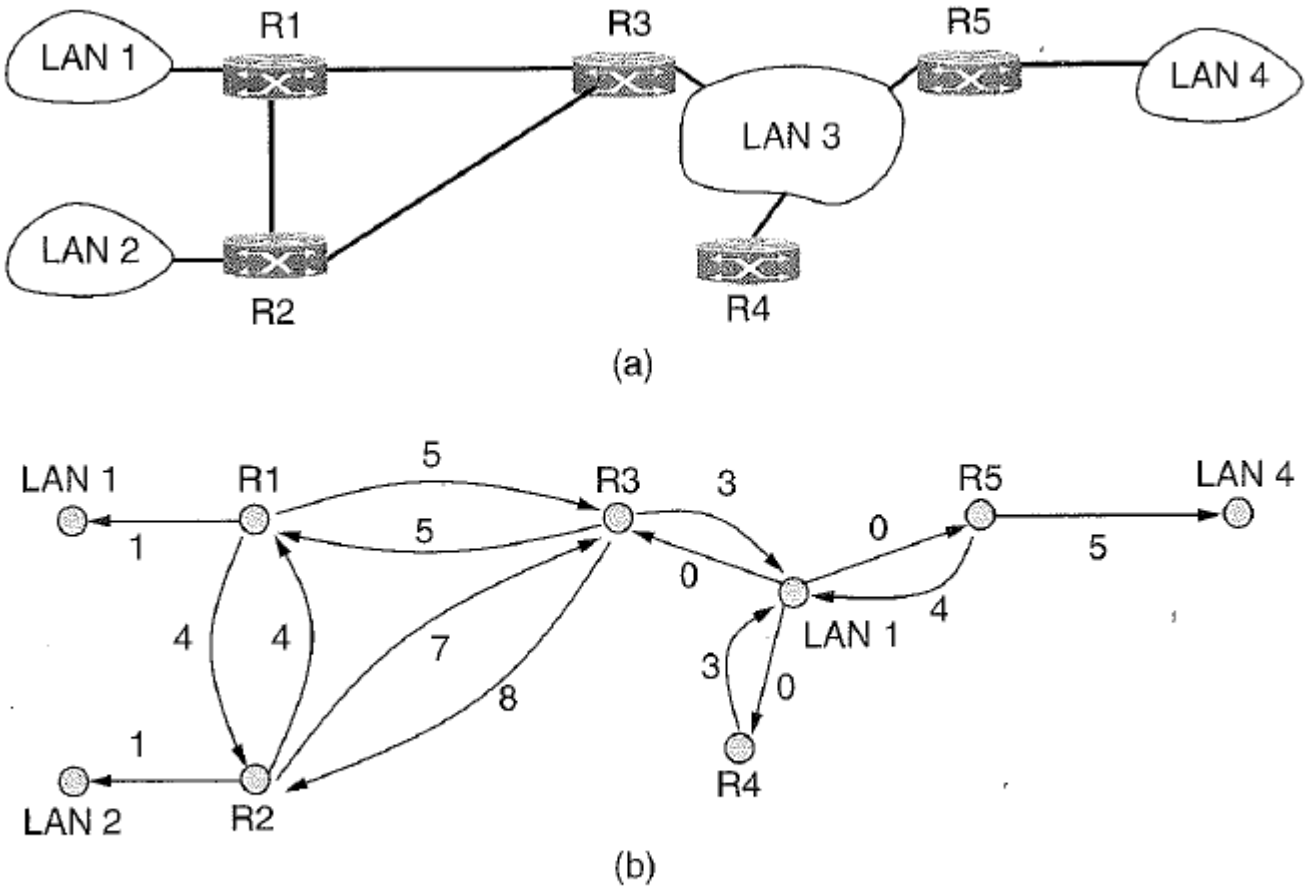


Figure 5-64. (a) An autonomous system. (b) A graph representation of (a).

OSPF

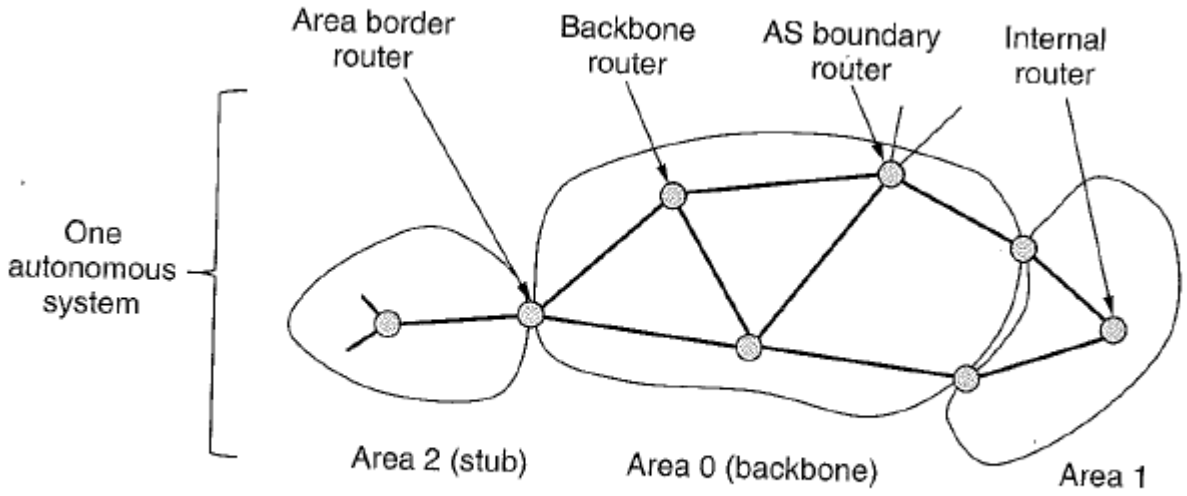


Figure 5-65. The relation between ASes, backbones, and areas in OSPF.

Border Gateway Protocol

- Inter-AS: BGP RFC 1771
  - how to I get to that AS over there?
  - glues the Internet together

What's in a Router?

Congestion Control