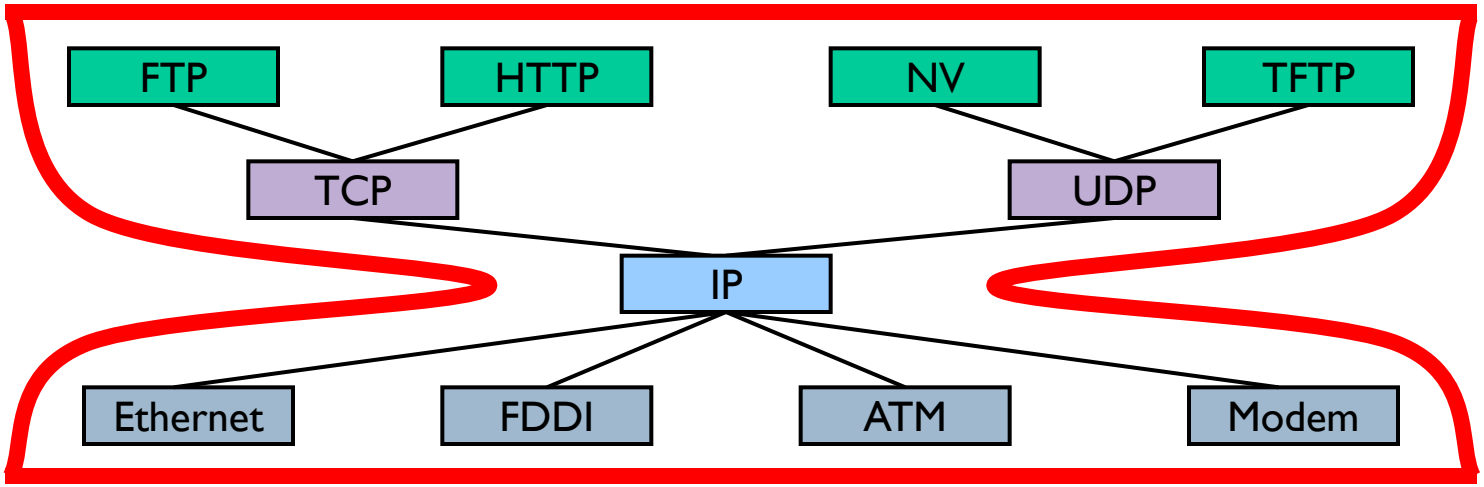
CS/ECE 439: Wireless Networking

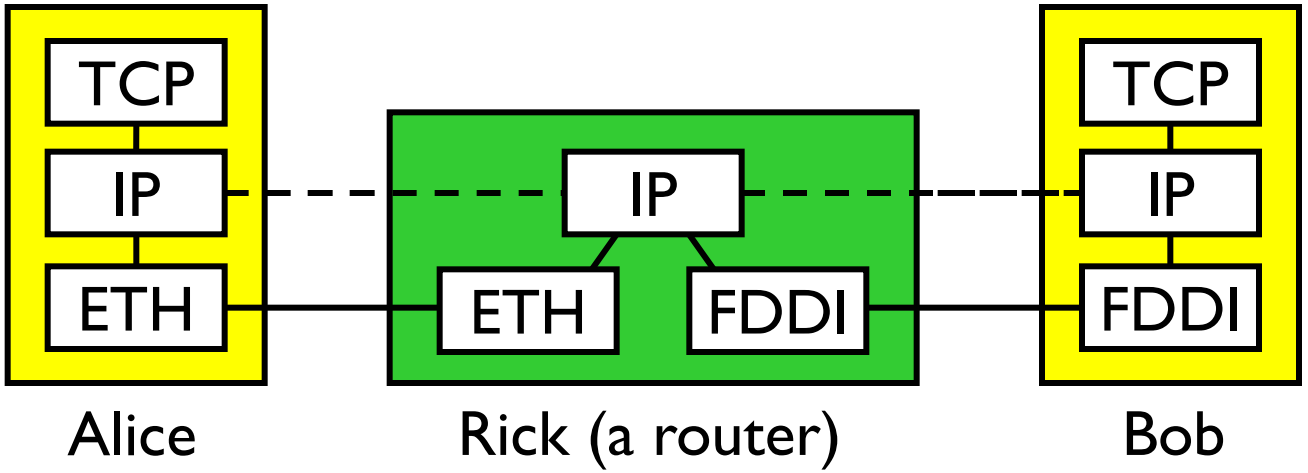
What you need to know about the Internet to understand the challenges of wireless and mobile hosts

IP and the Internet

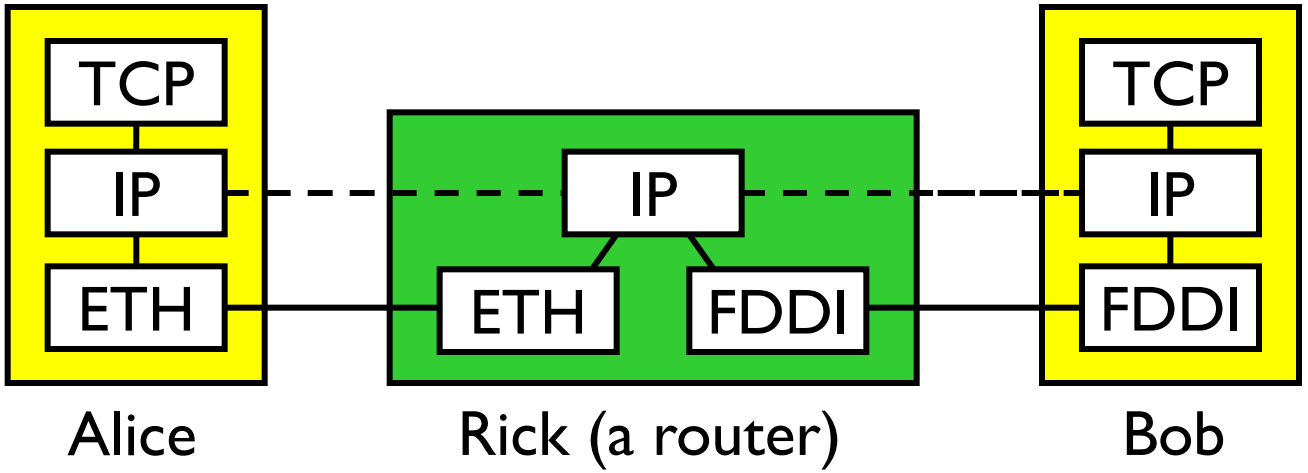
- Network-level protocol for the Internet
- Operates on all hosts and routers
  - Routers are nodes connecting distinct networks to the Internet



Layering



Message Transmission

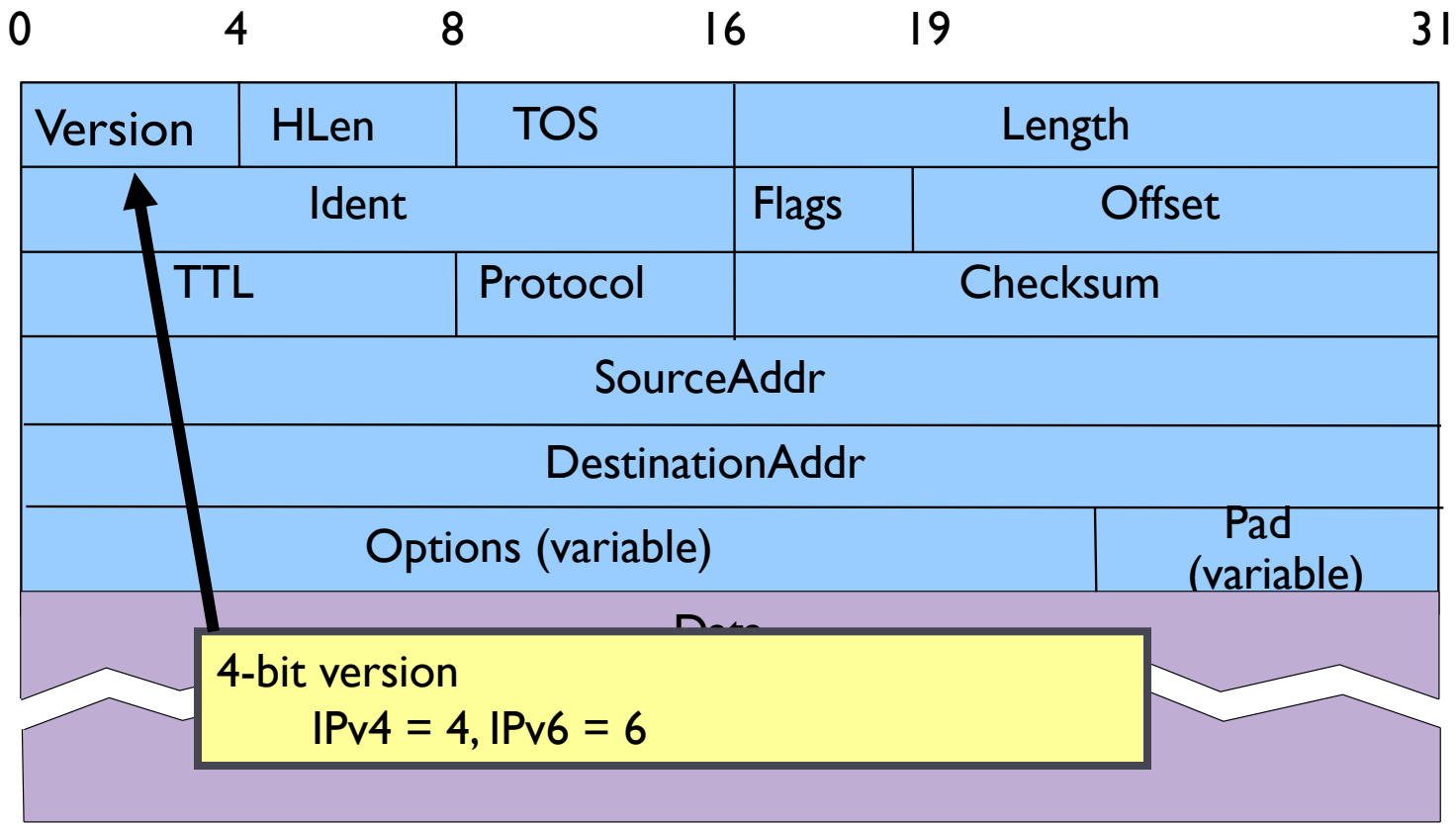


1. Alice/application finds Bob's IP address, sends packet
2. Alice/IP forwards packet to Rick
3. Alice/IP looks up Rick's Ethernet address and sends
4. Rick/IP forwards packet to Bob
5. Rick/IP looks up Bob's FDDI address and sends

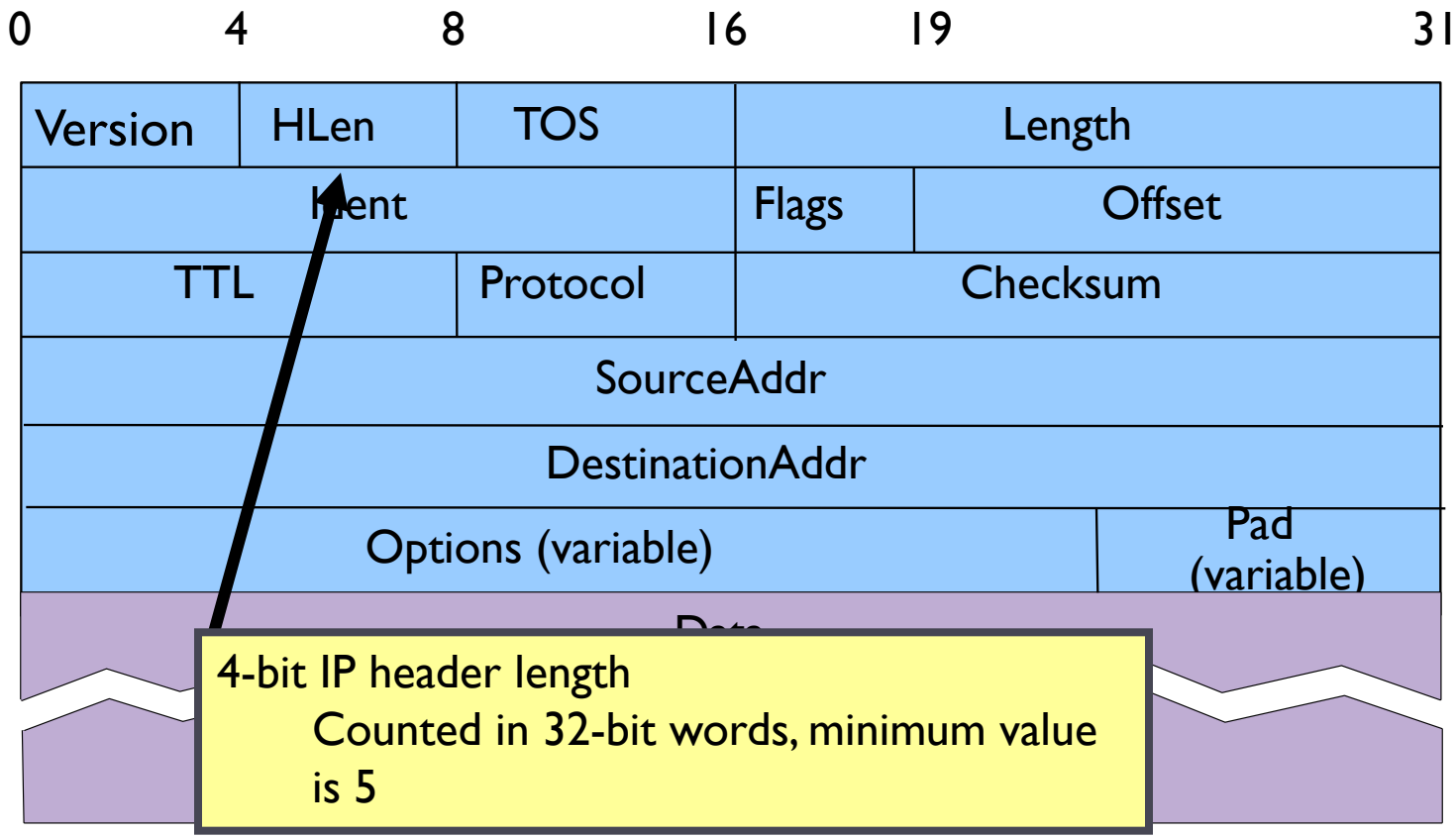
Internet Protocol Service Model

- Service provided to transport layer (TCP, UDP)
  - Global name space
  - Host-to-host connectivity (connectionless)
  - Best-effort packet delivery
- Not in IP service model
  - Delivery guarantees on bandwidth, delay or loss
- Delivery failure modes
  - Packet delayed for a very long time
  - Packet loss
  - Packet delivered more than once
  - Packets delivered out of order

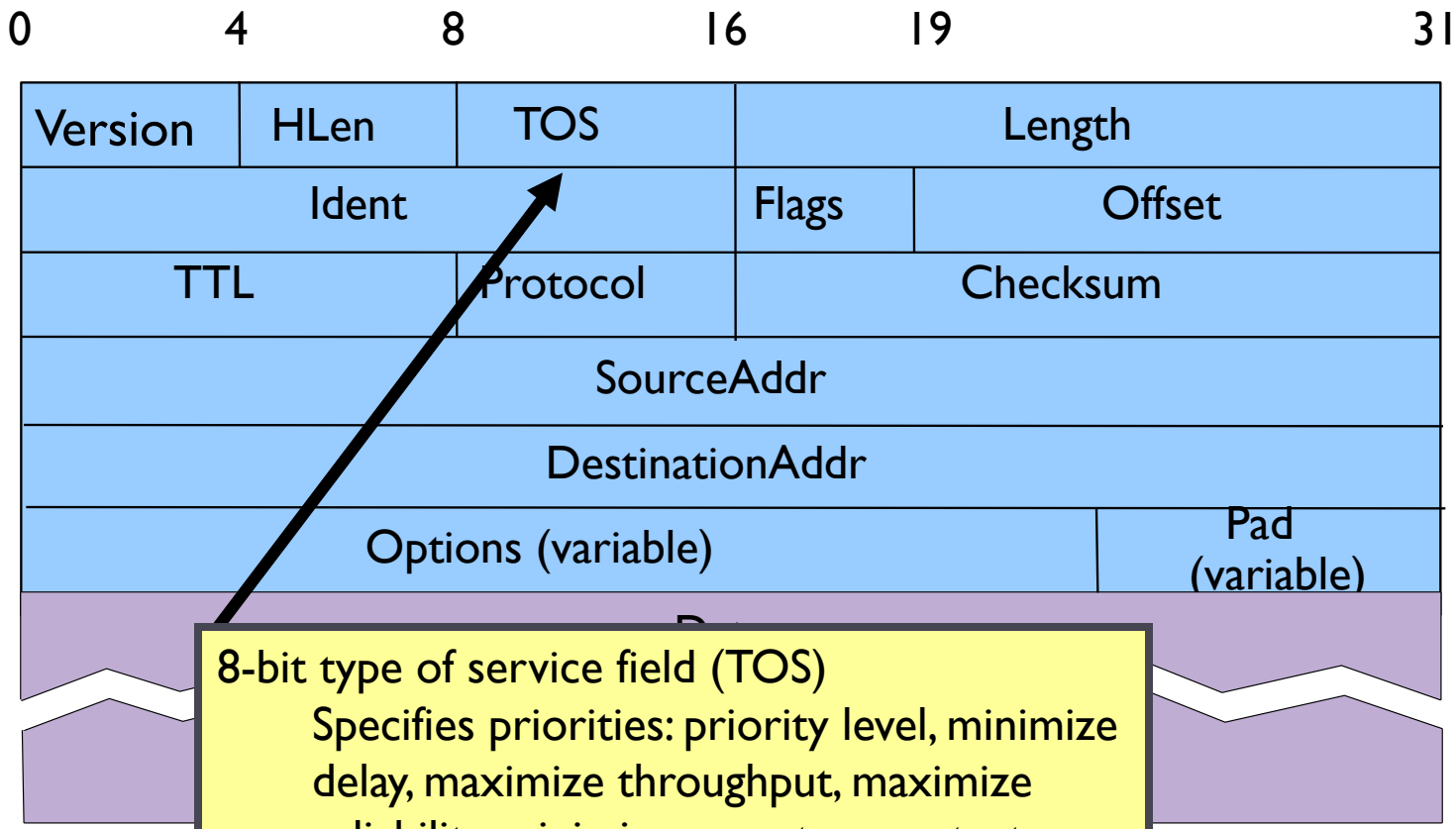
IP Packet Format



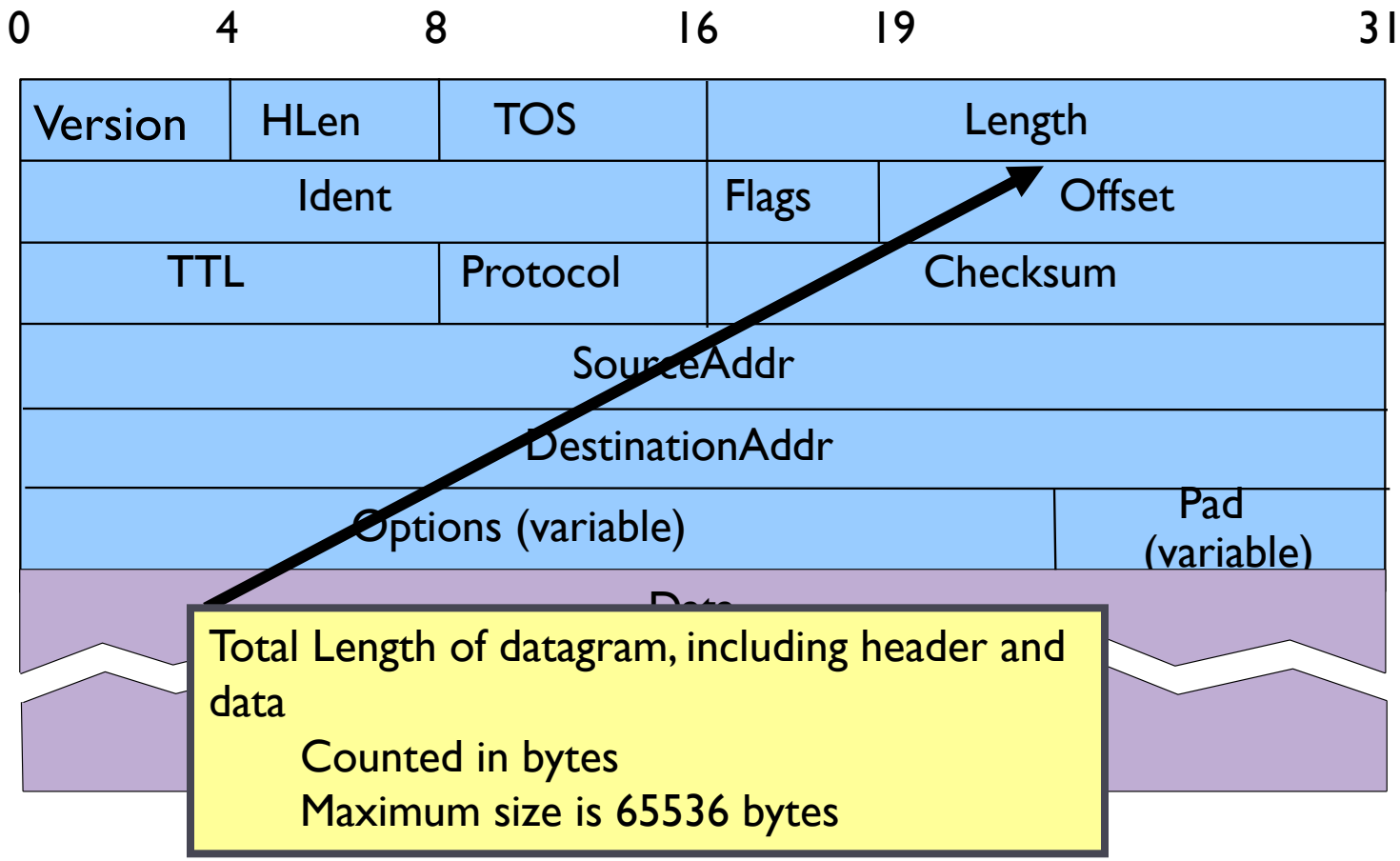
IP Packet Format



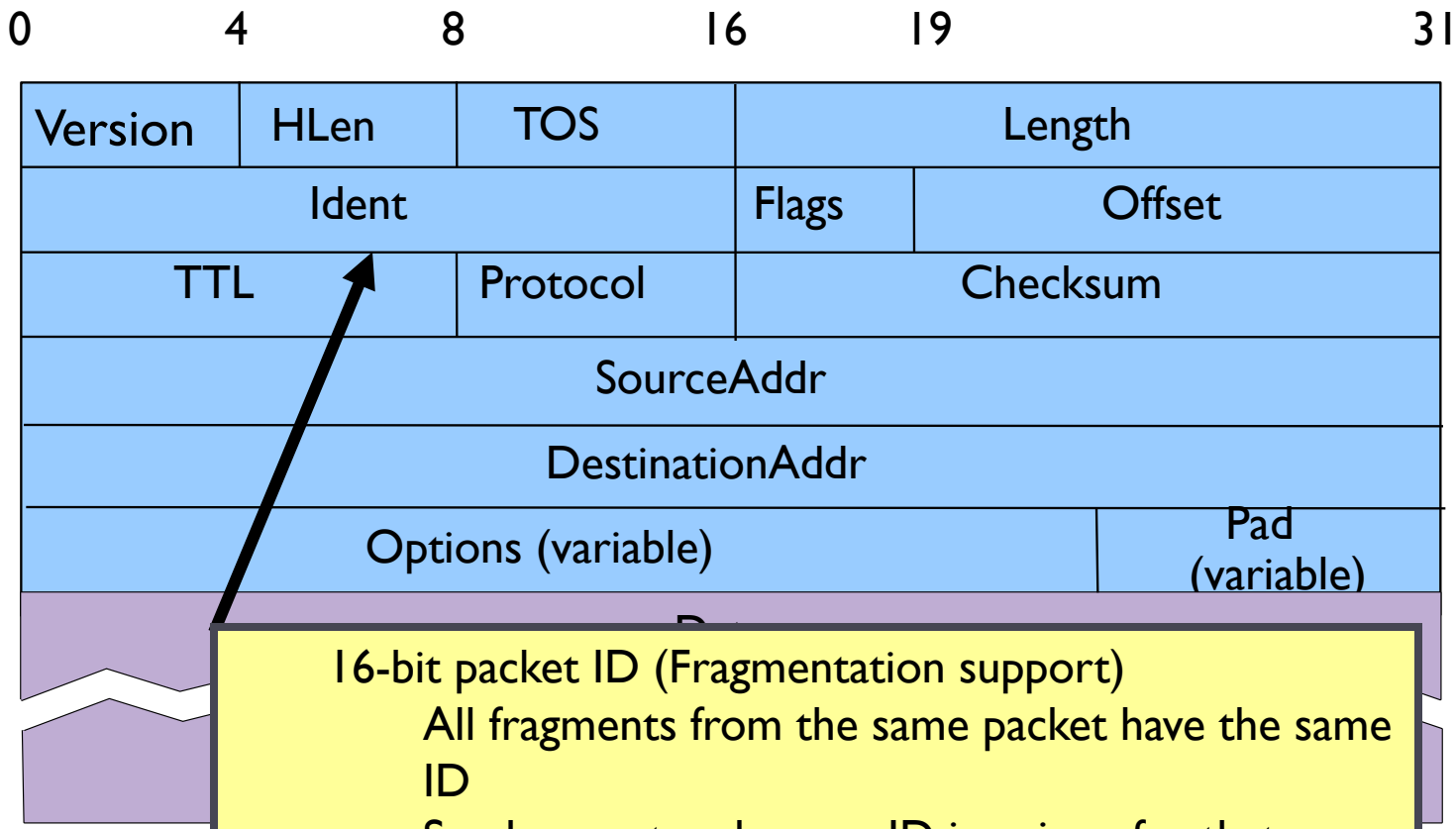
IP Packet Format



IP Packet Format



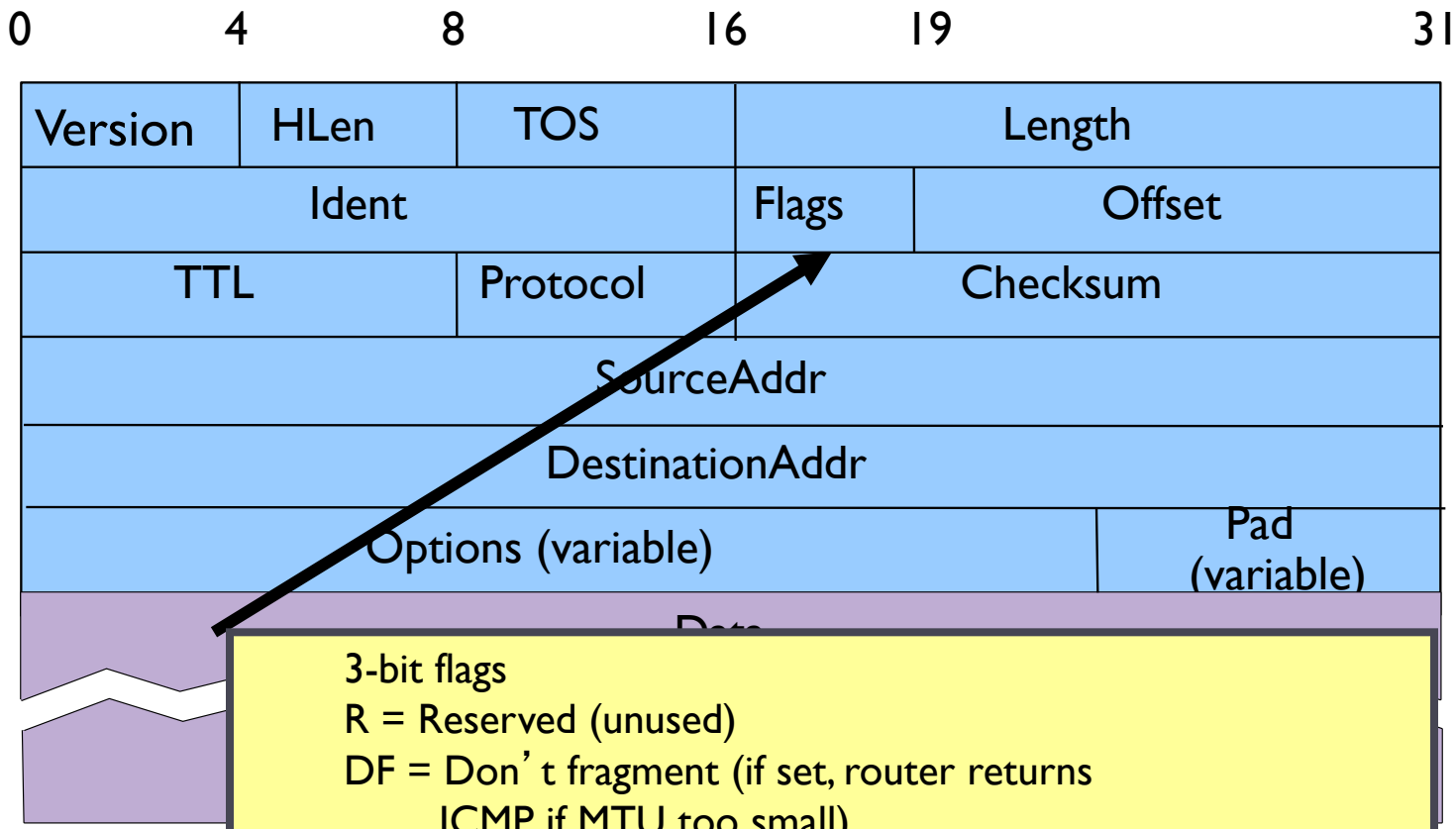
IP Packet Format



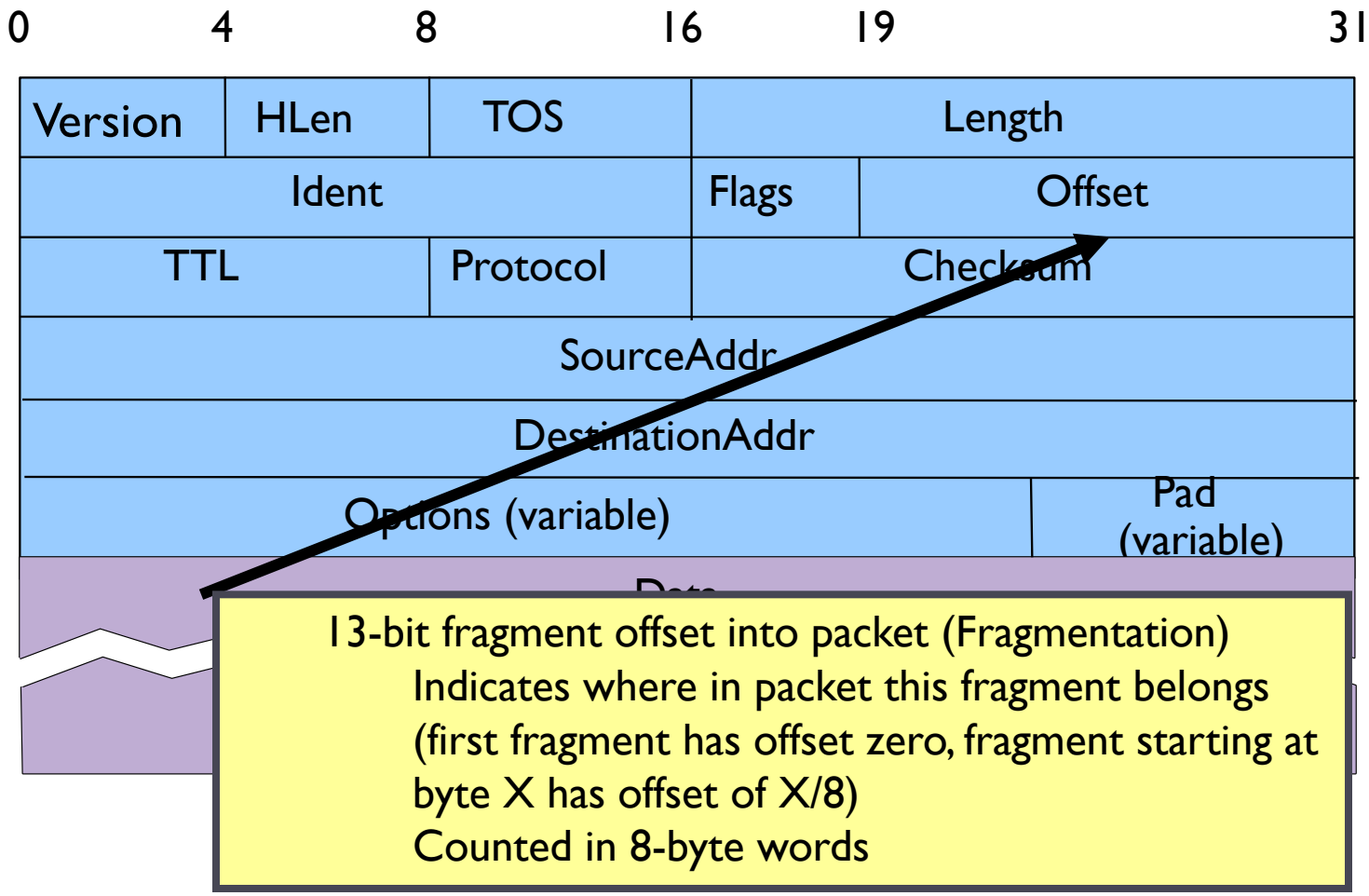
16-bit packet ID (Fragmentation support)

- All fragments from the same packet have the same ID
- Sender must make sure ID is unique for that (src,dest) pair, for the time the datagram will be active in the Internet

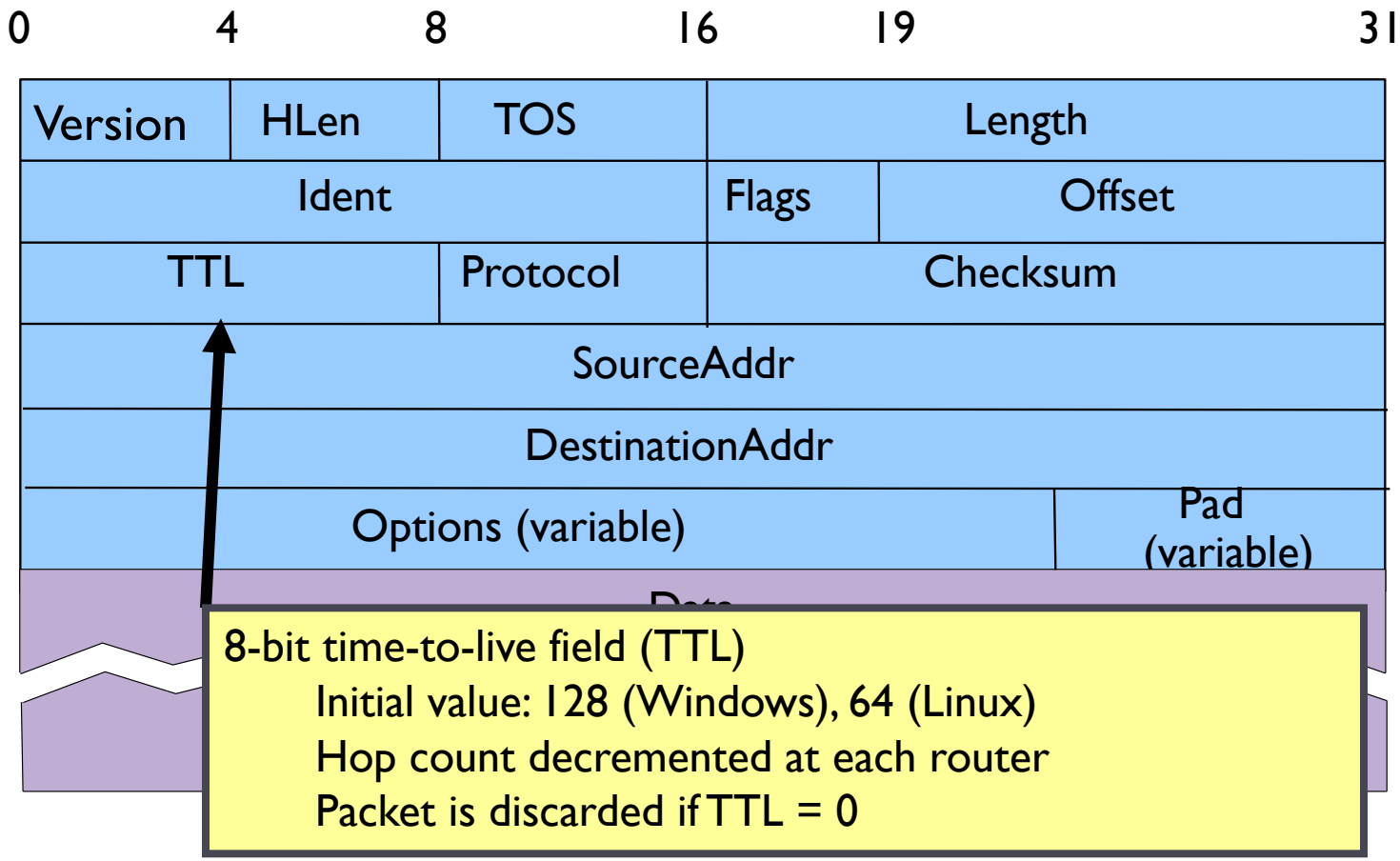
IP Packet Format



IP Packet Format



IP Packet Format



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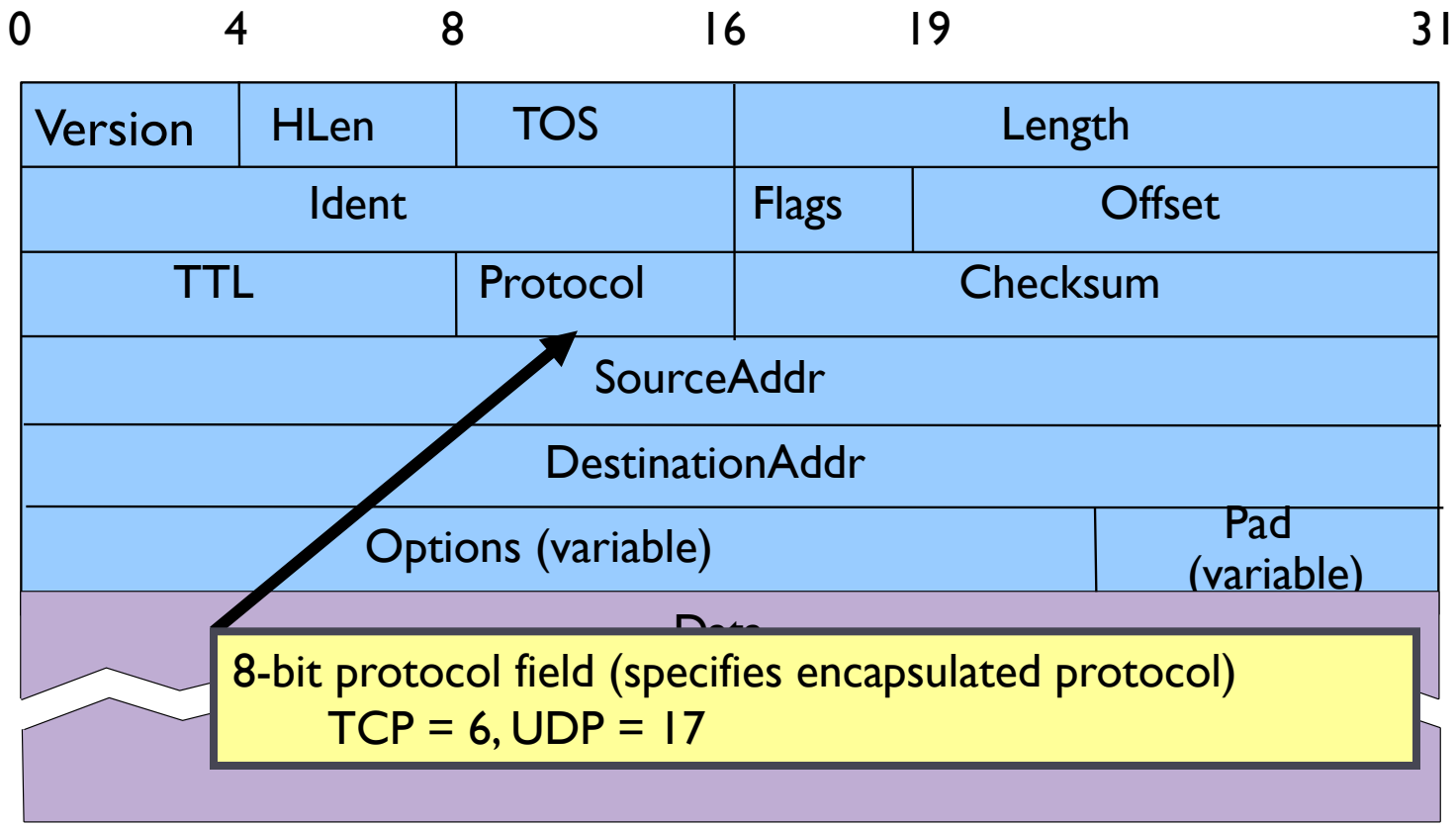

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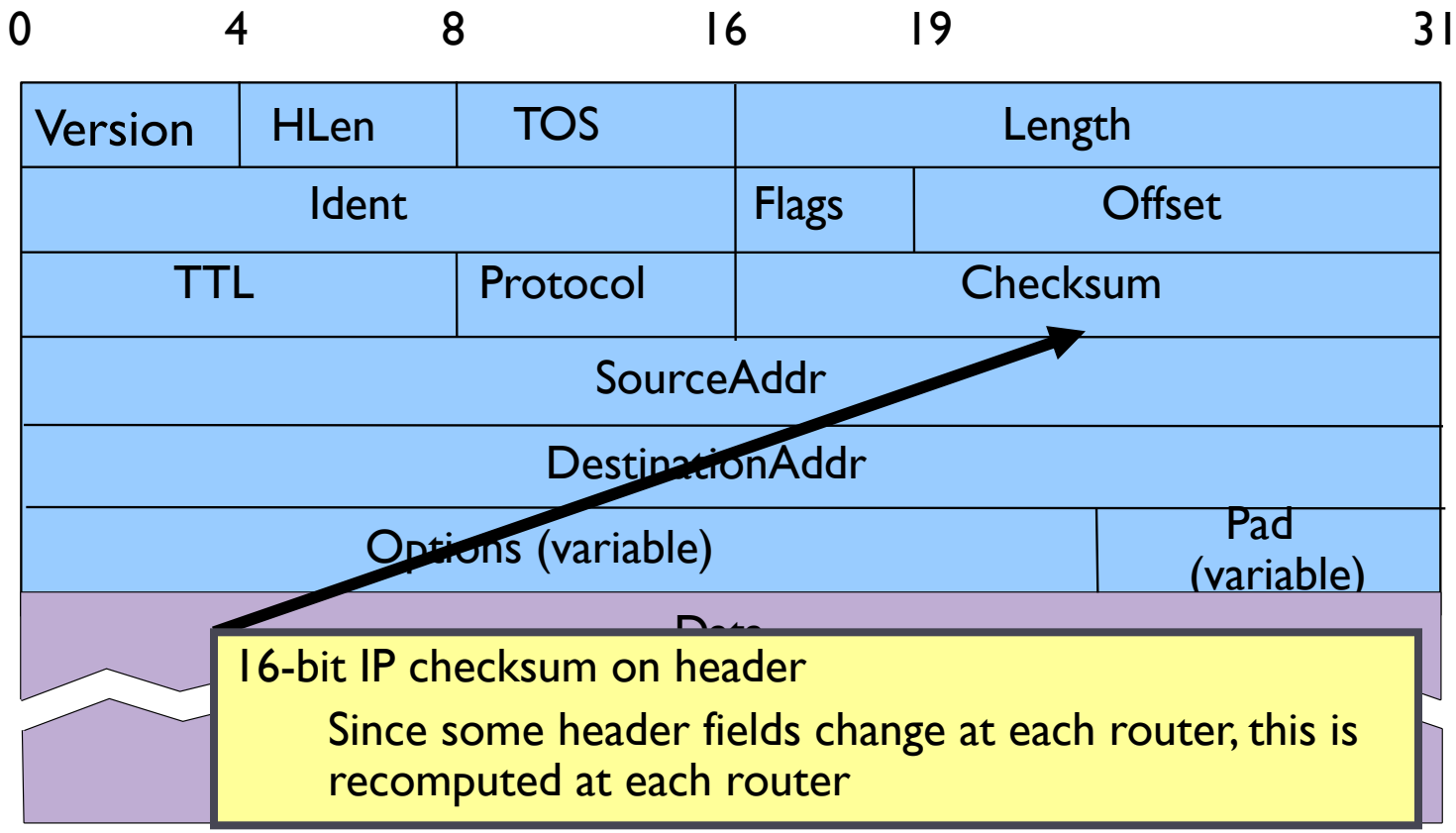
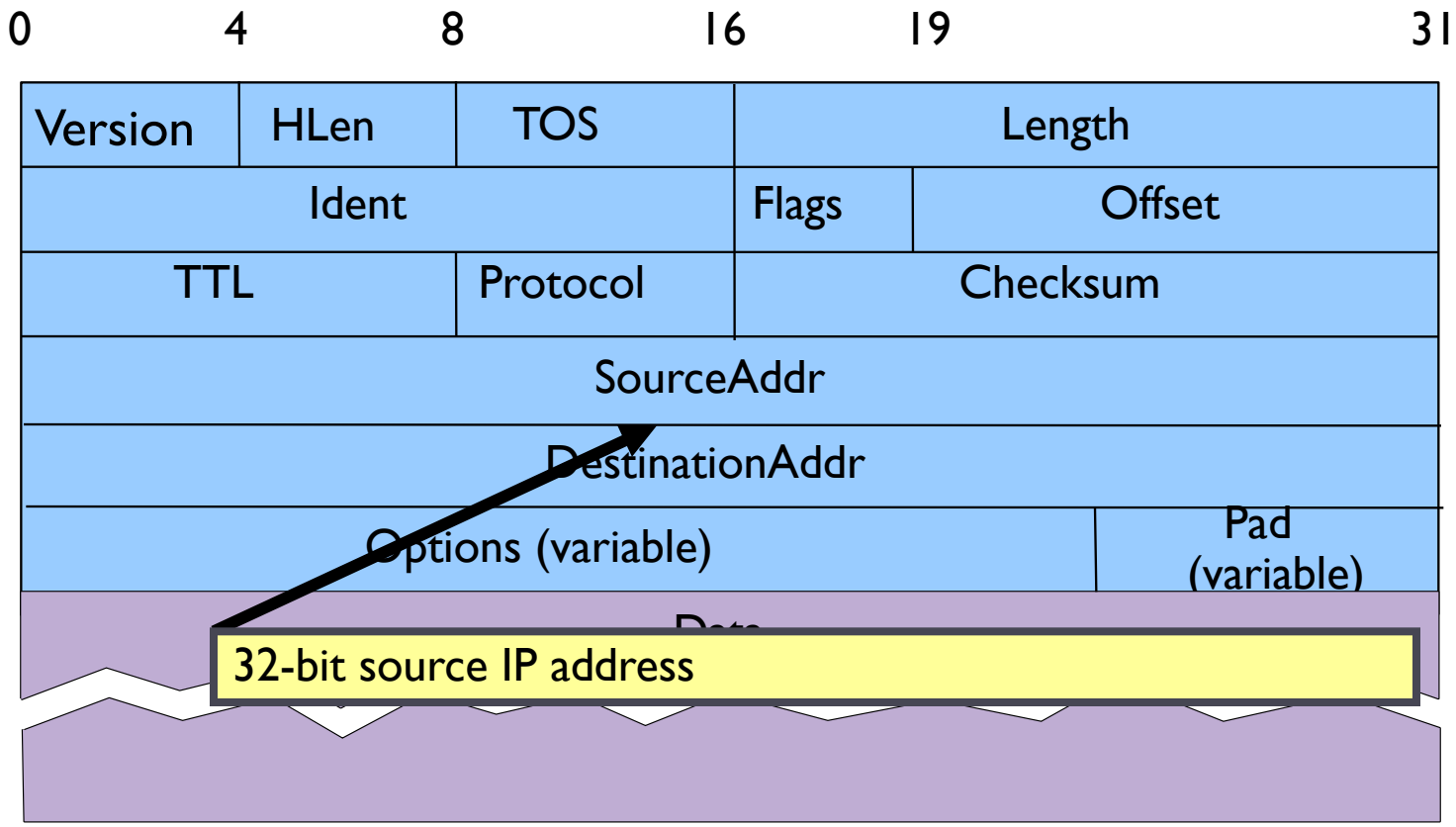
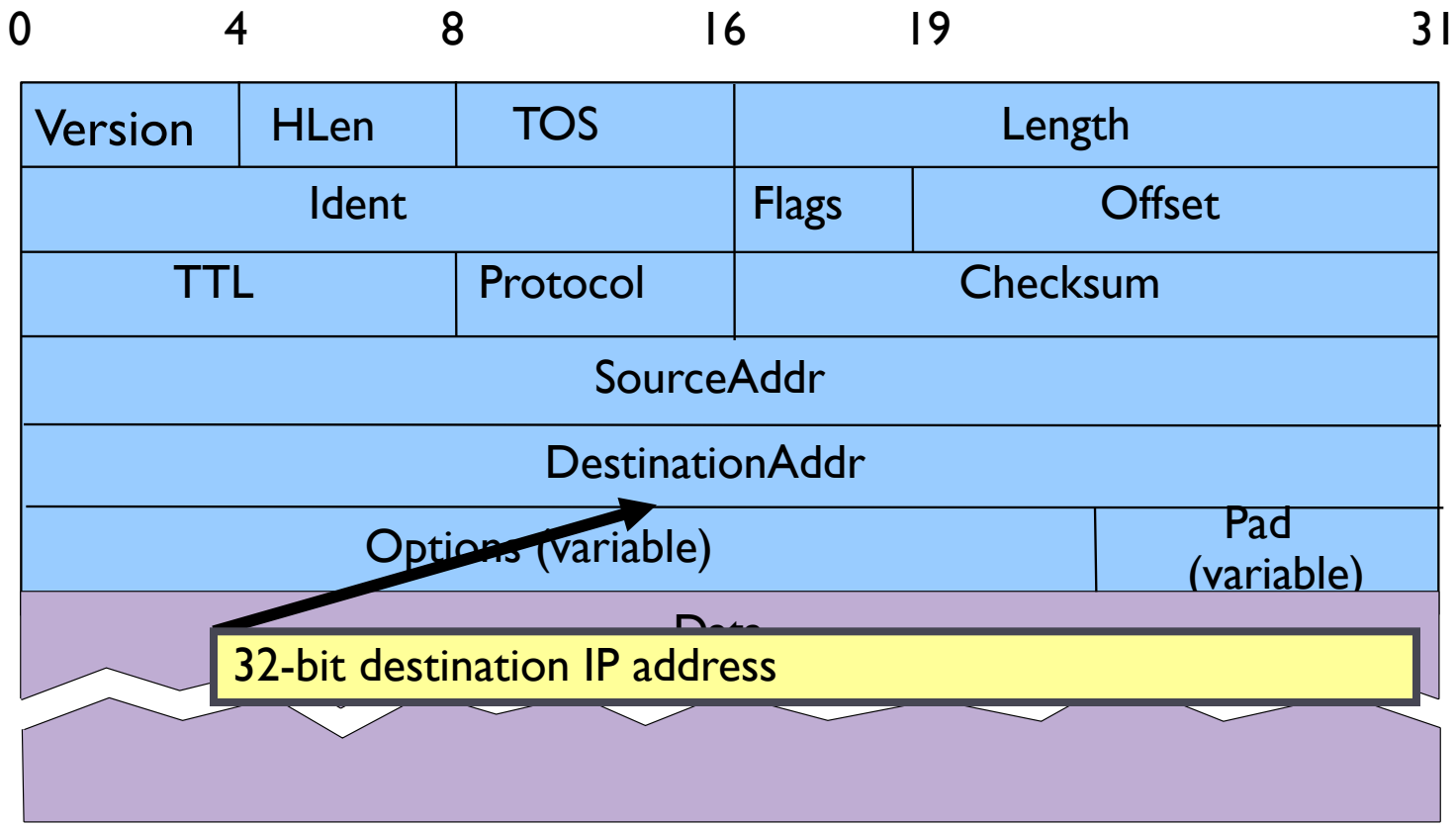


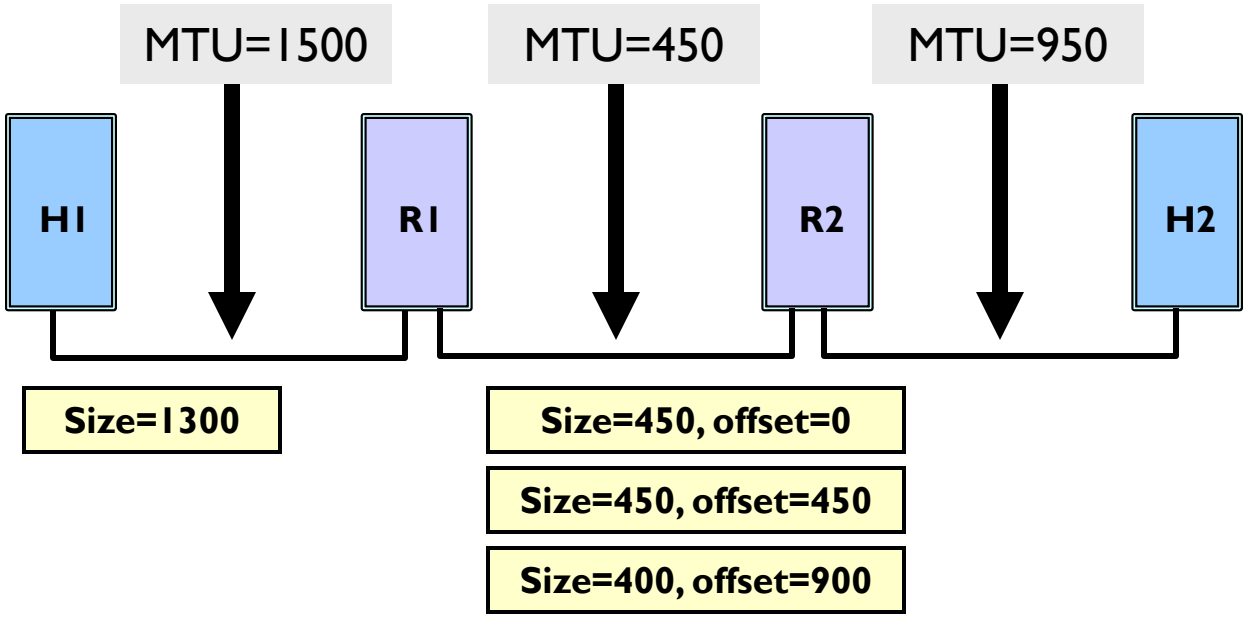
IP Packet Format



IP Packet Format

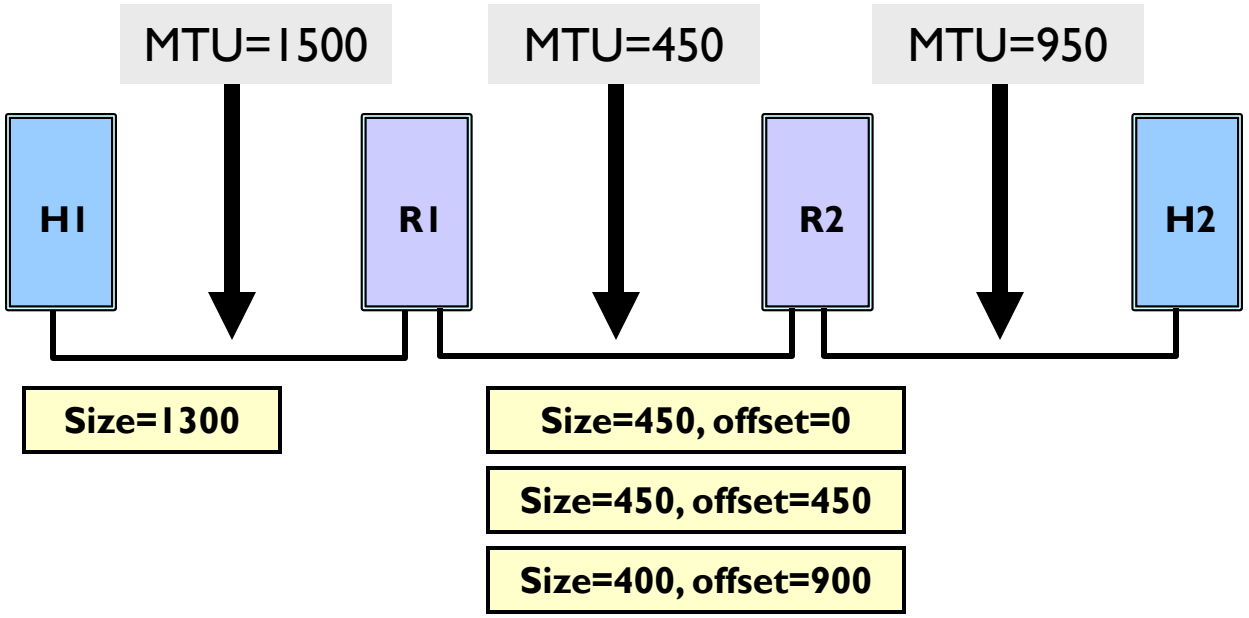


IP Fragmentation and Reassembly



- Solution
  - When necessary, split IP packet into acceptably sized packets prior to sending over physical link

IP Fragmentation and Reassembly

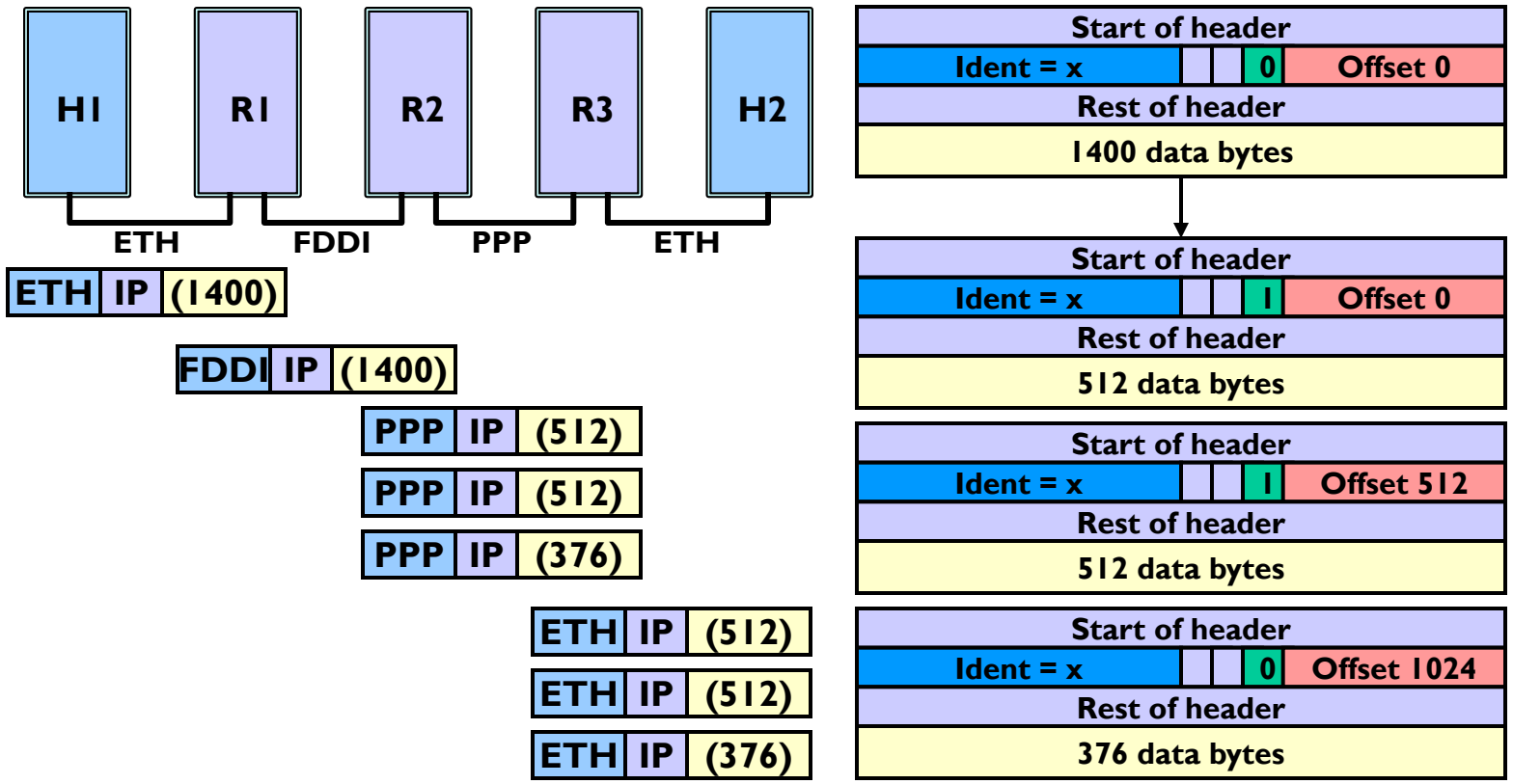


- Questions
  - Where should reassembly occur?
  - What happens when a fragment is damaged/lost?

IP Fragmentation and Reassembly

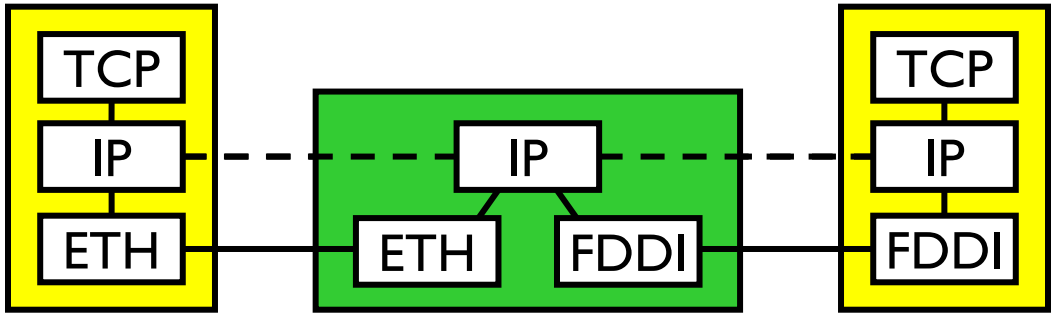
- Fragments
  - self-contained IP datagrams
- Reassemble at destination
  - Minimizes refragmentation
- If one or more fragments are lost
  - Drop all fragments in packet
- Avoid fragmentation at source host
  - Transport layer should send packets small enough to fit into one MTU of local physical network
  - Must consider IP header

IP Fragmentation and Reassembly



IPv4 Address Translation support

- IP addresses to LAN physical addresses
- Problem
  - An IP route can pass through many physical networks
  - Data must be delivered to destination's physical network
  - Hosts only listen for packets marked with physical interface names
    - Each hop along route
    - Destination host



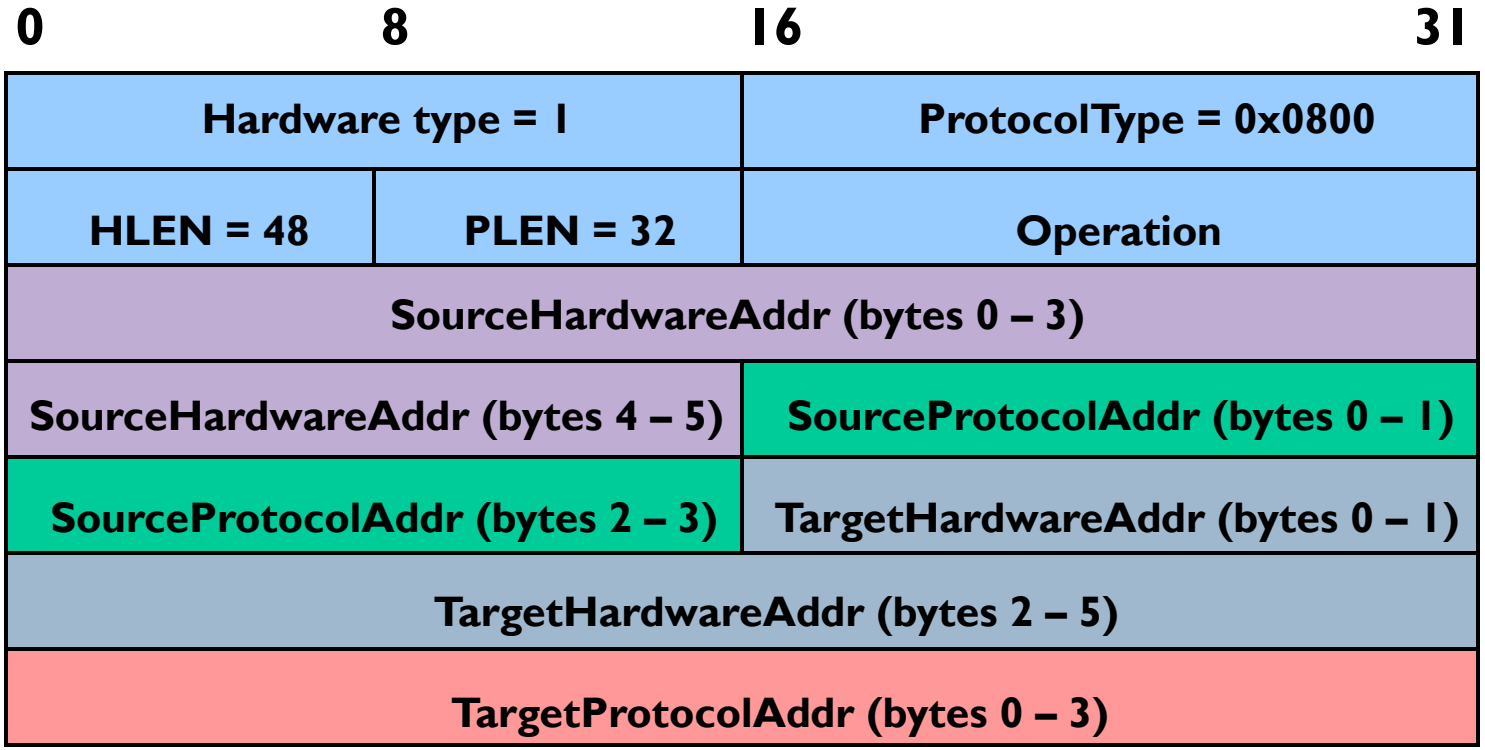
IP to Physical Address Translation

- Hard-coded
  - Encode physical address in IP address
  - Ex: Map Ethernet addresses to IP addresses
    - Makes it impossible to associate address with topology
- Fixed table
  - Maintain a central repository and distribute to hosts
    - Bottleneck for queries and updates
- Automatically generated table
  - Use ARP to build table at each host
  - Use timeouts to clean up table

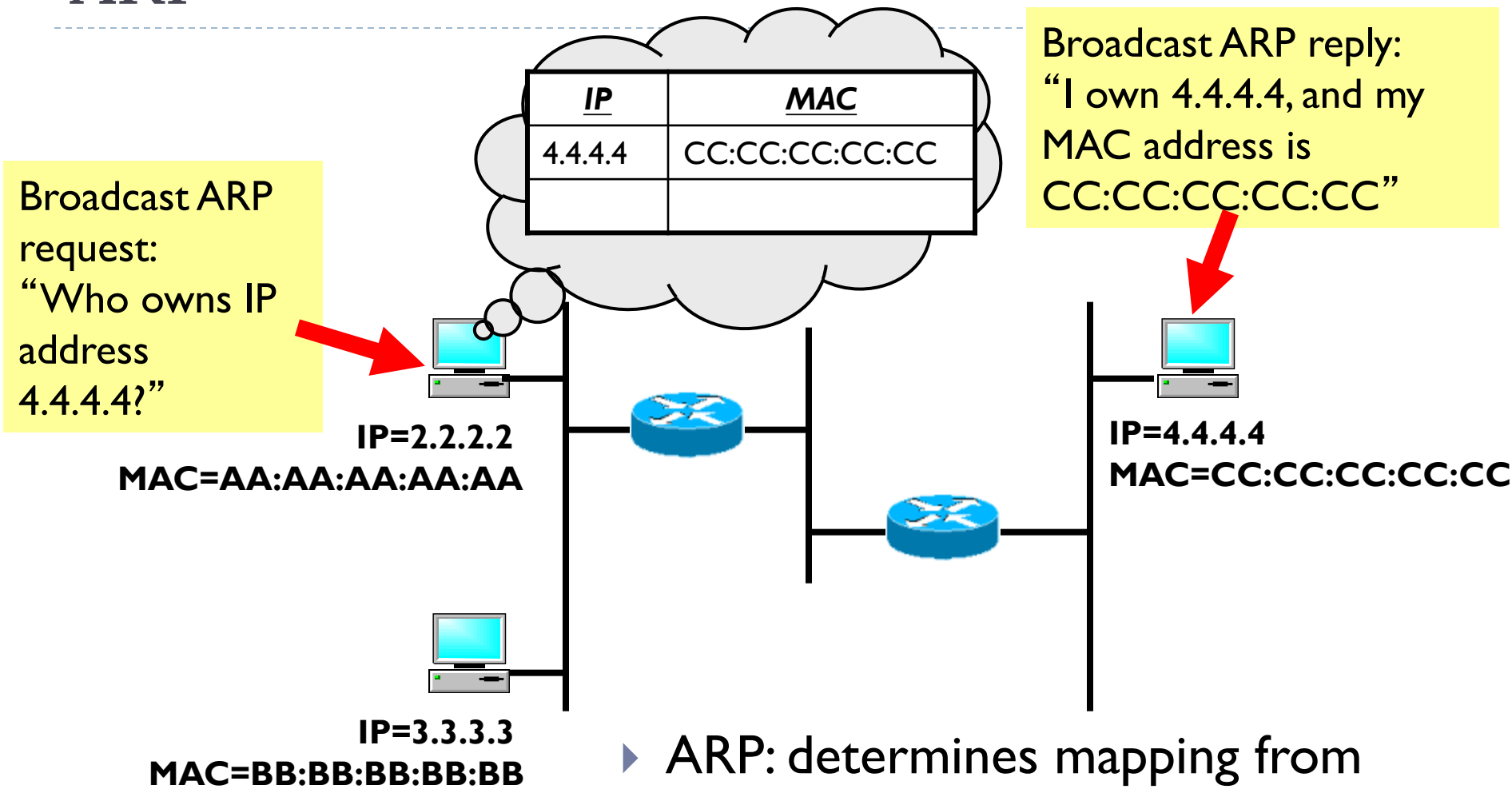
ARP: Address Resolution Protocol

- ARP table contains physical address mappings
- If target address not present
  - Broadcast an ARP query, include querying host's translation
  - Wait for an ARP response
- Upon receipt of ARP query/response
  - Targeted host responds with address translation
  - If address already present
    - Refresh entry and reset timeout
  - If address not present
    - Add entry for requesting host
    - Ignore for other hosts
- Timeout and discard entries after O(10) minutes

ARP Packet


0
8
16
31
Hardware type = 1
ProtocolType = 0x0800
HLEN = 48
PLEN = 32
Operation
SourceHardwareAddr (bytes 0 – 3)
SourceHardwareAddr (bytes 4 – 5)
SourceProtocolAddr (bytes 0 – 1)
SourceProtocolAddr (bytes 2 – 3)
TargetHardwareAddr (bytes 0 – 1)
TargetHardwareAddr (bytes 2 – 5)
TargetProtocolAddr (bytes 0 – 3)

ARP



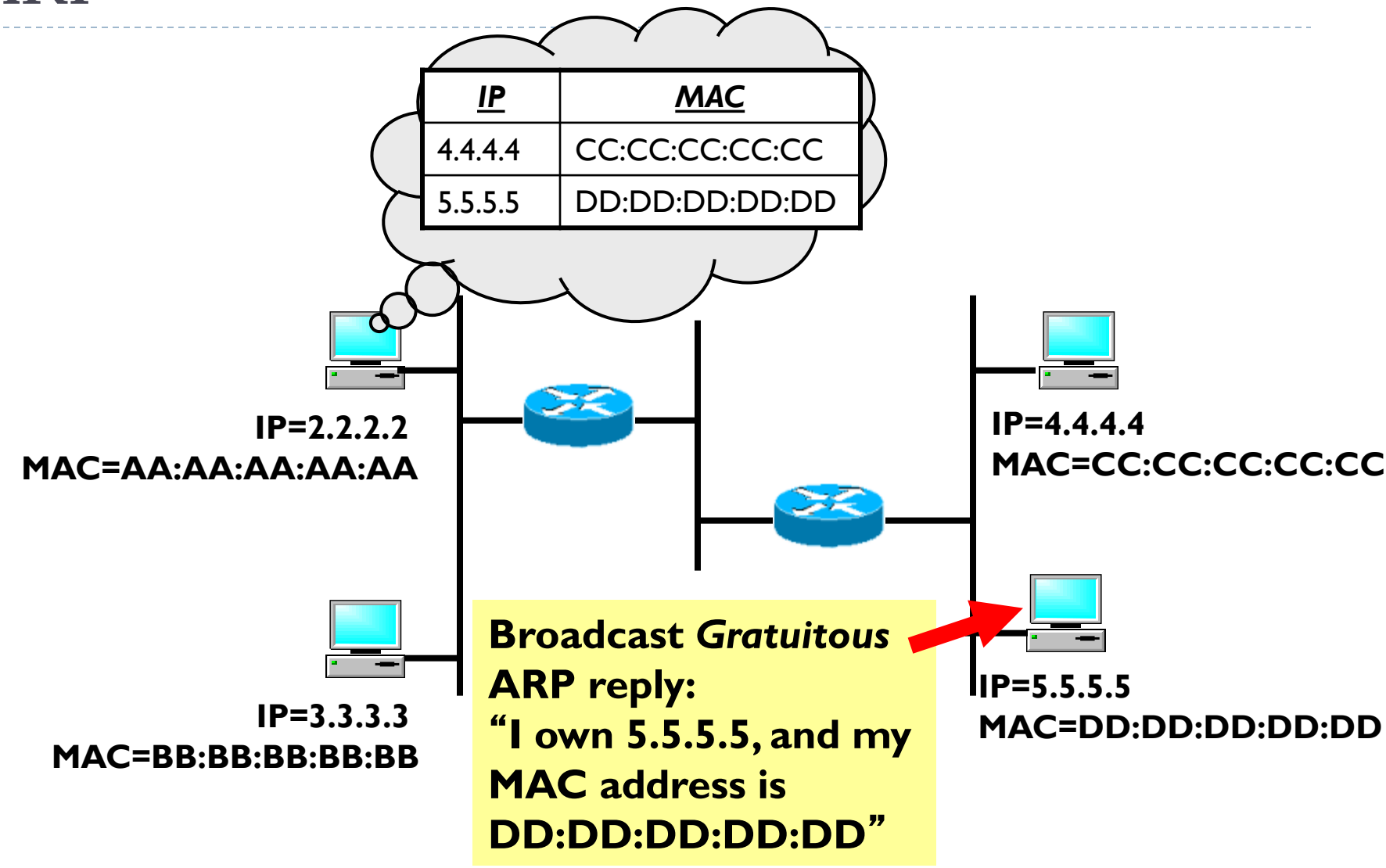
- ARP: determines mapping from IP to MAC address

ARP

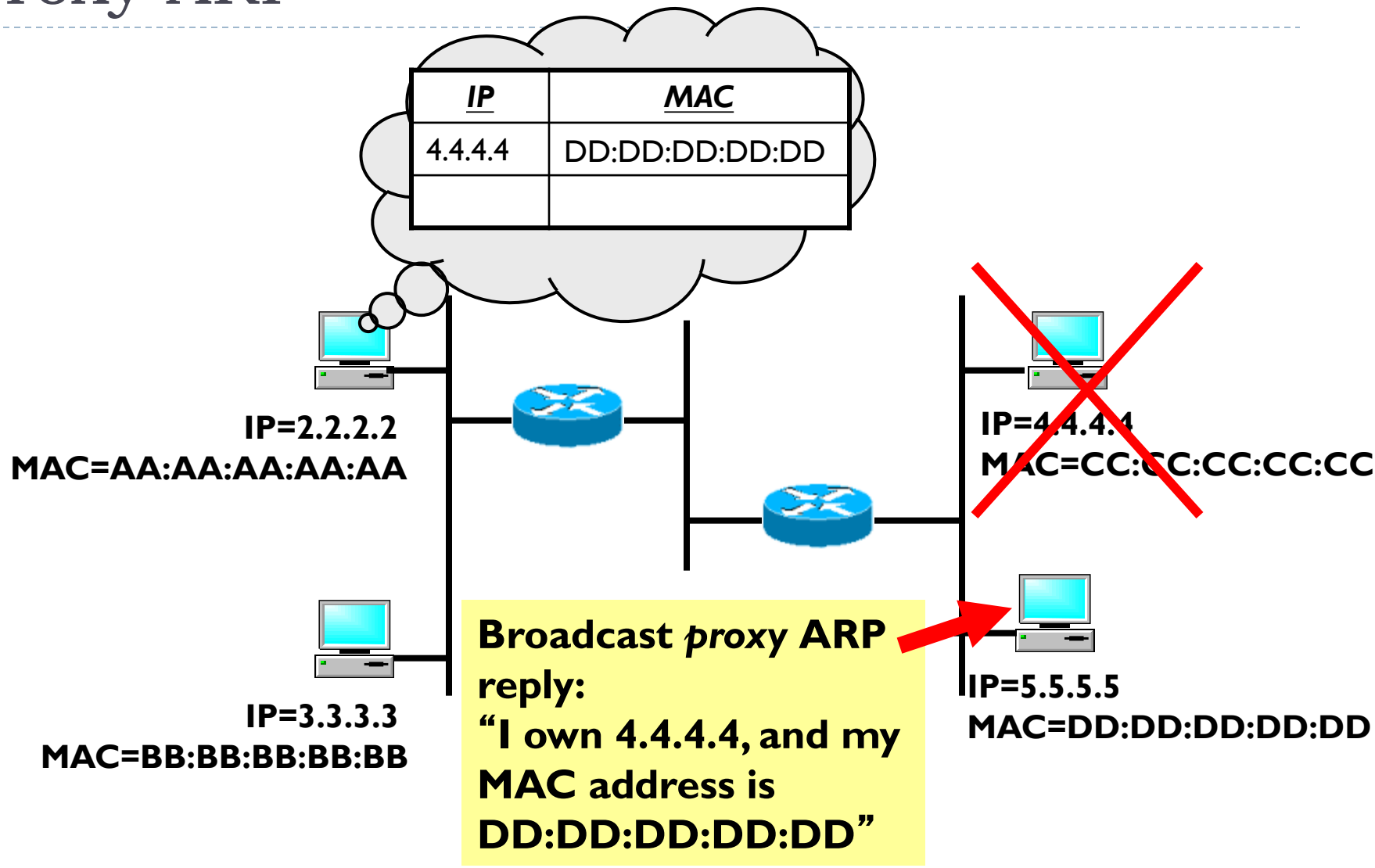
- What if IP address is not on subnet?
  - Each host configured with "default gateway"
  - Use ARP to resolve its IP address

- Gratuitous ARP: tell network your IP to MAC mapping
  - Used to detect IP conflicts, IP address changes; update other machines' ARP tables, update bridges' learned information

ARP


IP
MAC
4.4.4.4
CC:CC:CC:CC:CC
5.5.5.5
DD:DD:DD:DD:DD
IP=2.2.2.2
MAC=AA:AA:AA:AA:AA
IP=4.4.4.4
MAC=CC:CC:CC:CC:CC
IP=3.3.3.3
MAC=BB:BB:BB:BB:BB
IP=5.5.5.5
MAC=DD:DD:DD:DD:DD
Broadcast Gratuitous ARP reply:
"I own 5.5.5.5, and my MAC address is DD:DD:DD:DD:DD"

Proxy ARP


IP
MAC
4.4.4.4
DD:DD:DD:DD:DD
IP=2.2.2.2
MAC=AA:AA:AA:AA:AA
IP=4.4.4.4
MAC=CC:CC:CC:CC:CC
IP=3.3.3.3
MAC=BB:BB:BB:BB:BB
IP=5.5.5.5
MAC=DD:DD:DD:DD:DD
Broadcast *proxy* ARP reply:
"I own 4.4.4.4, and my MAC address is DD:DD:DD:DD:DD"

Host Configuration

- Plug new host into network
  - How much information must be known?
  - What new information must be assigned?
  - How can process be automated?

- Some answers
  - Host needs an IP address (must know it)
  - Host must also
    - Send packets out of physical (direct) network
    - Thus needs physical address of router

Host Configuration

- Reverse Address Resolution Protocol (RARP)
  - Translate physical address to IP address
  - Used to boot diskless hosts
  - Host broadcasts request to boot
  - RARP server tells host the host's own IP address

- Boot protocol (BOOTP)
  - Use UDP packets for same purpose as RARP
  - Allows boot requests to traverse routers
  - IP address of BOOTP server must be known
  - Also returns file server IP, subnet mask, and default router for host

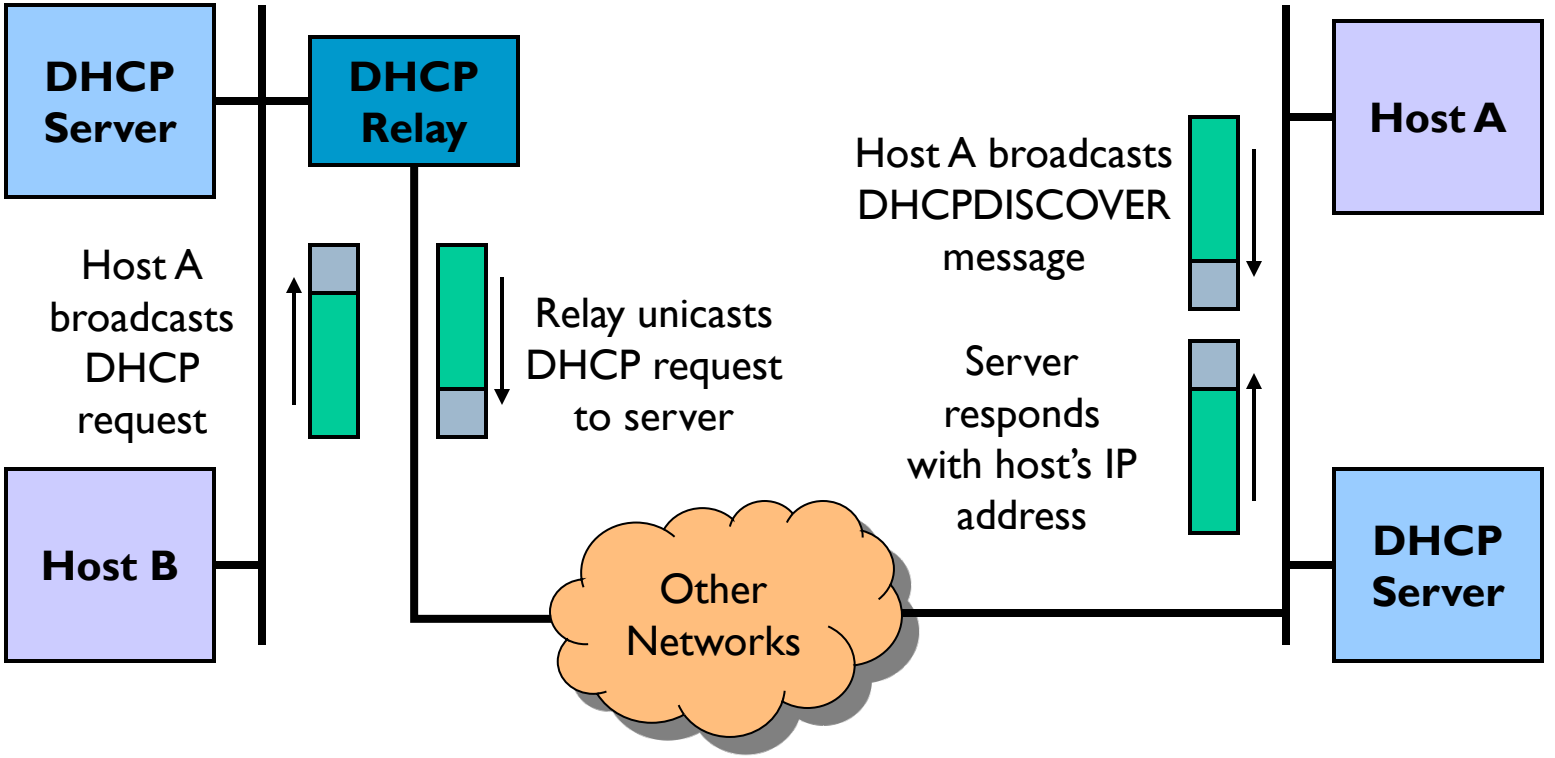
Dynamic Host Configuration Protocol (DHCP)

- A simple way to automate configuration information
  - Network administrator does not need to enter host IP address by hand
  - Good for large and/or dynamic networks

Dynamic Host Configuration Protocol (DHCP)

- New machine sends request to DHCP server for assignment and information
- Server receives
  - Directly
    - If new machine given server's IP address
  - Through broadcast
    - If on same physical network
    - Via DHCP relay nodes
      - Forward requests onto the server's physical network
- Server assigns IP address and provides other info
- Can be made secure
  - Present signed request or just a "valid" physical address

DHCP

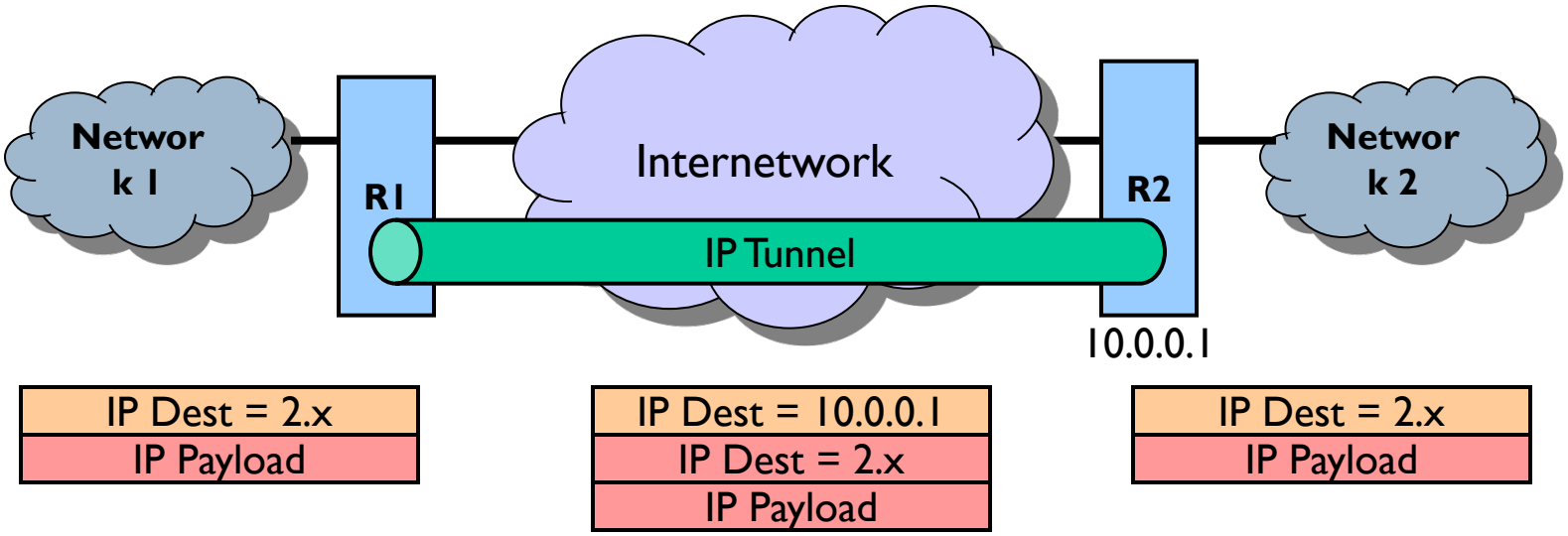

DHCP Server
DHCP Relay
Host A
Host A broadcasts DHCPDISCOVER message
Host A broadcasts DHCP request
Relay unicasts DHCP request to server
Server responds with host's IP address
Host B
Other Networks
DHCP Server

DHCP

- Remaining challenge: configuring DHCP servers
  - Need to ensure consistency across servers, between servers and network, address assignment across routers
  - But simpler than directly managing end hosts

Tunneling

- IP Tunnel
  - Virtual point-to-point link between an arbitrarily connected pair of nodes



Tunneling

- Advantages
  - Transparent transmission of packets over a heterogeneous network
  - Only need to change relevant routers
- Disadvantages
  - Increases packet size
  - Processing time needed to encapsulate and unencapsulate packets
  - Management at tunnel-aware routers

What does this all have to do with Mobility?

- Internet Architecture Assumptions
  - Hosts are (mostly) stationary
    - Address assignment, routing

- But
  - Many clients today are mobile
  - Mobility inside a subnet is supported
    - e.g. moving across APs that are part of a single network
  - Mobility across subnets is harder
    - IP address is used as address and identifier
      - Identifier: who are you?
      - Address: where can I find you?

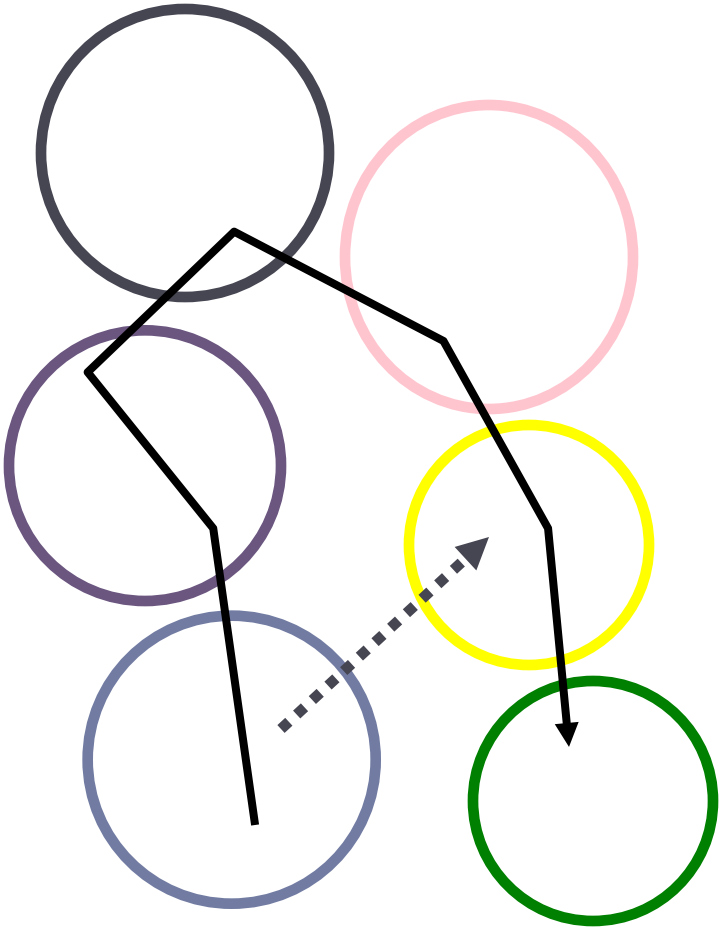
Mobility options

- Keep IP address
  - Network gets confused
  - Delivers packets to wrong "old" subnet

- New IP address
  - Host gets confused
  - Transport protocols, applications, etc.

Mobility across IP Subnets

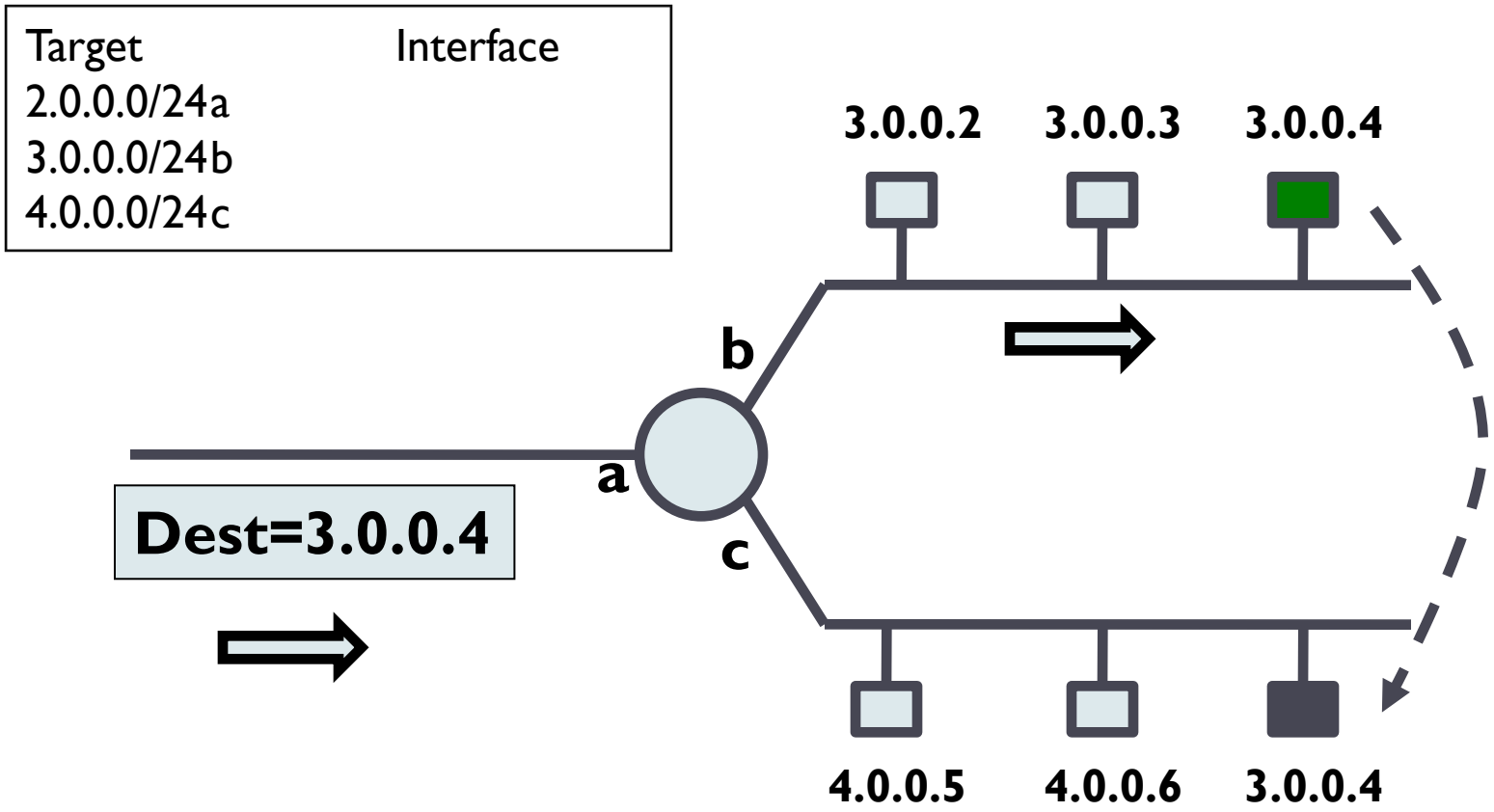
- Moving across IP subnets
  - Different protocols have conflicting requirements
- Network layer
  - Wants IP address in current subnet
  - Needed for routing of packets
- Transport layer
  - Wants IP address that was used to create connection
  - Needed to identify the connection
- Applications
  - Often do not care
  - In practice, they want to keep the IP address the same
  - Tied to sockets



IP Address Problem

- Internet hosts/interfaces are identified by IP address
  - DNS translates host name to IP address
  - IP address identifies host/interface and locates its network
  - Mixes *naming* and *location*

Traditional Routing for a Mobile Host



IP Address Problem

- Internet hosts/interfaces are identified by IP address
  - DNS translates host name to IP address
  - IP address identifies host/interface and locates its network
  - Mixes *naming* and *location*
- Moving to another network requires different network address
  - But this would change the host's identity
  - How can we still reach that host?

Mobile IP Goals

- Communicate with mobile hosts using their "home" IP address
  - Allows any host to contact mobile host using its "usual" IP address
- Mobility should be transparent to applications and higher level protocols
  - No need to modify the software
- Minimize changes to host and router software
  - No changes to communicating host

Routing for Mobile Hosts

- Problem
  - How can mobility be supported in view of the fact that a portion of an IP address is a network address?
- Solution: Location Registry
  - Mobile IP

Routing for Mobile Hosts

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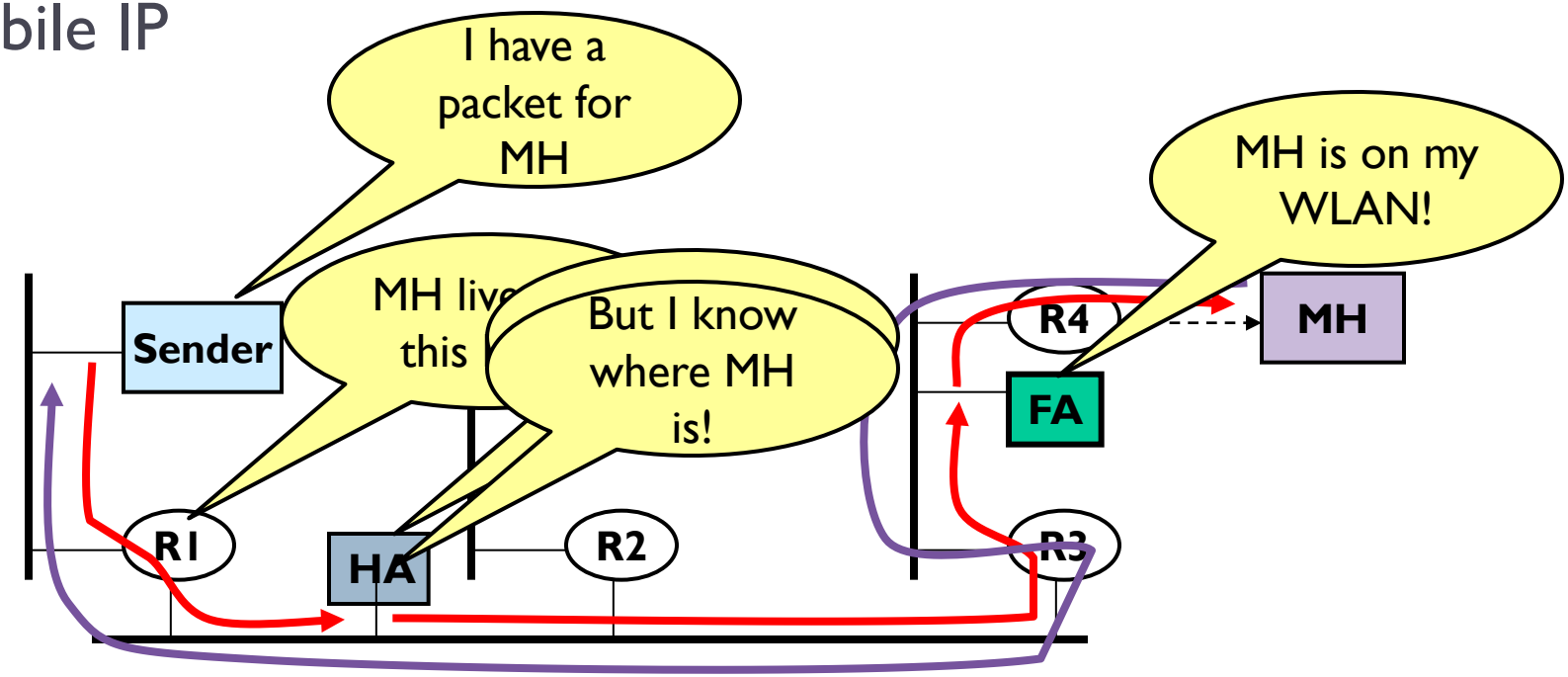


Why Mobile IP?

- Goal
  - IP-based protocol that allows network connectivity across host movement
- Features
  - Doesn't require global changes to deployed router software, etc.
  - Compatible with large installed base of IPv4 networks/hosts
  - Confines changes to mobile hosts and a few support hosts which enable mobility

Basic Mobile IP

- Features
  - Transparent routing of packets to a mobile host
  - No modification of existing routers or non-mobility supporting hosts

- Problem
  - Indirect routing places unnecessary burden on the internet and significant increases latency

Components

- Mobile Host (MH)
  - Assigned a unique *home address* within its *home network*
- Corresponding Hosts (CH)
  - Other hosts communicating with the MH
  - Always use MH's *home address*

Routing for Mobile Hosts

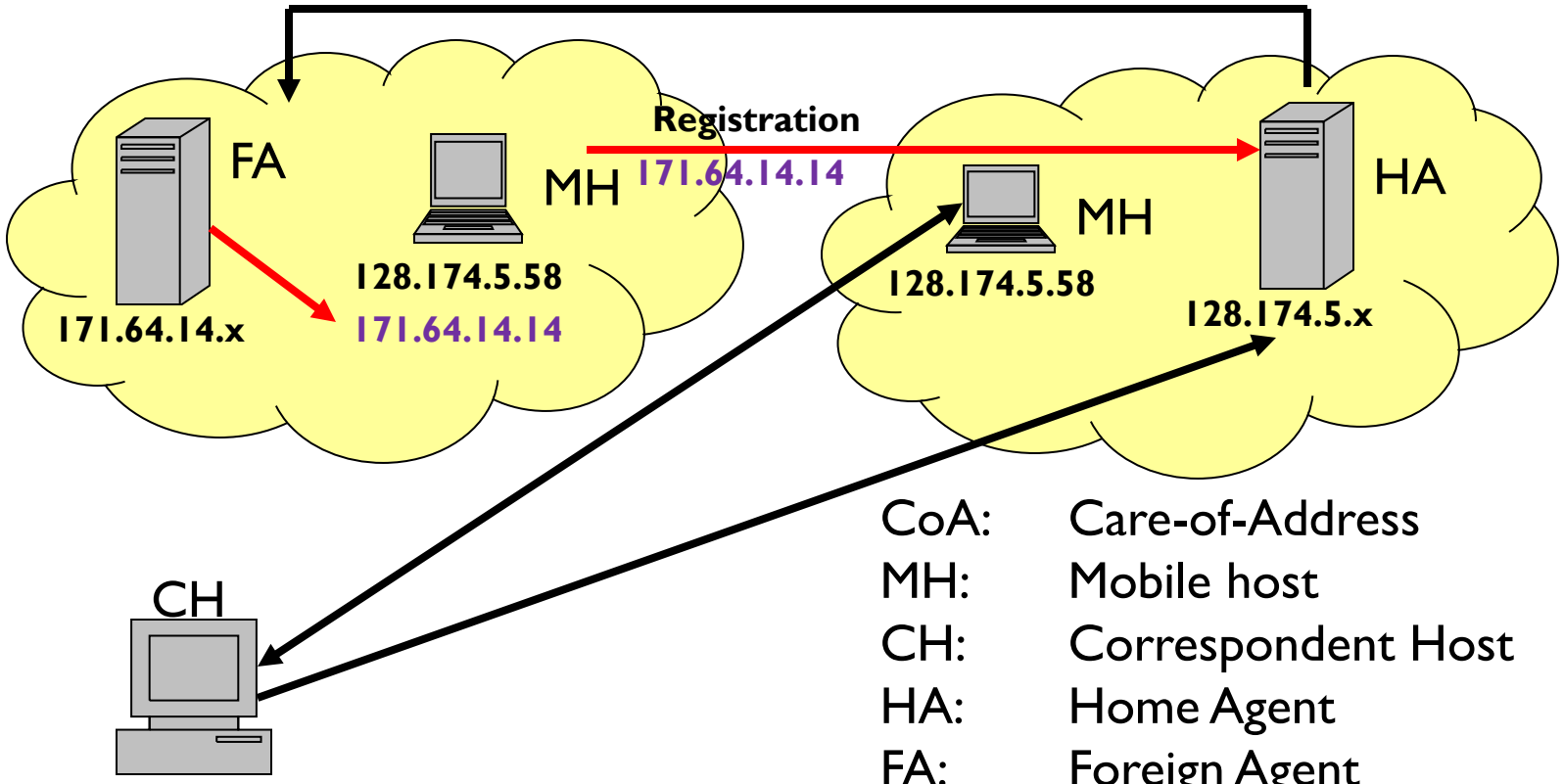
- Home Agent (HA):
  - An agent on the MH's *home network*
  - Maintains registry of MH's *care-of-address*
  - Mobility binding is the connection between the MH's *home address* and *care-of-address*
  - Each time the MH establishes a new *care-of-address*, it must register with its HA

- Foreign Agent (FA):
  - An agent on the MH's *local network*
  - Maintains a mapping from the *MH's home address* to its *care-of-address*

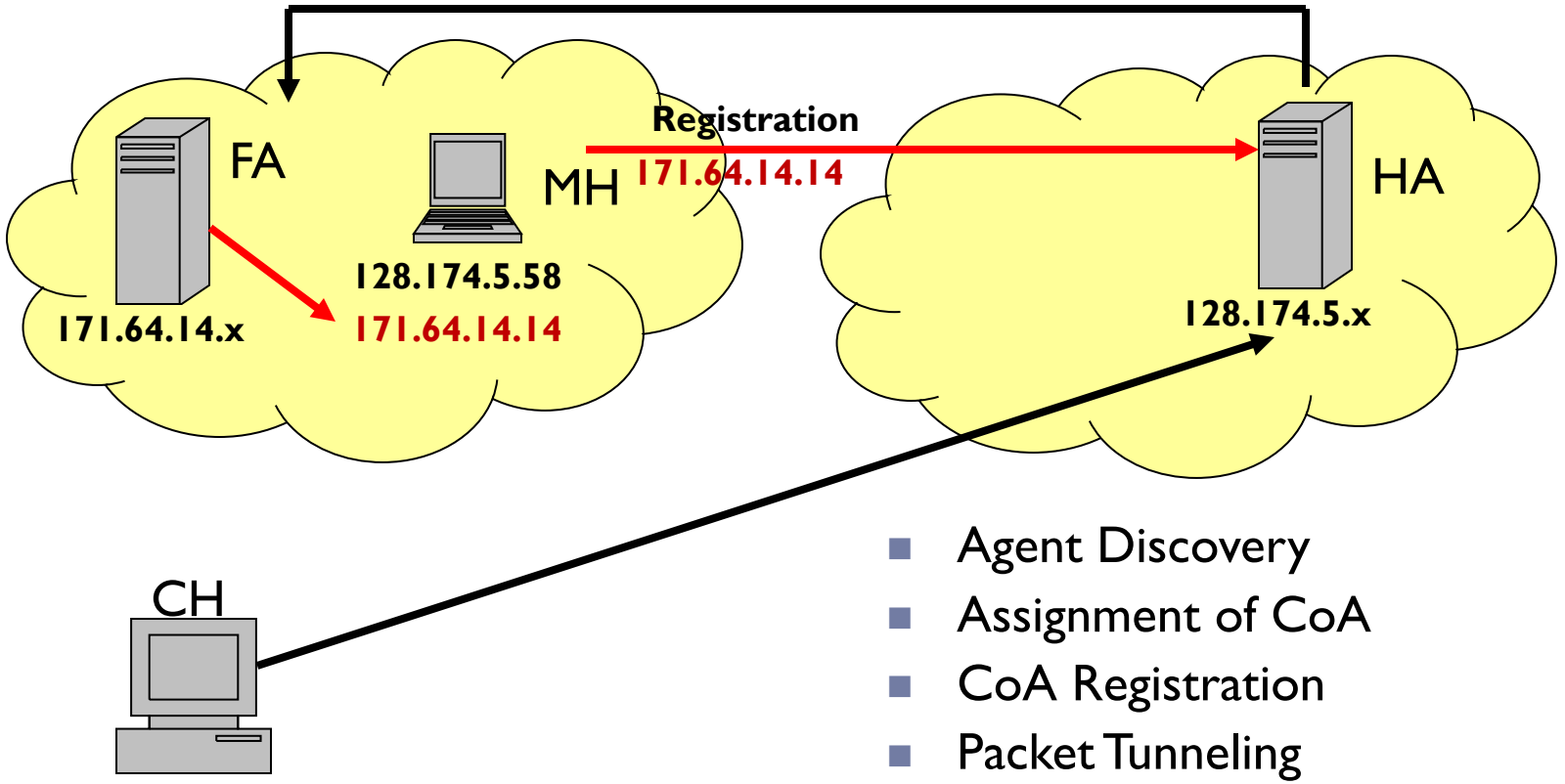
Issues

- Scenario
  - CH sends packet to home network
- Challenges
  - How does the MH get a local IP address?
  - How can a mobile host tell where it is?
  - How does the HA intercept a packet that is destined for the MH?
  - How does the HA then deliver the packet to the FA?
  - How does the FA deliver the packet to the MH?

Basic Mobile IP



Basic Mobile IP



- Agent Discovery
- Assignment of CoA
- CoA Registration
- Packet Tunneling

Addressing

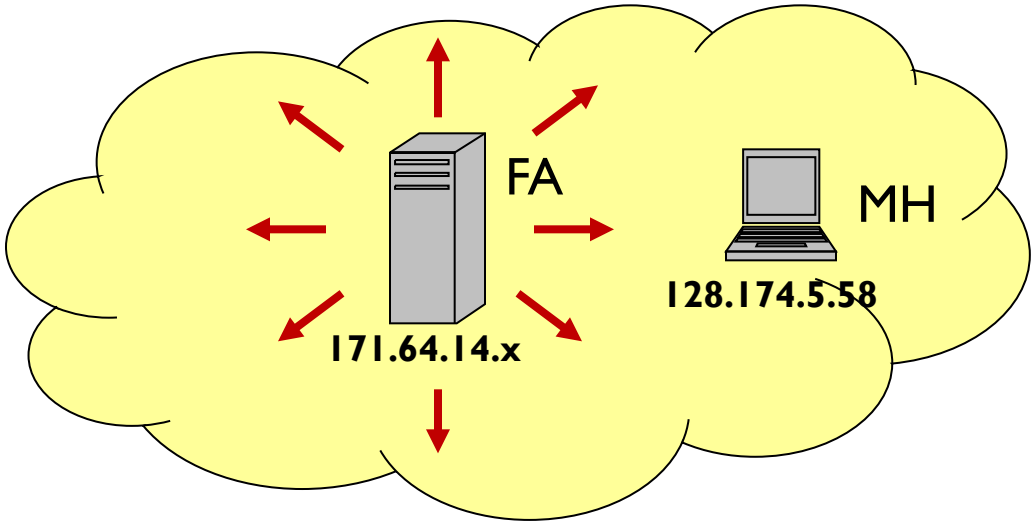
- How does the mobile host get a remote IP address?
  - Listen for router advertisements
  - Use DHCP
  - Manual assignment
- Assigning *care-of-address*
  - MH discovers *foreign agent* (FA) using an agent discovery protocol
  - MH registers with FA and FA's address becomes MH's *care-of-address*
  - MH obtains a temporary IP address from FA or via DHCP-like procedures

Location

- How can a mobile host tell where it is?
  - Am I at home?
  - Am I visiting a foreign network?
  - Have I moved?
- Same!
  - Listen for router advertisements
  - Put network interface into promiscuous mode and watch traffic

Agent Discovery

- How can a mobile host tell where it is?
  - Extension of ICMP protocol
    - Allows MH to detect when it has moved from one network to another, or to home
  - FA Periodically broadcasts agent advertisement message



Agent Discovery

- Register with FA
  - MH determines a suitable FA (or its HA)
- Send agent solicitation message
  - If MA has not received a broadcast for a period of time

Packet Delivery

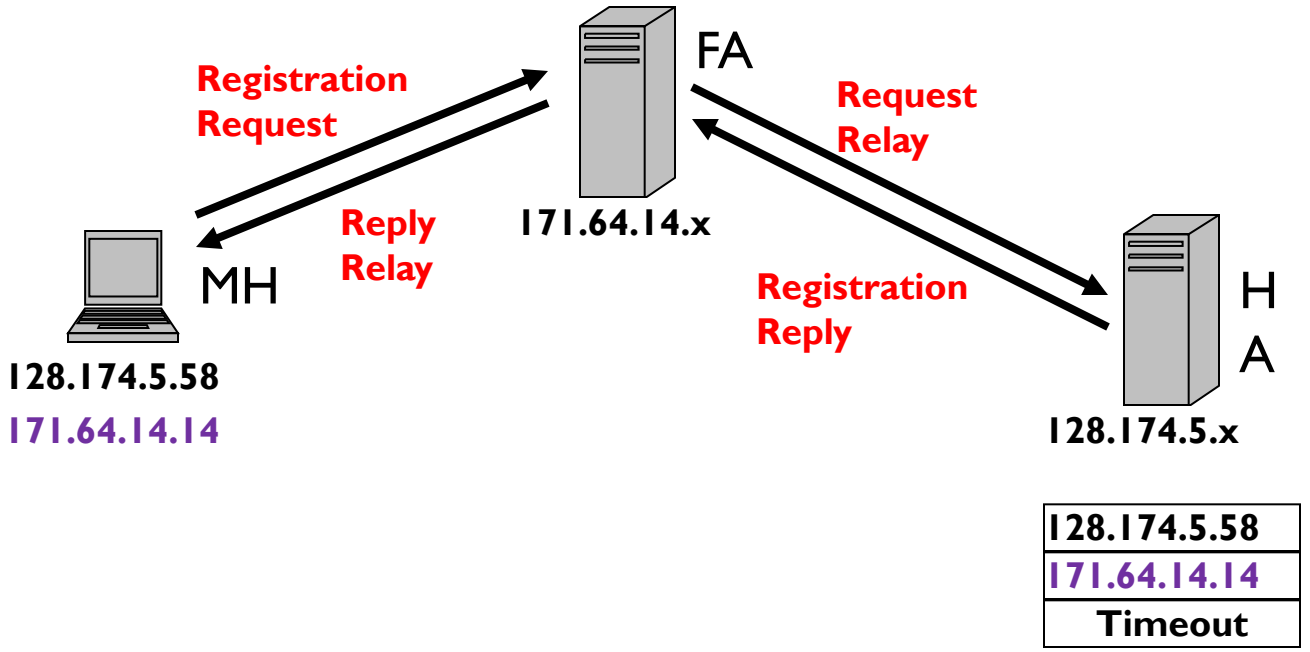
- How does the HA intercept a packet that is destined for the MH?

- While MH in foreign location
  - HA intercepts all packets for MH
    - Using proxy ARP
  - HA tunnels all packets to FA
    - IPIP - "IP within IP"
    - Upon receipt of an IP datagram
      - Packet is encapsulated in an IP packet of type IPPROTO_IPIP and sent to FA
      - FA strips IPIP header and sends packet to MH using local IP address
  - FA strips packet and forwards to MH

Registration

- MA must register with FA and tell HA its new care-of-address
  - MH sends registration request message to FA
  - FA forwards request to HA
  - HA returns registration reply message to FA
  - FA forwards reply to MH
- Registration may have a set lifetime

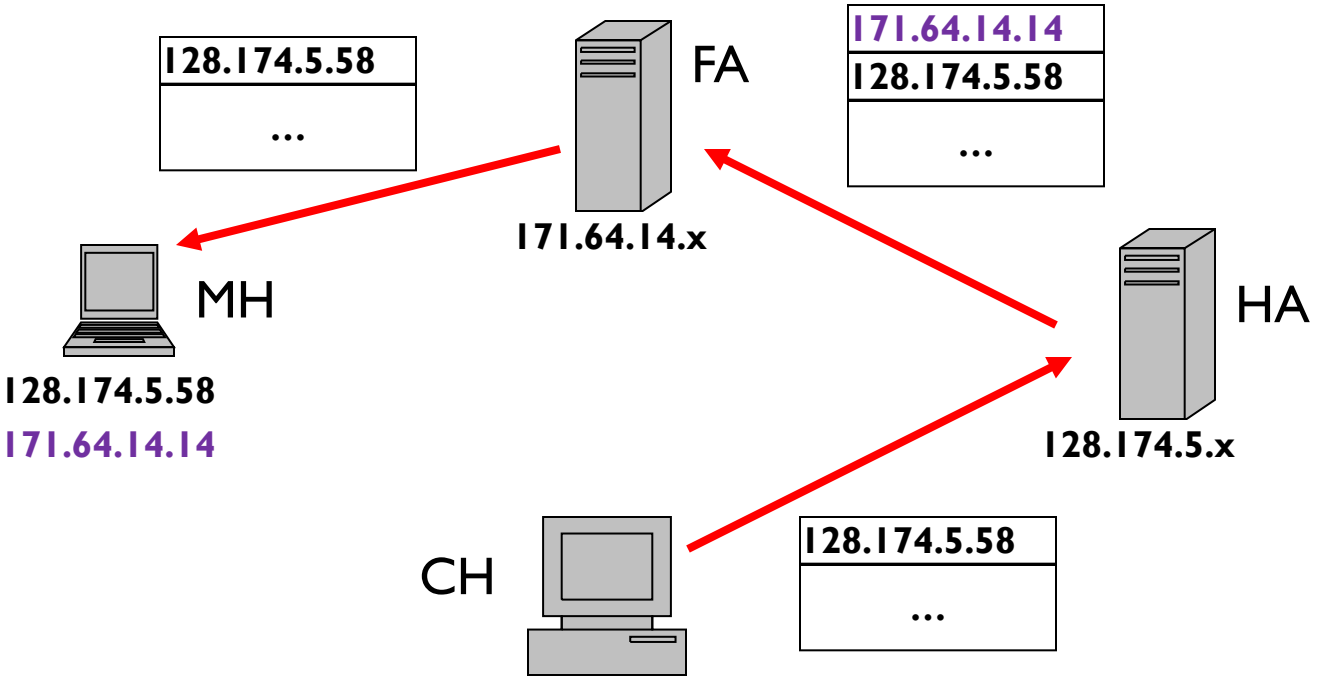
Care-of-Address Registration



Network Layer

- IPIP - "IP within IP"
  - Tunnel IP datagrams from one cell to another
  - Upon receipt of an IP datagram
    - Packet is encapsulated in an IP packet of type IPPROTO_IPIP and sent to remote MSS
    - Remote MSS strips IPIP header and sends packet to MH using "real" IP address

Tunneling


128.174.5.58
...
FA
171.64.14.14
128.174.5.58
...
171.64.14.x
MH
128.174.5.58
171.64.14.14
HA
128.174.5.x
CH
128.174.5.58
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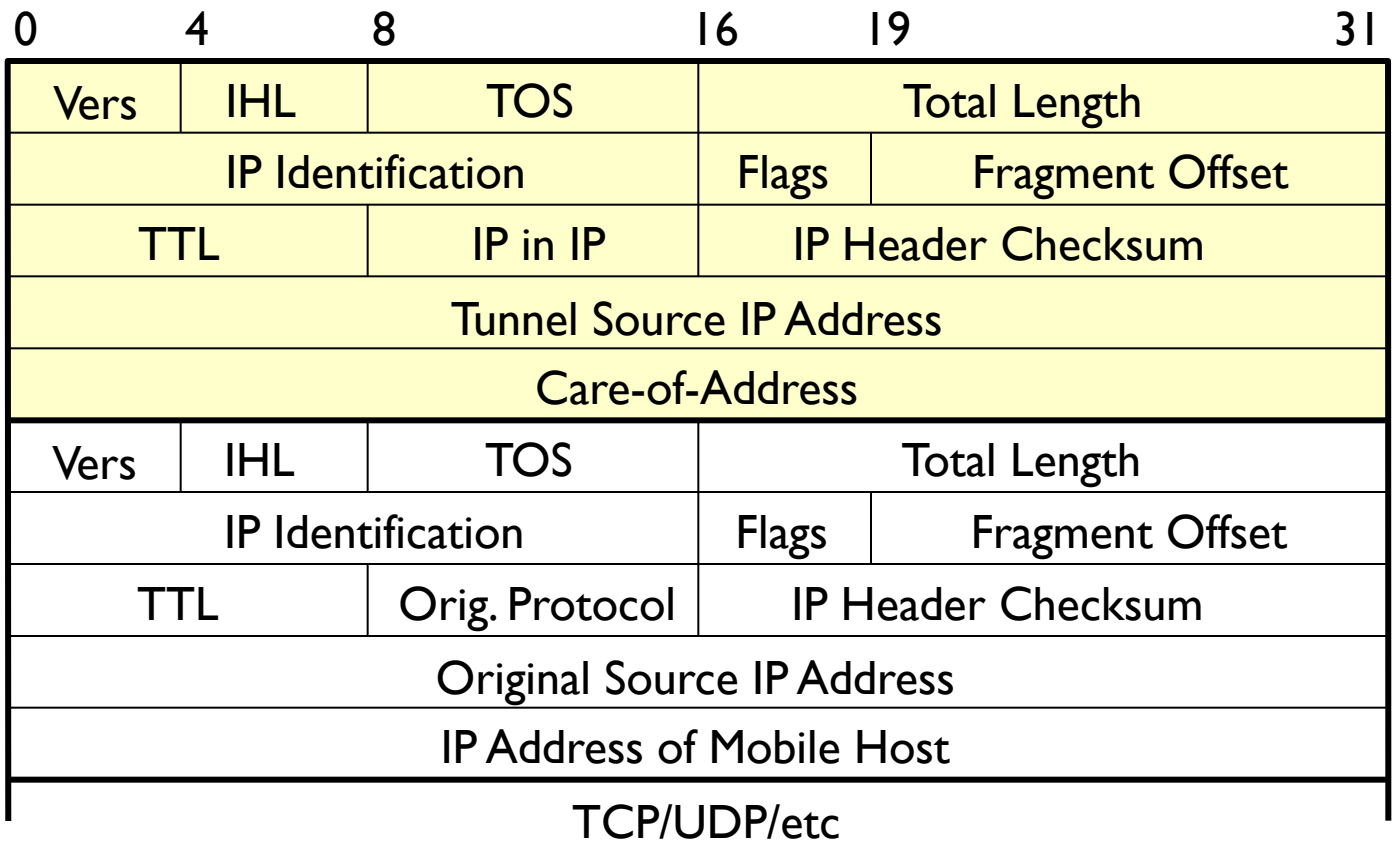
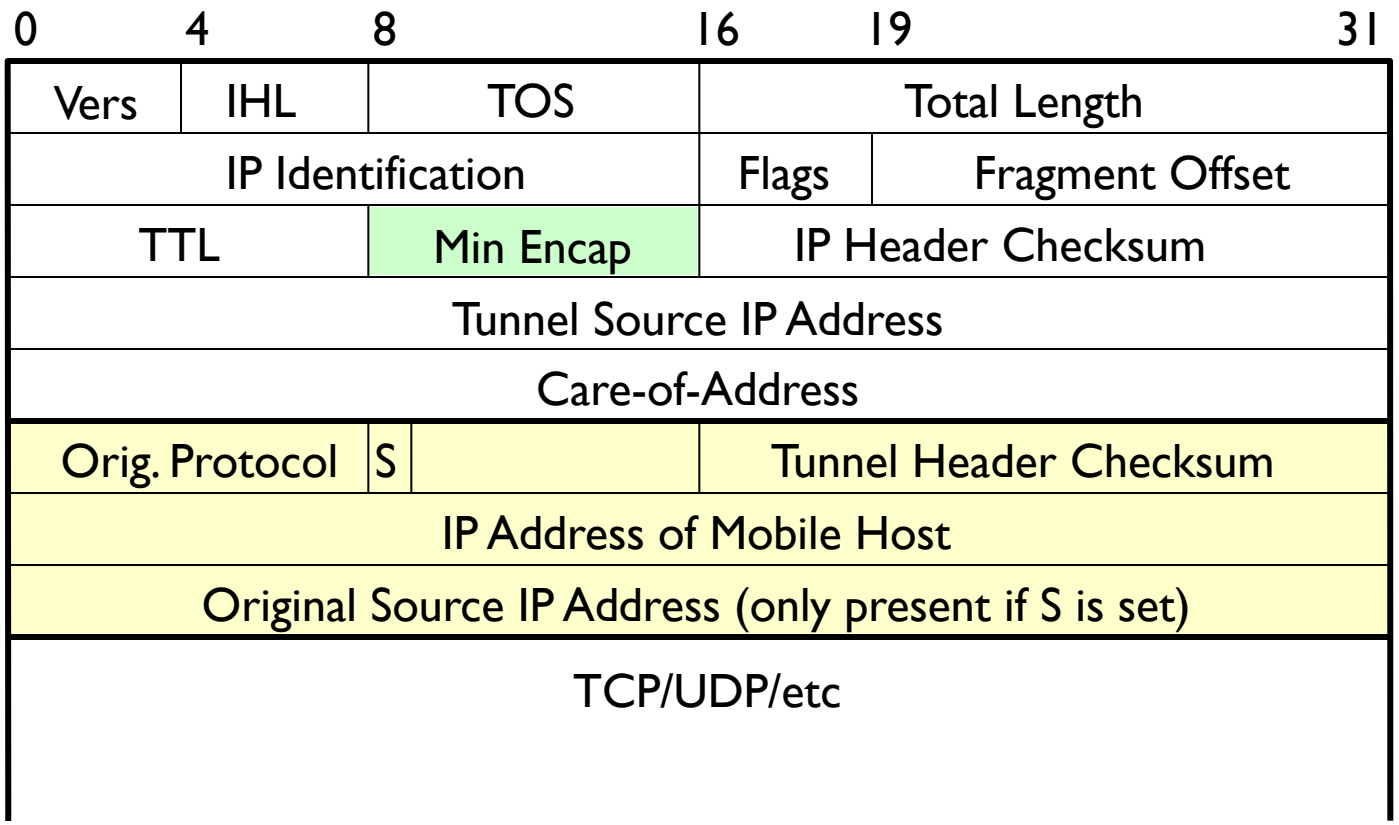
Tunneling Using IP-in-IP Encapsulation



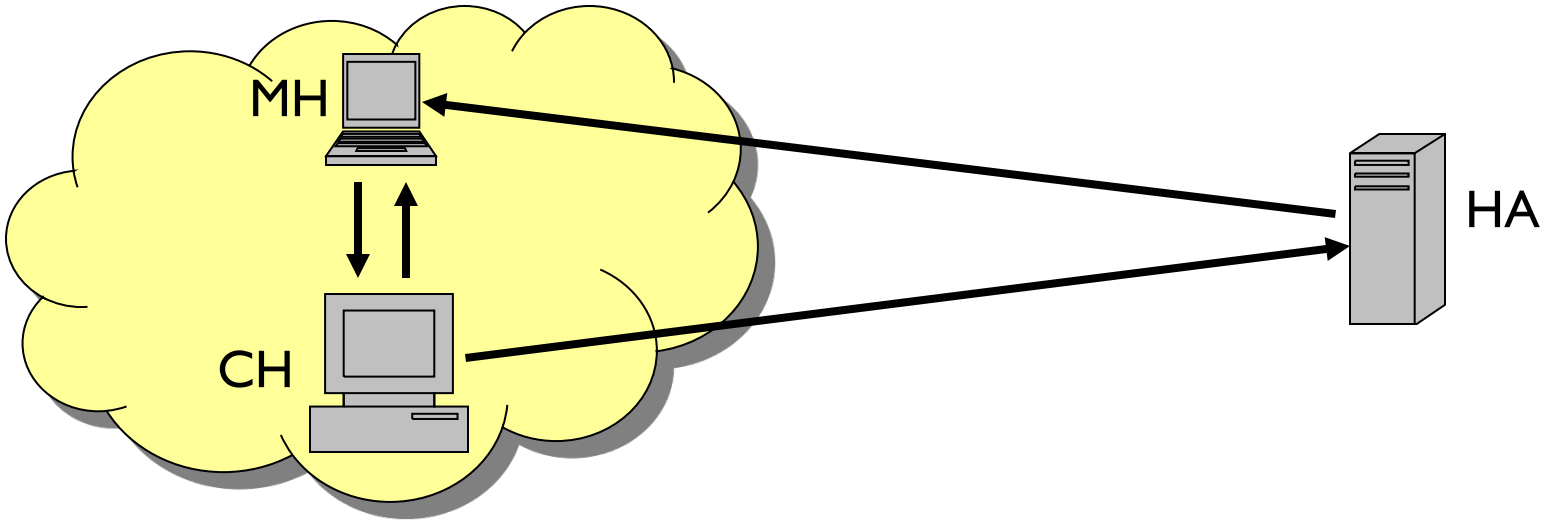
Tunneling Using Minimal Tunneling Protocol



Basic Mobile IP

- ✓ Transparent mobility support at network layer
- ✓ No modification to network infrastructure
- × Routing Inefficiency
  - × Triangle Routing Problem
- × Security Issues
  - × Firewalls, Ingress filtering router

Triangle Routing



Route Optimization

- Basic Mobile IP routes all packets for a MH through its home network and HA
  - Limits performance
  - Potential bottleneck
  - Not scalable
- Solution
  - Cache MH location and care-of address

Protocol Scalability

- The Home Network
  - Home agents provide a decentralized, scalable solution
  - No overhead for MH when they are at their home network
- The Foreign Network
  - Foreign agents provide a local scalable solution
- Binding Caches
  - Provide tradeoff between performance and state
- Impact on the network
  - Routing packets directly to MH reduces overhead in the Internet

Mobile IP Discussion

- Mobile IP not used in practice
- Not designed for truly mobile users
  - i.e. for continuous operation across subnets
  - Switching between subnets is heavy weight
  - Designed for nomadic users, e.g. visitors to a remote site
- Was designed for mobile devices that are contacted by a "client"
  - Very rare: mobile devices usually only run client apps
  - They rarely run services
- Correct solution is to separate identifiers and "locators"