Routing

CSC 512 – Networks: Architectures and Protocols

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Definitions

- Routing
- Router
- Forwarding
- IP Forwarding

Forwarding

- Direct Delivery
- Indirect Delivery

Direct Delivery

- Steps
  - Encapsulate datagram
  - Map IP to Physical address
  - Transfer frame
- How does the sender know if the DIP is on the same physical network?

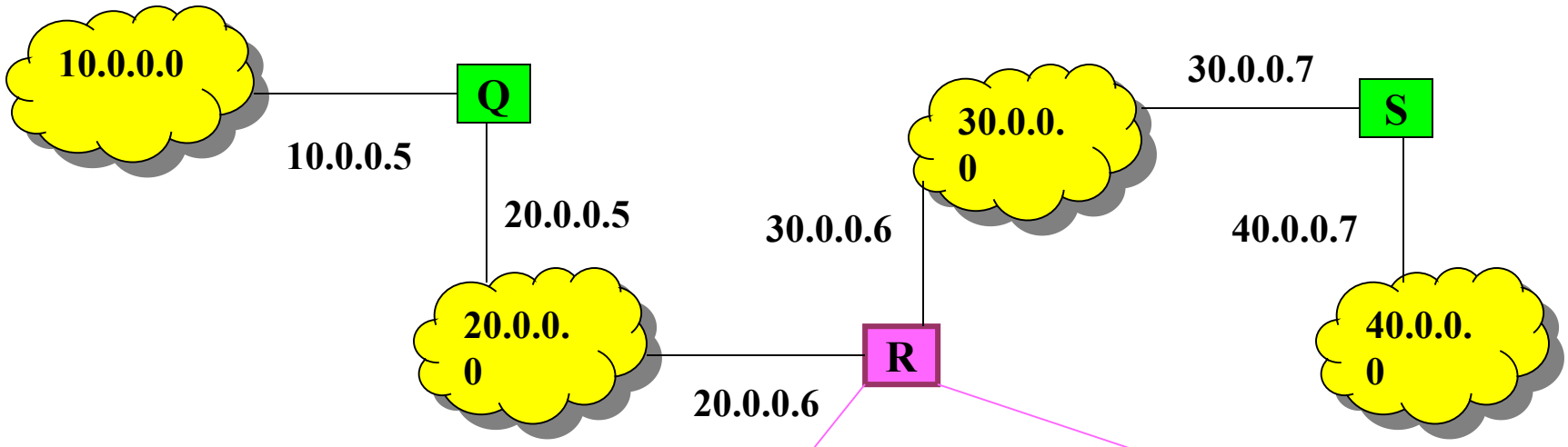
Indirect Delivery

- Destination on different network
- Steps
  - First router – direct delivery
  - Extract datagram
  - Process header
  - Select next router
  - Encapsulate datagram
  - Forward datagram

Routing Table

- Hosts and Routers
- Stores network portion of destination address
- Typical entry is a pair (N, R)
  - N – network address
  - R – next hop / router
- Default route

Routing Basics



To reach hosts on network	Route to this address
20.0.0.0	Deliver Directly
30.0.0.0	Deliver Directly
10.0.0.0	20.0.0.5
40.0.0.0	30.0.0.7

Subnet Routing

- Routing table
  - IP address
  - Subnet mask
  - Next hop
- Routing algorithm
  - Bitwise AND
    - Destination IP address
    - Subnet mask field in routing table entry
  - Value = network address for entry → match

Routing Table Example

Destination Address	Address Mask	Next-Hop Address	Interface Number
192.5.48.0	255.255.255.0	128.210.30.5	2
128.10.0.0	255.255.0.0	128.210.141.12	1
0.0.0.0	0.0.0.0	128.210.30.5	2

Forwarding Algorithm

```
Given: destination address A and routing table R.
Find: a next hop and interface used to route datagrams to A.
For each entry in table R  {
      Set MASK to the Address Mask in the entry;
      Set DEST to the Destination Address in the entry;
      If (A & MASK) == DEST  {
            Stop; use the next hop and interface in the entry;
      }
}
If this point is reached, declare error: no route exists;
```

Forwarding Algorithm

ForwardDatagram(Datagram,RoutingTable)

Extract destination IP address, D from datagram;
If the table contains a host-specific route for D
    send datagram to next-hop specified in the table and quit;
Compute N, the network prefix of address D;
If N matches any directly connected network address
    deliver datagram to destination D over that network;
    (Involves resolving D to a physical address, encapsulating the datagram, and sending the frame.)
Else if the table contains a route for network N
    send datagram to next-hop specified in table;
Else if the table contains a default route
    send datagram to the default router specified in table;
Else declare a forwarding error

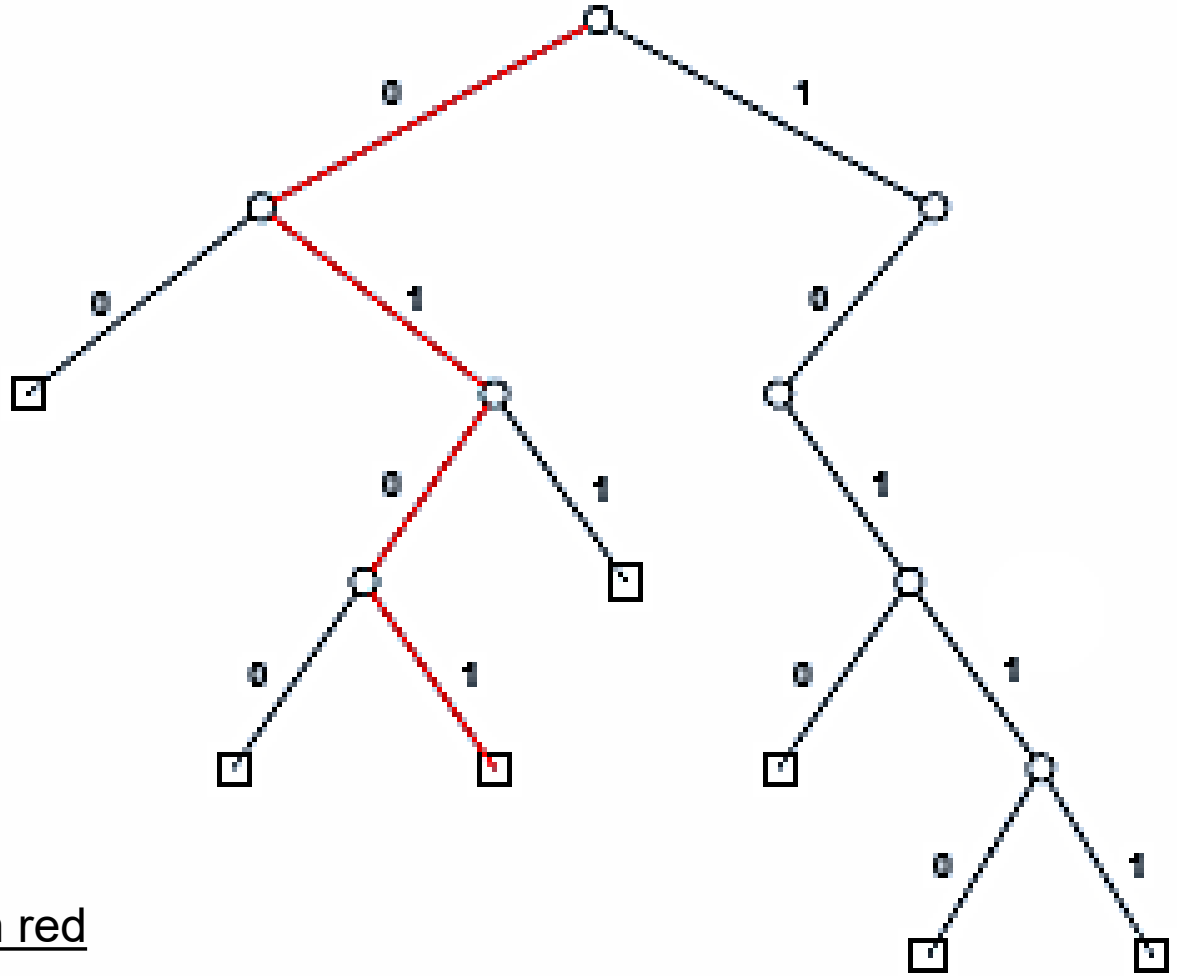
Longest Prefix Match (LPM)

- Longest prefix of bits matching
- Try all possible prefix divisions
  - Inefficient
- Hierarchical data structure
  - Binary Trie

Binary Trie Example

32-Bit Address	Unique Prefix
00110101 00000000 00000000 00000000	00
01000110 00000000 00000000 00000000	0100
01010110 00000000 00000000 00000000	0101
01100001 00000000 00000000 00000000	011
10101010 11110000 00000000 00000000	1010
10110000 00000010 00000000 00000000	10110
10111011 00001010 00000000 00000000	10111

Binary Trie



Path for 0101 in red

Forwarding Questions

- Routes are chosen based only on the DIP. Are there any problems related to this?
- IP forwarding does not alter the original datagram except for what fields?
- If the DIP is not altered, where does it store the IP address of the next hop?
- If many packets are sent to the same 'next hop', doesn't it seem like a waste of time for the software to convert the IP address to MAC address every time? Why not just store the MAC address in the routing table?

Routing Review

- Host
  - If DIP = host's IP address, process
  - Otherwise, drop
- Router
  - If DIP = router's IP address, process
  - Otherwise, forward

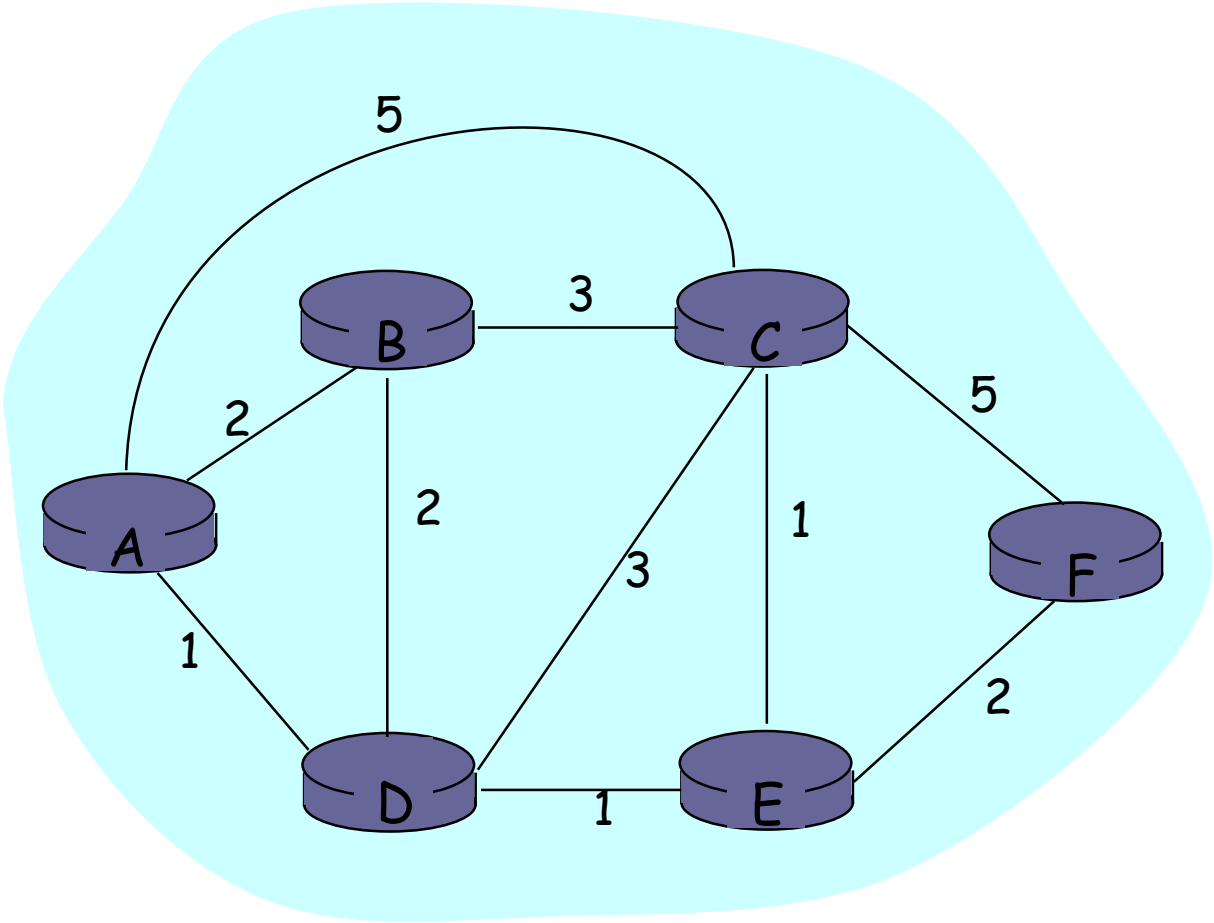
Routing Table Maintenance

- Two main steps
  - Initialization
  - Update
- Initialization
  - Read initial routes from a file
  - Read a script containing initial routes
  - Empty table
  - Determine initial routes from networks it can reach

Routing Protocols

- Learn routes
- Select routes
- Maintain routes

Routing Algorithms



Routing Algorithms

- Core router architecture
- Global routing algorithm
  - Global knowledge about network
- Decentralized routing algorithm
  - Iterative, distributed
- Static vs. Dynamic Routing Algorithms

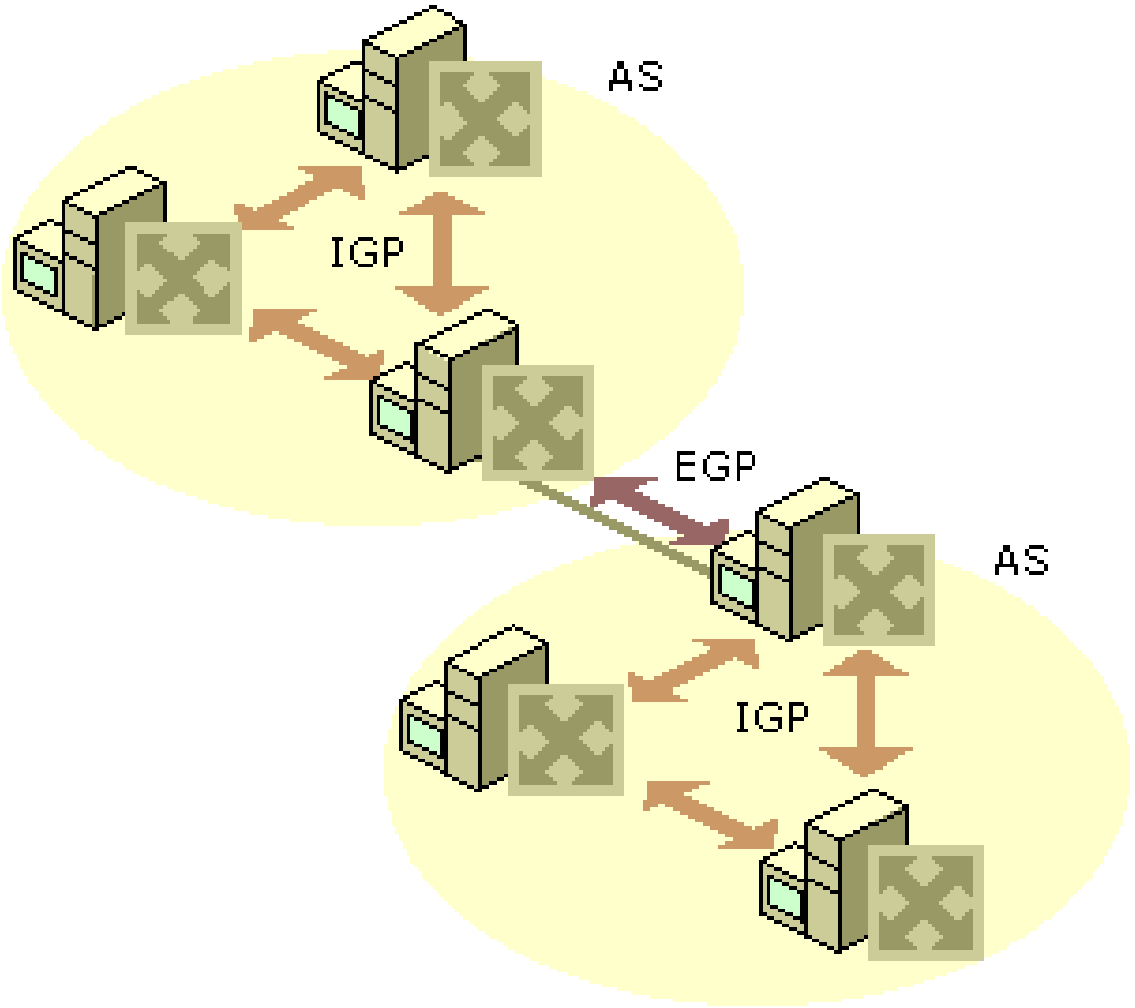
Distance Vector (DV) Algorithm

- Decentralized
- Easy to implement
- Traffic-intensive
- Exchange large amounts of information
- Routing table initialization
- Iterative
- Asynchronous
- Distributed
- Does not scale well

Link State (LS) Algorithm

- Global
- Network topology and link costs known
- More software intensive
- Responds quickly to network performance
- Routers check status of neighbor routers
- Routers broadcast routing table entries
- Dijkstra's shortest path algorithm
- Scale better than DV algorithms

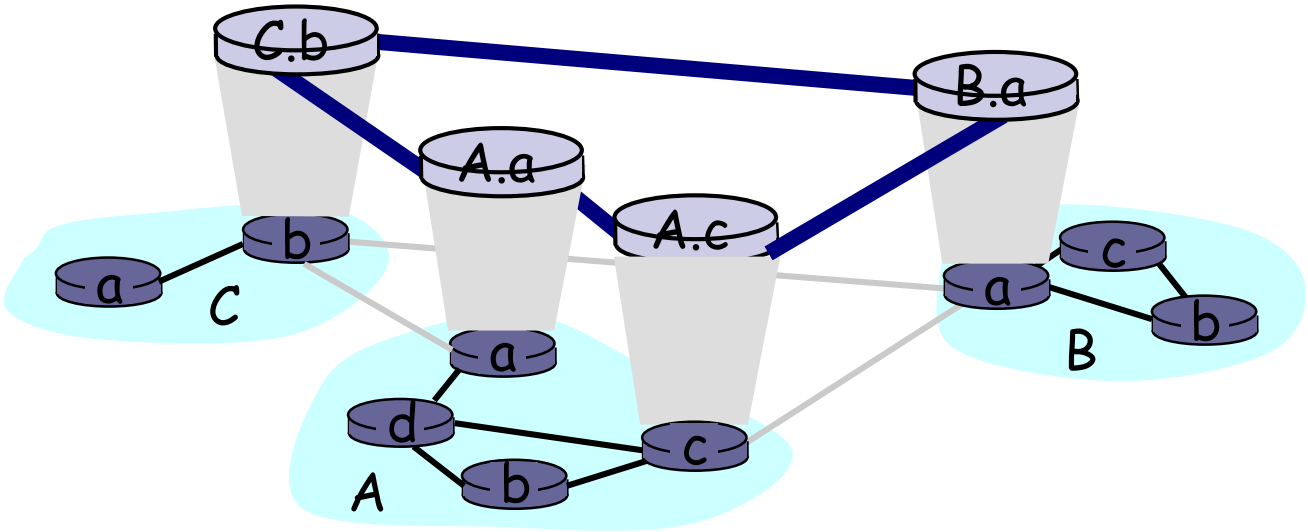
Autonomous Systems



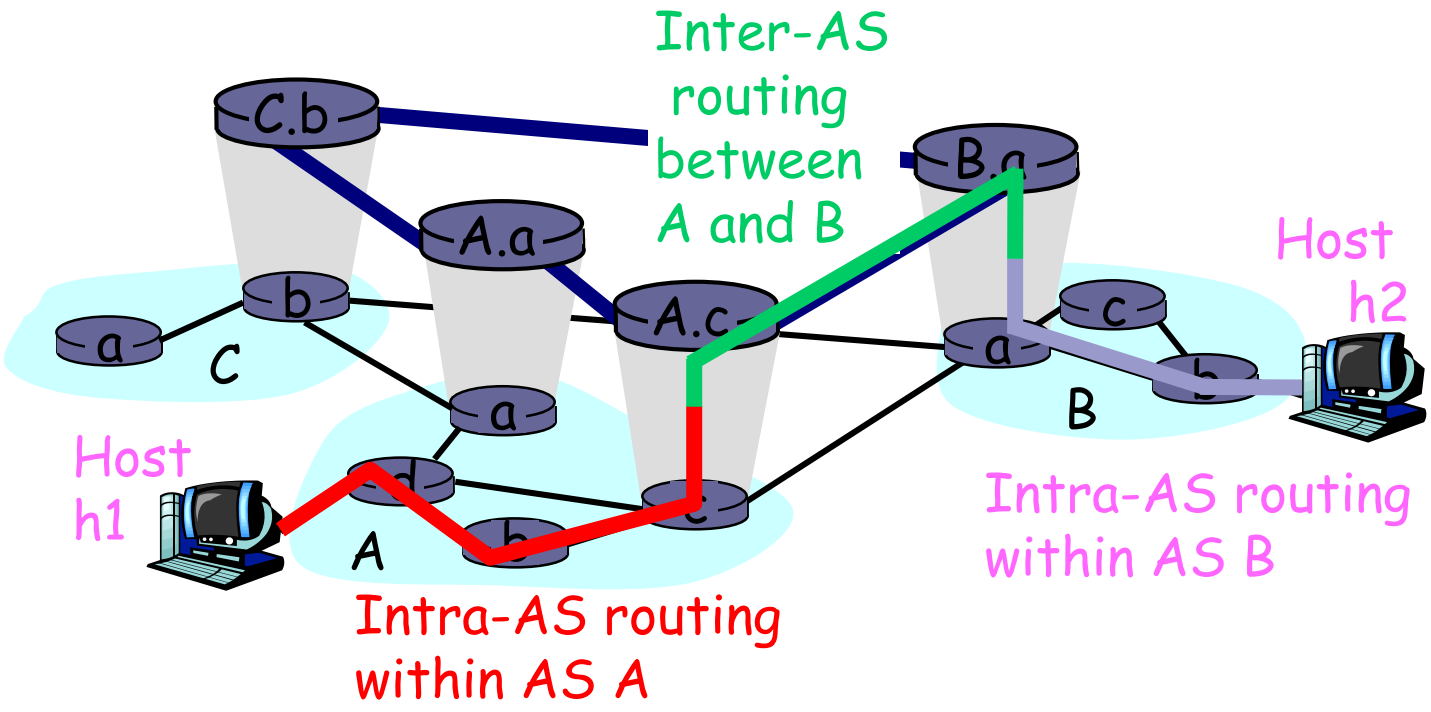
Autonomous Systems

- Intra-autonomous system routing protocol
- Inter-autonomous system routing protocol
- Gateway router – router designated to talk to other autonomous systems

Intra-AS and Inter-AS Routing Protocols



Route from A.d to B.b



Internet Routing Protocols

- Routing inside the LAN or inside an AS
- Intra-AS routing protocols
- Interior Gateway Protocols (IGP)

- RIP
- OSPF
- Hello
- EIGRP

Exterior Gateway Protocols (EGPs)

- Inter-AS Routing Protocols

- Gateway to Gateway Protocol (GGP)
- Exterior Gateway Protocol (EGP)
- Border Gateway Protocol (BGP)
- Inter-Domain Routing Protocol (IDRP)

Discussion Question

- Create forwarding tables for all the routers in the Figure below.
- Which router or routers will benefit most from using a default route?