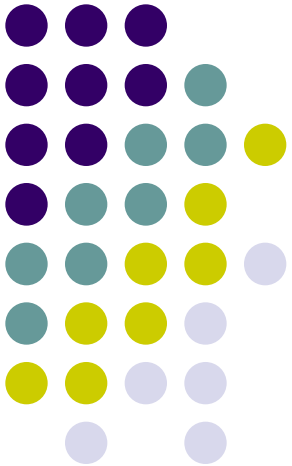
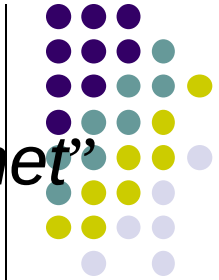
TCP/IP Networks

A Brief Introduction



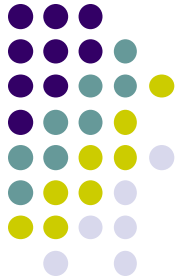
Internet Evolution (I)



- In 1969, ARPA funded and created the "ARPA*net*" network
  - Robust, reliable, vendor-independent data communications
- In 1975
  - Convert from experimental to operational network
  - TCP/IP begun to be developed
- In 1983
  - The TCP/IP is adopted as Military Standards
  - ARPnet → MILNET + ARPnet = Internet
- In 1985
  - The NSF created the NSFnet to connect to Internet
- In 1990
  - ARPA passed out of existence, and in 1995, the NSFnet became the primary Internet backbone network

ARPA = Advanced Research Project Agency NSF = National Science Foundation

Internet Evolution (II)

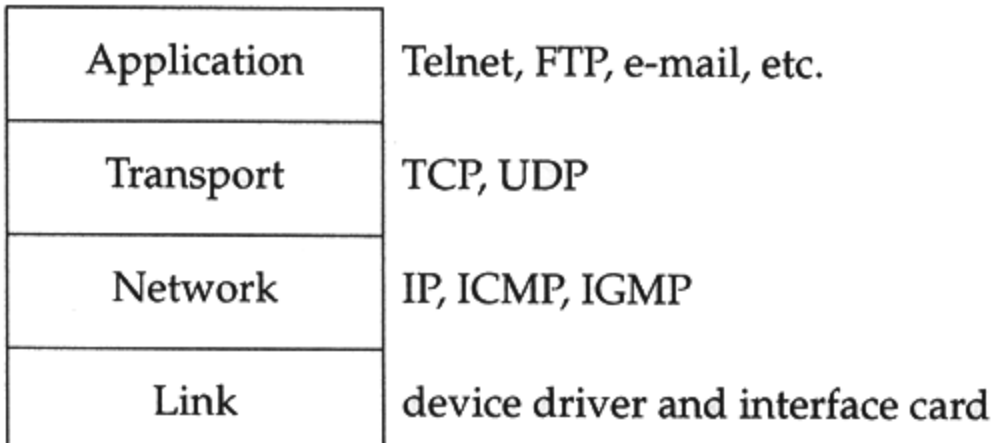


- In 1995
  - IETF issued a specification for a next-generation IP
- In 1996
  - IPv6 is standardized
- In 1998
  - RFC2373 IP Version 6 Addressing Architecture
  - RFC2463 ICMPv6 for IPv6
- In 2003
  - RFC3513 IPv6 Addressing Architecture (replace RFC2373)
- In 2006
  - RFC4295 Mobile IPv6 Management Information Base
  - RFC4487 Mobile IPv6 and Firewalls: Problem Statement
- In 2008
  - RFC5380 Hierarchical Mobile IPv6(HMIPv6) Mobility management
- In 2009
  - RFC5568 Mobile IPv6 Fast Handovers

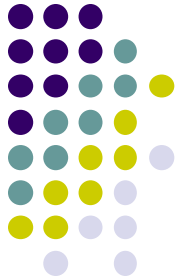
IETF= Internet Engineering Task Force

General Introduction (1)

- TCP/IP
  - Used to provide data communication between hosts
    - How to delivery data reliably
    - How to address remote host on the network
    - How to handle different type of hardware devices
  - 4 layers architecture
    - Each layer perform certain tasks
    - Each layer only need to know how to pass data to adjacent layers

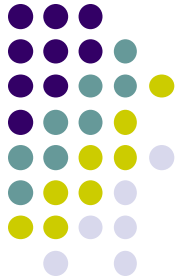


General Introduction (2)



- Four layer architecture
  - Physical + Network Access Layer (or Interface)
    - Network Interface Card + Driver
    - Handle all the hardware details of whatever type of media
  - Network Layer (or say, Internet Layer)
    - Handle the movement of packets on the network
  - Transport Layer
    - Provide end-to-end data delivery services
  - Application Layer
    - Handle details of the particular application

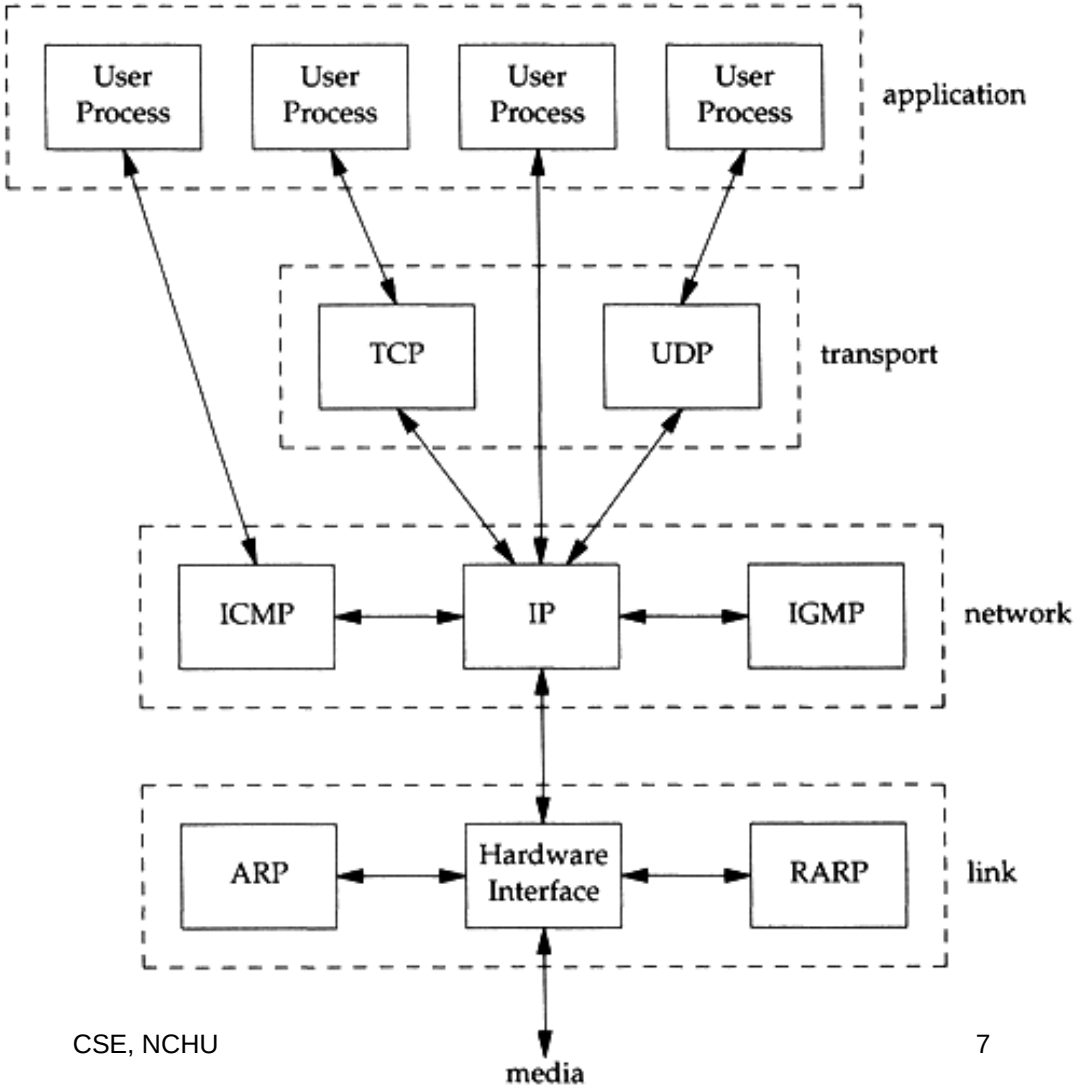
General Introduction (3)



- Various Addresses
  - MAC Address
    - Media Access Control Address
    - 48-bit Network Interface Card Hardware Address
      - 24bit manufacture ID
      - 24bit serial number
    - Ex: 00:07:e9:10:e6:6b
  - IP Address
    - 32-bit Internet Address
    - Ex:140.120.13.254
  - Port
    - 16-bit uniquely application identification
    - Ex:FTP port 21, ssh port 22, telnet port 23

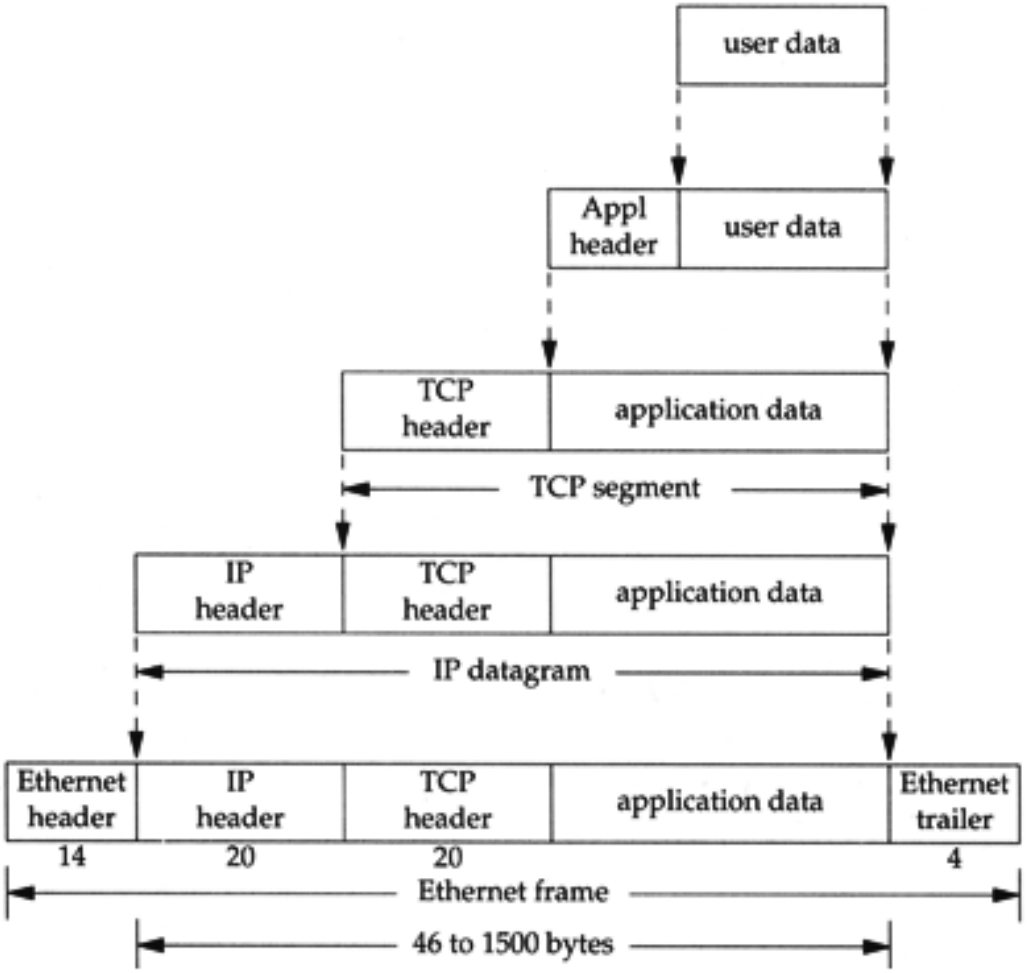
General Introduction (4)

- Each layer has several protocols
  - A layer defines a data comm. function that may be performed by certain protocols
  - A protocol provides a service suitable to the function of that layer.



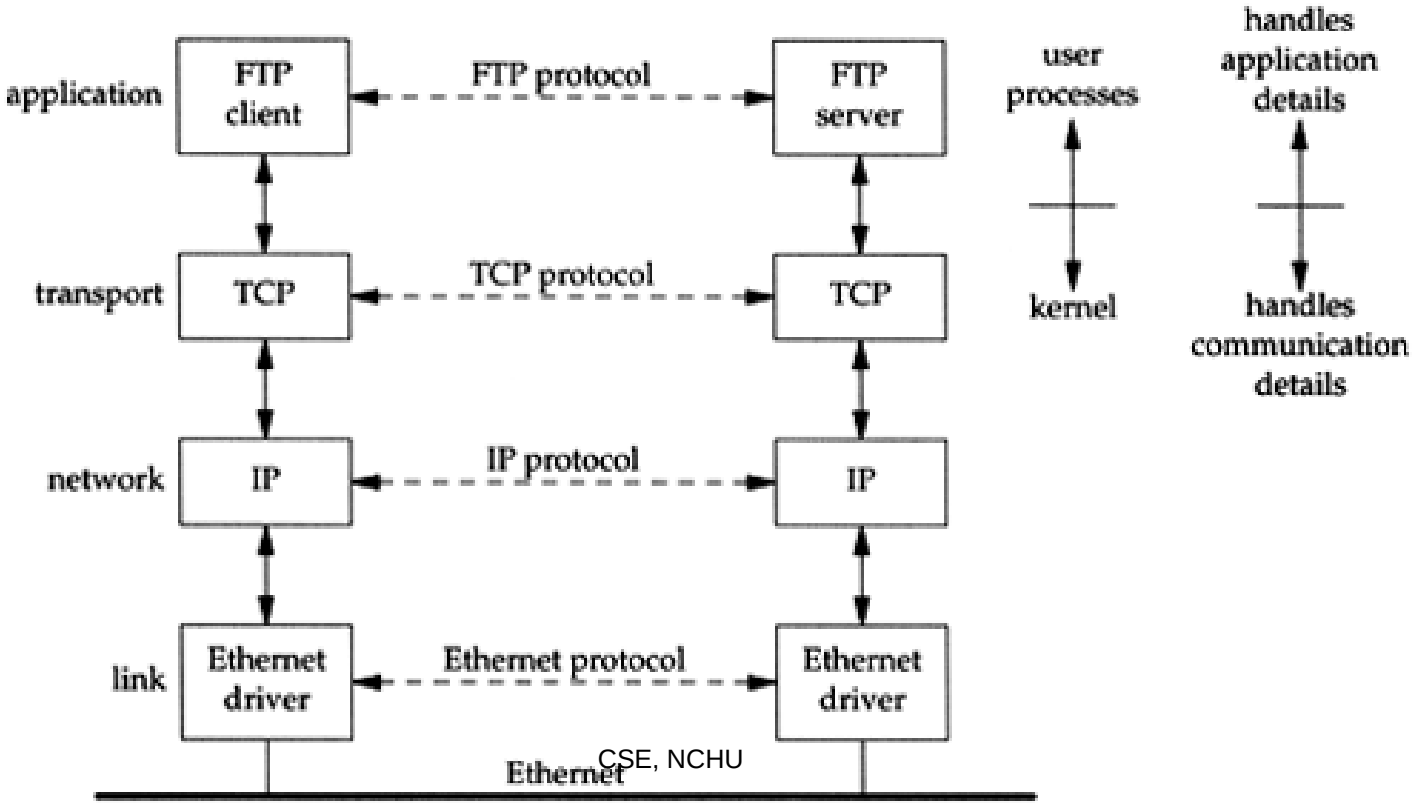
General Introduction (5)

- Send data (encapsulation)



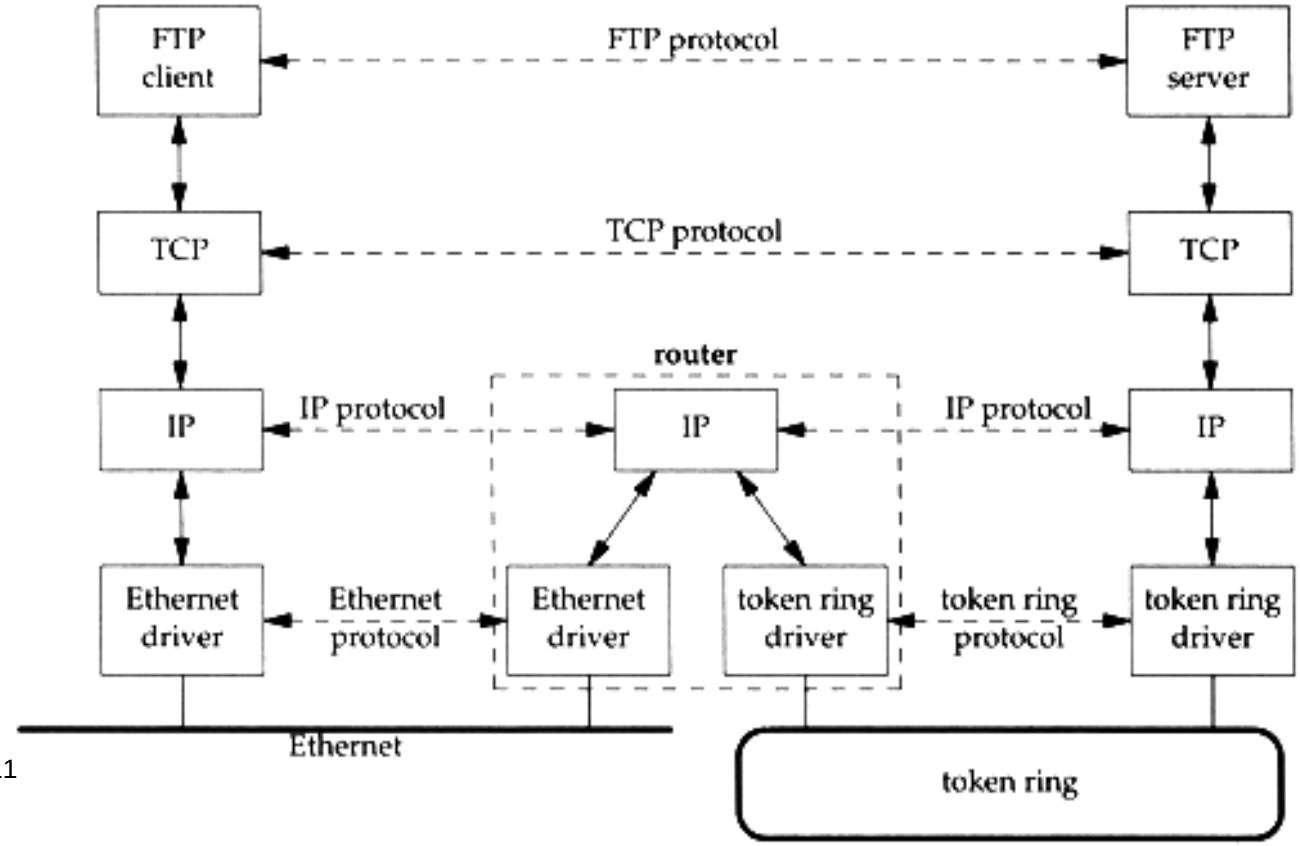
General Introduction (6)

- Addressing --- nearby
  (same network)



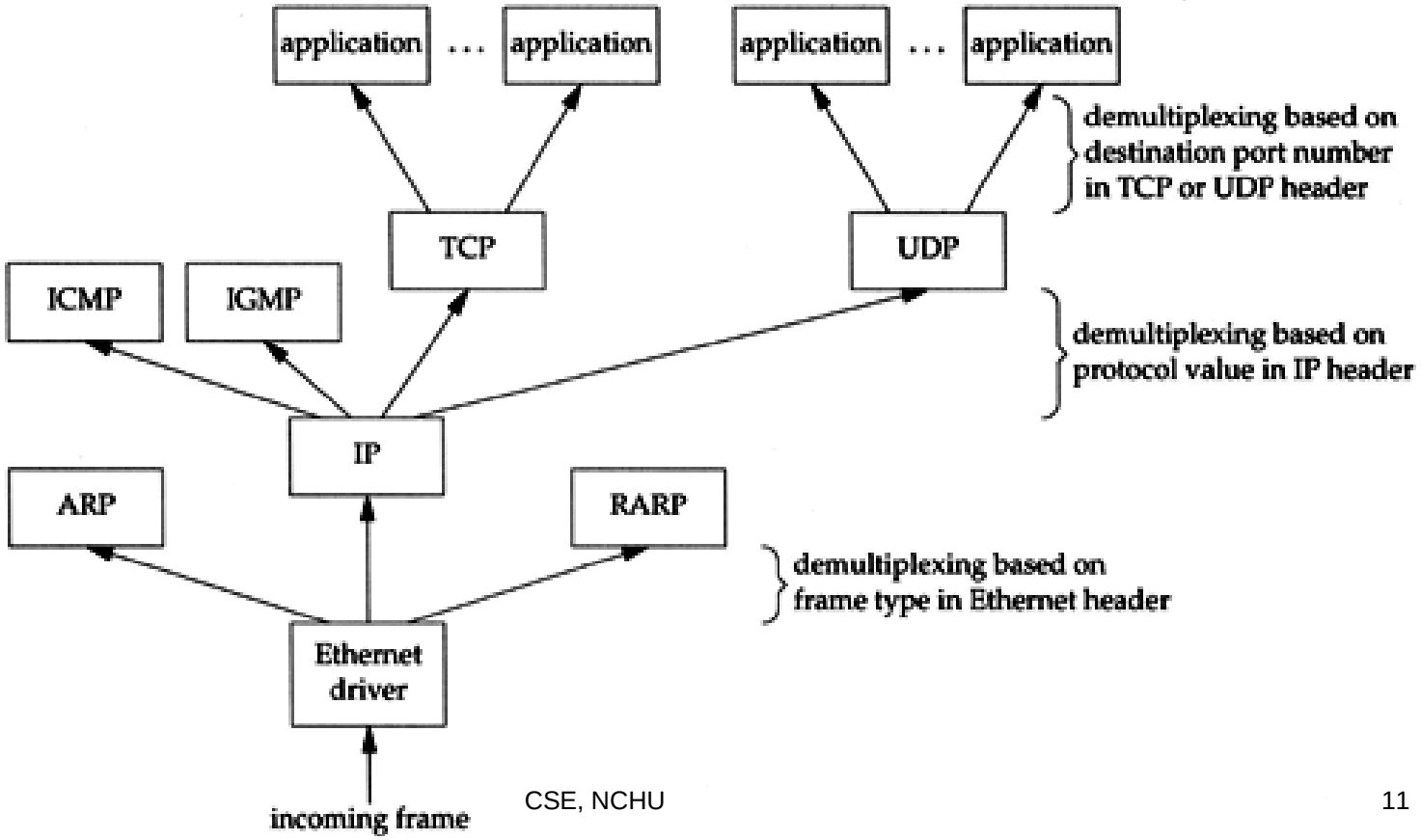
General Introduction (7)

- Addressing --- faraway (across network)

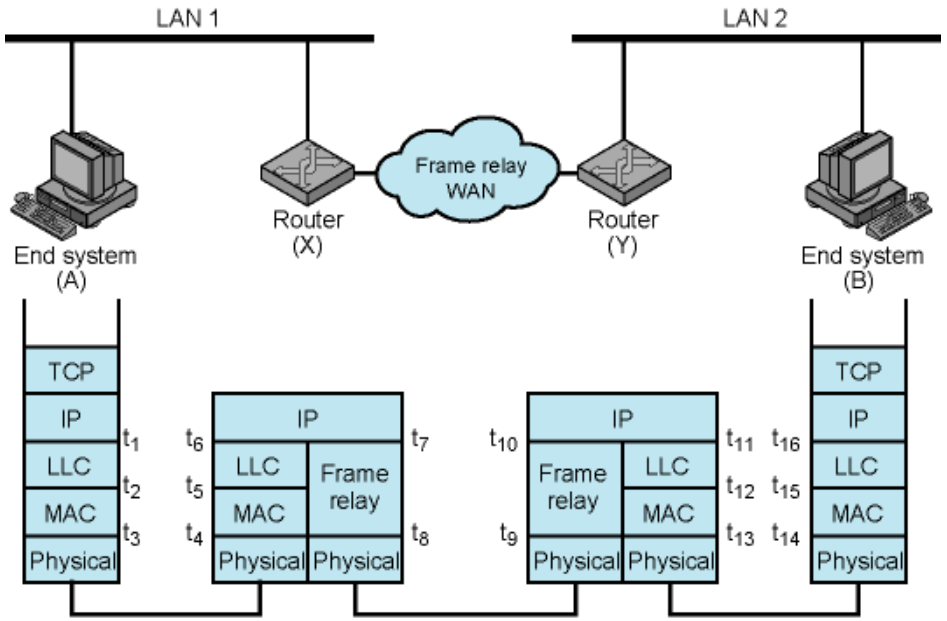


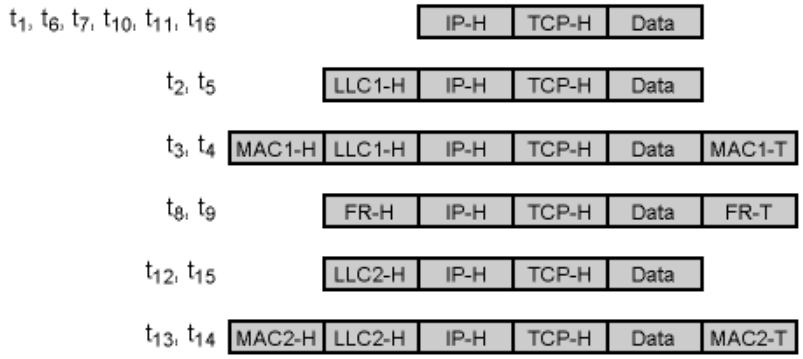
General Introduction (8)

- Receive Data --- demultiplexing



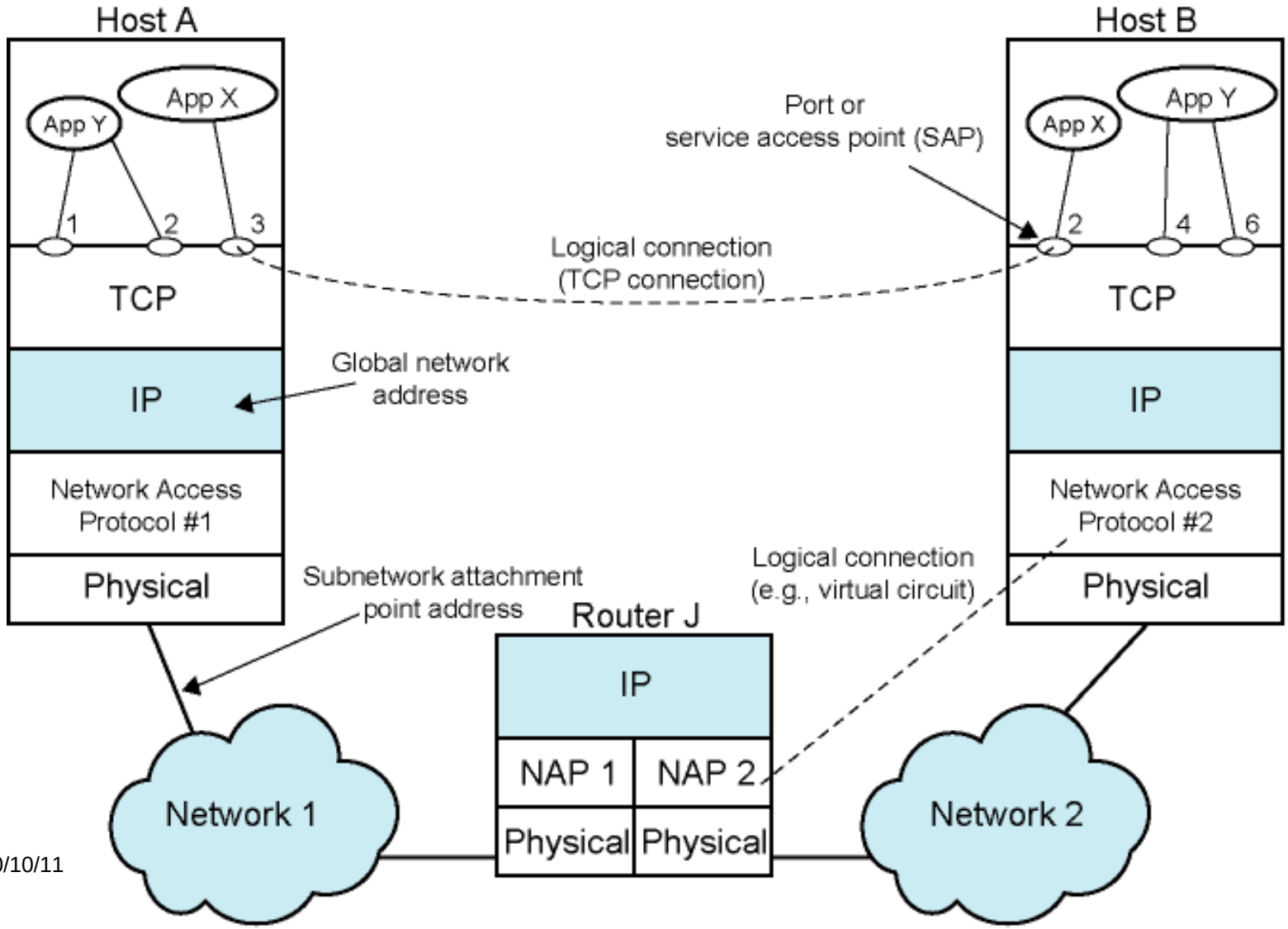
General Introduction (9)





TCP-H = TCP header
IP-H = IP header
LLCi-H = LLC header
MACi-H = MAC header
MACi-T = MAC trailer
FR-H = Frame relay header
FR-T = Frame relay trailer

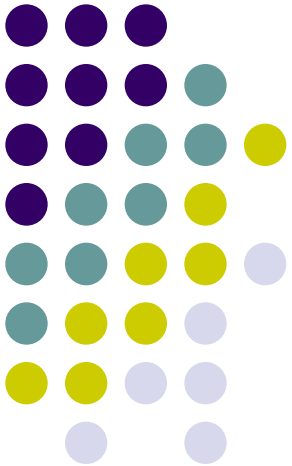
General Introduction (10)



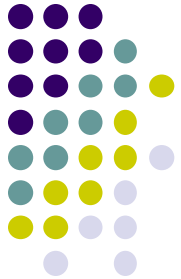
Interface Layer

Provides 2 services for IP:

- Mapping IP addresses to Interface specific addresses
- Encapsulating IP datagrams for transmission over a specific medium



Introduction of Interface Layer



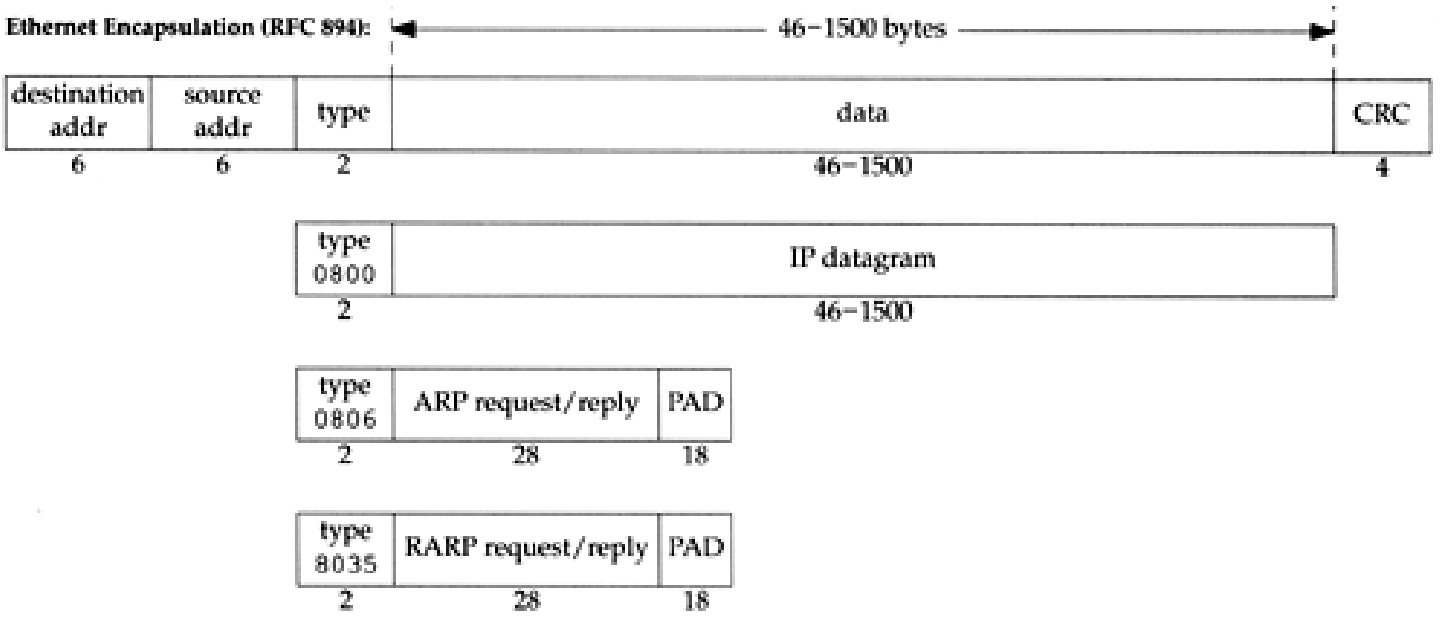
- Tasks of Interface layer
  - Send and receive IP datagrams for IP module
  - ARP request and reply
  - RARP request and reply
- TCP/IP support various link layers, depending on the type of hardware used:
  - Ethernet
  - Token Ring
  - FDDI (Fiber Distributed Data Interface)
  - Serial Line

Ethernet

- Features
  - Predominant form of local LAN technology used today
  - Use CSMA/CD
    - Carrier Sense, Multiple Access with Collision Detection
  - Use 48bit MAC address
  - Operate at 10/100/1000 Mbps
  - Ethernet frame format is defined in RFC894
    - This is the actually used format in reality

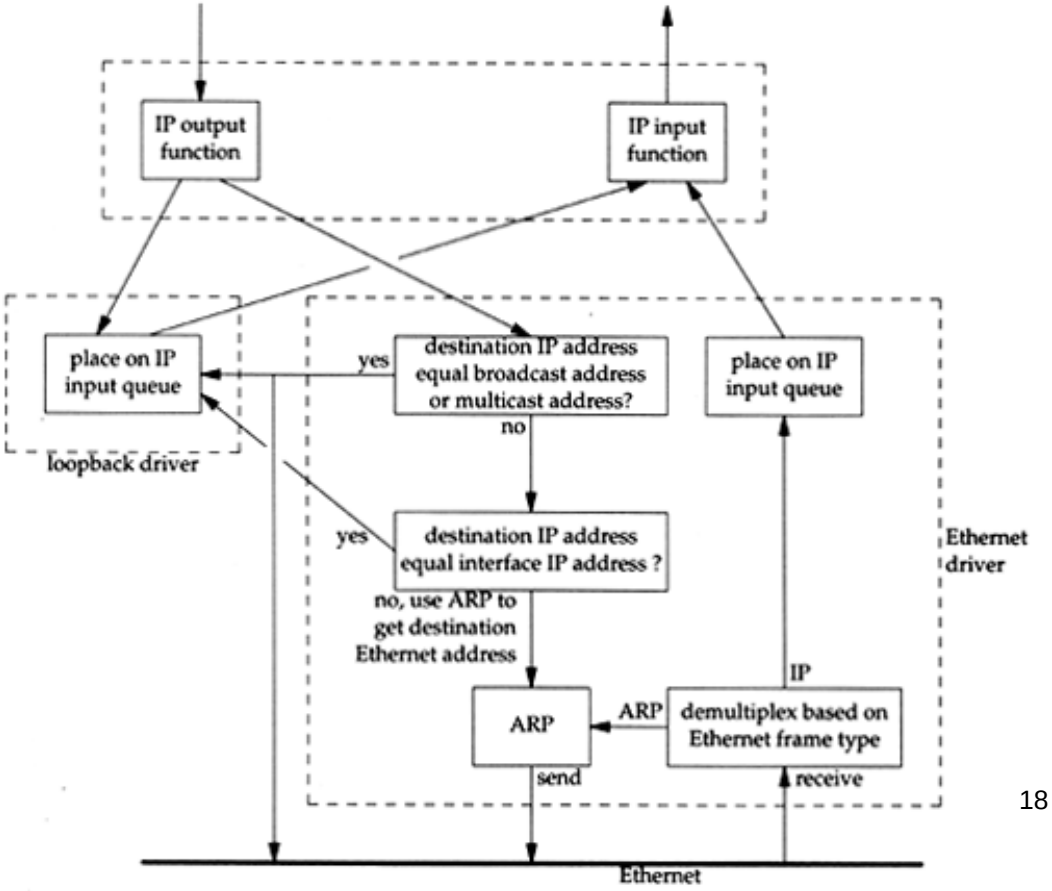
Ethernet Frame Format

- 48 bits hardware address
  - For both destination and source address
  - 16-bit type is used to specify the type of data
    - 0800 → IP datagram
    - 0806 → ARP, 8035 → RARP

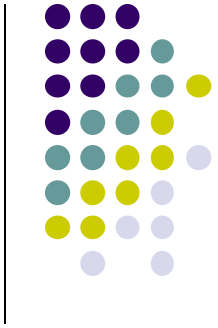


Loopback Interface

- Pseudo NIC
  - Allow client and server on the same host to communicate with each other using TCP/IP
  - IP
    - 127.0.0.1
  - Hostname
    - localhost



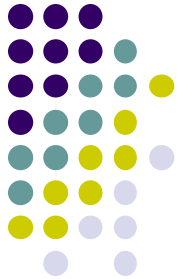
MTU



- Maximum Transmission Unit
  - Limit size of payload part of Ethernet frame
    - 1500 bytes
  - If the IP datagram is larger than MTU,
    - IP performs “fragmentation”
- MTU of various physical device, 576B by default
- Path MTU
  - Smallest MTU of any data link MTU between the two hosts
  - Depend on route

Network	MTU (bytes)
Hyperchannel	65535
16 Mbits/sec token ring (IBM)	17914
4 Mbits/sec token ring (IEEE 802.5)	4464
FDDI	4352
Ethernet	1500
IEEE 802.3/802.2	1492
X.25	576
Point-to-point (low delay)	296

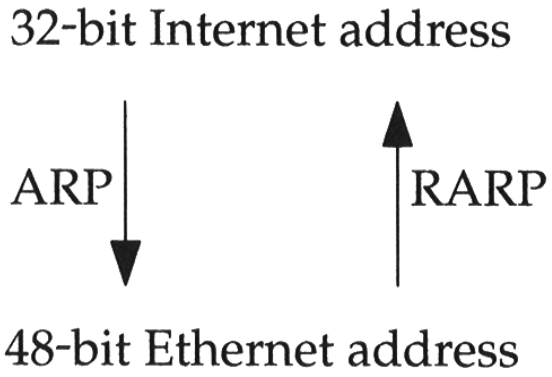
Address translation Mechanisms



1. **Algorithmically** --- deterministic method for achieving one-to-one mapping
2. **Statically** --- a static table is built during system configuration
3. **Dynamically** --- a decentralized fashion using a protocol to determine the mapping

ARP and RARP

- Mapping between IP and Ethernet address



- When an Ethernet frame is sent on LAN from one host to another,
  - It is the 48bit Ethernet address that determines for which interface the frame is destined

Address Resolution Protocol

- **Is a dynamic mechanism and use the broadcasting facility**

When the local IP wants to send a datagram to a device on an attached Ethernet, the interface layer performs the following:

(1) ARP cache is first consulted

(2) If the IP-MAC address is not in cache, give up the IP datagram and send out an ARP frame

(3) Upon receiving an ARP frame,
  a) check the sender protocol address and update
    its corresponding media address
  b) check the target protocol address, if not the local IP
    then discards, otherwise construct ARP response frame
    to the original sender

ARP Example

% ftp ccbsd5

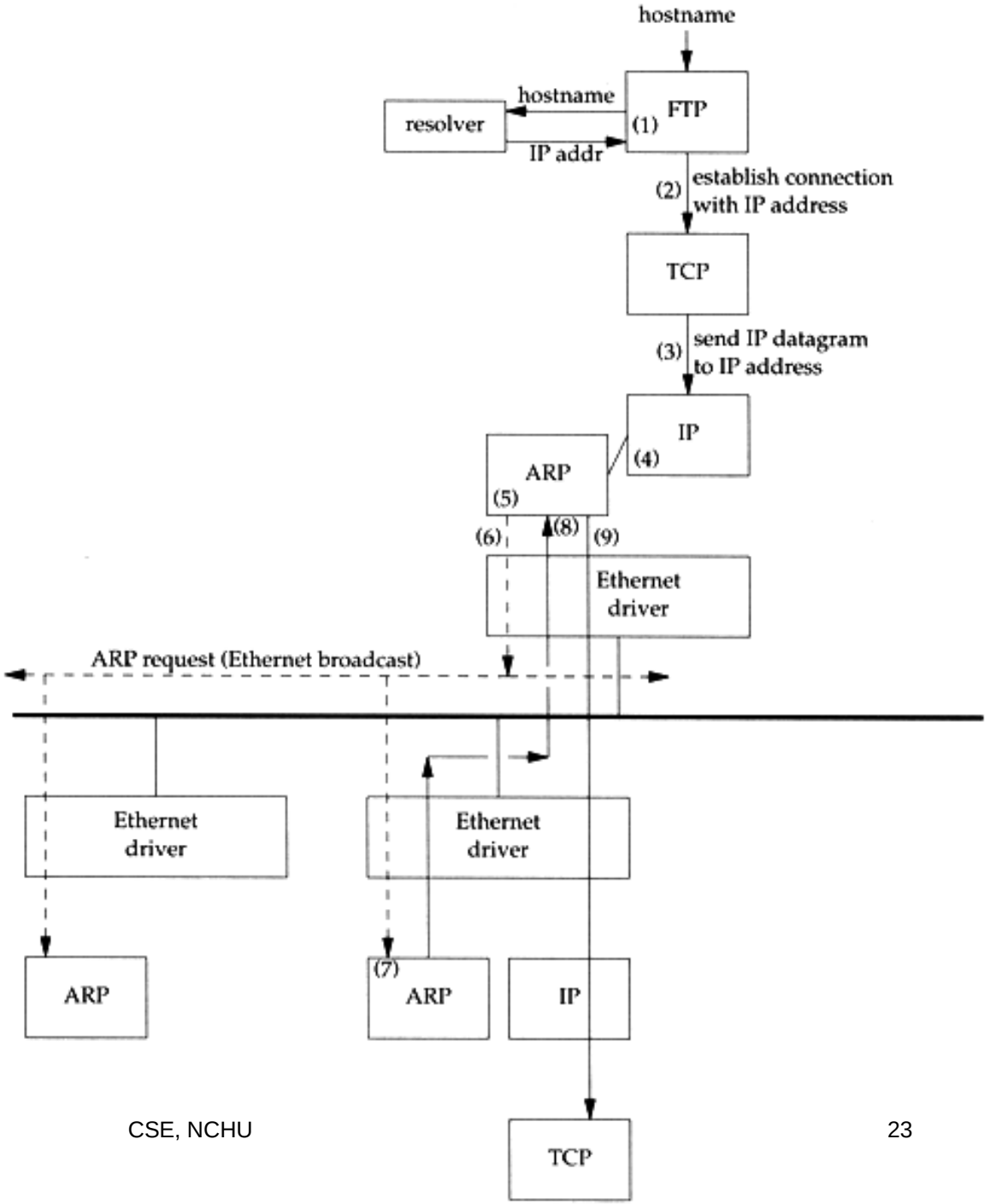
(4) next-hop or direct host

(5) Search ARP cache

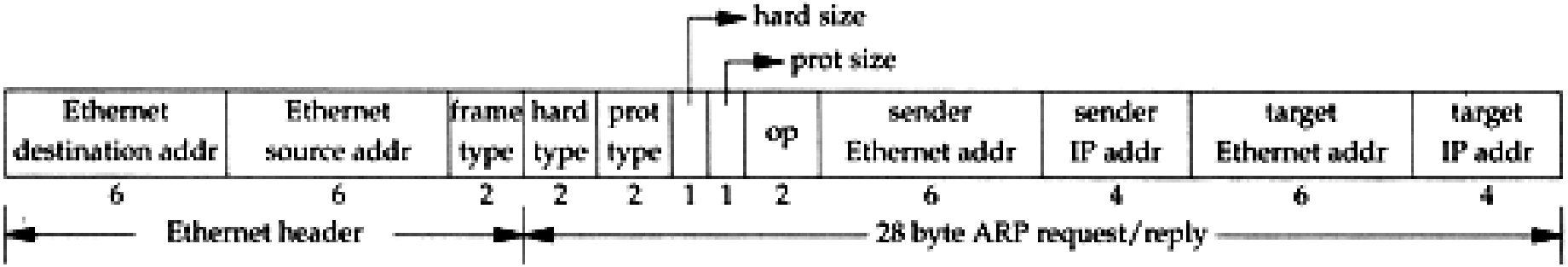
(6) Broadcast ARP request

(7) ccbsd5 response ARP reply

(9) Send original IP datagram

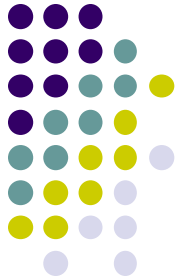


ARP/RARP Packet Format



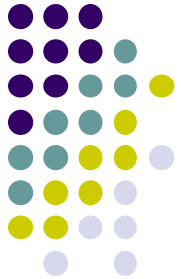
- Ethernet dest. addr: all 1's (broadcast)
- Known value for IP <-> Ethernet
  - Frame type: 0x0806 (ARP), 0x8035 (RARP)

ARP Frame



- **Frame type**: 0x0806 (ARP), 0x8035 (RARP)
- **Hardware type**: type of hardware address (1 for Ethernet)
- **Protocol type**: type of upper layer address (0x0800 for IP)
- **Hard size**: size in bytes of hardware address (6 for Ethernet)
- **Protocol size**: size in bytes of upper layer address (4 for IP)
- **Op**: 1, 2, 3, 4 for ARP request, reply, RARP request, reply

ARP Cache



- Maintain recent ARP results
  - come from both ARP request and reply
  - expiration time
    - Complete entry = 20 minutes
    - Incomplete entry = 3 minutes
  - Use arp command to see the cache
  - Ex: % arp –a

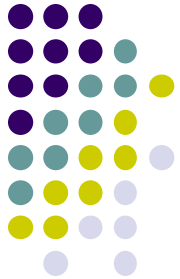
    % arp –da

    % arp –S ccbsd5.csie.nctu.edu.tw

    00:07:e9:39:66:77

```
tytsai@tybsd:~> arp -a
ccamd.csie.nctu.edu.tw (140.113.235.1) at 00:0f:ea:48:92:85 on fxp0 [ethernet]
tybsd.csie.nctu.edu.tw (140.113.235.4) at 00:09:6b:7a:25:f7 on fxp0 permanent [ethernet]
e3rtn-235.csie.nctu.edu.tw (140.113.235.254) at 00:0e:38:a4:c2:00 on fxp0 [ethernet]
? (192.168.1.30) at (incomplete) on fxp1 [ethernet]
```

Ex: Use tcpdump to see ARP



- Host 140.113.214.22 → 140.113.214.49
  - Clear ARP cache of 140.113.214.22 (**0:20:ed:6d:eb:c**)
  - Run tcpdump on 140.113.214.49 (**0:2:a5:6e:8d:42**)
    - % sudo tcpdump –i fxp0 –e arp
    - % sudo tcpdump –i fxp0 –n –e arp
    - % sudo tcpdump –i fxp0 –n –t –e arp
  - On 140.113.214.22, ssh to 140.113.214.49

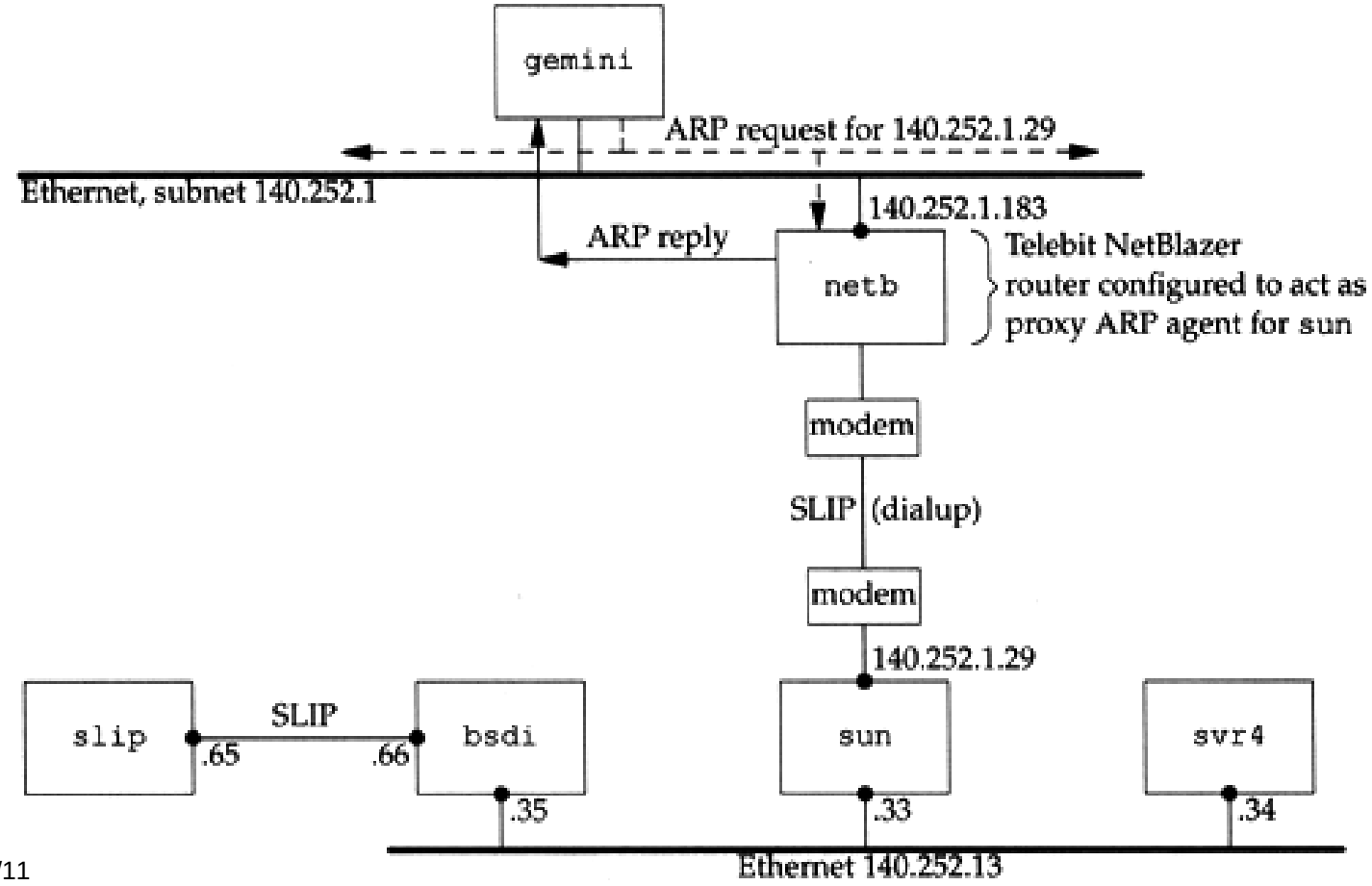
```
23:35:04.971913 0:20:ed:6d:eb:c Broadcast arp 60: arp who-has r21619.csie.nctu.edu.tw tel
l u214.csie.nctu.edu.tw
23:35:04.971921 0:2:a5:6e:8d:42 0:20:ed:6d:eb:c arp 60: arp reply r21619.csie.nctu.edu.tw
 is-at 0:2:a5:6e:8d:42
```

```
23:44:12.407720 0:20:ed:6d:eb:c ff:ff:ff:ff:ff:ff 0806 60: arp who-has 140.113.214.49 tel
l 140.113.214.22
23:44:12.407730 0:2:a5:6e:8d:42 0:20:ed:6d:eb:c 0806 60: arp reply 140.113.214.49 is-at 0
:2:a5:6e:8d:42
```

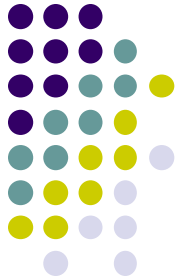
```
0:20:ed:6d:eb:c ff:ff:ff:ff:ff:ff 0806 60: arp who-has 140.113.214.49 tell 140.113.214.22
0:2:a5:6e:8d:42 0:20:ed:6d:eb:c 0806 60: arp reply 140.113.214.49 is-at 0:2:a5:6e:8d:42
```

Proxy ARP

- Let router answer ARP request on one of its networks for a host on another network

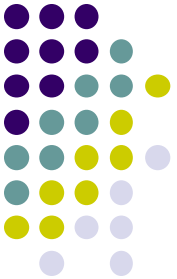


Gratuitous ARP



- Gratuitous ARP
  - The host sends an ARP request looking for its own IP
  - Provide two features
    - Used to determine whether there is another host configured with the same IP
    - Used to cause other host to update ARP cache when changing its hardware address

Examples of ARP Spoofing & ARP Proxy Agent



- Provided by the instructor as shown in the classroom.

  (refer to CH09 ARP協定.ppt, p41- p55)

RARP

- Principle
  - Used for the diskless system to read its hardware address from the NIC and send an RARP request to gain its IP
- RARP Server Design
  - RARP server must maintain the map from hardware address to an IP address for many hosts
  - Link-layer broadcast
    - This prevents most routers from forwarding an RARP request

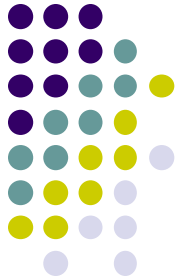
RARP, BOOTP, and DHCP (1/2)

- RARP server sends the broadcasts query and back with an IP address
- RARP broadcast message can't get through routers, an RARP server needs on each network
- BOOTP uses UDP and forwards over routers, but requires manual configuration of table mapping
- DHCP server and client use DHCPDISCOVER, DHCPOFFER, DHCPREQUEST, and DHCPACK to build the communication. (only the later 2 messages if the client has been admitted.)

RARP, BOOTP, and DHCP(2/2)

- RARP is replaced by BOOTP, and DHCP is an enhanced version of BOOTP.
- Rather than static allocation, DHCP uses lease-based IP allocation, either automatic allocation or dynamic allocation, depending upon the duration of the lease.
- DHCP server may offer TCP/IP setups for its clients, for instances, router address, DNS address, netmask, etc.
- DHCP server may exist over distance, newly booted host requires DHCP relay agent (by broadcasting DHCP recovery packet) to unicast message to DHCP server.

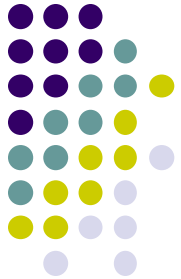
IP Assignment (1/2)



- IP assignment is a process where a subnets are created for each subgroup or department.
- The IP assignment is tracked by the network operations center (NOC).
- For example, the subnet 192.168.12.64 has broadcast address 192.168.12.127. Any computer in the subnet is assigned in the range of 65 to 126.
- IP assignment can be done either manually or dynamically,

  BOOTP and DHCP are two well-known approaches for IP assignment.

IP Assignment (2/2)



- DHCP is a superset of BOOTP and runs on the same port number.
- DHCP requests an IP address from the DHCP server. The DHCP server retrieves an available IP address from a pool dedicated to the subnet of the requesting client, and the DHCP server also specifies a lease time together with the IP address.
- Router doesn't pass broadcast addresses, so a DHCP relay server is required for over distance (out of a LAN).
- DHCP requires UDP and uses port 68 for client, 67 for server. Message Type (MT) include discover, offer, request, and ack (later two MTs are unicasts between relay and server).