EEL-4736/5737
Principles of Computer System Design

Lecture Slides 17

Textbook Chapter 7

Case study – Mapping Internet to Ethernet

Introduction

- Case studies/discussions
  - Data link and network layer common-case example: devices connected to Internet network using Ethernet
  - Network Address Translation

Ethernet

- Generic name for a family of local area networks based on broadcast over shared media
  - All participants can hear one another's transmissions.
- Ethernet was demonstrated in 1974 and documented in a 1976 paper
- Standard, Fast, Gigabit Ethernet - all share the same basic protocol design and format.

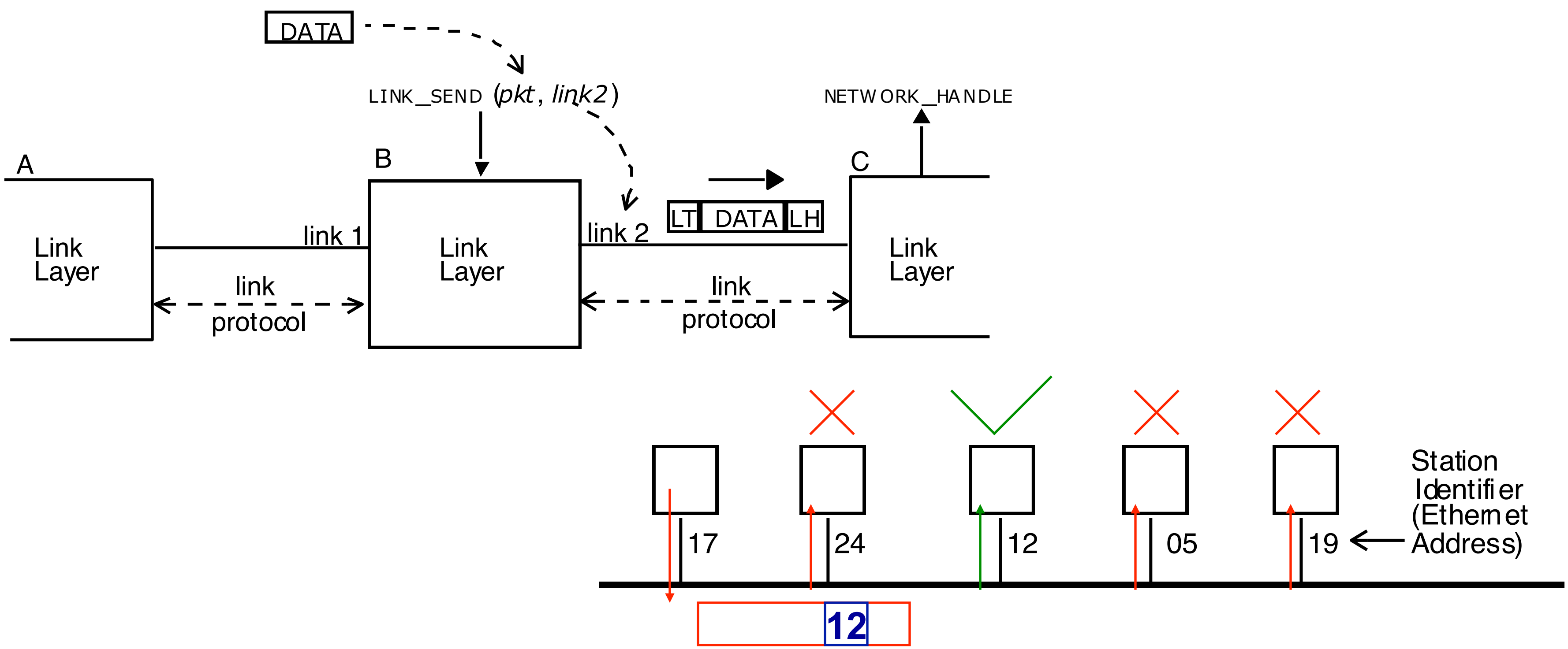
leader	destination	source	type	data	checksum
64 bits	48 bits	48 bits	16 bits	368 to 12,000 bits	32 bits

Broadcast in Ethernet

- Ethernet builds upon the assumption that messages inserted by a sender are delivered to all recipients
  - Original design – shared media (e.g. coaxial cable), naturally matches this requirement
  - Later designs – point-to-point switched Ethernet; yet still supporting broadcast assumption through forwarding

Broadcast in Ethernet

- Example – multiple devices (stations) connected to a shared media
  - Note: since link is shared, message must identify receiver: station identifier (Ethernet address)



Broadcast in Ethernet

- Link and network layer
  - Every frame delivered to every station – no need for any forwarding
  - Ethernet network-layer address specifies which device should ‘upcall’ frame
  - Ethernet supports frames with broadcast address – all listeners then ‘upcall’

Ethernet network layer

- Sending side
  - Just pass call along to link layer
- Receiving side:
  - Identifier (Ethernet MAC address) hardwired in interface – IEEE handles allocation
  - Often, address can be re-programmed

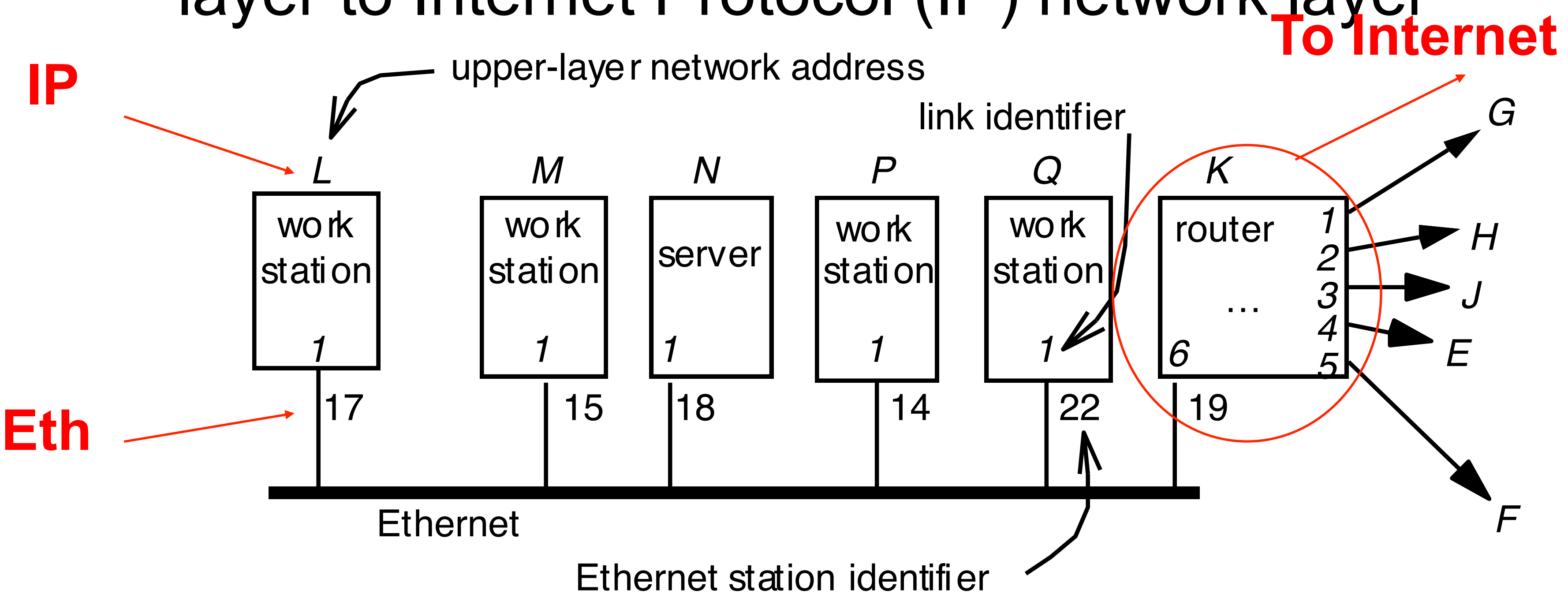
procedure ETHERNET_HANDLE (*net_packet*, *length*)
    destination ← *net_packet*.*target_id*
    if *destination* = *my_station_id* **or** *destination* = BROADCAST_ID **then**
        GIVE_TO_END_LAYER (*net_packet.data*,
                net_packet.end_protocol,
                net_packet.source_id)
    else
        ignore packet

Broadcast – discussion

- Broadcast in a shared media facilitates design and leads to reduced costs
  - Same motivation for buses in computers
- Protocols that require acknowledgement present a problem
  - Multiple replies near the same time cause contention
- Errors/malicious usage can flood the network

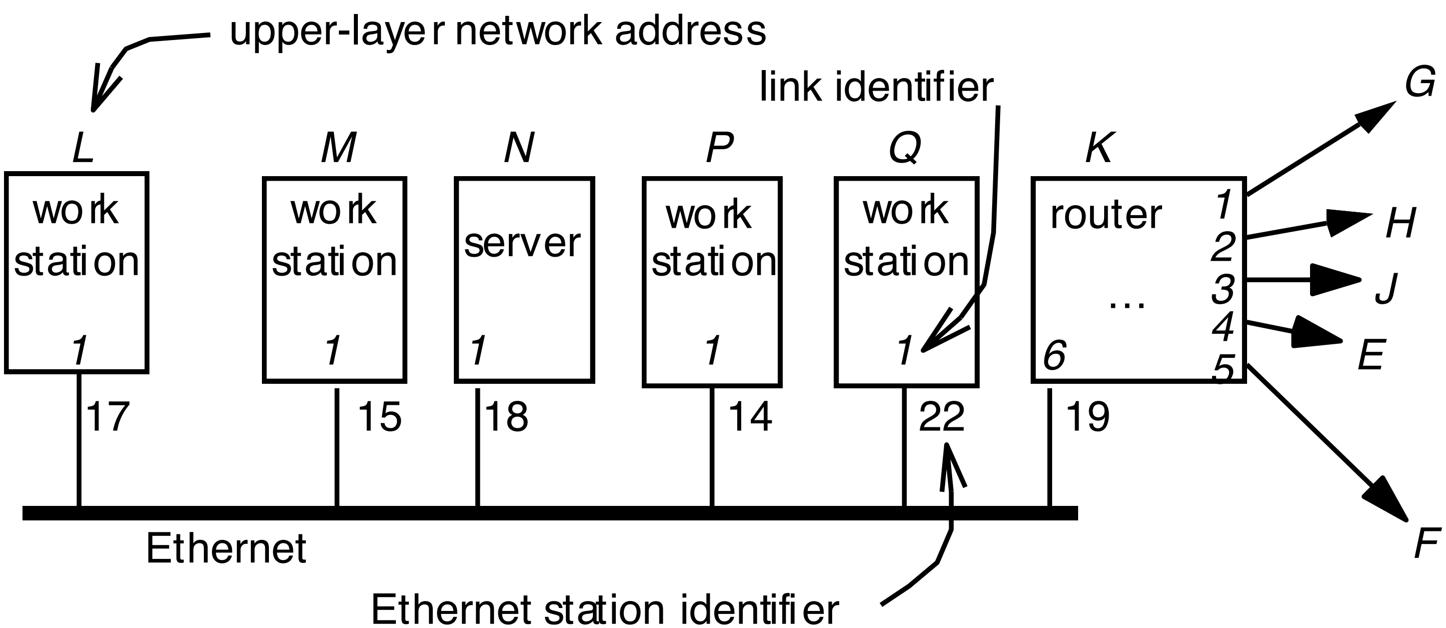
Layer mapping

- Ethernet works as described within a “local area network” (LAN)
- To connect Ethernet network to the Internet, need a mechanism to map Ethernet network layer to Internet Protocol (IP) network layer



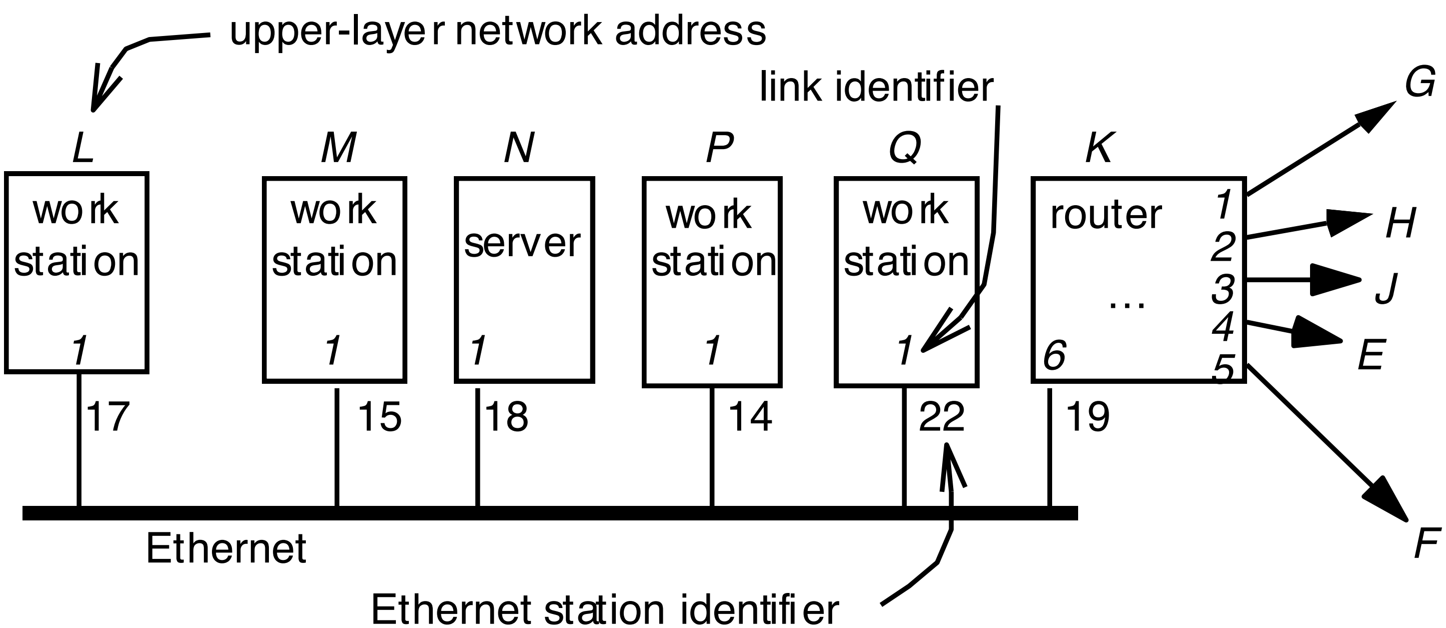
Layer mapping

- Ethernet device on station also has upper-layer network address (IP) bound to it
- End-to-end layer uses IP address
  - L: RPC request names N; reply from N names L



Layer mapping

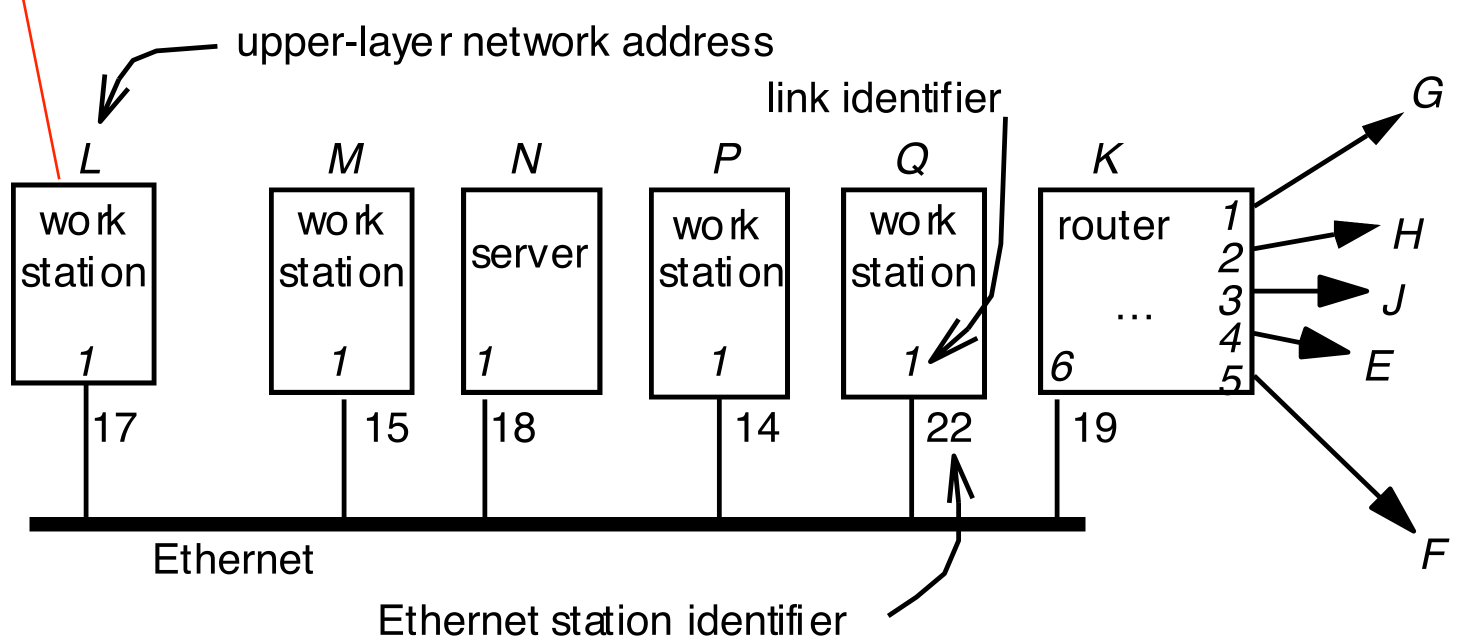
- L sends message to N
  - What is needed is for L to have a record of mapping L=17, N=18
- How does L find this layer mapping information?
- What if L needs to send message to G, E?



Forwarding table

internet address	Ethernet/ station
M	enet/15
N	enet/18
P	enet/14
Q	enet/22
K	enet/19
E	enet/19

Manual configuration
Cumbersome, error-prone

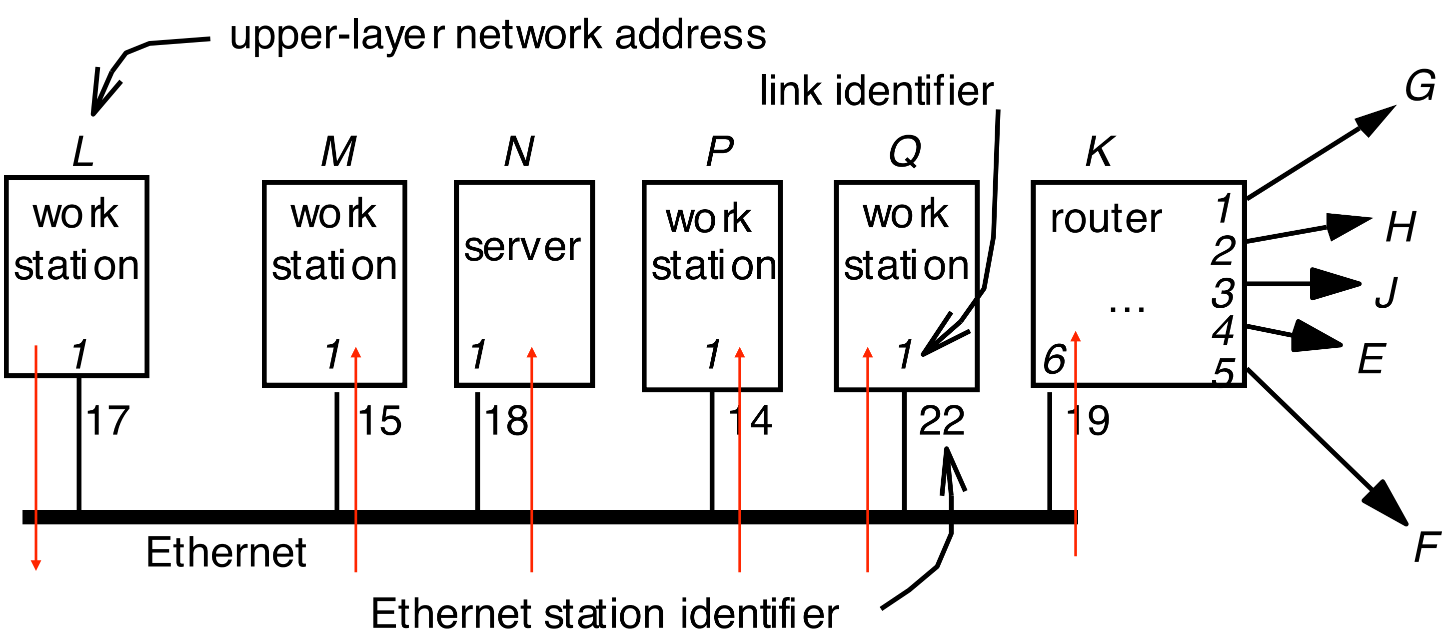


Address Resolution Protocol

- ARP
  - Leverages broadcast nature of Ethernet
  - Supports auto-configuration of layer mapping

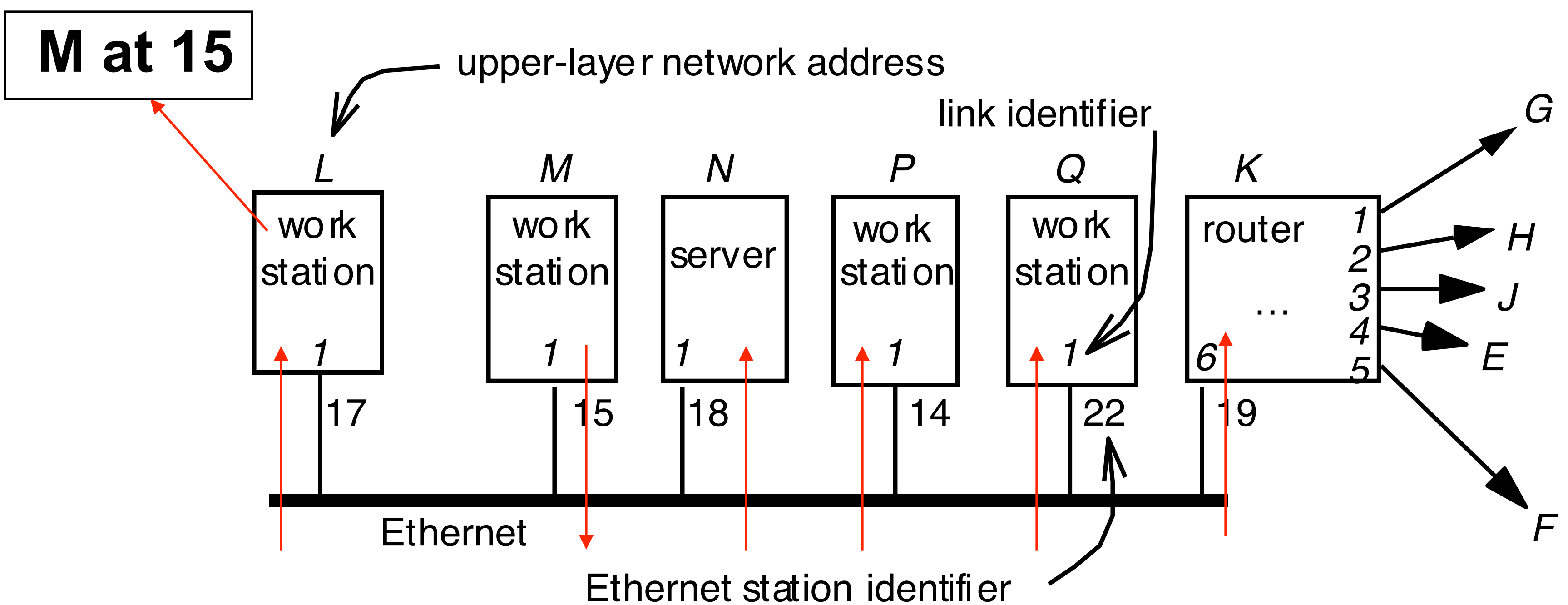
ARP

- Start with an empty table
- If L needs to send a message to M
  - First send ARP protocol message
  - NETWORK_SEND("where is M?", ARP, ENET, broadcast)



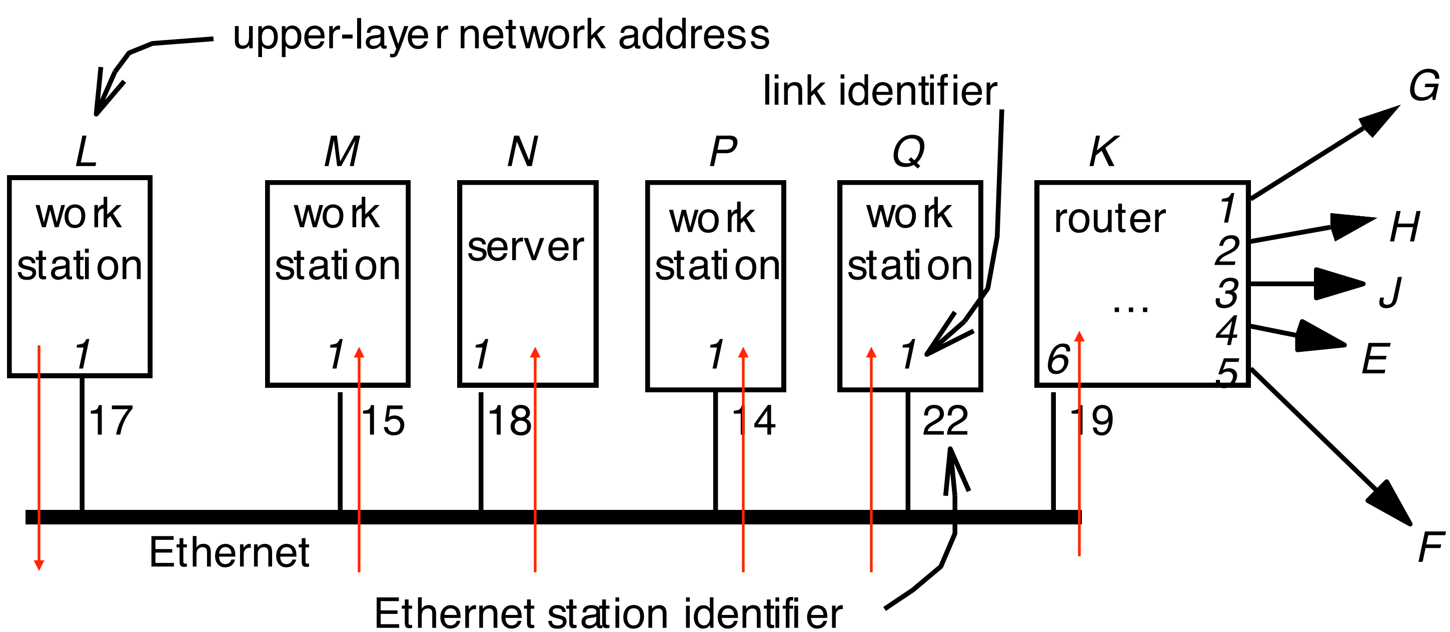
ARP

- All nodes receive message
- All nodes look up whether their upper-layer address match M; at most one replies
  - NETWORK_SEND("M is at 15", ARP, ENET, broadcast)



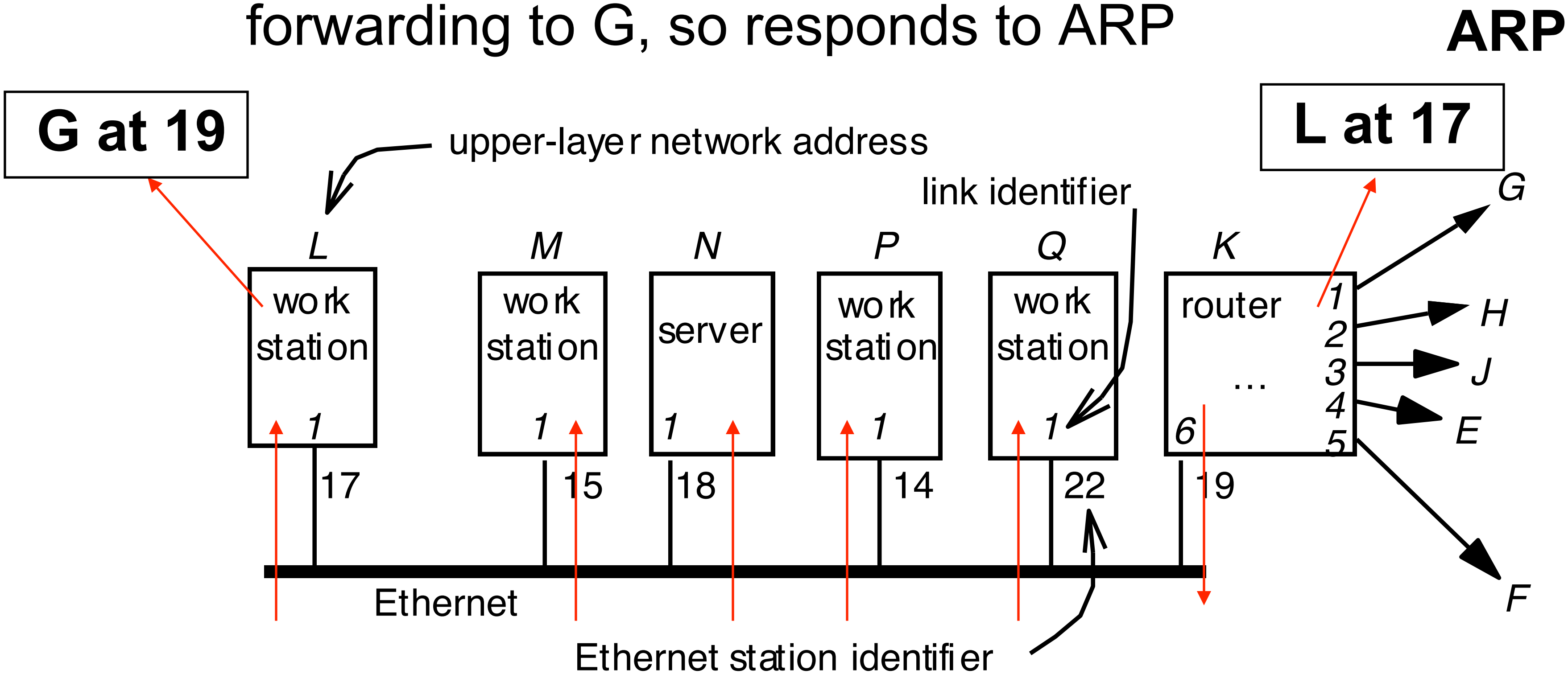
ARP

- If L needs to send a message to G
  - First send ARP protocol message
  - NETWORK_SEND("where is G?", ARP, ENET, broadcast)



ARP

- All nodes receive message
- All nodes look up whether their upper-layer address match G
  - No match; but router takes responsibility of forwarding to G, so responds to ARP

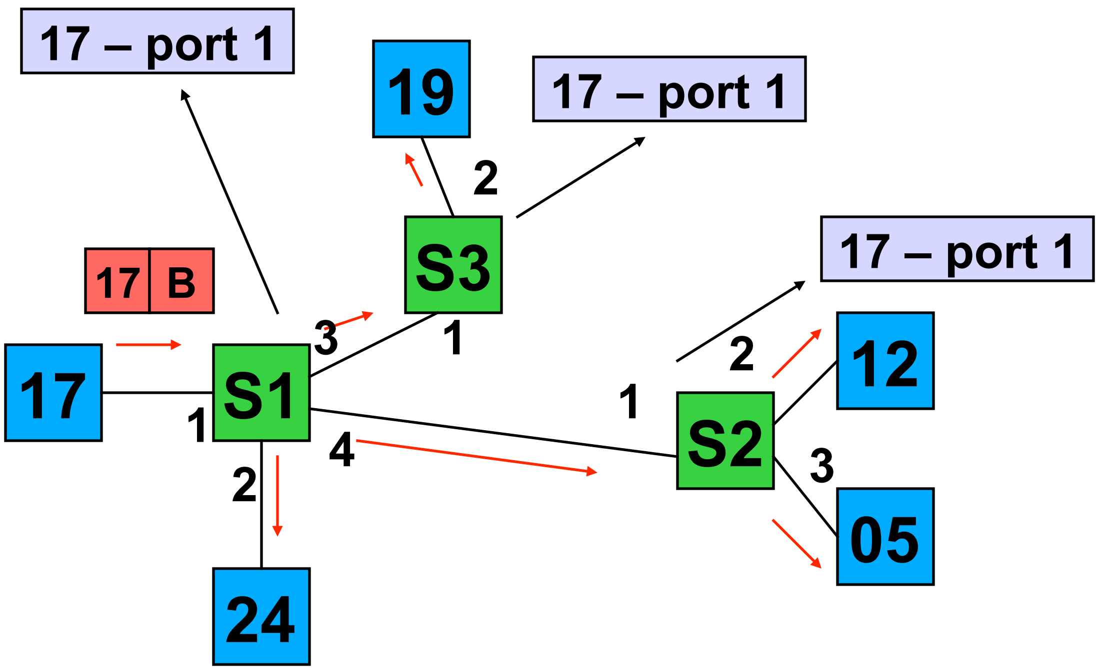


Switched Ethernet

- Shared media does not scale well
- Typical Ethernet networks are switched
  - Forwarding within Ethernet
  - Switches must preserve broadcast feature

Switched Ethernet

- Broadcast – allows switches to learn address of devices connected to them



Switched Ethernet

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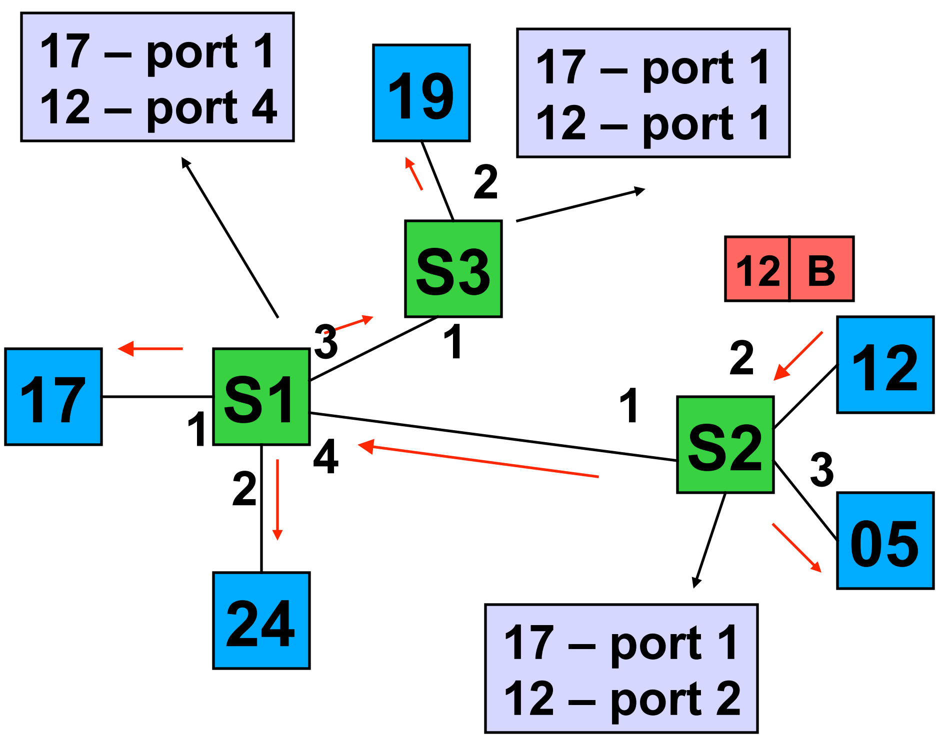
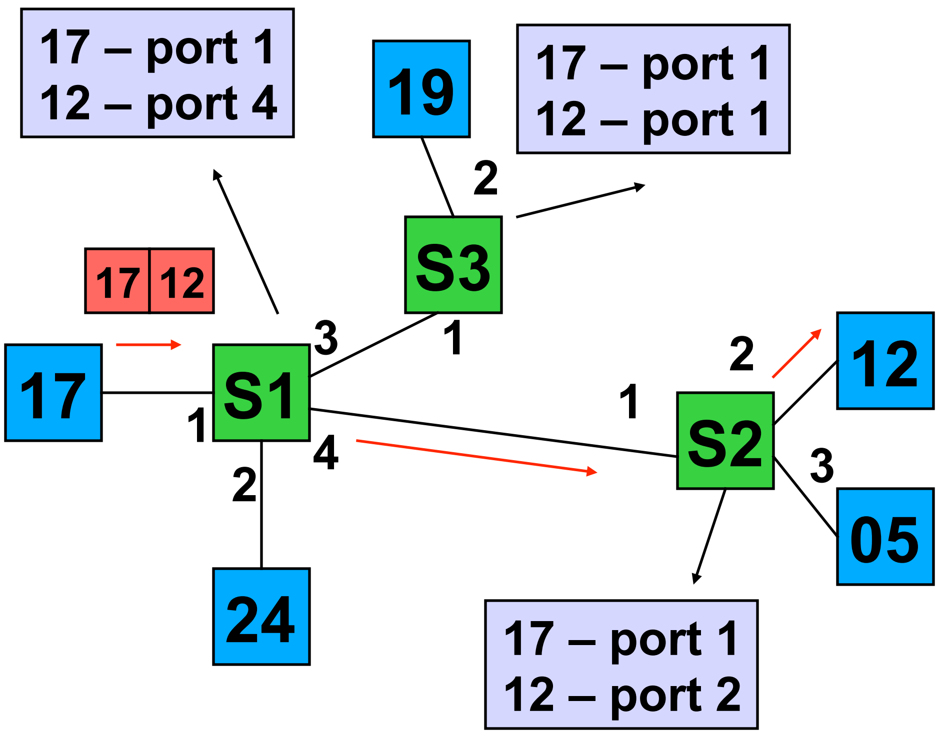


Switched Ethernet

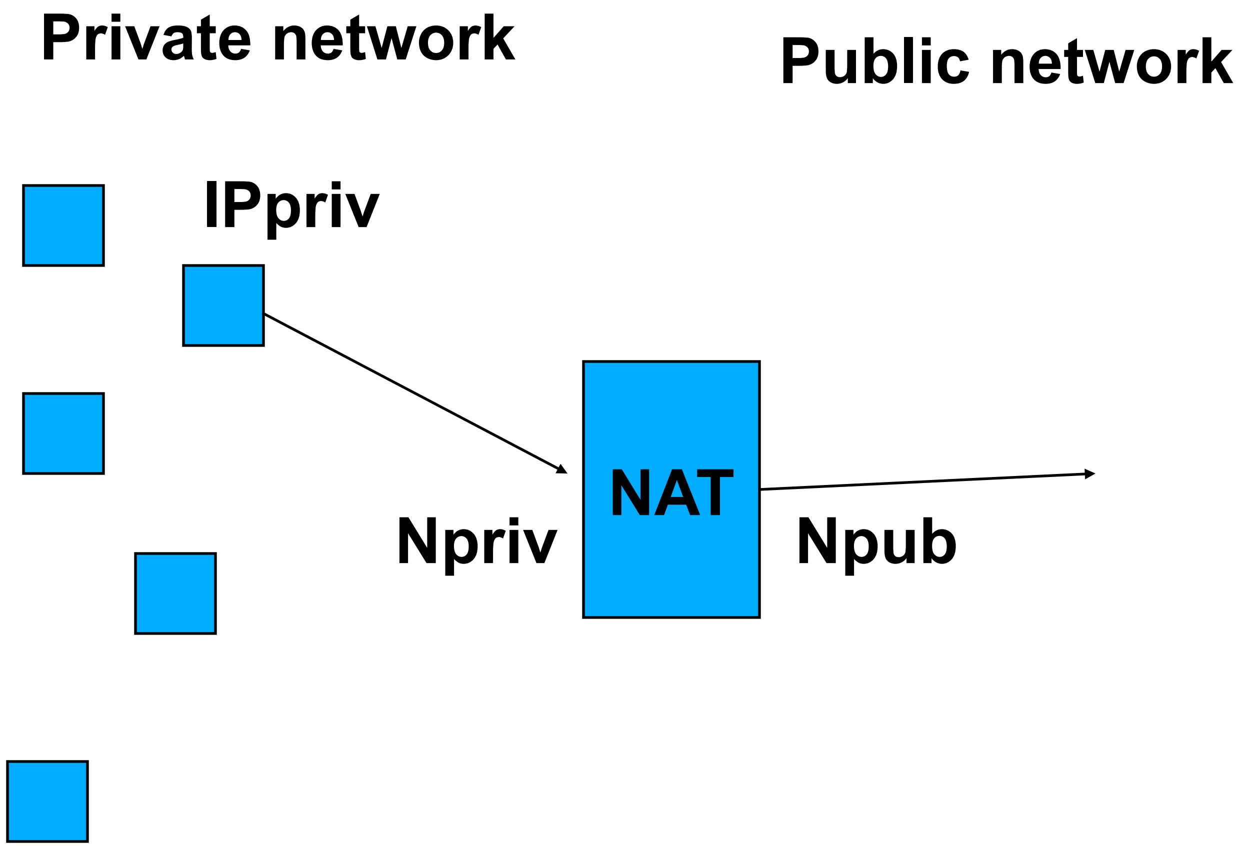
- Message addressed to a device – follow forwarding path learned; not delivered to all stations, save bandwidth/processing



Network Address Translation

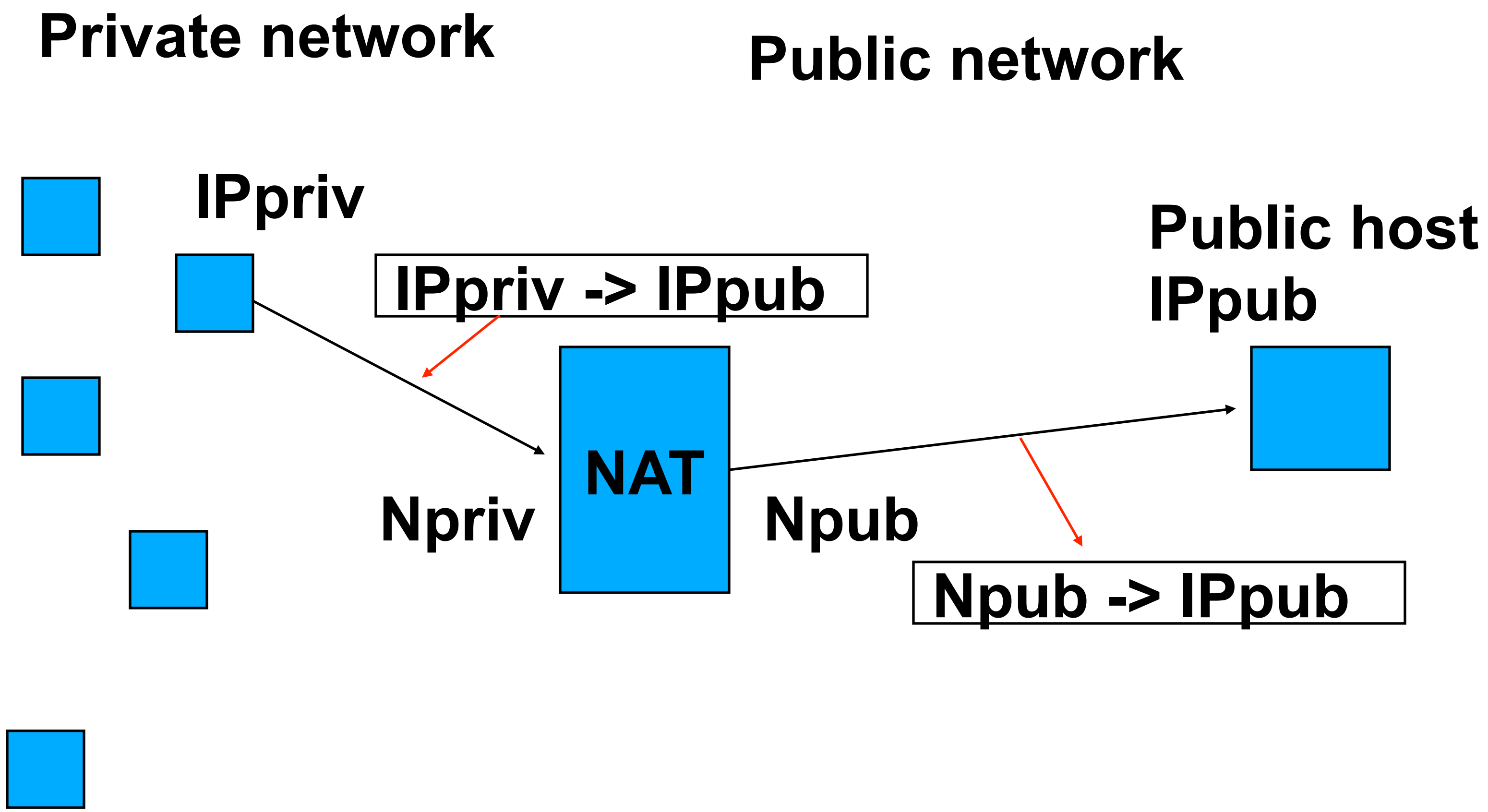
- IPv4 addresses – 32 bits
  - Blocks are reserved and assigned to institutions; fragmentation; effectively, less than 4 billion unique network identifiers
- Many institutions have shortage of "public" IP addresses
  - I.e. those that are routable over the public Internet
- Network address translation (NAT): approach that has been used to address this issue
  - Note: Ethernet addresses – much larger address space (2^48); not hierarchical
  - IPv6: 128-bits; not widely adopted yet

Network Address Translation

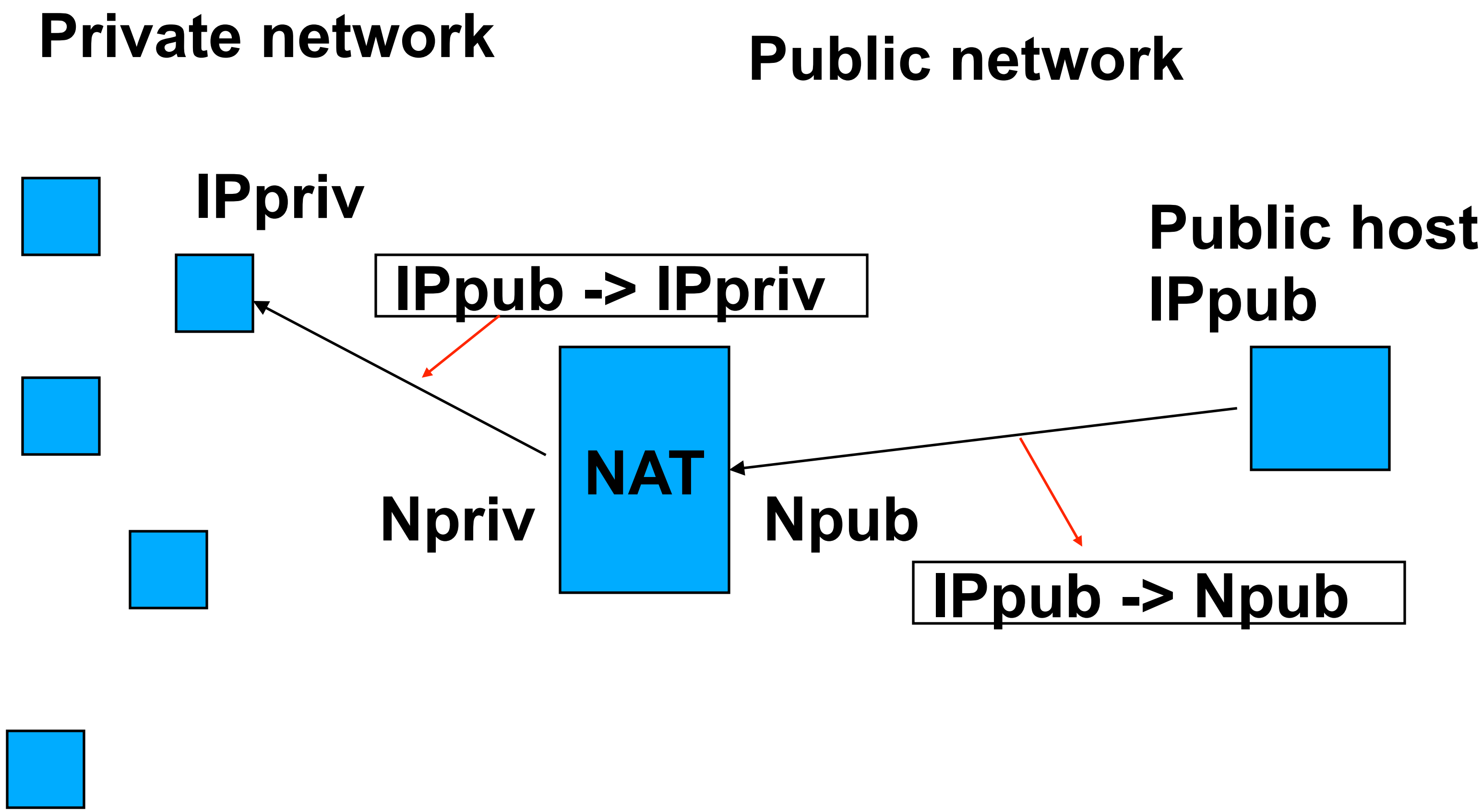


Reserved ranges:
10.x.x.x; 192.168.x.x; 172.16.x.x

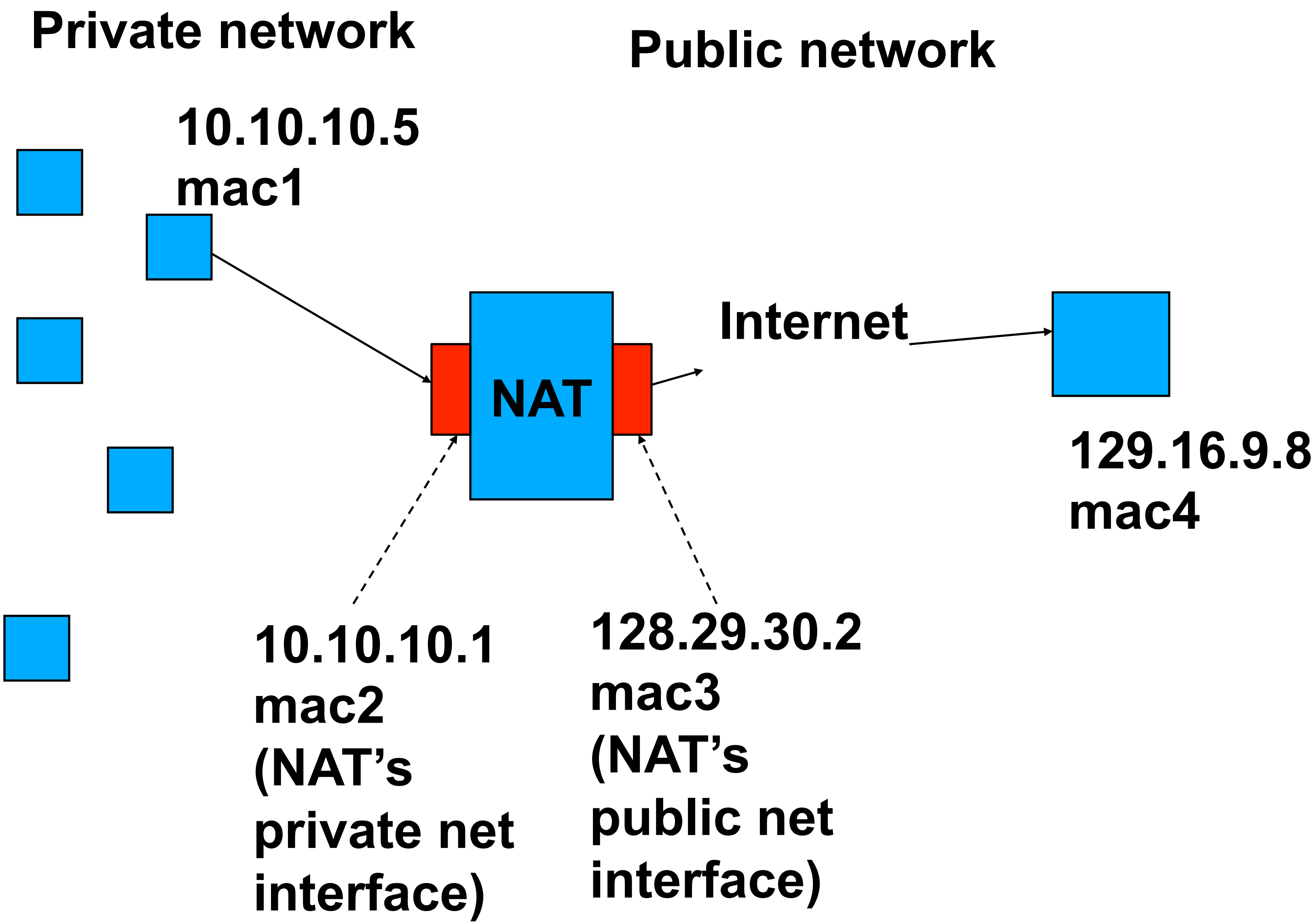
Network Address Translation



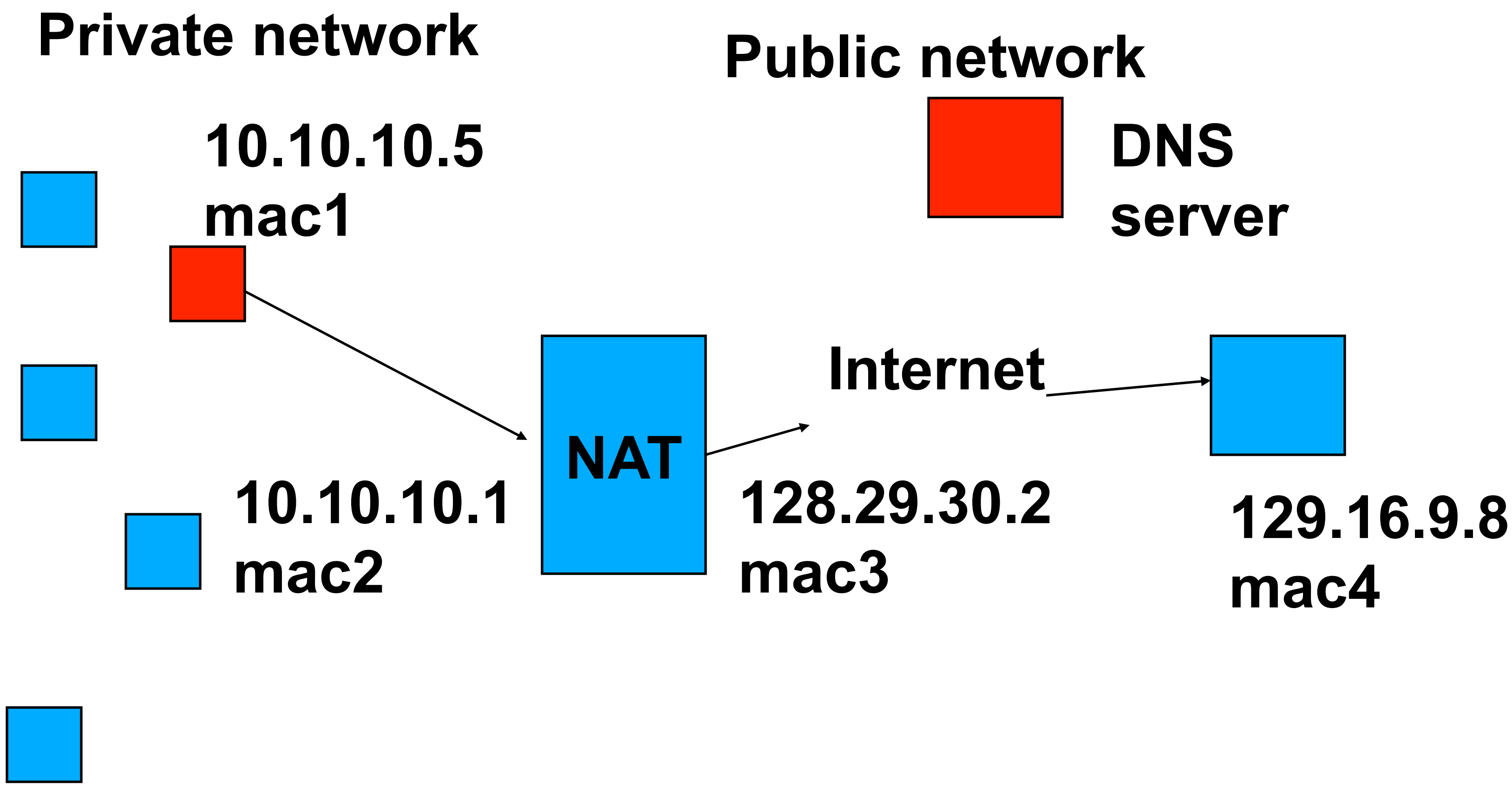
Network Address Translation



NAT example – naming layers

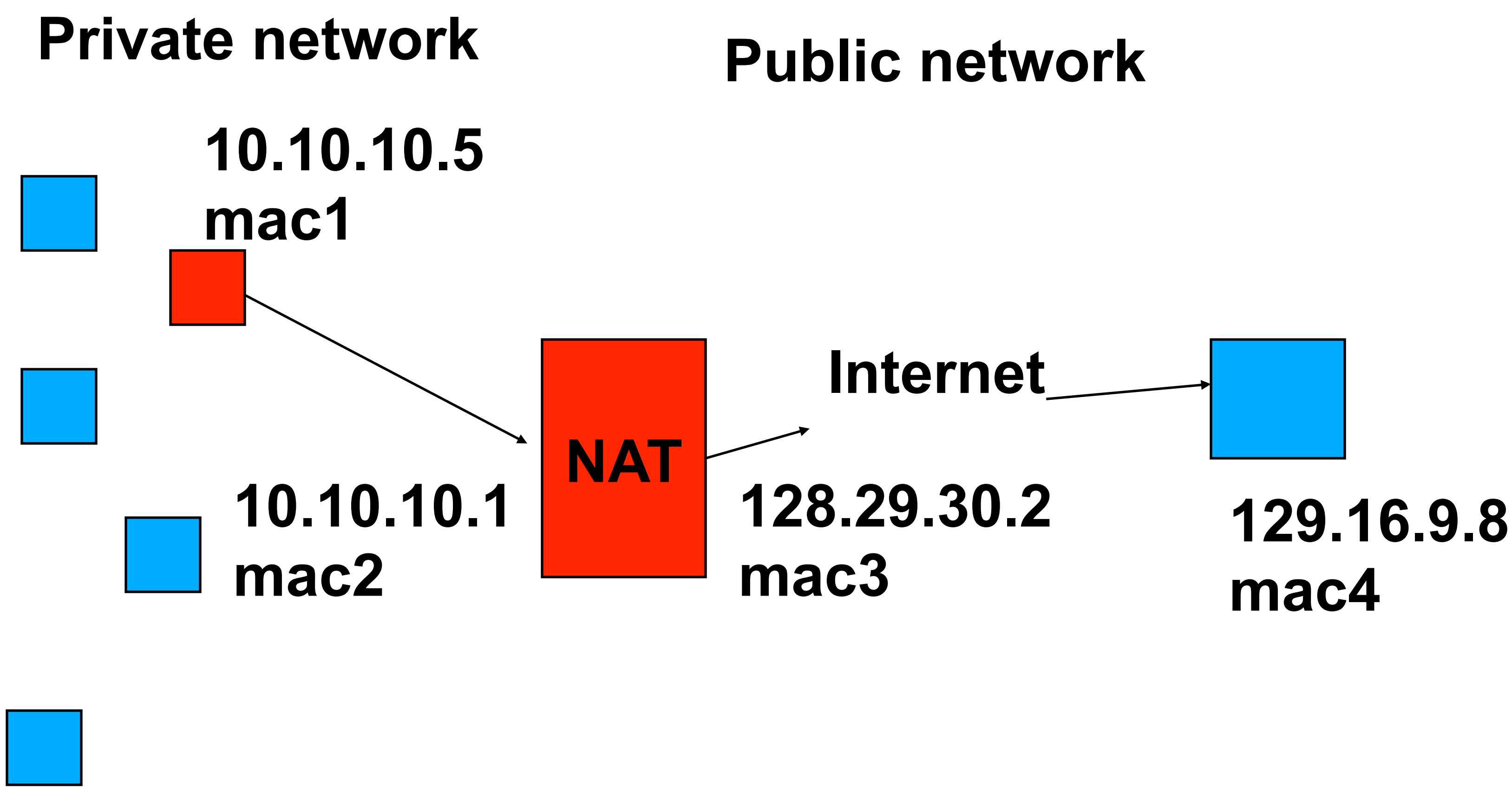


NAT example – naming layers



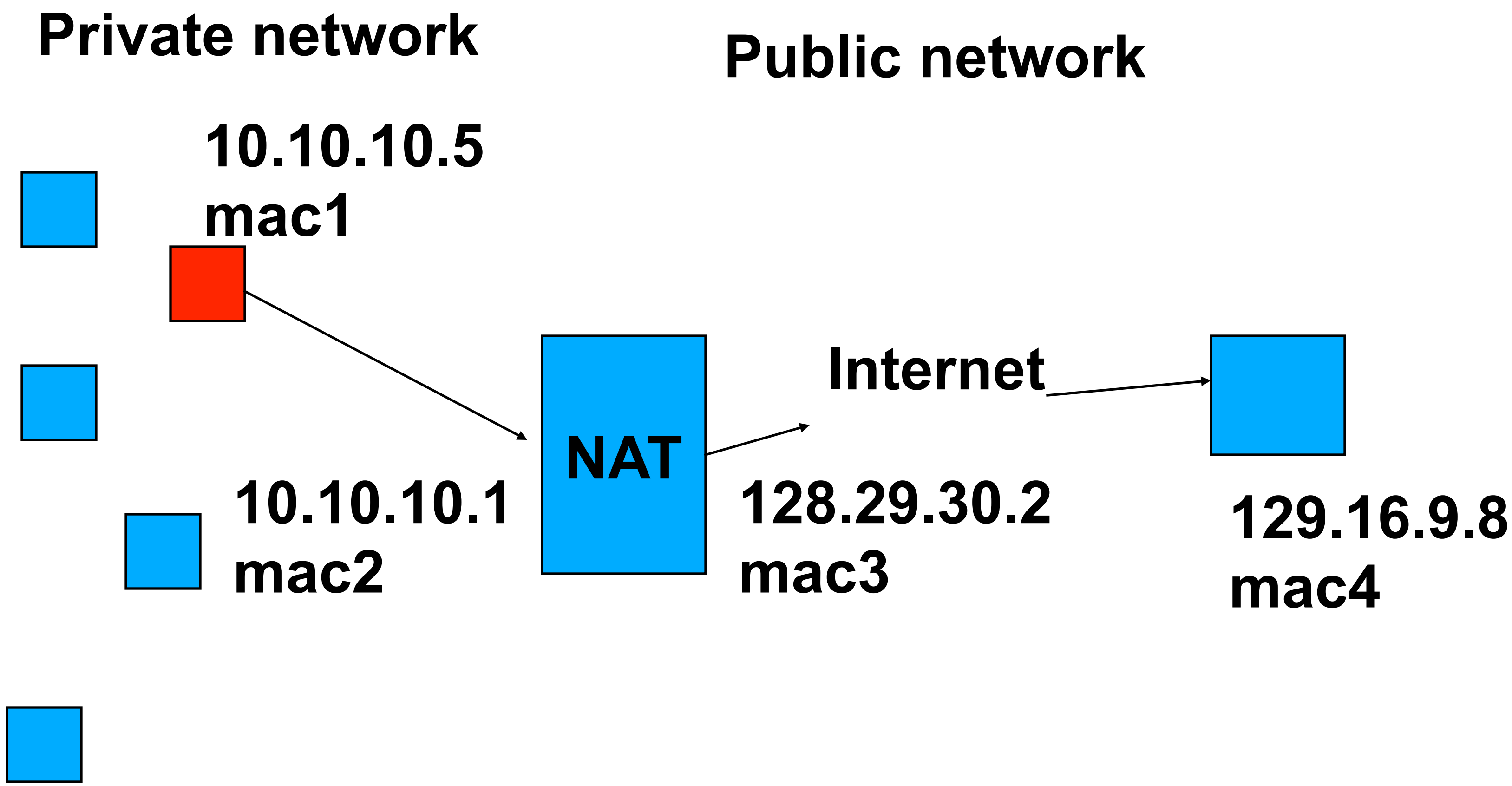
DNS-Lookup(site.com) <- 129.16.9.8

NAT example – naming layers



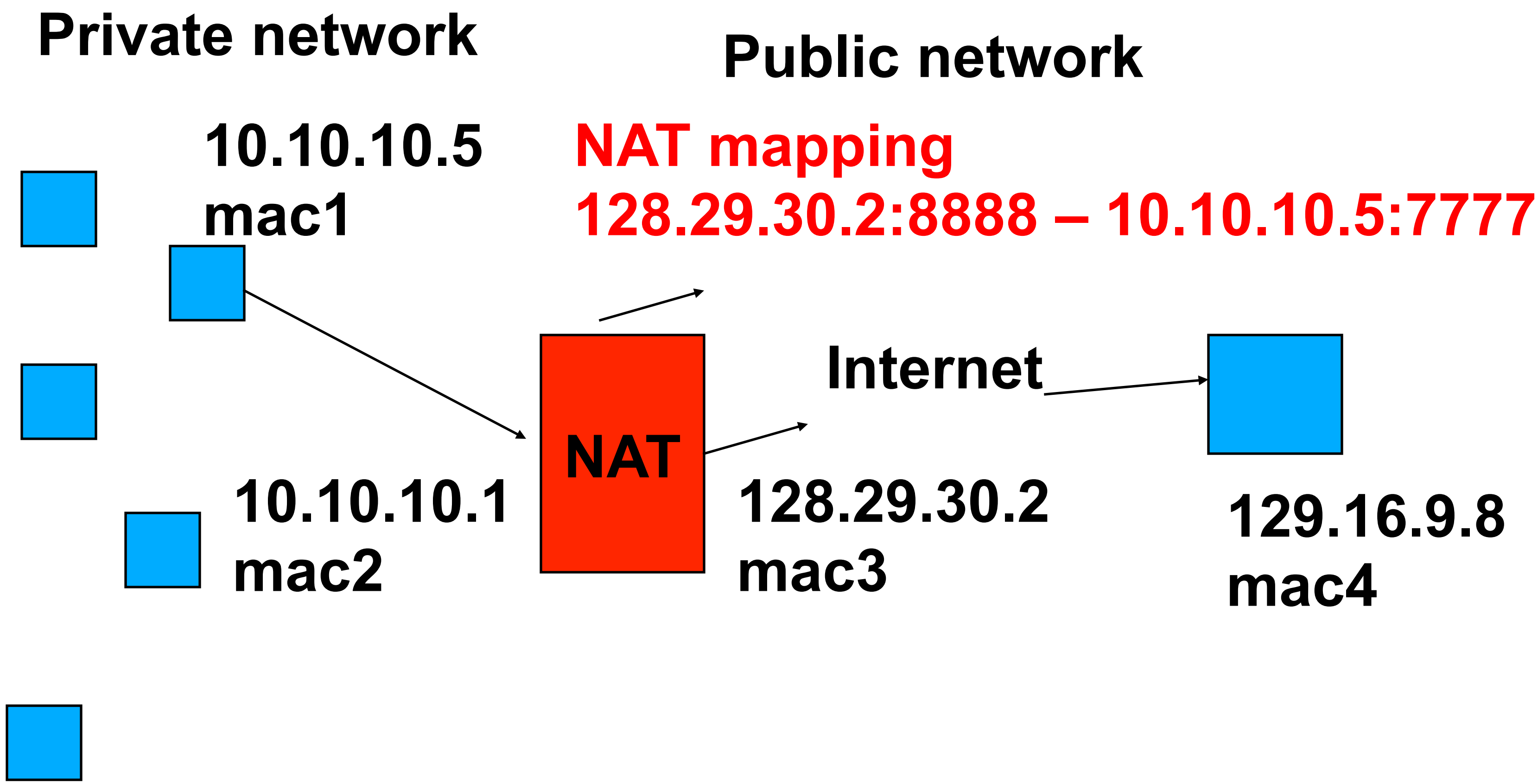
ARP(129.16.9.8) <- mac2

NAT example – naming layers



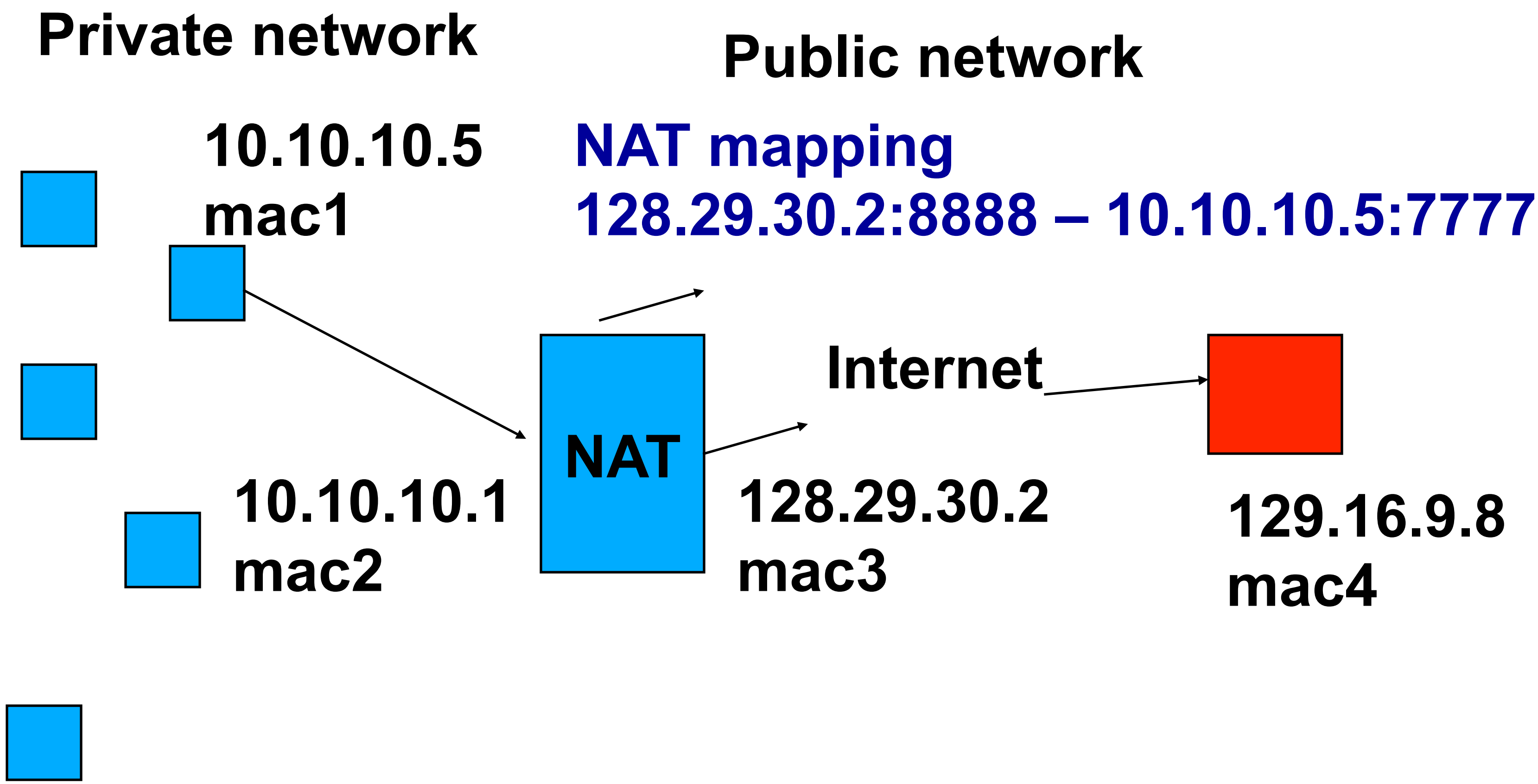
send (eth,mac1,mac2,
IP,src=10.10.10.5, port=7777,
dst=129.16.9.8, port=80)

NAT example – naming layers



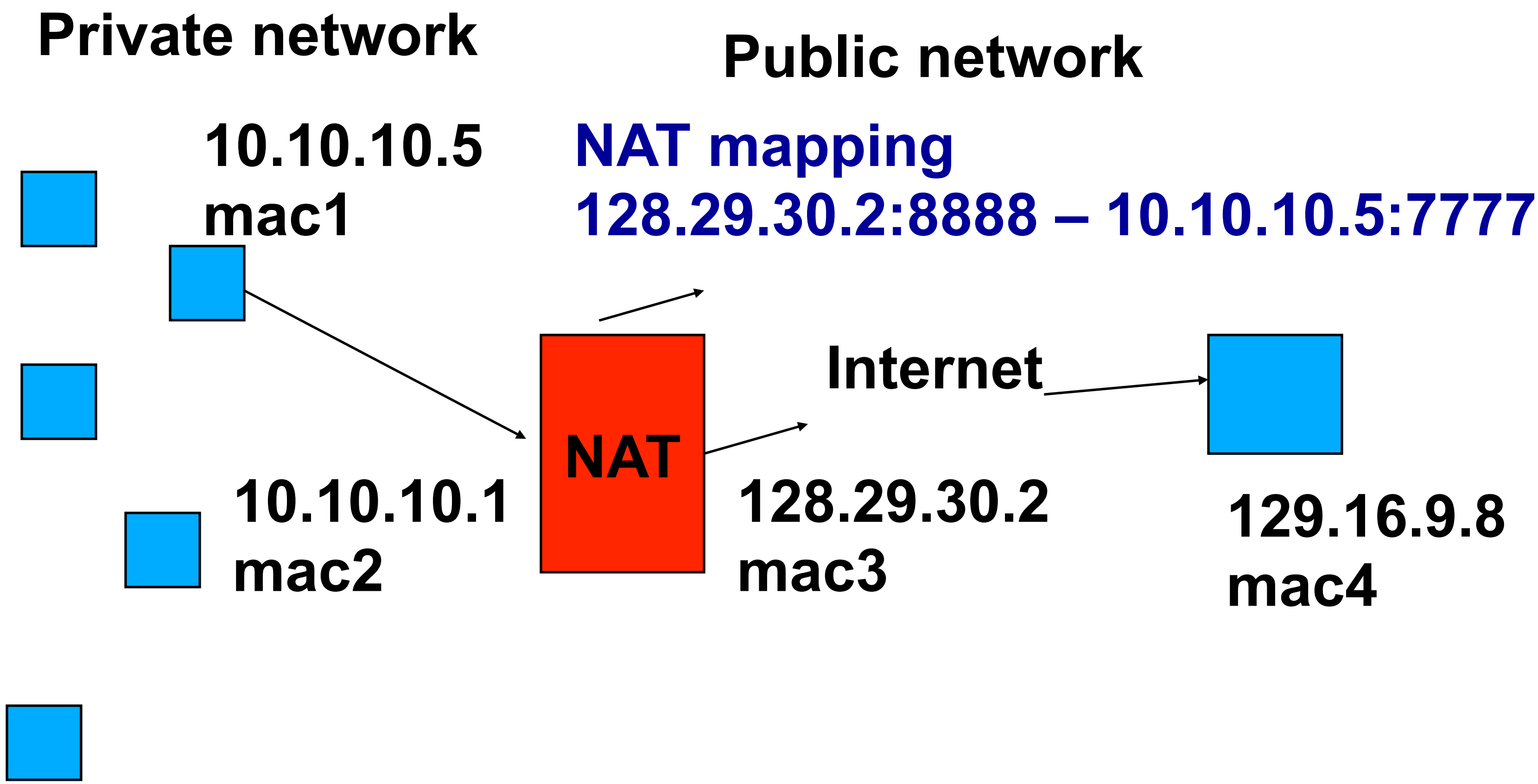
send (eth,mac3,nexthop1,
IP,src=128.29.30.2, port=8888,
dst=129.16.9.8, port=80)

NAT example – naming layers



send (eth,mac4,nexthop2,
IP,src=129.16.9.8, port=80,
dst=128.29.30.2, port=8888)

NAT example – naming layers



send (eth,mac2,mac1,
IP,src=129.16.9.8, port=80,
dst=10.10.10.5, port=7777)

NAT challenges

- Clients behind NATs communicating with public services is generally transparent
- However, services behind NATs cannot be directly addressed by clients
  - Peer-to-peer communication when both peers are behind NATs require "NAT traversal" techniques
    - E.g. voice-over-IP; UDP "hole punching"
  - Protocols/applications that include IP addresses in the payload – no translation
- Breaks symmetry of Internet; makes it difficult to deploy end-to-end applications among end users

Reading

- Section 8.1-8.2