The Address Resolution Protocol

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Routing

- IP routers determine next hop IP address using longest prefix match
  - Given a destination IP address, what is the IP address of the router to which the datagram should be forwarded next?
- Why do they need the next hop IP address?
  - Destination IP address remains unchanged in the datagram
  - Actually need the next hop *Ethernet* address!

IP vs. Ethernet Addresses

- Why store next hop IP address?
- Why not just store next hop Ethernet address?

- Ethernet address
  - Unique identifier for a piece of hardware
- IP address
  - Unique identifier for a system performing a function

Address Resolution Protocol

- Find link layer address given a network layer address
  - i.e., what is the Ethernet address for a given IP address?
- Every IP node (hosts and routers) has an ARP table
  - Mapping from IP to Ethernet addresses on their LAN
  - May be incomplete
  - Can include both static and dynamic entries

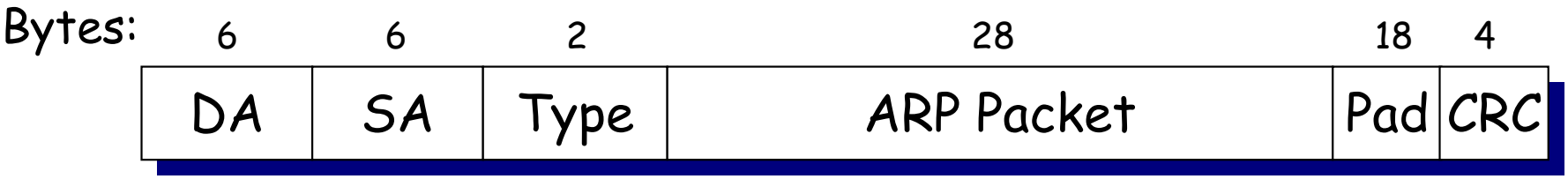
Static ARP Entries

- IP address 128.42.6.32 has Ethernet address 00:E0:81:5A:71:AB
- Must be managed by the system administrator
  - What if that NIC fails and is replaced?
  - What if that system's IP address is changed?
- Actively managing IP → Ethernet address mappings for all nodes in a LAN will get pretty tedious pretty fast

Dynamic ARP Entries

- Systems “discover” IP → Ethernet address mappings, as needed
- Each entry has an IP address, an Ethernet address, and a timeout (typically around 20 minutes)
- ARP packets are broadcast on the LAN to discover mappings
  - ARP packets are encapsulated in Ethernet frames

Encapsulated ARP Request

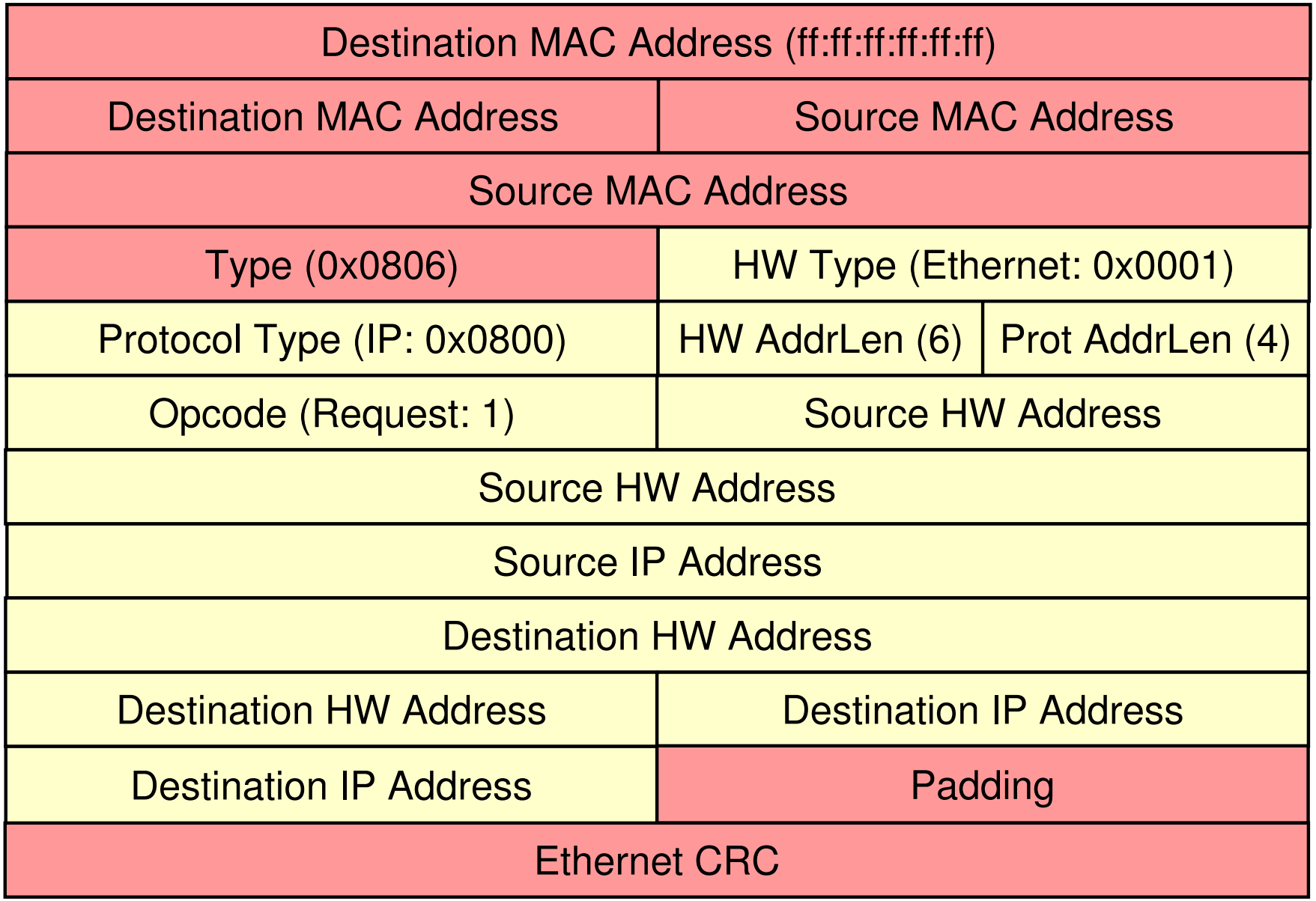


- Ethernet destination
  - If you knew the Ethernet address, you wouldn't need to send an ARP request!
  - Broadcast address: ff:ff:ff:ff:ff:ff
- Ethernet type
  - ARP: 0x0806

ARP Request

- Hardware Type (2 bytes)
  - Ethernet 0x0001
- Protocol Type (2 bytes)
  - IP: 0x0800
- Hardware Address Length (1 byte)
  - Ethernet: 6
- Protocol Address Length (1 byte)
  - IPv4: 4
- Opcode (2 bytes)
  - Request: 1 (Response: 2)
- Source address (hardware and protocol)
- Destination address (hardware (unknown) and protocol)

Full ARP Request



Sending a Packet from a Host

- Host setup
  - IP address
  - Subnet – what IP addresses are on the same LAN
  - Gateway – where to send traffic outside the LAN
- Destination on LAN
  - Create ARP request for destination IP
  - Broadcast to everyone on the LAN
  - Destination should reply with its MAC address
- Destination not on LAN
  - Create ARP request for gateway IP
  - Broadcast to everyone on the LAN
  - Gateway should reply with its MAC address

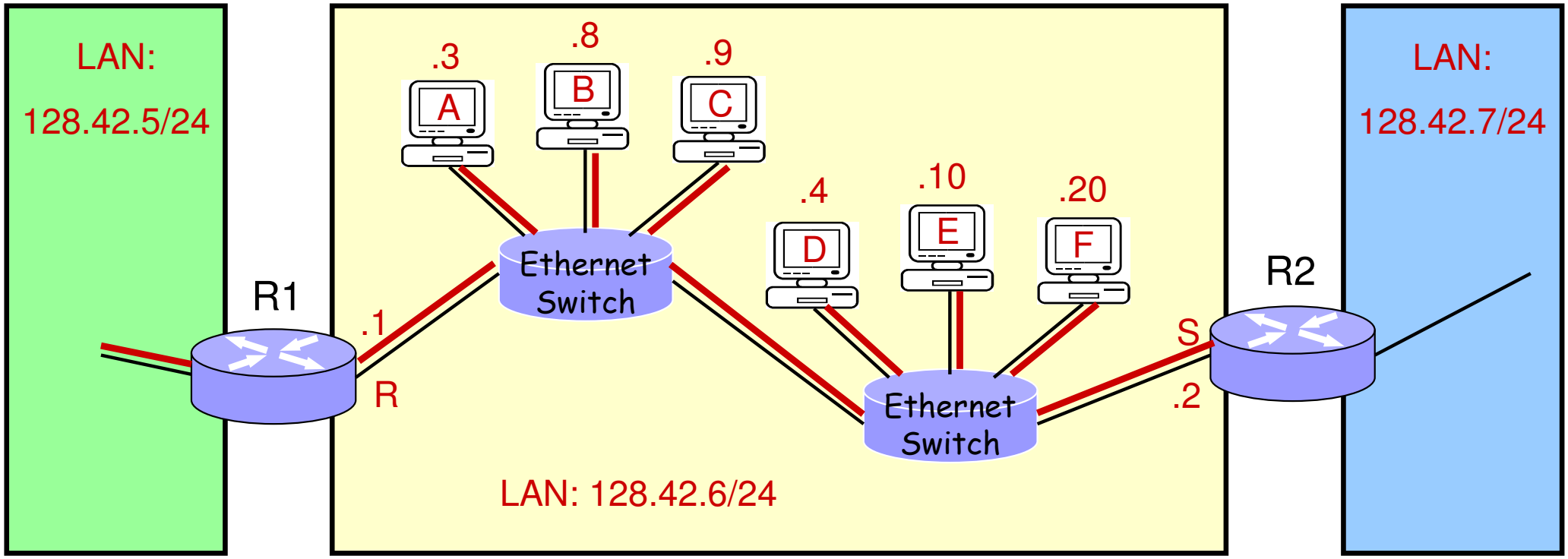
Learning MAC addresses

- Hosts learn IP → Ethernet address mappings
  - ARP responses are stored in ARP tables
  - ARP requests are stored in ARP tables (whether the host is the target or not!)
- ARP entries time out
  - Allow machines to change IP and/or MAC addresses transparently
  - Eliminate stale entries (machines turn off, move, crash, etc.)

Forwarding a Packet in a Router

- Lookup destination IP address in forwarding table
  - Yields a next hop port and IP address
  - What if it doesn't?
- Lookup next hop IP address in ARP table
  - Yields a next hop MAC address
  - What if it doesn't?
- Forward modified packet out the next hop port with the next hop MAC address

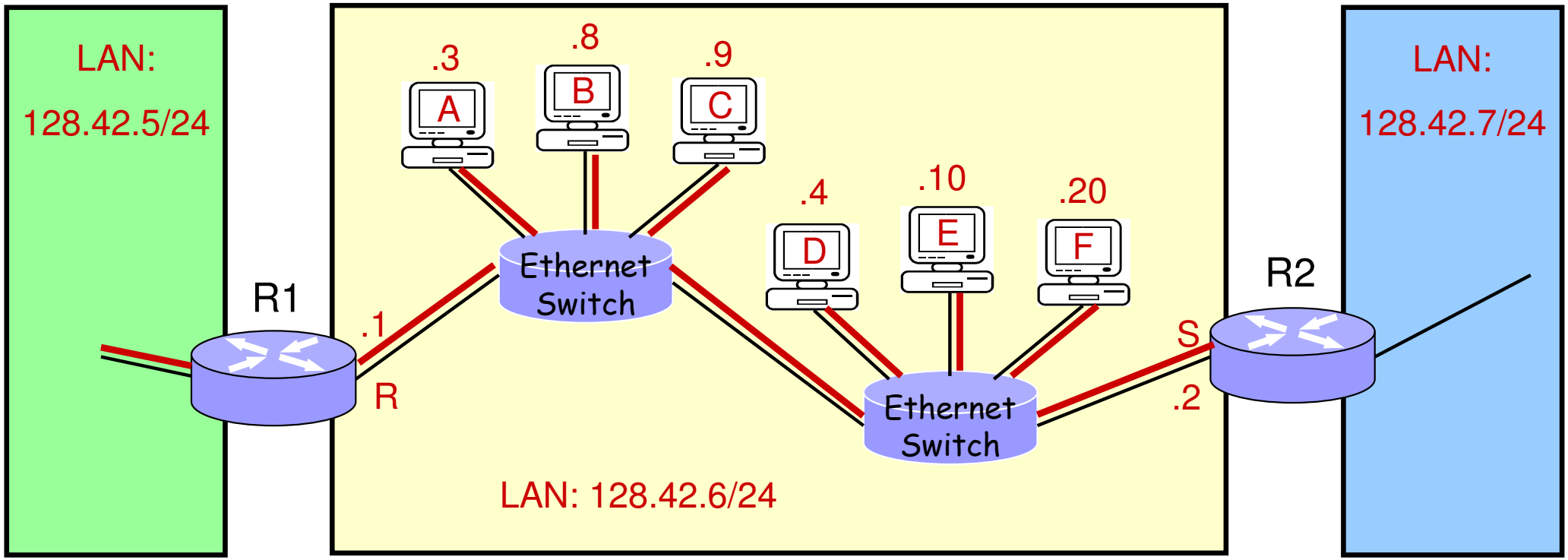
Forwarding Packets



5. Packet arrives at R1

Result: next hop: 128.42.6.9, port: 128.42.6.1

Forwarding Packets



5. [illegible] arrives at R1

Result: next hop: 128.42.6.2, port: 128.42.6.1

Next Time

- ICMP – Internet Control Message Protocol