Introduction to Computer Networks

COSC 4377

Lecture 17

Spring 2012

March 26, 2012

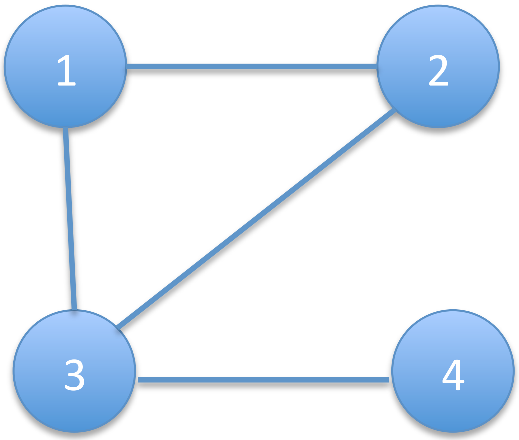
Announcements

- HW8 due this week
- HW9 is out
- Student presentations

```
$ dig uh.edu

; <<>> DiG 9.7.3-P3 <<>> uh.edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 44950
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 4, ADDITIONAL: 4

;; QUESTION SECTION:
;uh.edu.                         IN      A

;; ANSWER SECTION:
uh.edu.                  16306   IN      A       129.7.97.54

;; AUTHORITY SECTION:
uh.edu.                  90      IN      NS      mesquite.cc.uh.edu.
uh.edu.                  90      IN      NS      ns2.uh.edu.
uh.edu.                  90      IN      NS      ns1.uh.edu.
uh.edu.                  90      IN      NS      ncc.uky.edu.

;; ADDITIONAL SECTION:
ncc.uky.edu.             80512   IN      A       128.163.1.6
ns2.uh.edu.              22524   IN      A       129.7.1.6
ns1.uh.edu.              27472   IN      A       129.7.1.1
mesquite.cc.uh.edu.      27584   IN      A       66.140.111.1

;; Query time: 0 msec
;; SERVER: 129.7.240.1#53(129.7.240.1)
;; WHEN: Mon Mar 26 12:00:34 2012
;; MSG SIZE  rcvd: 188
```

HW8

- Distance Vector Routing
- Count-to-infinity
- Split-horizon



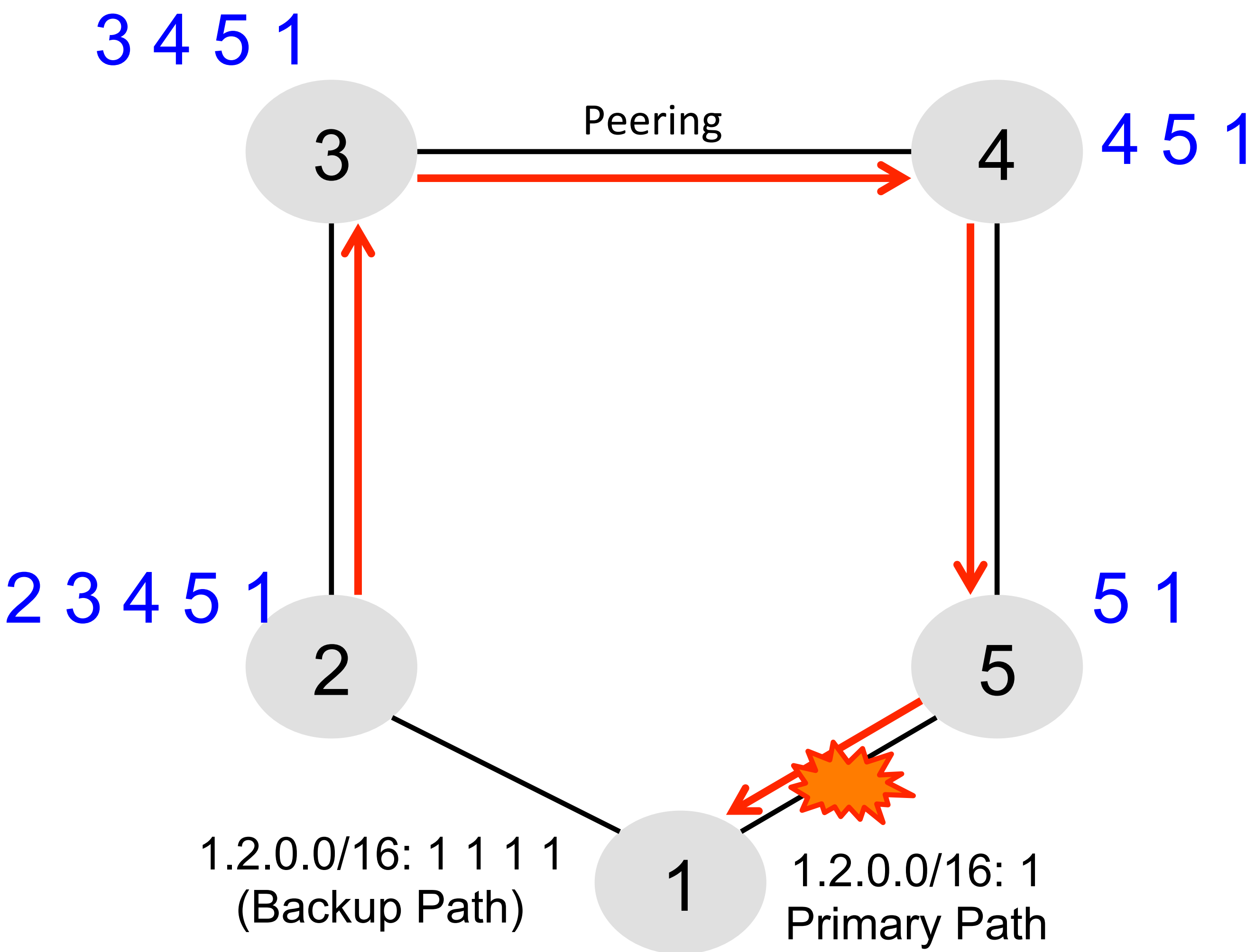
Today's Topics

- BGP Wedgies
- IP
- NAT
- Student presentations

Multiple Stable Configurations BGP Wedgies [RFC 4264]

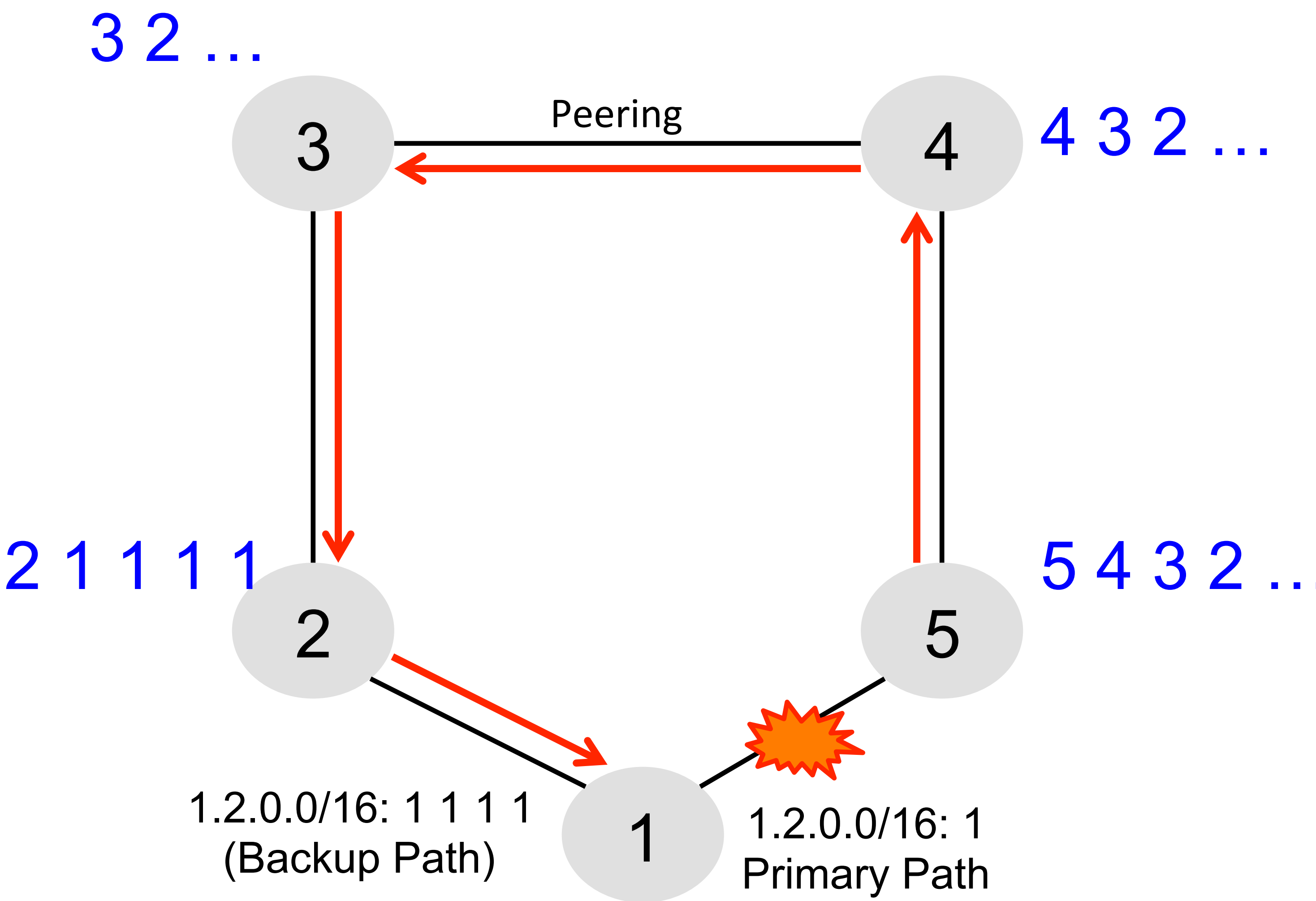
- Typical policy:
  - Prefer routes from customers
  - Then prefer shortest paths

BGP Wedgies



3 4 5 1
3
Peering
4
4 5 1
2 3 4 5 1
2
5 1
5
1.2.0.0/16: 1 1 1 1
(Backup Path)
1
1.2.0.0/16: 1
Primary Path

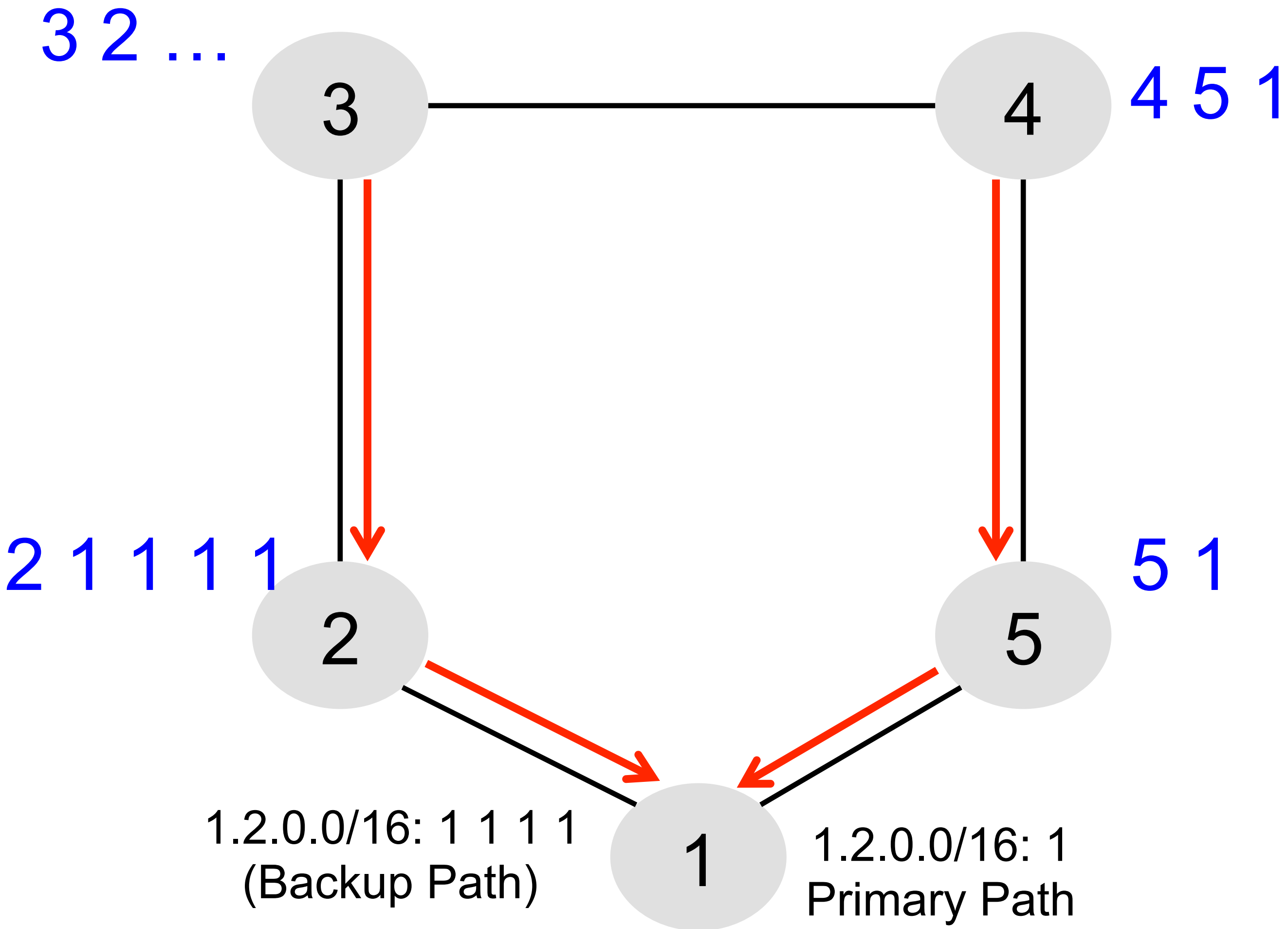
BGP Wedgies



3 2 …
Peering
3
4
4 3 2 …
2 1 1 1 1
2
5
5 4 3 2 …
1
1.2.0.0/16: 1 1 1 1
(Backup Path)
1.2.0.0/16: 1
Primary Path

BGP Wedgies

3 prefers customer route: stable configuration!



BGP Security Goals

- Confidential message exchange between neighbors
- Validity of routing information
  - Origin, Path, Policy
- Correspondence to the data path

Proposed Solution: S-BGP

- Based on a public key infrastructure
- Address attestations
  - Claims the right to originate a prefix
  - Signed and distributed out of band
  - Checked through delegation chain from ICANN
- Route attestations
  - Attribute in BGP update message
  - Signed by each AS as route along path
- S-BGP can avoid
  - Prefix hijacking
  - Addition, removal, or reordering of intermediate ASes

S-BGP Deployment

- Very challenging
  - PKI
  - Accurate address registries
  - Need to perform cryptographic operations on all path operations
  - Flag day almost impossible
  - Incremental deployment offers little incentive
- But there is hope! [Goldberg et al, 2011]
  - Road to incremental deployment
  - Change rules to break ties for secure paths
  - If a few top Tier-1 ISPs
  - Plus their respective stub clients deploy simplified version (just sign, not validate)
  - Gains in traffic => $ => adoption!

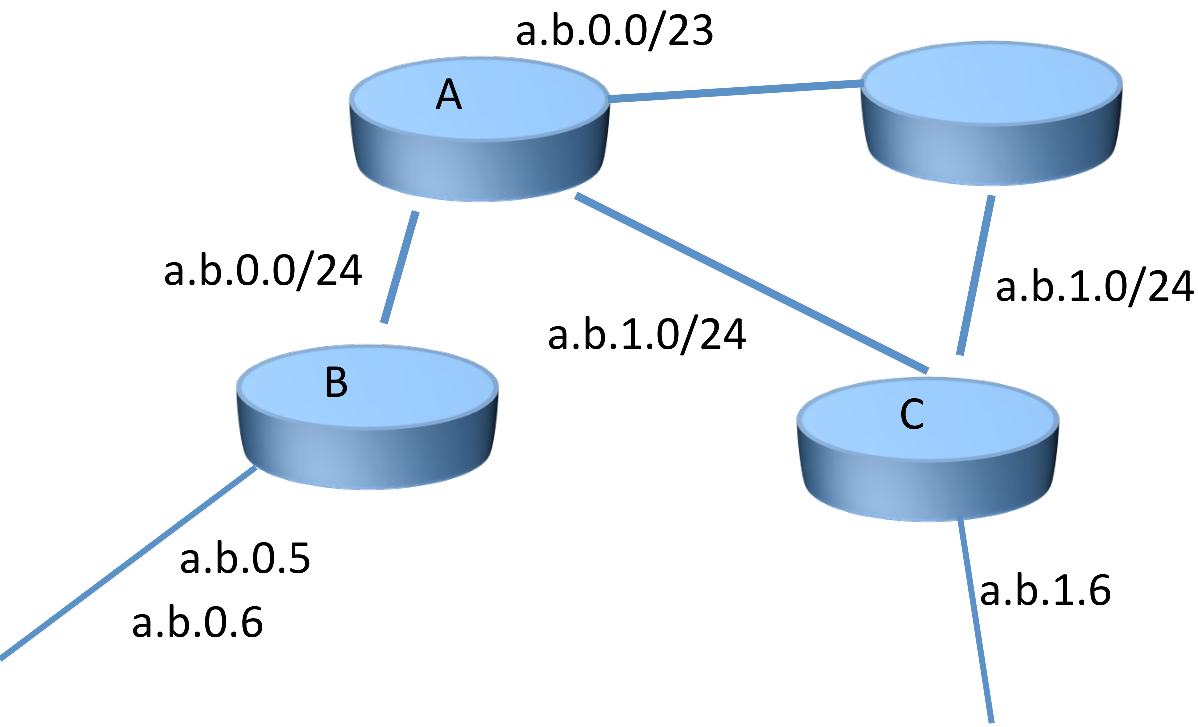
Data Plane Attacks

- Routers/ASes can advertise one route, but not necessarily follow it!
- May drop packets
  - Or a fraction of packets
  - What if you just slow down some traffic?
- Can send packets in a different direction
  - Impersonation attack
  - Snooping attack
- How to detect?
  - Congestion or an attack?
  - Can let ping/traceroute packets go through
  - End-to-end checks?
- Harder to pull off, as you need control of a router

Forwarding with CIDR

- Longest Prefix Match

Prefix	Nexthop
a.b.0.0/23	A
a.b.1.0/24	C



Where to forward these packets?
- dst: a.b.0.5
- dst: a.b.1.6

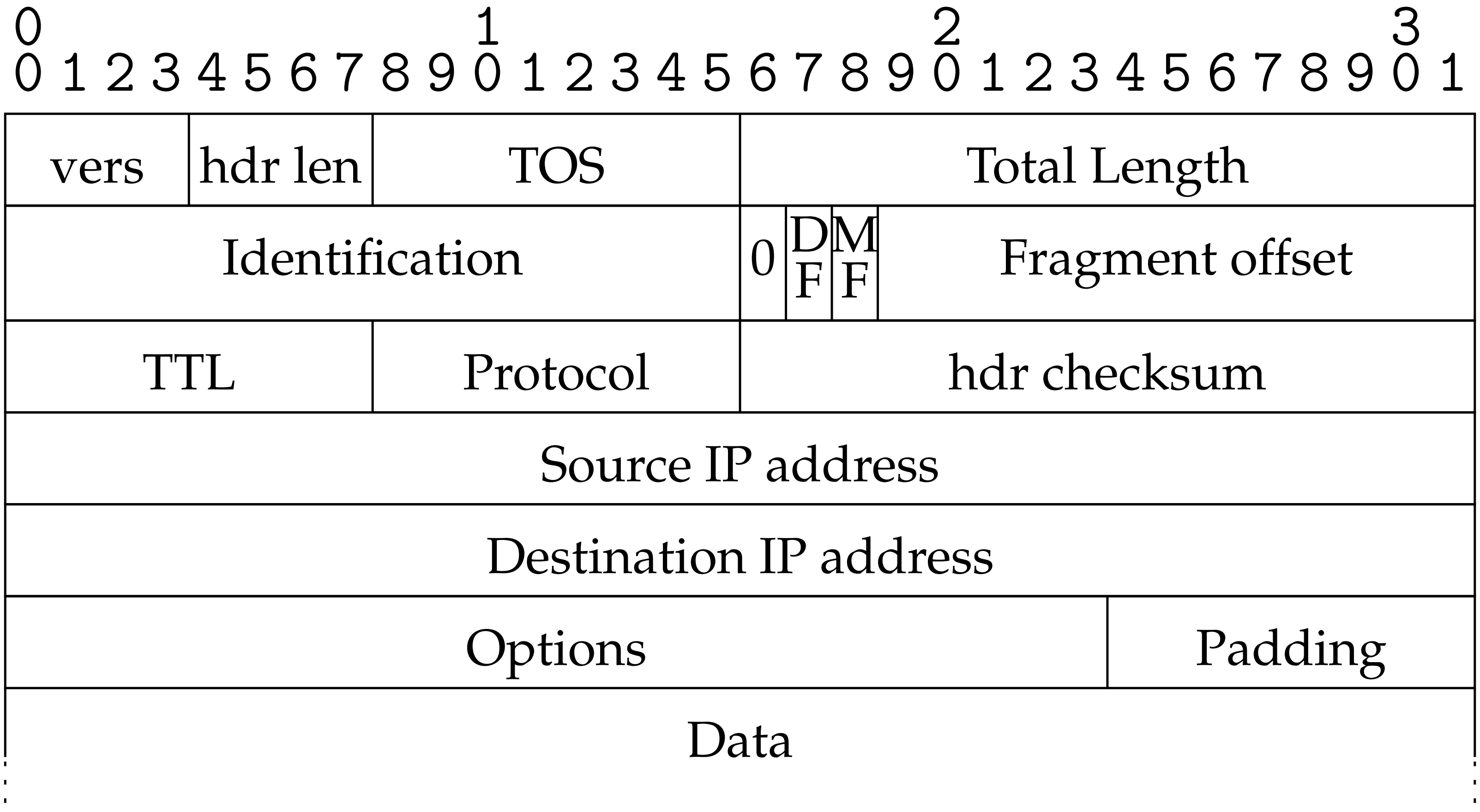
IP Protocol

- Provides addressing and *forwarding*
  - Addressing is a set of conventions for naming nodes in an IP network
  - Forwarding is a local action by a router: passing a packet from input to output port
- IP forwarding finds output port based on destination address
  - Also defines certain conventions on how to handle packets (e.g., fragmentation, time to live)
- Contrast with *routing*
  - Routing is the process of determining how to map packets to output ports (topic of next two lectures)

Service Model

- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
  - packets may be lost
  - packets may be delivered out of order
  - duplicate copies of packets may be delivered
  - packets may be delayed for a long time
- It's the lowest common denominator
  - A network that delivers no packets fits the bill!
  - All these can be dealt with above IP (if probability of delivery is non-zero…)

IP v4 packet format



IP header details

- Forwarding based on destination address
- TTL (time-to-live) decremented at each hop
  - Originally was in seconds (no longer)
  - Mostly prevents forwarding loops
  - Other cool uses…
- Fragmentation possible for large packets
  - Fragmented in network if crossing link w/ small frame
  - MF: more fragments for this IP packet
  - DF: don't fragment (returns error to sender)
- Following IP header is "payload" data
  - Typically beginning with TCP or UDP header

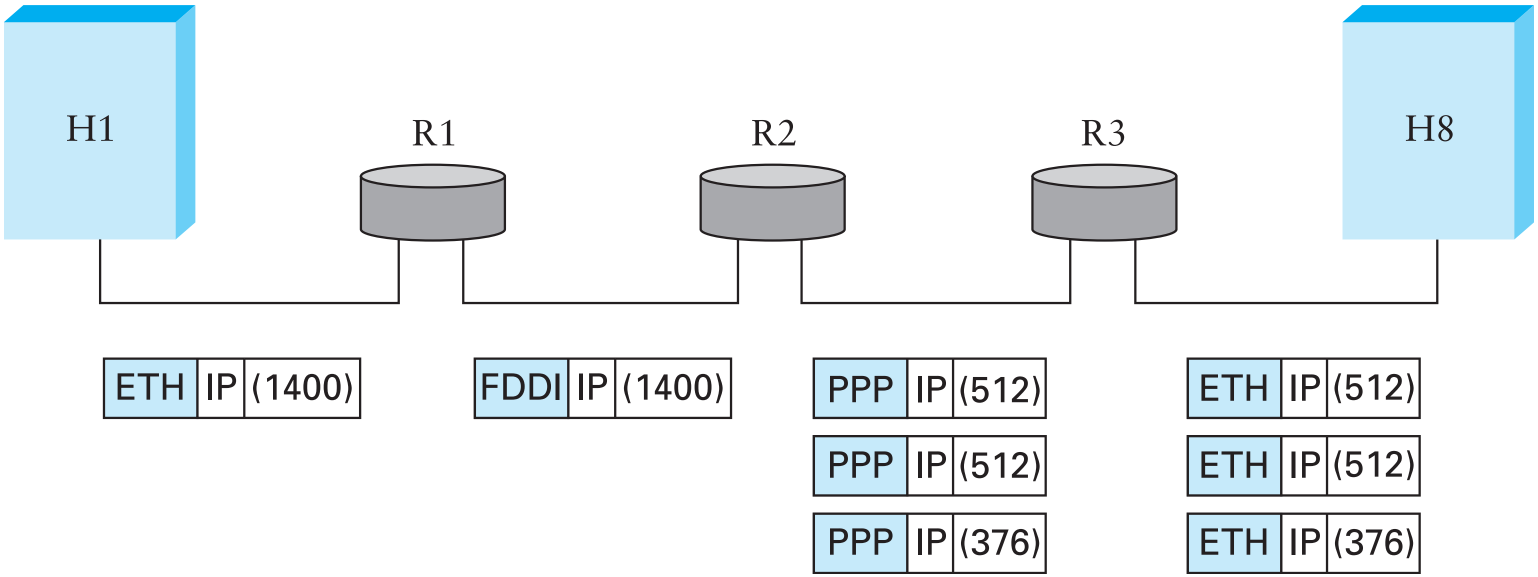
Other fields

- Version: 4 (IPv4) for most packets, there's also 6
- Header length: in 32-bit units (>5 implies options)
- Type of service (won't go into this)
- Protocol identifier (TCP: 6, UDP: 17, ICMP: 1, …)
- Checksum over the header

Fragmentation & Reassembly

- Each network has maximum transmission unit (MTU)
- Strategy
  - Fragment when necessary (MTU < size of datagram)
  - Source tries to avoid fragmentation (why?)
  - Re-fragmentation is possible
  - Fragments are self-contained datagrams
  - Delay reassembly until destination host
  - No recovery of lost fragments

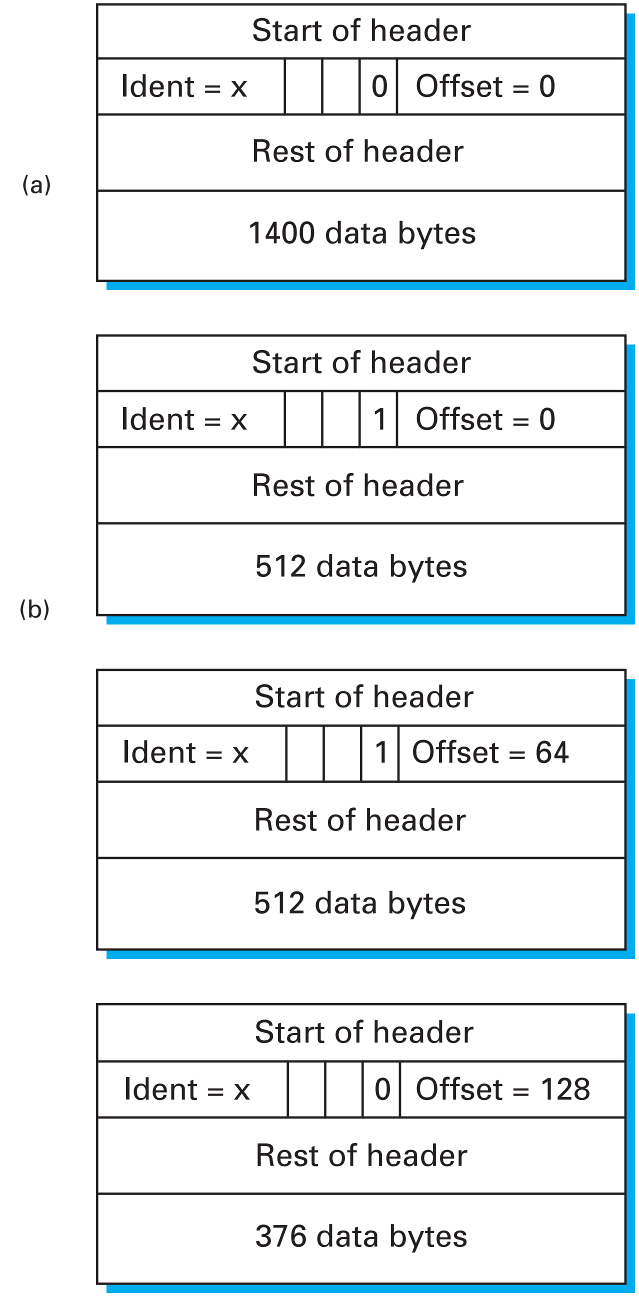
Fragmentation Example



- Ethernet MTU is 1,500 bytes
- PPP MTU is 576 bytes
  - R2 must fragment IP packets to forward them

Fragmentation Example (cont)

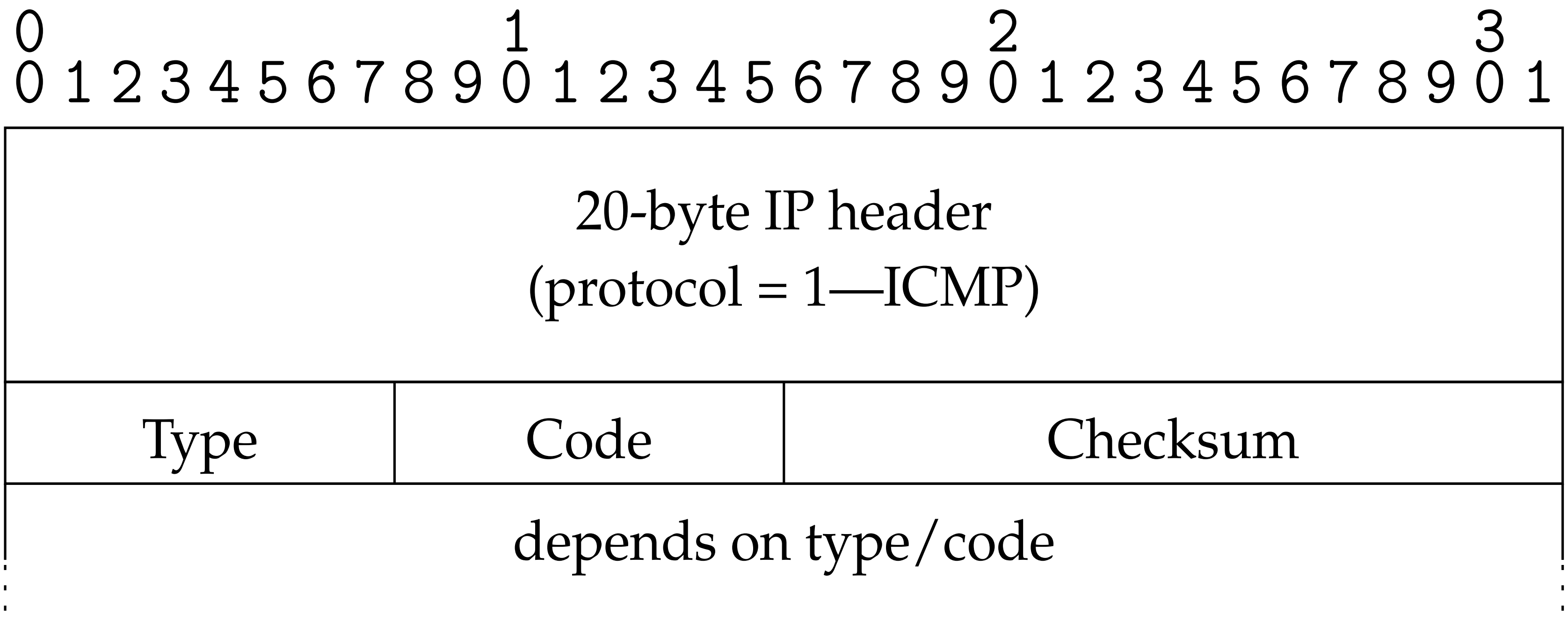
- IP addresses plus ident field identify fragments of same packet
- MF (more fragments bit) is 1 in all but last fragment
- Fragment offset multiple of 8 bytes
  - Multiply offset by 8 for fragment position original packet



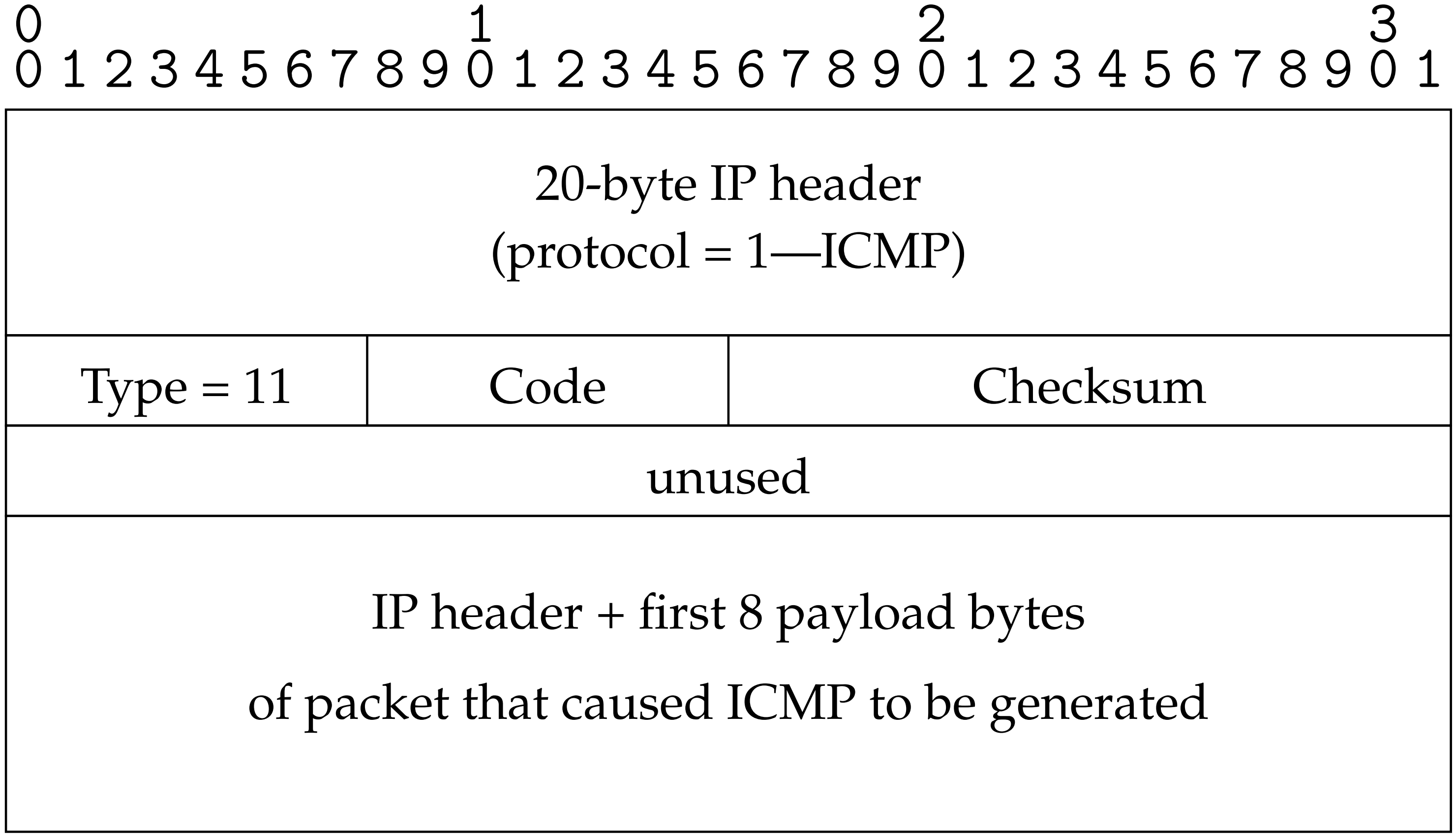
Internet Control Message Protocol (ICMP)

- Echo (ping)
- Redirect
- Destination unreachable (protocol, port, or host)
- TTL exceeded
- Checksum failed
- Reassembly failed
- Can't fragment
- Many ICMP messages include part of packet that triggered them
- See http://www.iana.org/assignments/icmp-parameters

ICMP message format



Example: Time Exceeded



- Student presentation: traceroute

Translating IP to lower level addresses

- Map IP addresses into physical addresses
  - E.g., Ethernet address of destination host
  - or Ethernet address of next hop router
- Techniques
  - Encode physical address in host part of IP address (IPv6)
  - Each network node maintains lookup table (IP->phys)

ARP – *address resolution protocol*

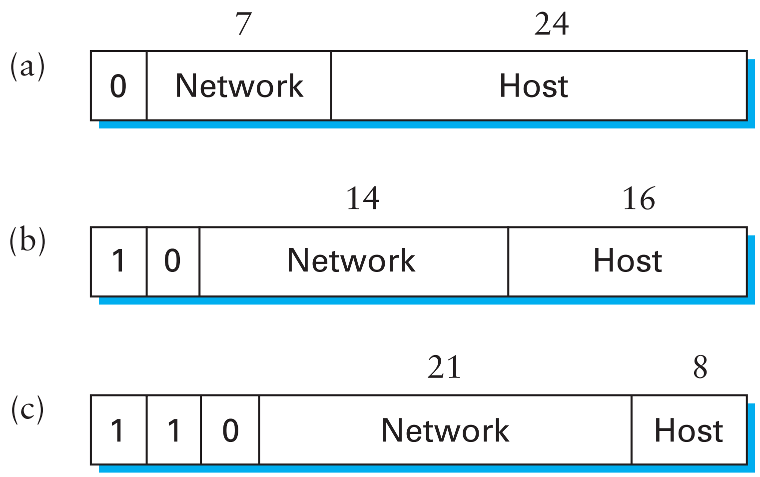
- Dynamically builds table of IP to physical address bindings
- Broadcast request if IP address not in table
- All learn IP address of requesting node (broadcast)
- Target machine responds with its physical address
- Table entries are discarded if not refreshed

ARP Ethernet frame format

<table>
<tr><th>0</th><th>8</th><th>16</th><th>31</th></tr>
<tr><td colspan="2">Hardware type = 1</td><td colspan="2">ProtocolType = 0x0800</td></tr>
<tr><td>HLen = 48</td><td>PLen = 32</td><td colspan="2">Operation</td></tr>
<tr><td colspan="4">SourceHardwareAddr (bytes 0–3)</td></tr>
<tr><td colspan="2">SourceHardwareAddr (bytes 4–5)</td><td colspan="2">SourceProtocolAddr (bytes 0–1)</td></tr>
<tr><td colspan="2">SourceProtocolAddr (bytes 2–3)</td><td colspan="2">TargetHardwareAddr (bytes 0–1)</td></tr>
<tr><td colspan="4">TargetHardwareAddr (bytes 2–5)</td></tr>
<tr><td colspan="4">TargetProtocolAddr (bytes 0–3)</td></tr>
</table>

Format of IP addresses

- Globally unique (or made seem that way)
  - 32-bit integers, read in groups of 8-bits: 128.148.32.110
- Hierarchical: network + host
- Originally, routing prefix embedded in address



  - Class A (8-bit prefix), B (16-bit), C (24-bit)
  - Routers need only know route for each network

Forwarding Tables

- Exploit hierarchical structure of addresses: need to know how to reach *networks*, not hosts

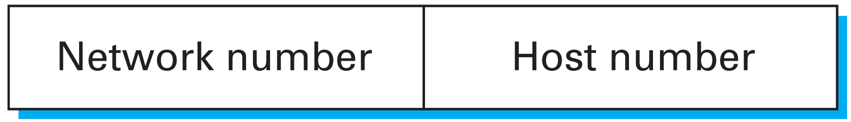
Network	Next Address
212.31.32.*	0.0.0.0
18.*.*.*	212.31.32.5
128.148.*.*	212.31.32.4
Default	212.31.32.1

- Keyed by network portion, not entire address
- Next address should be local

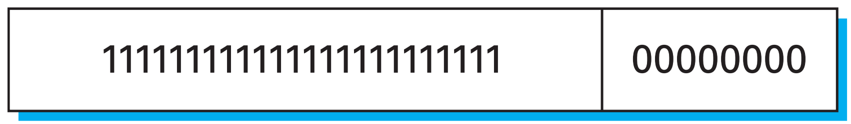
Classed Addresses

- Hierarchical: network + host
  - Saves memory in backbone routers (no default routes)
  - Originally, routing prefix embedded in address
  - Routers in same network must share network part
- Inefficient use of address space
  - Class C with 2 hosts (2/255 = 0.78% efficient)
  - Class B with 256 hosts (256/65535 = 0.39% efficient)
  - Shortage of IP addresses
  - Makes address authorities reluctant to give out class B's
- Still too many networks
  - Routing tables do not scale
- Routing protocols do not scale

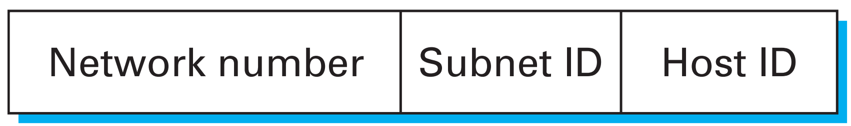
Subnetting



Class B address



Subnet mask (255.255.255.0)

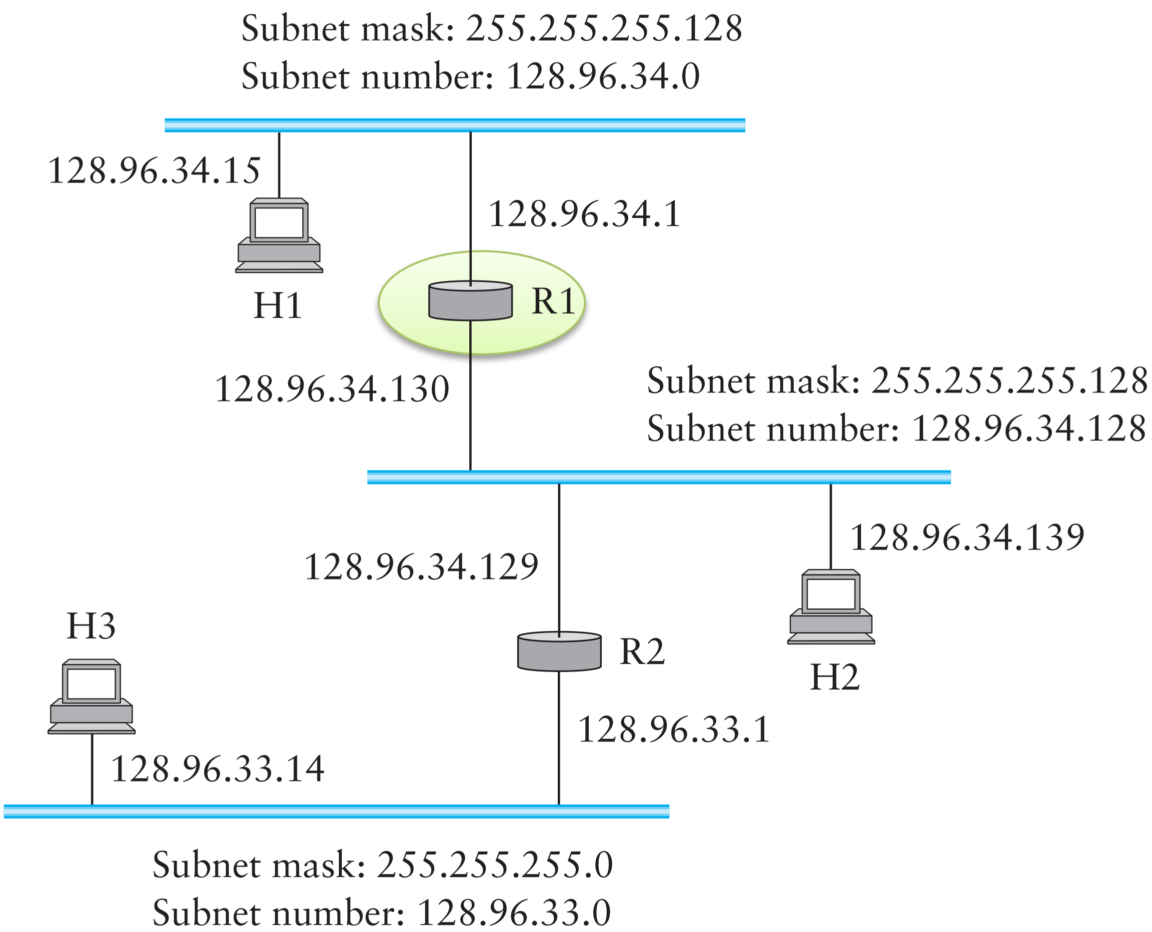


Subnetted address

- Add another level to address/routing hierarchy
- Subnet mask defines variable portion of host part
- Subnets visible only within site
- Better use of address space

R1's Forwarding Table

Network	Subnet Mask	Next Address
128.96.34.0	255.255.255.128	128.96.34.1
128.96.34.128	255.255.255.128	128.96.34.130
128.96.33.0	255.255.255.0	128.96.34.129



Supernetting

- Assign blocks of contiguous networks to nearby networks
- Called CIDR: Classless Inter-Domain Routing
- Represent blocks with a single pair
  - (first network address, count)
- Restrict block sizes to powers of 2
- Use a bit mask (CIDR mask) to identify block size
- Address aggregation: reduce routing tables

CIDR Forwarding Table

Network	Next Address
212.31.32/24	0.0.0.0
18/8	212.31.32.5
128.148/16	212.31.32.4
128.148.128/17	212.31.32.8
0/0	212.31.32.1

Obtaining IP Addresses

- Blocks of IP addresses allocated hierarchically
  - ISP obtains an address block, may subdivide

ISP: 128.35.16/20 10000000 00100011 00010000 00000000

Client 1: 128.35.16/22 10000000 00100011 00010000 00000000

Client 2: 128.35.20/22 10000000 00100011 00010100 00000000

Client 3: 128.35.24/21 10000000 00100011 00011000 00000000

- Global allocation: ICANN, /8's (ran out!)
- Regional registries: ARIN, RIPE, APNIC, LACNIC, AFRINIC