TCP/IP Networking

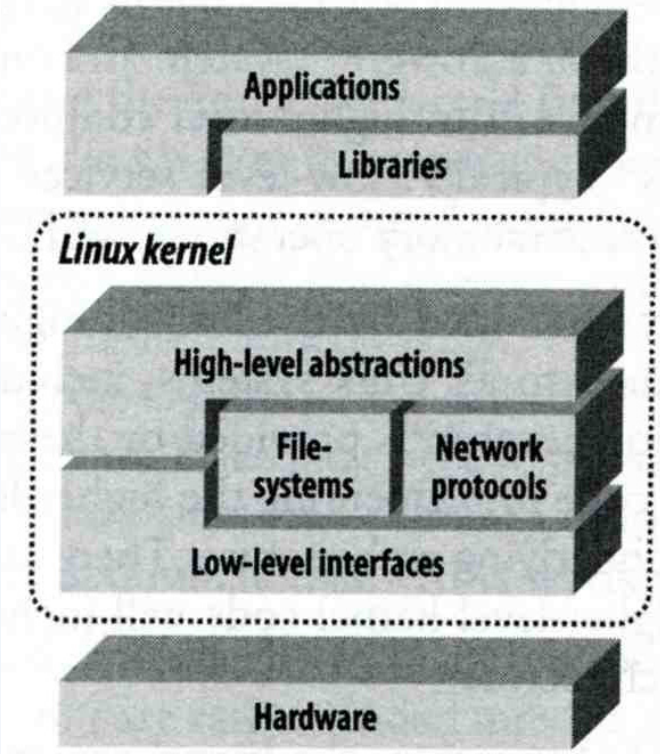
Basic Term

- IP
  - 32-bit, Unique Internet Address of a host
- Port
  - 16-bit, Uniquely identify application
- MAC Address
  - Media Access Control Address
  - 48-bit, Network Interface Card (NIC) Hardware address

```
tytsai@qkmj:~> ifconfig
em0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        options=43<RXCSUM,TXCSUM,POLLING>
        inet 140.113.209.32 netmask 0xffffff00 broadcast 140.113.209.255
inet 140.113.209.65 netmask 0xffffffff broadcast 140.113.209.65
ether 00:07:e9:39:66:77
        media: Ethernet autoselect (100baseTX <full-duplex>)
        status: active
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
        inet 127.0.0.1 netmask 0xff000000
```

Why TCP/IP ?

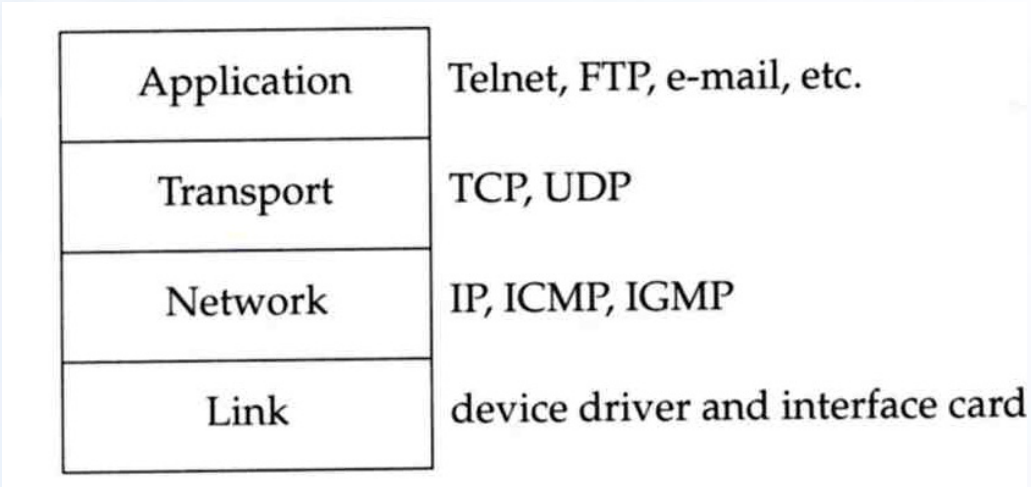
- The gap between applications and Network
  - Network
    - **802.3 Ethernet**
    - **802.4 Token bus**
    - **802.5 Token Ring**
    - **802.11 Wireless**
  - Application
    - **Reliable**
    - **Performance**



We need something to do the translating work!
TCP/IP it is!!

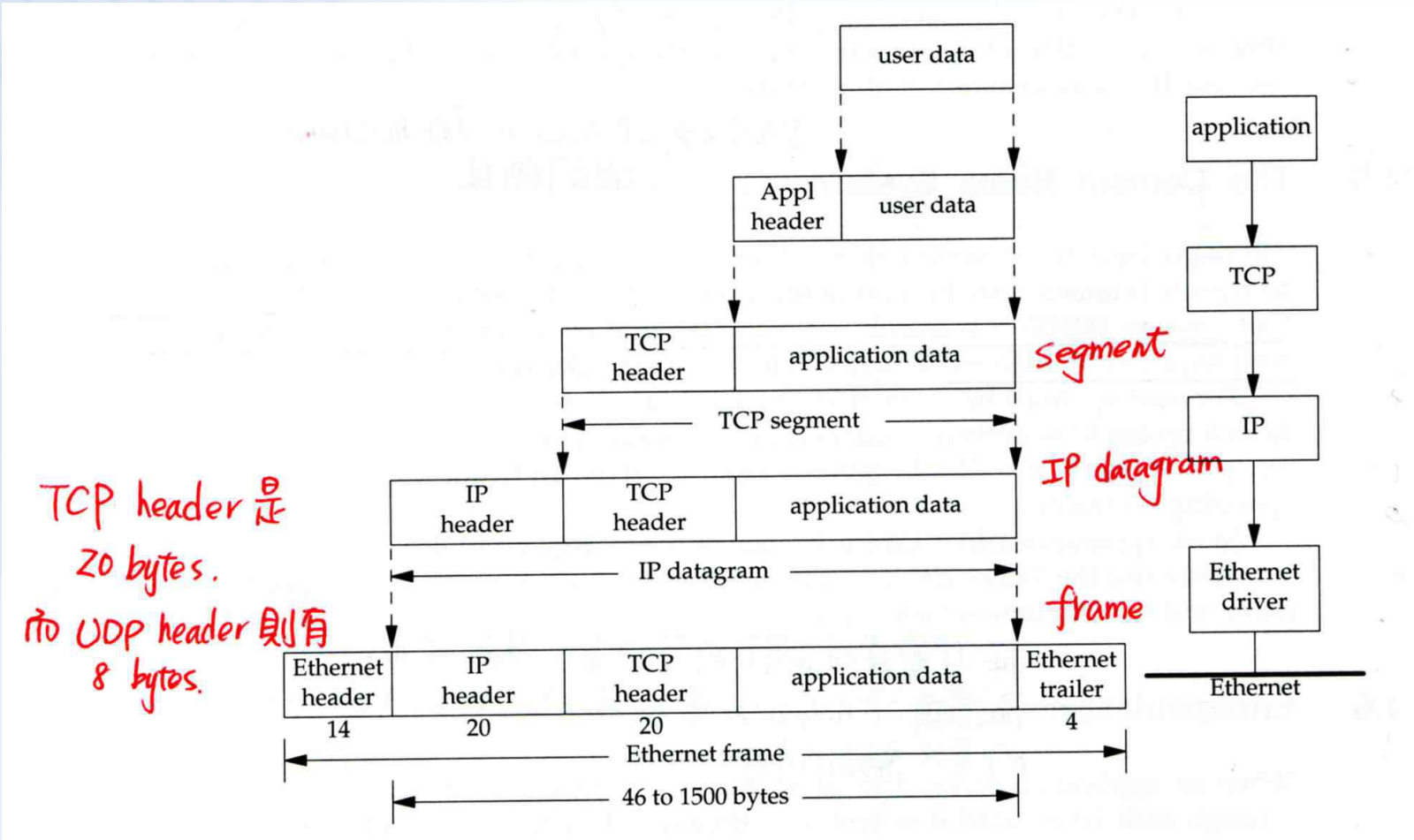
TCP/IP protocol stack (1)

- TCP/IP is a suite of networking protocols
  - 4 layers Layering architecture
    - **Link layer (data-link layer)**
      - Include device drivers to handle hardware details
    - **Network layer (IP)**
      - Handle the movement of packets around the network
    - **Transport layer (Port)**
      - Handle flow of data between hosts
    - **Application**



TCP/IP protocol stack (2)

- When we want to transfer data across the network
  - Encapsulation



TCP/IP protocol stack (3)

> Receiving data (Demultiplexing)

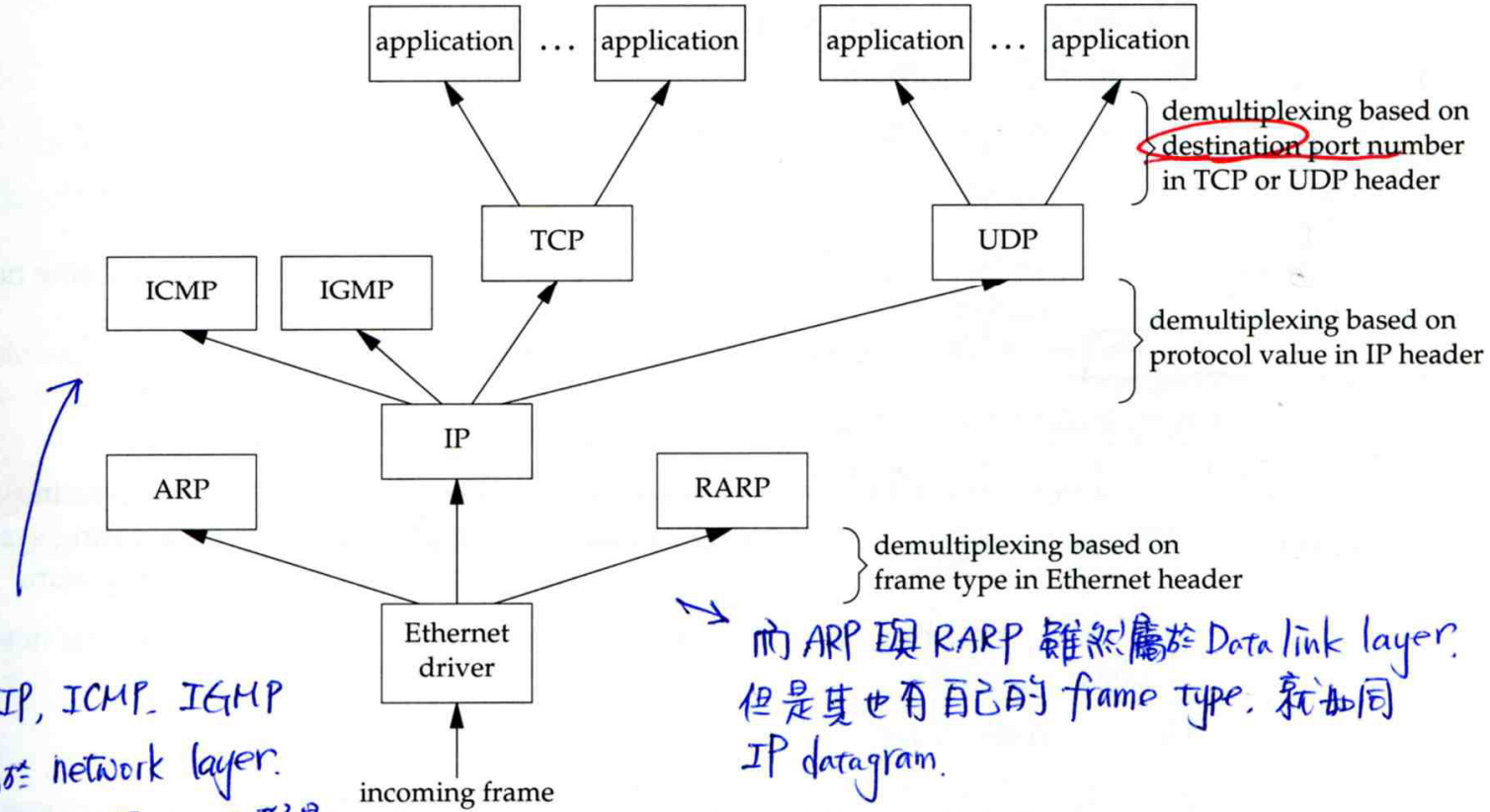


Figure 1.8 The demultiplexing of a received Ethernet frame.

TCP/IP protocol stack (4)

> Transmission on the same network …

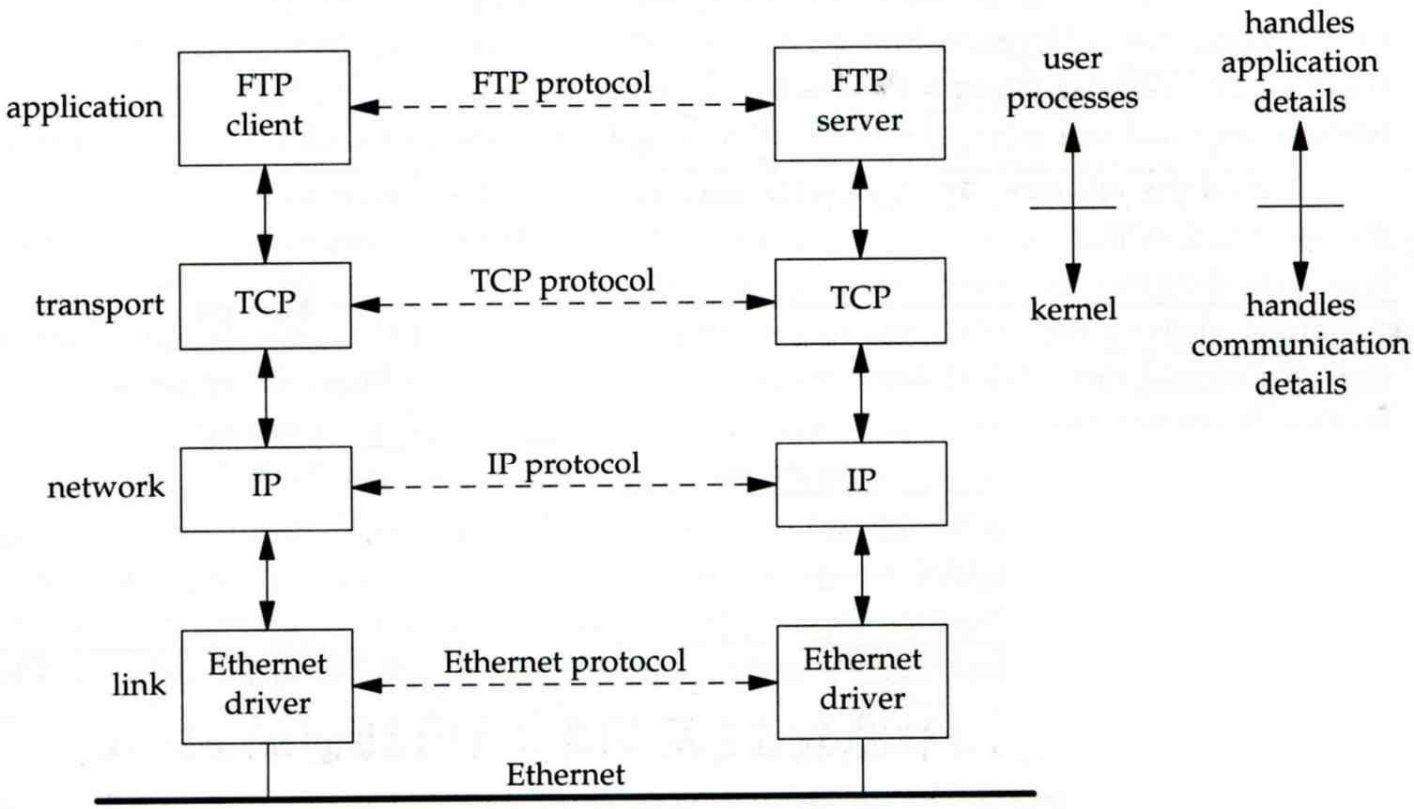


Figure 1.2 Two hosts on a LAN running FTP.

TCP/IP protocol stack (5)

- Transmission across different network
  - Require "Routing"

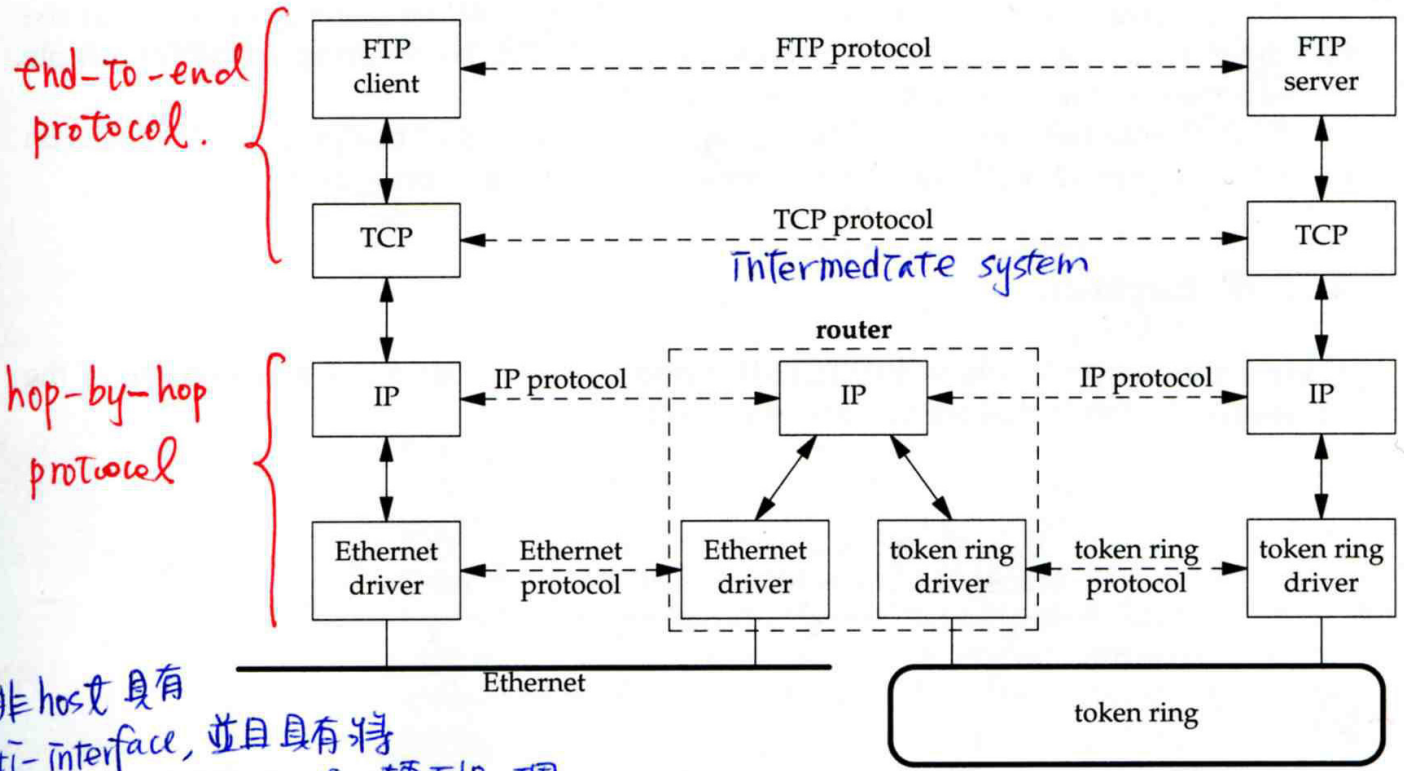


Figure 1.3 Two networks connected with a router.

loopback interface (1)

- Allow a client and a server to be on the same host
- Special device name
  - lo0
- Special hostname and IP
  - 127.0.0.1
  - localhost
- Anything that is sent to loopback interface will not go to network

loopback interface (2)

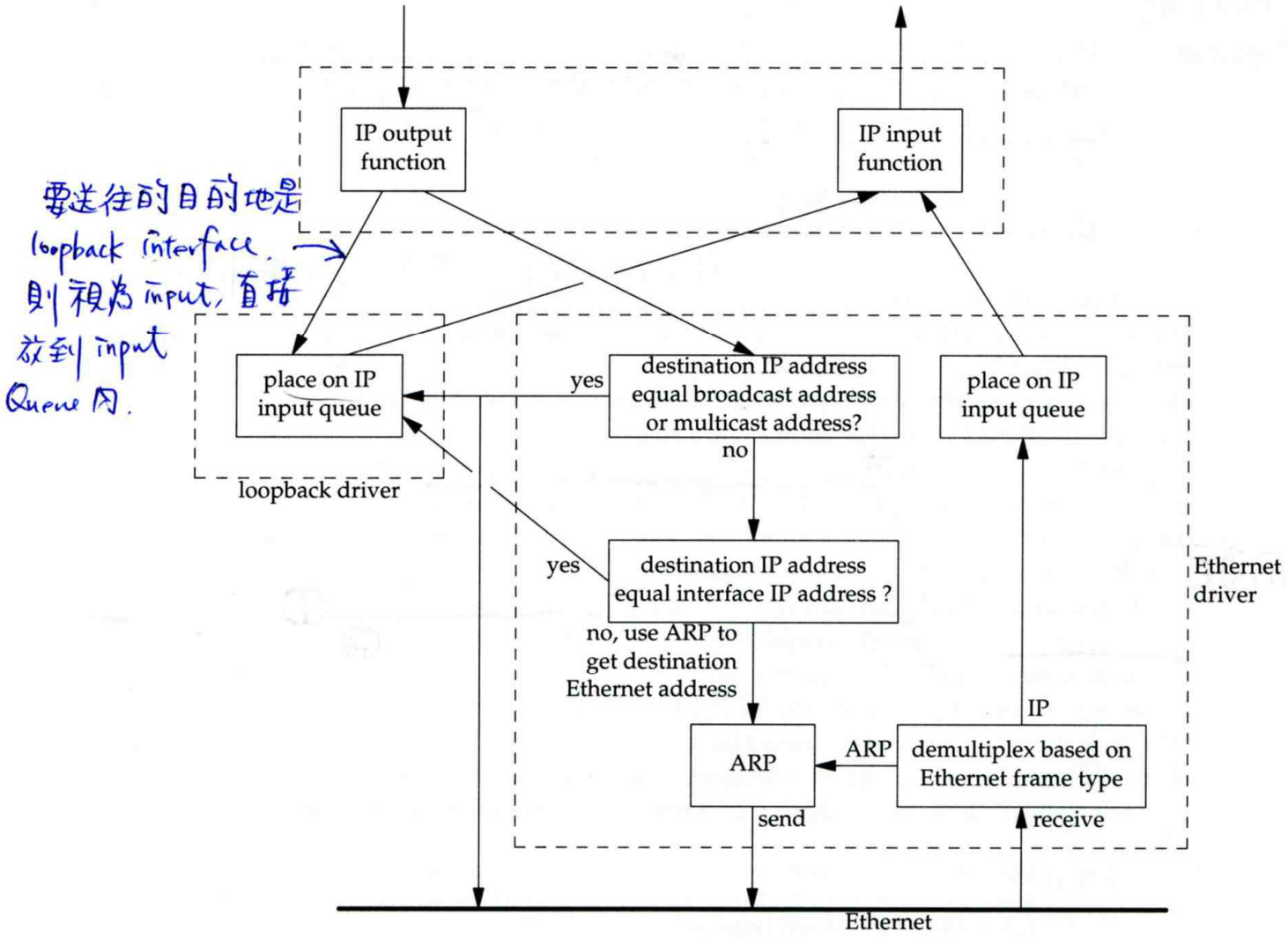
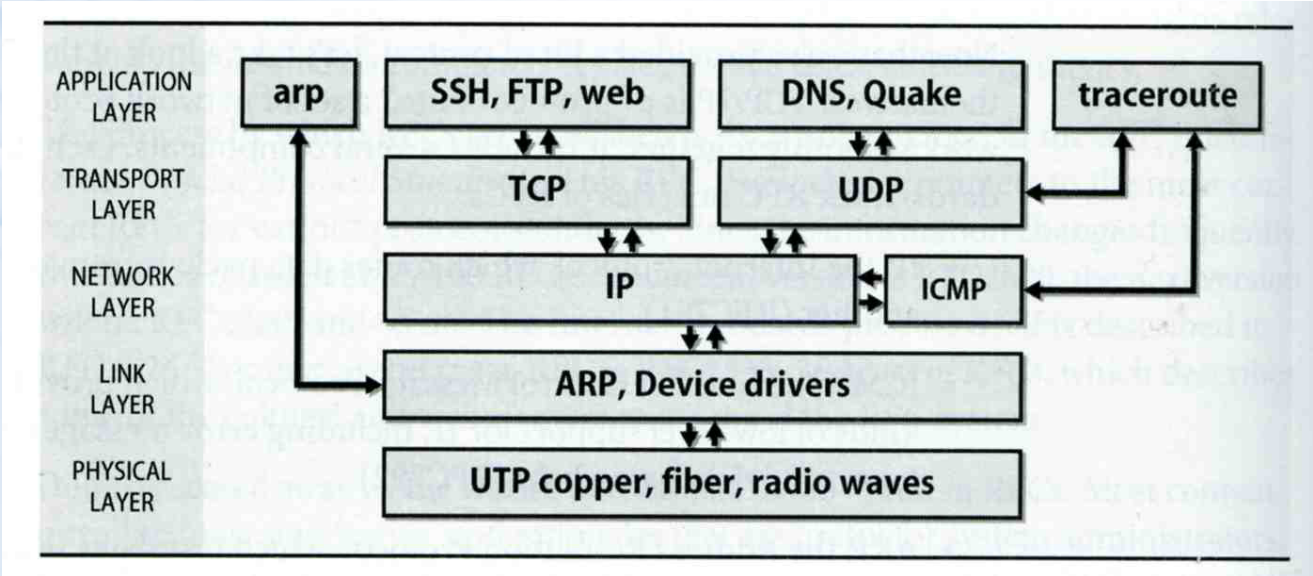


Figure 2.4 Processing of IP datagrams by loopback interface.

Chapter 13
TCP/IP Networking

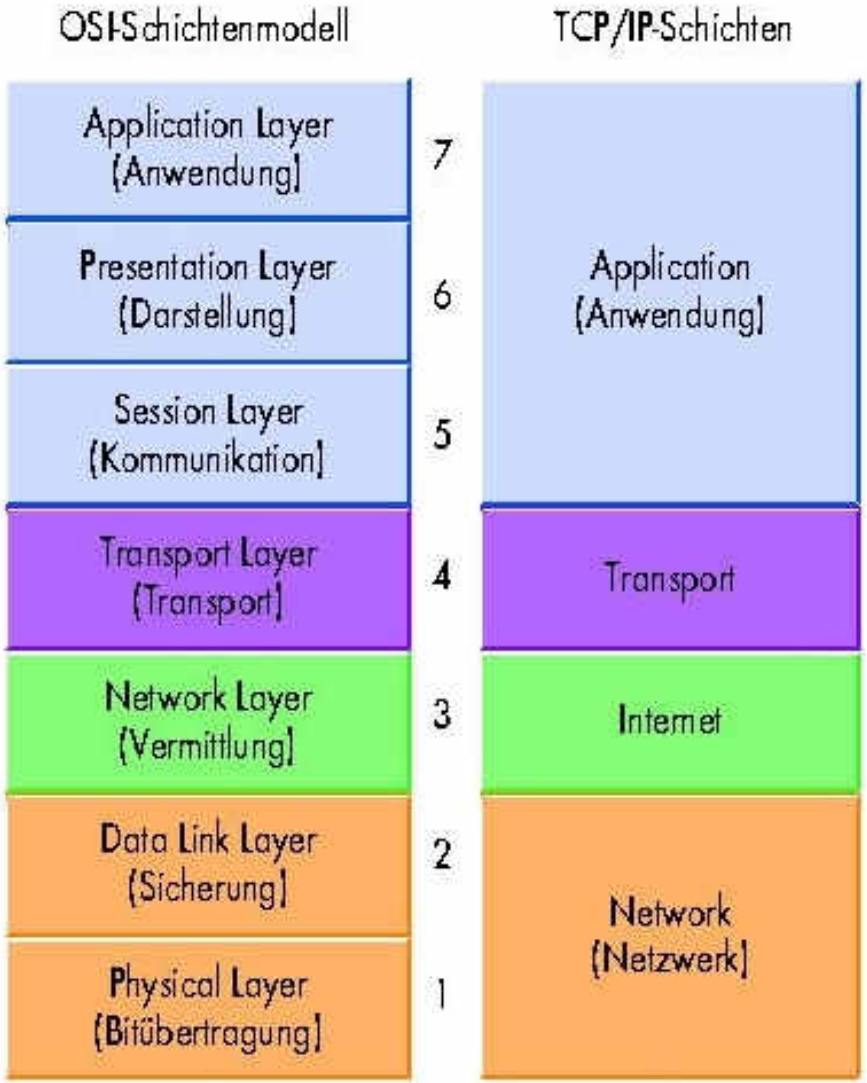
One Big happy TCP/IP family

- Layering architecture



OSI 7-layer vs. TCP/IP

- Layer2 device
  - MAC
- Layer3 device
  - IP



IP Address (1)

- 32-bit long
  - Network part
    - **Identify a logical network**
  - Host part
    - **Identify a machine on certain network**
- IP address category

Class	1st byte[a]	Format	Comments
A	1-126	N.H.H.H	Very early networks, or reserved for DOD
B	128-191	N.N.H.H	Large sites, usually subnetted, were hard to get
C	192-223	N.N.N.H	Easy to get, often obtained in sets
D	224-239	–	Multicast addresses, not permanently assigned
E	240-254	–	Experimental addresses

a. The values 0 and 255 are special and are not used as the first byte of regular IP addresses. 127 is reserved for the loopback address.

IP Address (2)

- Ex:
  - NCTU
    - **Class B address: 140.113.0.0**
    - **Network ID: 140.113**
    - **Number of hosts: 255*255 = 65535**

subnetting and netmask (1)

- Subnetting
  - Borrow some bits from network ID to extends hosts ID
  - Ex:
    - **ClassB address : 140.113.0.0**
      = 256 ClassC-like IP addresses
      in N.N.N.H subnetting method
    - **140.113.209.0 subnet**
- netmask
  - Specify how many bits of network-ID are used for network-ID
  - Continuous 1 bits form the network part
  - Ex:
    - **255.255.255.0 in NCTU-CSIE example**
      - 256 hosts available
    - **255.255.255.248 in ADSL example**
      - Only 8 hosts available

subnetting and netmask (2)

- How to determine your network ID?
  - Bit-wise-and IP and netmask
  - Ex:
    - 140.113.214.37 & 255.255.255.0 ➔ 140.113.214.0
    - 140.113.209.37 & 255.255.255.0 ➔ 140.113.209.0
    - 140.113.214.37 & 255.255.0.0 ➔ 140.113.0.0
    - 140.113.209.37 & 255.255.0.0 ➔ 140.113.0.0
    - 211.23.188.78 & 255.255.255.248 ➔ 211.23.188.76
      - **78 = 01001110**
      - **78 & 248= 01001110 & 11111000 =72**

subnetting and netmask (3)

- In a subnet, not all IP are usable
  - The first one IP ➔ network ID
  - The last one IP ➔ broadcast address
  - Ex:
    - **Netmask 255.255.255.0**
    - **140.113.209.32/24**
    - **140.113.209.0 ➔ network ID**
    - **140.113.209.255 ➔ broadcast address**
    - **1 ~ 254, total 254 IPs are usable**
  - Ex:
    - **Netmask 255.255.255.252**
    - **211.23.188.78/29**
    - **211.23.188.72 ➔ network ID**
    - **211.23.188.79 ➔ broadcast address**
    - **73 ~ 78, total 6 IPs are usable**

subnetting and netmask (4)

- The smallest subnetting
  - Network portion : 30 bits
  - Host portion : 2 bits
  - ➔ 4 hosts, but only 2 IPs are available
- ipcalc.pl

```
[shrang@r21607 ~]$ ./ipcalc 211.23.188.78/29
IP address           211    .   23    .  188    .   78     / 29  211.23.188.78/29
Netmask bits      11111111 11111111 11111111 11111000
Netmask bytes        255    .  255    .  255    .  248           255.255.255.248
Address bits      11010011 00010111 10111100 01001110
Network              211    .   23    .  188    .   72           211.23.188.72
Broadcast            211    .   23    .  188    .   79           211.23.188.79
First Host           211    .   23    .  188    .   73           211.23.188.73
Last Host            211    .   23    .  188    .   78           211.23.188.78
Total Hosts       6
PTR               78.188.23.211.in-addr.arpa
IP Address (hex)  D317BC4E
[shrang@r21607 ~]$
```

subnetting and netmask (5)

- Network configuration for various lengths of netmask

Length[a]	Host bits	Hosts/net[b]	Dec. netmask	Hex netmask
/20	12	4094	255.255.240.0	0xFFFFF000
/21	11	2046	255.255.248.0	0xFFFFF800
/22	10	1022	255.255.252.0	0xFFFFFC00
/23	9	510	255.255.254.0	0xFFFFFE00
/24	8	254	255.255.255.0	0xFFFFFF00
/25	7	126	255.255.255.128	0xFFFFFF80
/26	6	62	255.255.255.192	0xFFFFFFC0
/27	5	30	255.255.255.224	0xFFFFFFE0
/28	4	14	255.255.255.240	0xFFFFFFF0
/29	3	6	255.255.255.248	0xFFFFFFF8
/30	2	2	255.255.255.252	0xFFFFFFFC

port

- 16-bits number
- Preserve ports
  - 1 ~ 1024 (root access only)
- Well-known port
  - **/etc/services**

```
…
chargen     19/tcp     ttytst source       #Character Generator
chargen     19/udp     ttytst source       #Character Generator
ftp-data    20/tcp     #File Transfer [Default Data]
ftp-data    20/udp     #File Transfer [Default Data]
ftp         21/tcp     #File Transfer [Control]
ftp         21/udp     #File Transfer [Control]
ssh         22/tcp     #Secure Shell Login
ssh         22/udp     #Secure Shell Login
telnet      23/tcp
telnet      23/udp
…
```

Address Type

- Unicast
  - Address refer to a single hosts, only the host with that IP will receive the data
  - Ex:
    - **ssh 140.113.209.65**
- Broadcast
  - Addresses that include all hosts on the local network
  - All hosts on the same network will receive the data
  - Ex:
    - **arp packet**
- Multicast
  - Addresses that identify a group of hosts
  - Only hosts on the same group will receive the data
  - Ex:
    - **Video conference**

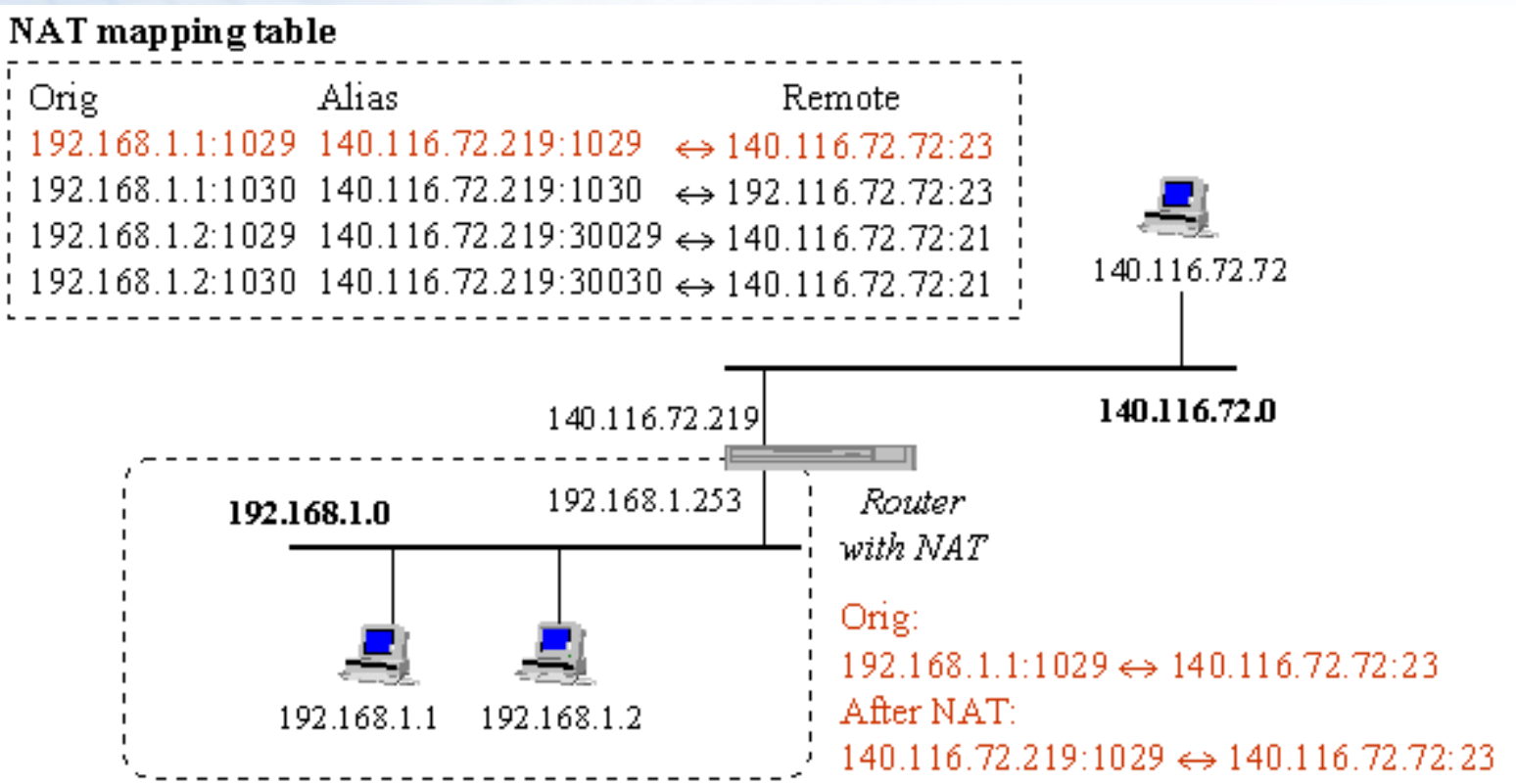
Private address (1)

- Packets that bearing private address will not go out to the Internet
- 3 private addresses range
  - Depend on the size of your organization

IP class	From	To	CIDR range
Class A	10.0.0.0	10.255.255.255	10.0.0.0/8
Class B	172.16.0.0	172.31.255.255	172.16.0.0/12
Class C	192.168.0.0	192.168.255.255	192.168.0.0/16

Private address (2)

- NAT
  - Network Address Translation
  - Allow hosts using private address to talk with outside



Routing (1)

- Direct a packet closer to the destination
- Routing table
  - Routing information (which kind of packets to which way)
  - Rule-based information
  - Kernel will pick the most suitable way to route the packets

```
tytsai@tybsd:~> netstat -rn
Routing tables

Internet:
Destination        Gateway            Flags    Refs      Use      Netif  Expire
default            140.113.235.254    UGS         0  1120943      fxp0
127.0.0.1          127.0.0.1          UH          0      225      lo0
140.113.235/24     link#1             UC          0        0      fxp0
140.113.235.1      00:0f:ea:48:92:85  UHLW        0    89748      fxp0    882
140.113.235.248    00:05:1a:d2:24:00  UHLW        0        0      fxp0   1196
140.113.235.254    00:0e:38:48:be:ce  UHLW        1        0      fxp0   1200
192.168.1          link#4             UC          0        0      fxp1
192.168.1.30       00:d0:59:83:d9:16  UHLW        0   101125      fxp1    664
```

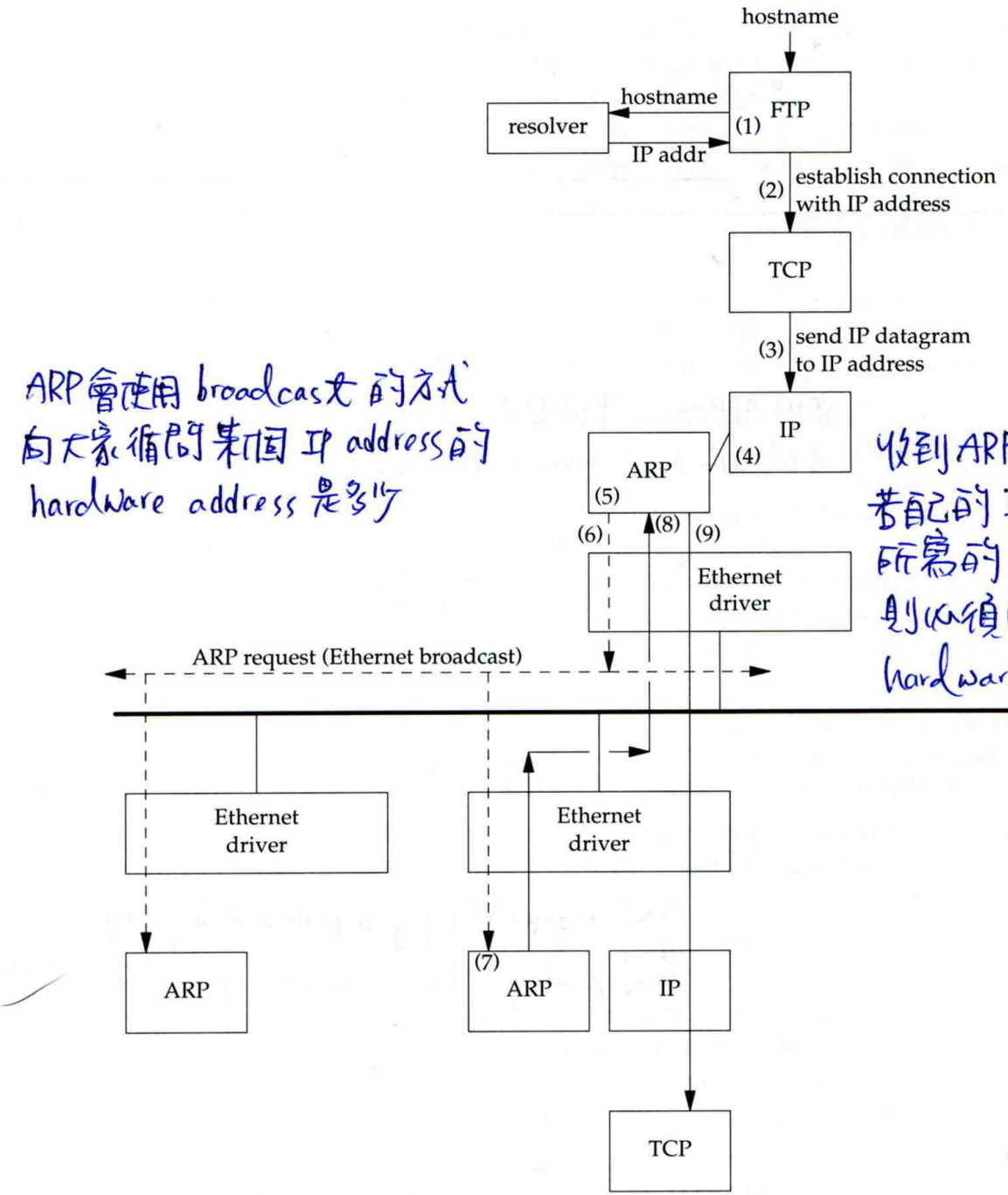
Routing (2)

- Static route
  - Statically configured by “route” command
  - Ex:
    - **% route add default 140.113.235.254**
    - **% route add 192.168.1.0/24 192.168.1.254**
- Dynamic route
  - gated

ARP (1)

- Address Resolution Protocol
  - Ask MAC address of certain IP
  - Broadcast
  - Any one receiving ARP packet and having this IP will reply to the sender
  - When the host owing this IP is not on the same network, sender will use the MAC address of next-hop router to send the packet

ARP (2)


hostname
resolver
hostname
IP addr
FTP
(1)
(2) establish connection with IP address
TCP
(3) send IP datagram to IP address
IP
(4)
ARP
(5)
(6)
(8)
(9)
Ethernet driver
ARP request (Ethernet broadcast)
Ethernet driver
Ethernet driver
ARP
(7)
ARP
IP
TCP
ARP會使用 broadcast 的方式 向大家詢問某個 IP address的 hardware address 是多少
收到ARP封包的 host 若自己的 IP是 ARP 所寫的 request IP. 則必須回應自己的 hardware address.

ARP (3)

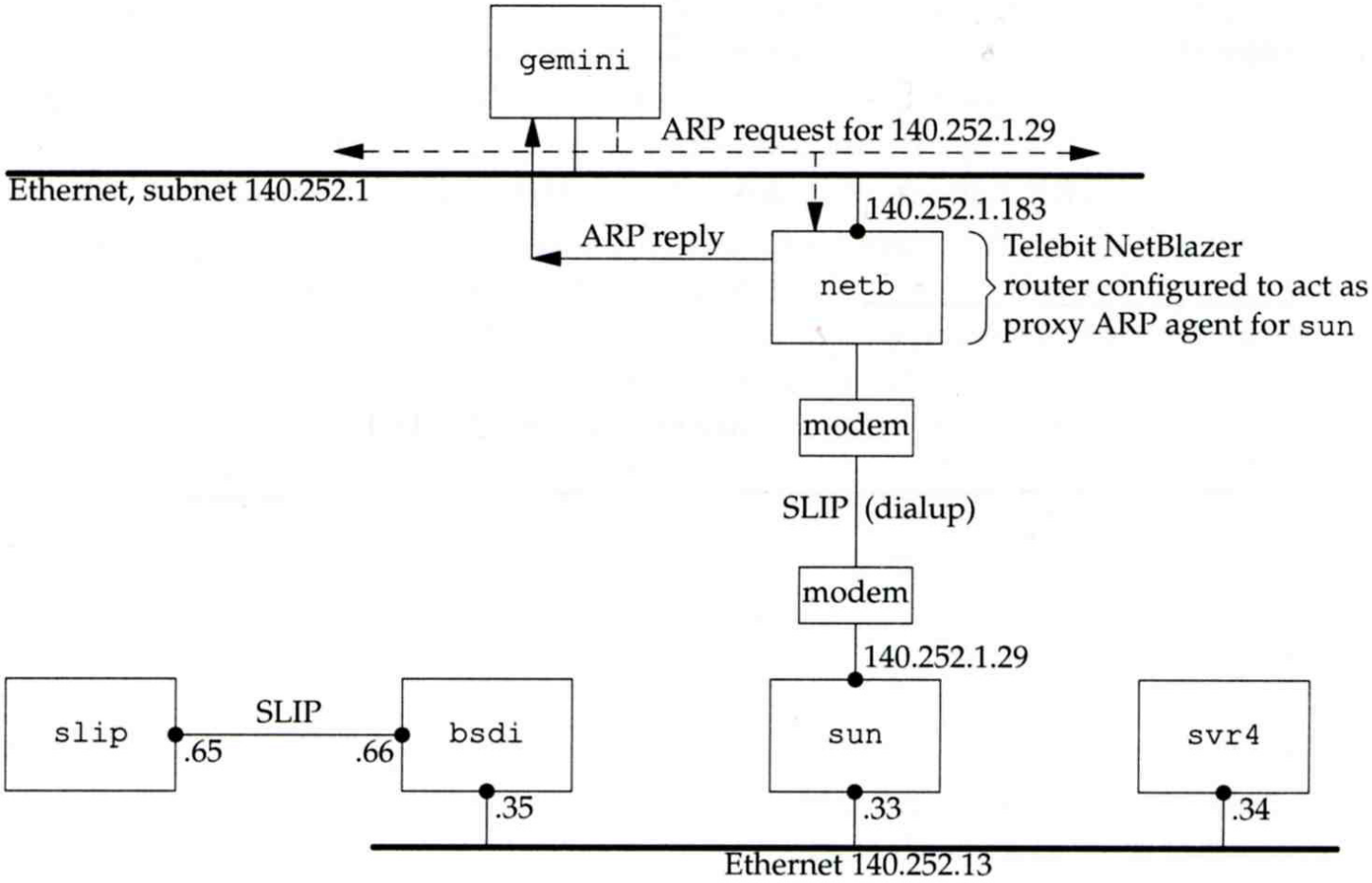


Figure 4.6 Example of proxy ARP.

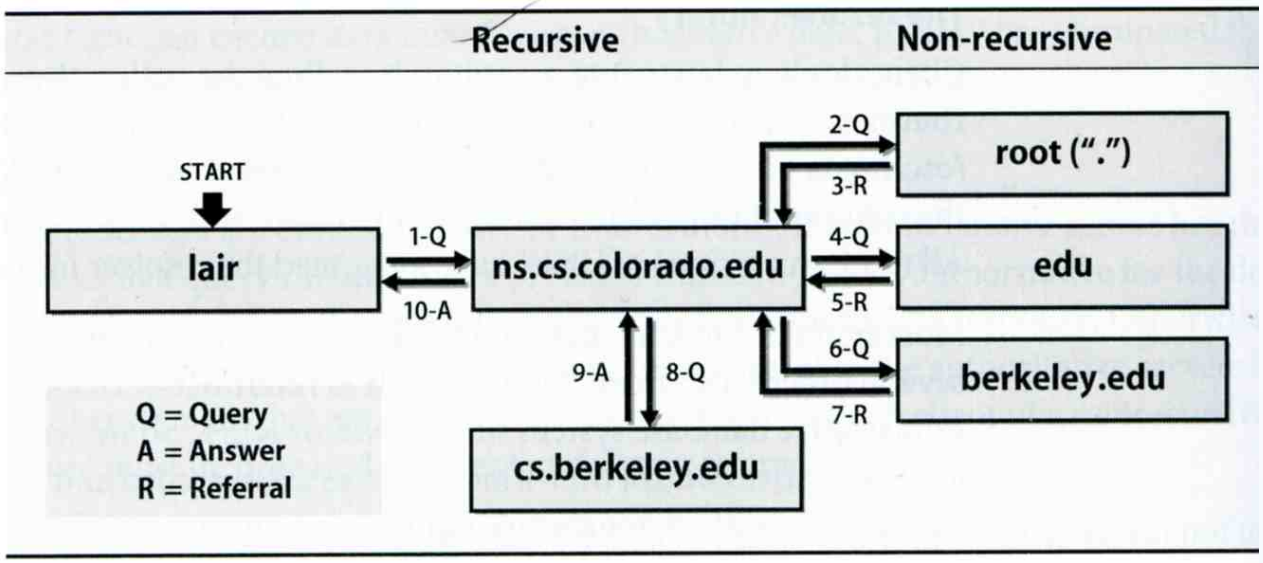
ARP (4)

- ARP cache
  - A table that contains the result of recent ARP queries
  - % arp –a

```
ccamd.csie.nctu.edu.tw (140.113.235.1) at 00:0f:ea:48:92:85 on fxp0 [ethernet]
3com-4900-235-EC318.csie.nctu.edu.tw (140.113.235.248) at 00:05:1a:d2:24:00 on fxp0
[ethernet]
e3rtn-235.csie.nctu.edu.tw (140.113.235.254) at 00:0e:38:48:be:ce on fxp0 [ethernet]
? (192.168.1.30) at 00:d0:59:83:d9:16 on fxp1 [ethernet]
```

DNS

- Domain Name System
  - Record IP-hostname mapping
  - DNS query
    - **"what is the IP of vangogh.cs.berkeley.edu" from lair.cs.colorado.edu**
  - Hierarchical architecture



Setup network connection

- Steps
  - Assign an IP address and hostname
  - Default route
  - DNS
  - Utility to test whether you connect to the Internet

Setup network connection -
assign IP, hostname and default route (1)

- FreeBSD
  - In /etc/rc.conf

```
defaultrouter="140.113.235.254"
hostname="tybsd.csie.nctu.edu.tw"
ifconfig_fxp0="inet 140.113.235.4  netmask 255.255.255.0 media autoselect"
ifconfig_fxp1="inet 192.168.1.254  netmask 255.255.255.0 media autoselect"
```

- Linux
  - /etc/sysconfig/network
  - /etc/sysconfig/network-scripts/ifcfg-eth0

```
NETWORKING=yes
HOSTNAME=linux3
GATEWAY=140.113.209.254
```

```
DEVICE=eth0
BOOTPROTO=static
BROADCAST=140.113.209.255
IPADDR=140.113.209.143
NETMASK=255.255.255.0
NETWORK=140.113.209.0
ONBOOT=yes
```

Setup network connection -
assign IP, hostname and default route (2)

> /etc/hosts

- Host name database
- Each line is a host
  - **Internet address**
  - **Official host name**
  - **aliases**

```
tytsai@qkmj:~> less /etc/hosts
127.0.0.1               localhost
140.113.209.74      ccbsd14 ccbsd14.csie.nctu.edu.tw
140.113.209.2       ccserv
140.113.209.6       ccduty
140.113.209.7       mailgate
140.113.209.32      qkmj
```

Setup network connection -
assign IP, hostname and default route (3)

- Solaris
  - /etc/inet/netmasks (network and netmask)
  - /etc/inet/hosts (hosts)
  - /etc/defaultrouter (default router)
  - /etc/nodename (host name)
  - /etc/resolv.conf (domain, nameserver, search)
  - /etc/hostname.*interface* (IP, either hostname in hosts or IP)

```
tytsai@ccsun3:/etc> cat hostname.hme0 nodename defaultrouter resolv.conf
140.113.209.3
ccsun3
140.113.209.254
domain csie.nctu.edu.tw
nameserver 140.113.209.1
nameserver 140.113.1.1
search csie.nctu.edu.tw nctu.edu.tw edu.tw tw
tytsai@ccsun3:/etc> cat /etc/inet/netmasks /etc/inet/hosts
140.113.209.0   255.255.255.0
140.113.209.103 ccsun3
140.113.209.110 ccsun10
```

Setup network connection -
assign IP, hostname and default route (3)

- Change IP manually
  - Ex:
    - % ifconfig fxp0 inet 140.113.235.4 netmask 255.255.255.0
    - % ifconfig fxp0 up
    - % ifconfig fxp0 down
- Specify default route manually
  - Ex:
    - **% route add default 140.113.235.254**

Setup network connection -
configuring DNS

> FreeBSD, Linux
- /etc/resolv.conf

```
tytsai@tybsd:/etc> less resolv.conf
domain              csie.nctu.edu.tw
nameserver          140.113.17.5
nameserver          140.113.1.1
```

> Host lookup order
- FreeBSD
  - **/etc/host.conf**
- Linux
  - **/etc/nsswitch.conf**

```
tytsai@tybsd:/etc> less host.conf
# Auto-generated from nsswitch.conf, do not edit
hosts
bind
```

```
hosts:      files nisplus nis dns
```

Utilities for network connection

> ping

- Send ICMP ECHO_REQUEST o a host

```
tytsai@tybsd:/etc> ping -c 1 -R www.nctu.edu.tw
PING www.nctu.edu.tw (140.113.250.5): 56 data bytes
64 bytes from 140.113.250.5: icmp_seq=0 ttl=60 time=3.022 ms

--- www.nctu.edu.tw ping statistics ---
1 packets transmitted, 1 packets received, 0% packet loss
round-trip min/avg/max/stddev = 3.022/3.022/3.022/0.000 ms
```

> traceroute

- Print the route packets take to network host

```
tytsai@tybsd:/etc> traceroute www.nctu.edu.tw
traceroute to www.nctu.edu.tw (140.113.250.5), 64 hops max, 40 byte packets
 1  e3rtn-235 (140.113.235.254)  0.640 ms  0.449 ms  0.474 ms
 2  140.113.0.210 (140.113.0.210)  0.465 ms  0.310 ms  0.361 ms
 3  140.113.0.166 (140.113.0.166)  0.415 ms  0.379 ms  0.403 ms
 4  140.113.0.149 (140.113.0.149)  0.678 ms  0.536 ms  0.574 ms
 5  www.NCTU.edu.tw (140.113.250.5)  0.533 ms  0.415 ms  0.438 ms
```

Other issues

- The following issues will be given in NA (Network Administration)
  - DHCP
  - PPP
  - NAT
  - DNS
  - Mail
  - ...