IP Layer

Michael Tsai
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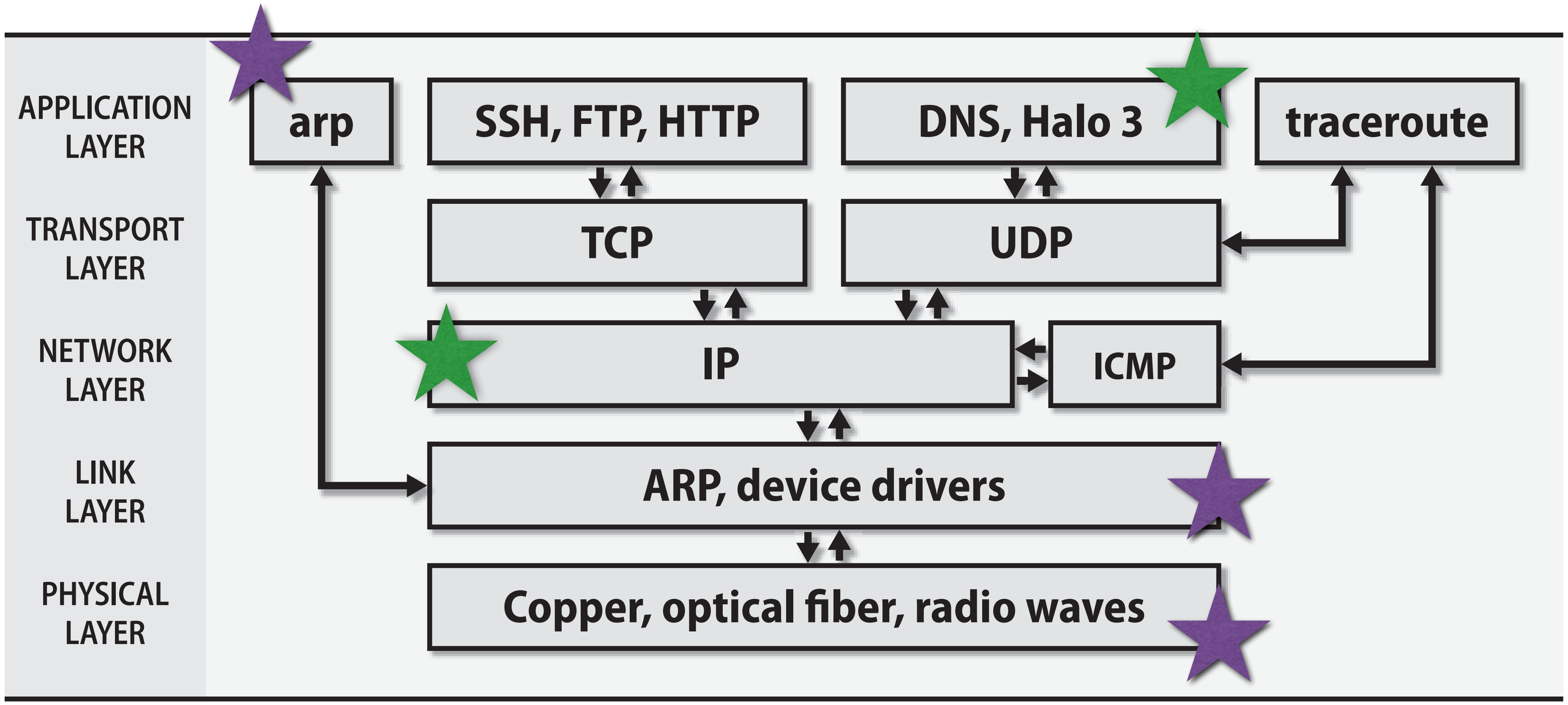
Internet Protocol Stack



★ Covered in previous lectures

★ Will cover today

IP (Network layer) 的主要功能

1. Forwarding: Router通常有多個interface (網卡)。把packet從來源的interface移到目的地方向的interface並發送出去叫做forwarding。
   - 一般client並不會開啟此一功能!
2. Routing: 找出往目的地方向的一條路徑。通常由routing algorithms/protocol決定。

- 因為系上通常到特定的目的地都只有一條路徑，我們網管的工作通常只會接觸到第一部分。

IP封包的格式(v4)

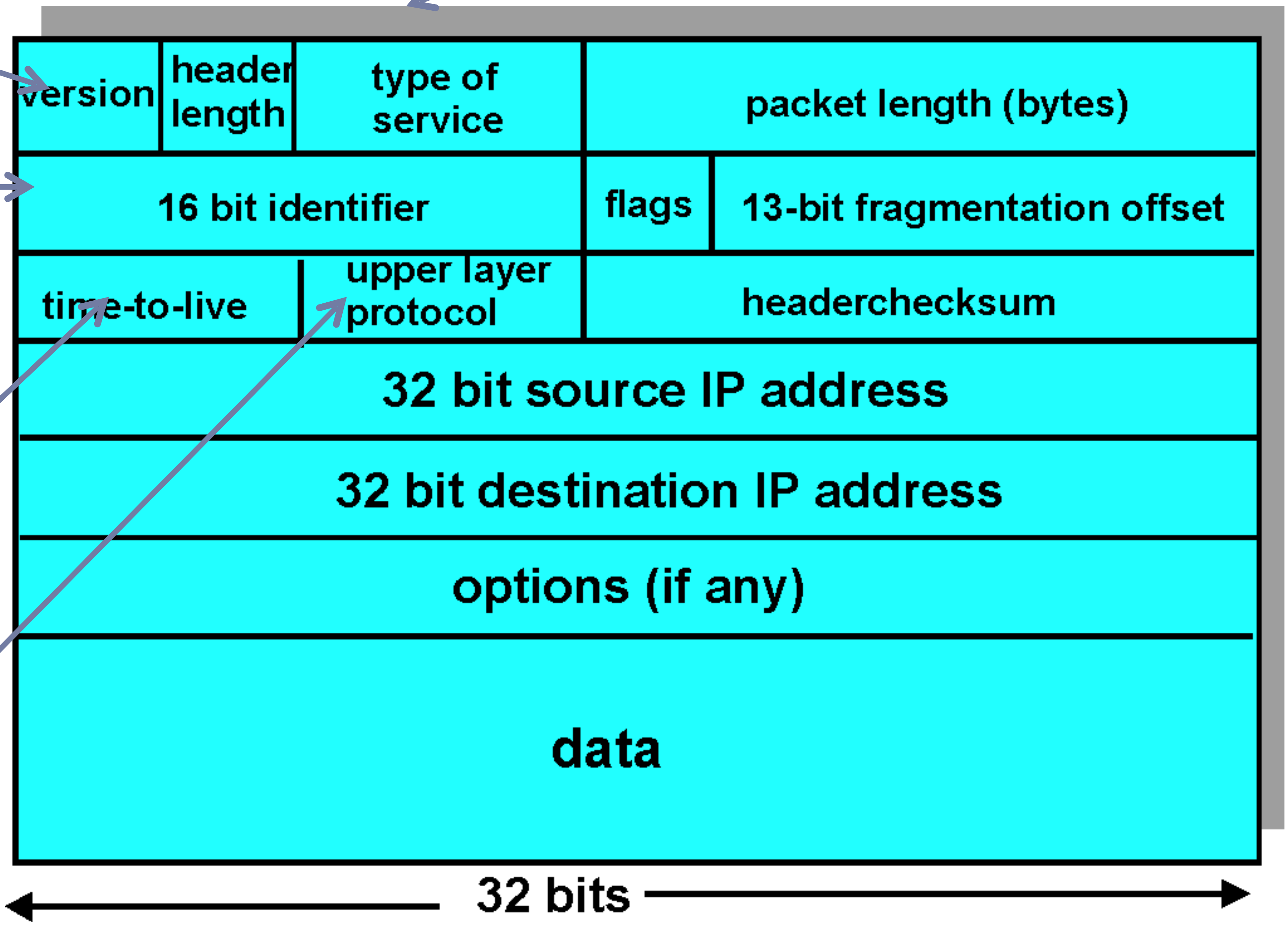
表示是否需要特殊處理(如即時的影像或聲音)

v4 or v6

用來處理
fragmentation
(想想MTU)

最多可以經過
幾台機器(router)

Transport layer使
用的協定
(通常為TCP or
UDP)



version | header length | type of service | packet length (bytes)

16 bit identifier | flags | 13-bit fragmentation offset

time-to-live | upper layer protocol | headerchecksum

32 bit source IP address

32 bit destination IP address

options (if any)

data

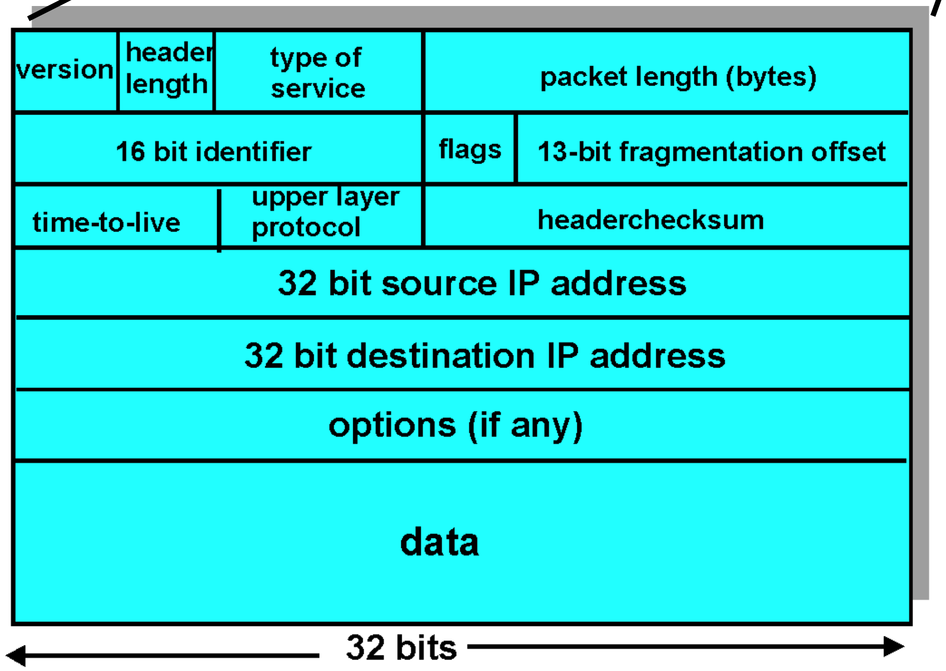
32 bits

Where is IP packet?

Ethernet **Frame**

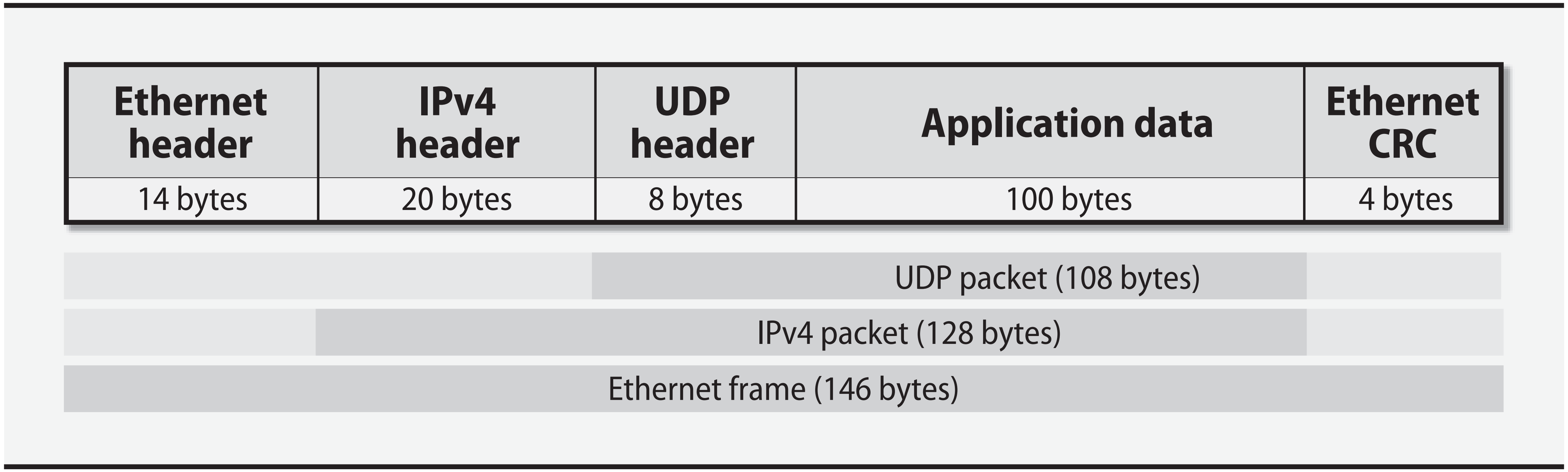
Preamble	Start of frame delimiter	MAC destination	MAC source	Length (IEEE 802.3)	802.1Q tag (optional)	Payload	Frame check sequence(
7 octets	1 octet	6 octets	6 octets	2 octets	(4 octets)	42–1500 octets	4 octets

IP **Packet** is in Ethernet’s payload!



version
header length
type of service
packet length (bytes)
16 bit identifier
flags
13-bit fragmentation offset
time-to-live
upper layer protocol
headerchecksum
32 bit source IP address
32 bit destination IP address
options (if any)
data
32 bits

Typical Internet Packet



Ethernet header	IPv4 header	UDP header	Application data	Ethernet CRC
14 bytes	20 bytes	8 bytes	100 bytes	4 bytes

UDP packet (108 bytes)

IPv4 packet (128 bytes)

Ethernet frame (146 bytes)

IP Address (v4)

- AAA.BBB.CCC.DDD (4 bytes) = ? # total hosts
- Network + host address —>
same network address == same network (subnet)

Historical Internet Classes (no mask)

Class	1st byte	Format	Comments
A	1-127	N.H.H.H	Very early networks
B	128-191	N.N.H.H	Large sites (hard to get)
C	192-223	N.N.N.H	Easy to get (often obtained in sets)
D	224-239	-	Multicast addresses
E	240-255	-	Experimental addresses

But this is inefficient

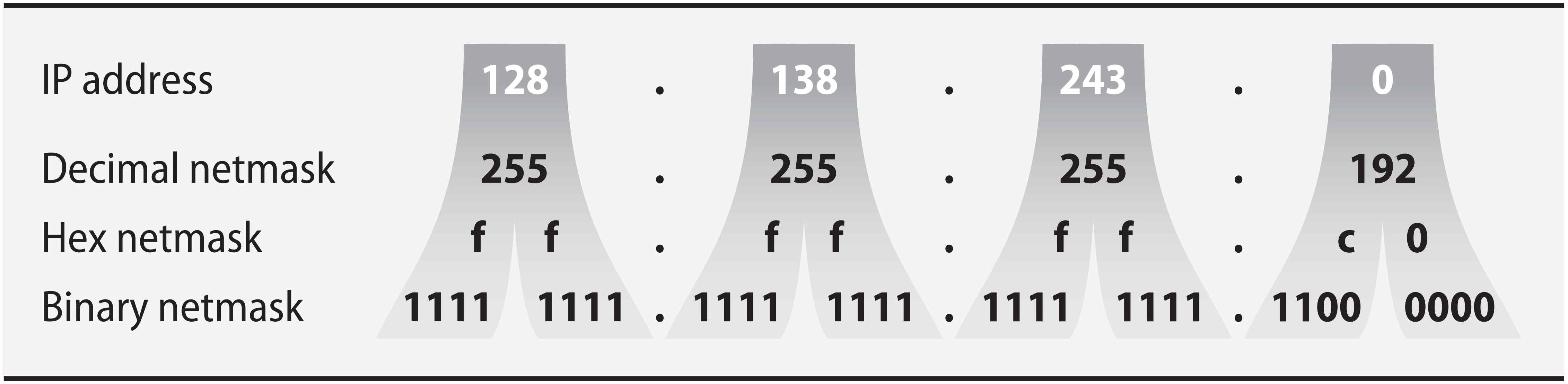
- Most networks only have ~100 hosts
- Class A & B addresses are wasted
- Thus we need to find a way to further split the networks! (subnetting)

Netmask

- Netmask ==
  32-bit number with leading 1’s + trailing 0’s

- Digits mapped to 1’s —> network address
  Digits mapped to 0’s —> host address

- Expressed as (a) 0xffffffc0 or (b) 255.255.255.192



IP address	128	.	138	.	243	.	0
Decimal netmask	255	.	255	.	255	.	192
Hex netmask	f f	.	f f	.	f f	.	c 0
Binary netmask	1111 1111	.	1111 1111	.	1111 1111	.	1100 0000

Two Special Addresses

- Network address
  = “network address” + “host address = 0”

- Broadcast address
  = “network address” + “host address = all 1’s”

Setting Interface Address

- ifconfig -a —> display all interfaces

- ifconfig eth0 192.168.25.1 netmask 255.255.255.0
—> set the IP and netmask of an interface

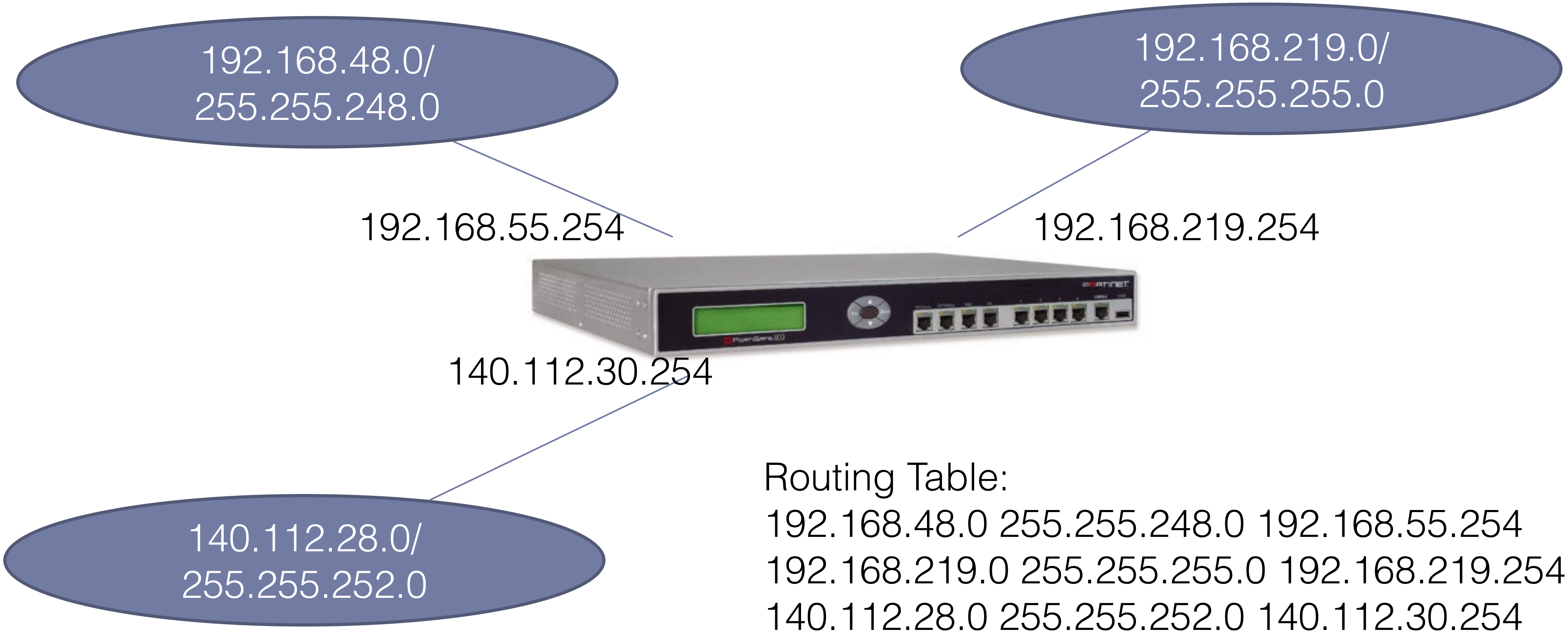
- ifconfig eth0 up
—> enable the interface

- ifconfig eth0 media auto
—> set the media type to auto-sense

Why do we need to know the “network address”?

- Answer: we need to know if the destination host can be reached directly (in the same network).
- How? Q: is the network address the same?
- Question: what if it is not on the same network?
- Answer: we ask a host to relay for us.
- Question: but, which host?
  (it has to be on the same network)

Example: 以前系上防火牆的Routing table (部分)



192.168.48.0/
255.255.248.0

192.168.219.0/
255.255.255.0

192.168.55.254

192.168.219.254

140.112.30.254

140.112.28.0/
255.255.252.0

Routing Table:
192.168.48.0 255.255.248.0 192.168.55.254
192.168.219.0 255.255.255.0 192.168.219.254
140.112.28.0 255.255.252.0 140.112.30.254
0.0.0.0 0.0.0.0 140.112.x.x

How to represent
a group of destination hosts?

- CIDR == Classless Inter-Domain Routing

- Borrowing the netmask idea:
  IPs from192.144.0.0 to 192.144.7.0,
  we can say 192.144.0.0/21 (21==255.255.248.0)

- Any IP address falls in that “network”
  (though might not be a real network), can be represented by that CIDR

Private IP

- Private IP
  ==IPs that are not globally allocated to anyone

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

Zuvio exercise

- Install “ipcalc” on your VM or the platform of your choice. You can also install it in your directory on the workstation. Learn how to use it.

- Suppose you would like to allocate some private IPs for a sub-network with around 20 hosts. Give the network address and the net mask such that it is not “oversized”.

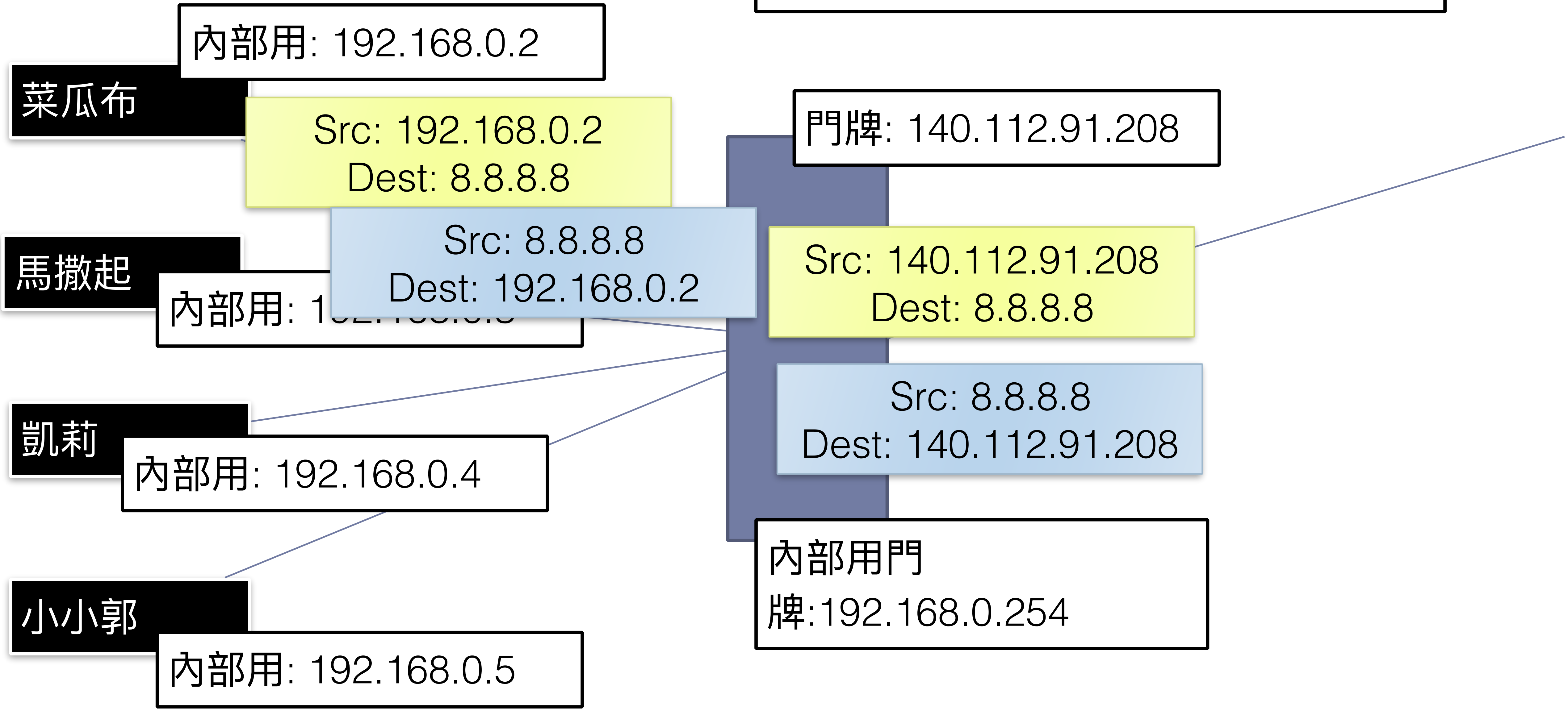
- Paste the output of ipcalc for that network address.

NAT (Network Address Translation)

只有一塊門牌發給我們，怎麼辦呢?

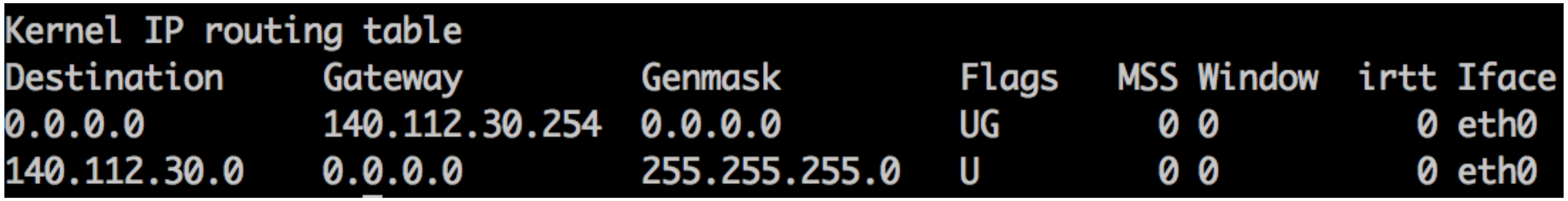
對照表:

- 菜瓜布有連到8.8.8.8
- 要找助教請轉到192.168.0.4



Routing Table

- netstat -nr (不看hostname) or
  netstat -r (看hostname)



```
Kernel IP routing table
Destination     Gateway         Genmask         Flags   MSS Window  irtt Iface
0.0.0.0         140.112.30.254  0.0.0.0         UG        0 0          0 eth0
140.112.30.0    0.0.0.0         255.255.255.0   U         0 0          0 eth0
```

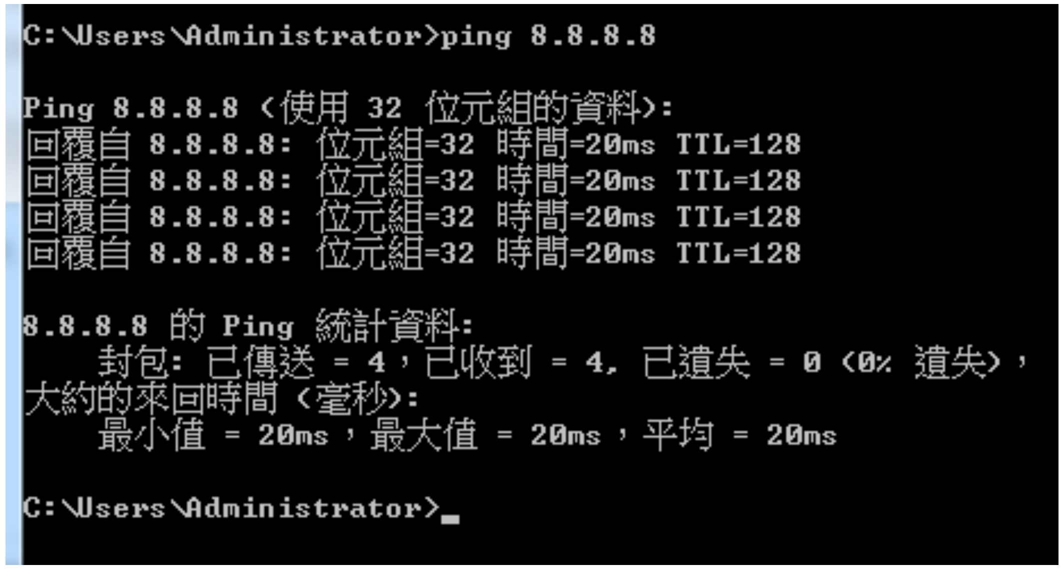
- route add default gw 140.112.30.254
  —> all traffic not to local subnets goes to the gw

- route add -net 132.236.220.64 netmask 255.255.255.192
  —> all traffic that has destination address with the described network address goes to 132.236.220.64

ICMP (Internet Control Message Protocol)

- 一些管理用的訊息，用來通知client關於網路的狀況。
- 常用的用途:

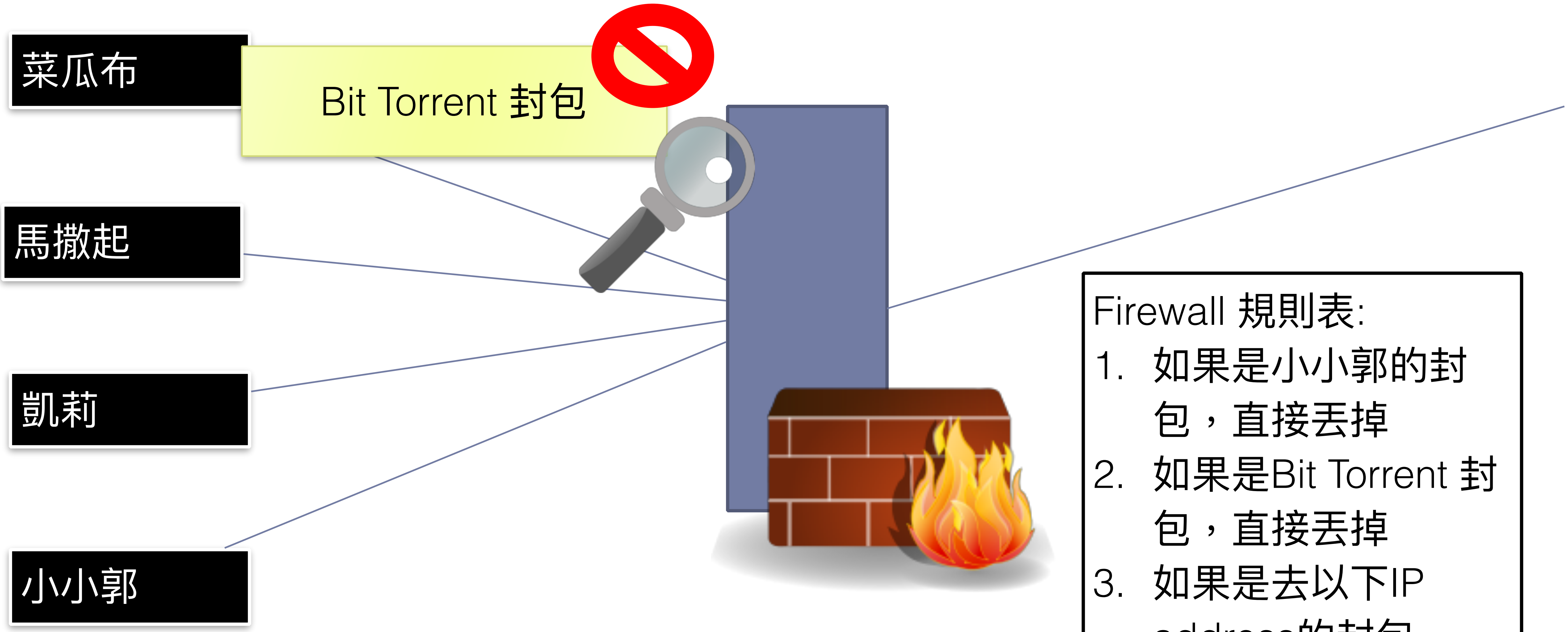
1. 通知client此路不通。(Destination network/host/protocol/port unreachable or unknown)
2. Ping使用的echo request & reply



```
C:\Users\Administrator>ping 8.8.8.8

Ping 8.8.8.8 (使用 32 位元組的資料):
回覆自 8.8.8.8: 位元組=32 時間=20ms TTL=128
回覆自 8.8.8.8: 位元組=32 時間=20ms TTL=128
回覆自 8.8.8.8: 位元組=32 時間=20ms TTL=128
回覆自 8.8.8.8: 位元組=32 時間=20ms TTL=128

8.8.8.8 的 Ping 統計資料:
    封包: 已傳送 = 4，已收到 = 4, 已遺失 = 0 (0% 遺失)，
大約的來回時間 (毫秒):
    最小值 = 20ms，最大值 = 20ms，平均 = 20ms

C:\Users\Administrator>_
```

3. TTL expire (用來偵測或預防路徑中的loop或是traceroute使用)

Firewall



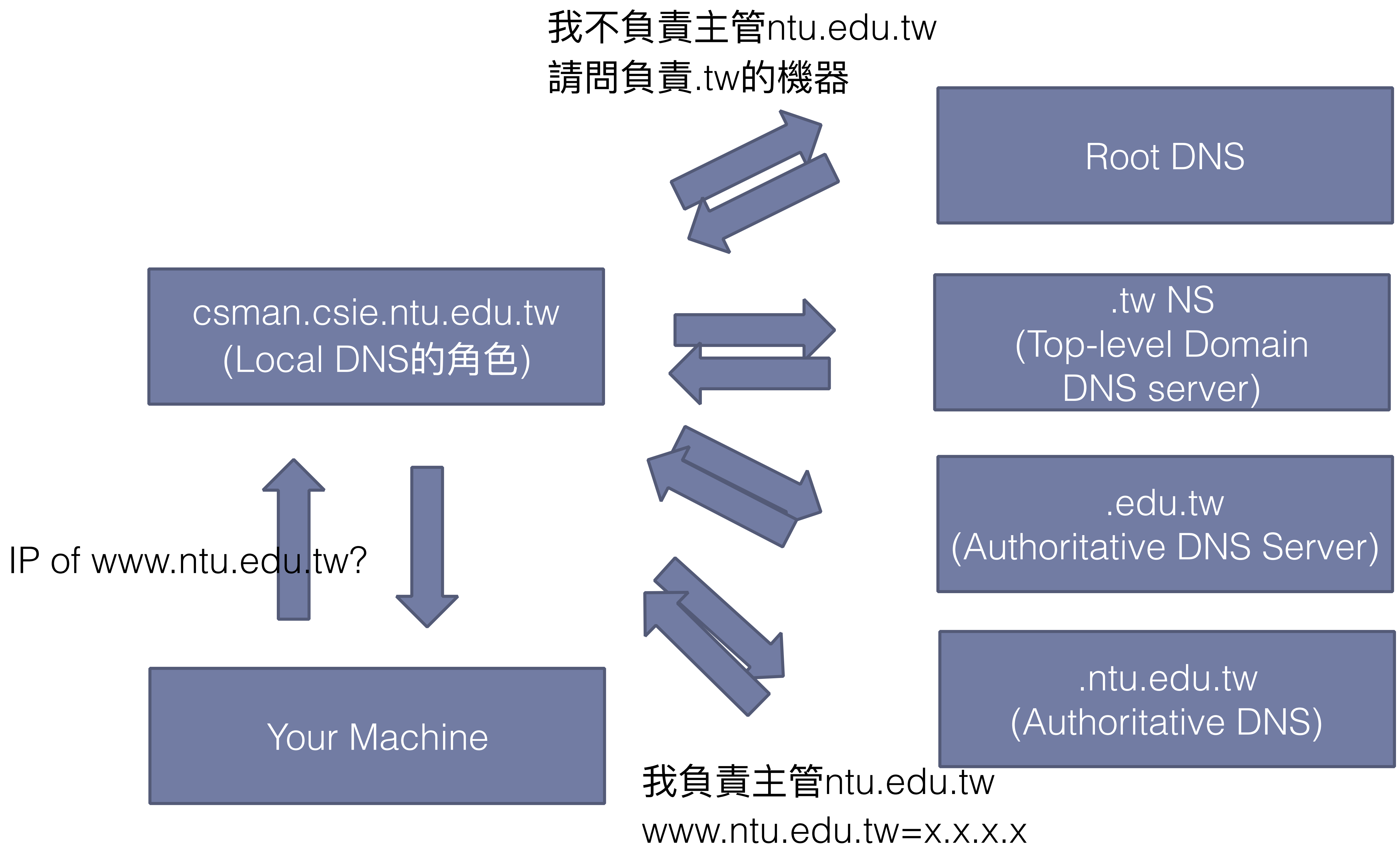
Firewall 規則表:

1. 如果是小小郭的封包，直接丟掉
2. 如果是Bit Torrent 封包，直接丟掉
3. 如果是去以下IP address的封包(x.x.x.x, y.y.y.y, z.z.z.z)直接丟掉
4. 剩下的可以過

DNS (Domain Name Service)

- 一言以蔽之: 將名稱轉為IP的服務
- 常見的轉換種類:
  - Domain name -> IP (type A):
    ntucsv.csie.ntu.edu.tw -> 140.112.30.28
  - @domainname的mail server (type MX):
    csie.ntu.edu.tw -> ms.csie.ntu.edu.tw
  - Domain name -> domain name (type CNAME):
    www.csie.ntu.edu.tw -> ntucsv.csie.ntu.edu.tw
  - IP -> domain name (type PTR)
    140.112.30.21 -> csman.csie.ntu.edu.tw
- 可以多重宣告: 增加可靠度或分散性.
  - 例如www.google.com的A指到了6個IP!

分散式的架構: 分層負責 (recursive query)



我不負責主管ntu.edu.tw
請問負責.tw的機器

Root DNS

csman.csie.ntu.edu.tw
(Local DNS的角色)

.tw NS
(Top-level Domain
DNS server)

.edu.tw
(Authoritative DNS Server)

IP of www.ntu.edu.tw?

.ntu.edu.tw
(Authoritative DNS)

Your Machine

我負責主管ntu.edu.tw
www.ntu.edu.tw=x.x.x.x

DNS的細節

- 如果local DNS本身主管被查詢的domain，則可以直接回覆。
  - 例如140.112.30.21如果被查詢www.csie.ntu.edu.tw
- Local DNS可以暫存之前查詢過的結果。
  - 主要用來減輕主管DNS server及網路的負擔。
  - 每筆在主管DNS server上的紀錄都有對應的TTL值，規範可以被占存多久。

/etc/resolv.conf

```
nameserver 140.112.30.21

nameserver 140.112.254.4

nameserver 140.112.2.2

search csie.ntu.edu.tw
```

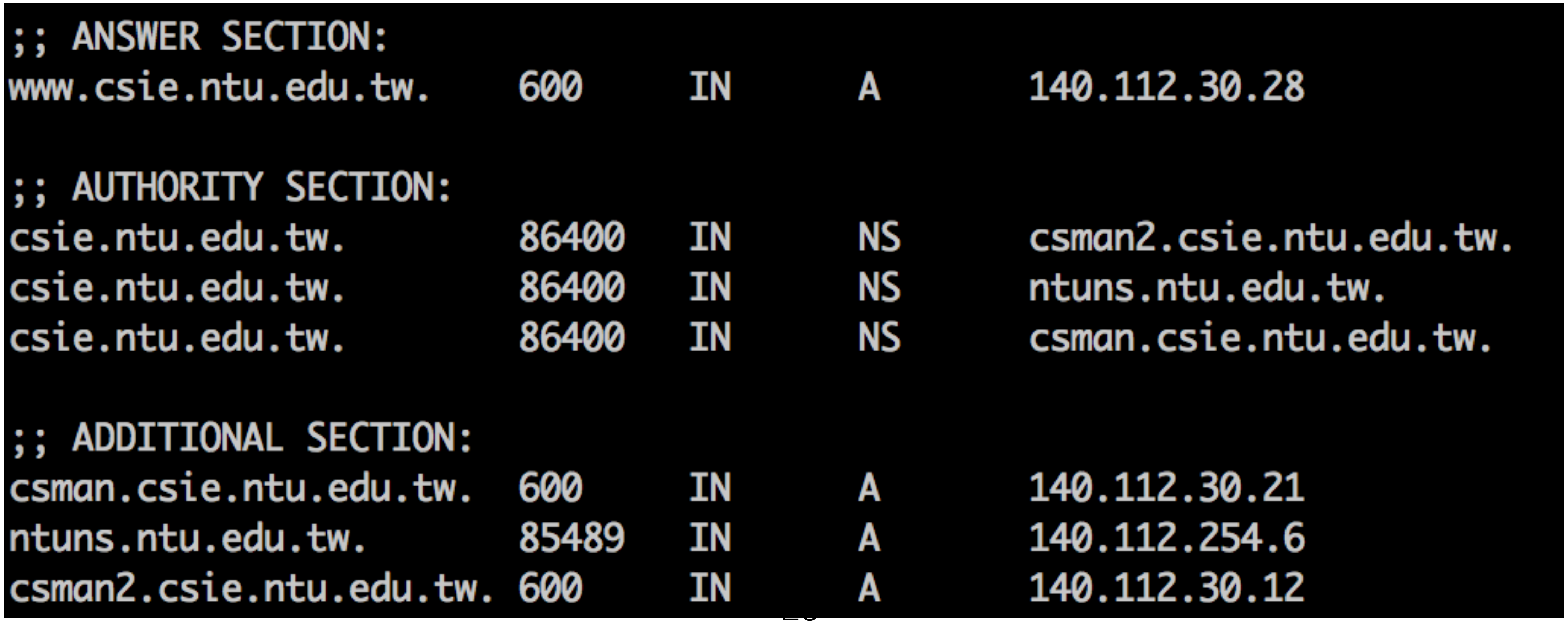
- search
  —> resolve incomplete names (linux1 —> linux1.csie.ntu.edu.tw)
- nameserver —> specify the address of the DNS server

DNS延伸閱讀

- Top 10 DNS attacks: http://www.networkworld.com/article/2886283/security0/top-10-dns-attacks-likely-to-infiltrate-your-network.html#slide1
- Distributed Reflection DoS attack
- Cache poisoning / DNS hijacking (sol: DNSSEC)
- TCP SYN floods

常用DNS指令

- Examples:
  - dig @8.8.8.8 -t MX csie.ntu.edu.tw
  - dig @140.112.30.21 www.csie.ntu.edu.tw



```
;; ANSWER SECTION:
www.csie.ntu.edu.tw.    600     IN      A       140.112.30.28

;; AUTHORITY SECTION:
csie.ntu.edu.tw.        86400   IN      NS      csman2.csie.ntu.edu.tw.
csie.ntu.edu.tw.        86400   IN      NS      ntuns.ntu.edu.tw.
csie.ntu.edu.tw.        86400   IN      NS      csman.csie.ntu.edu.tw.

;; ADDITIONAL SECTION:
csman.csie.ntu.edu.tw.  600     IN      A       140.112.30.21
ntuns.ntu.edu.tw.       85489   IN      A       140.112.254.6
csman2.csie.ntu.edu.tw. 600     IN      A       140.112.30.12
```

In-Class Exercise

- 找出linux1到www.nasa.gov經過了哪些機器(domain name可) keyword: mtr, traceroute
- 找出csie.ntu.edu.tw和ntu.edu.tw的mail server們(SMTP)的IP是什麼

延伸閱讀

- 前講師(小小郭)的線上投影片: http://xdlab.org/~math120908/slides/nettool.html#/introduction-to-network-tools