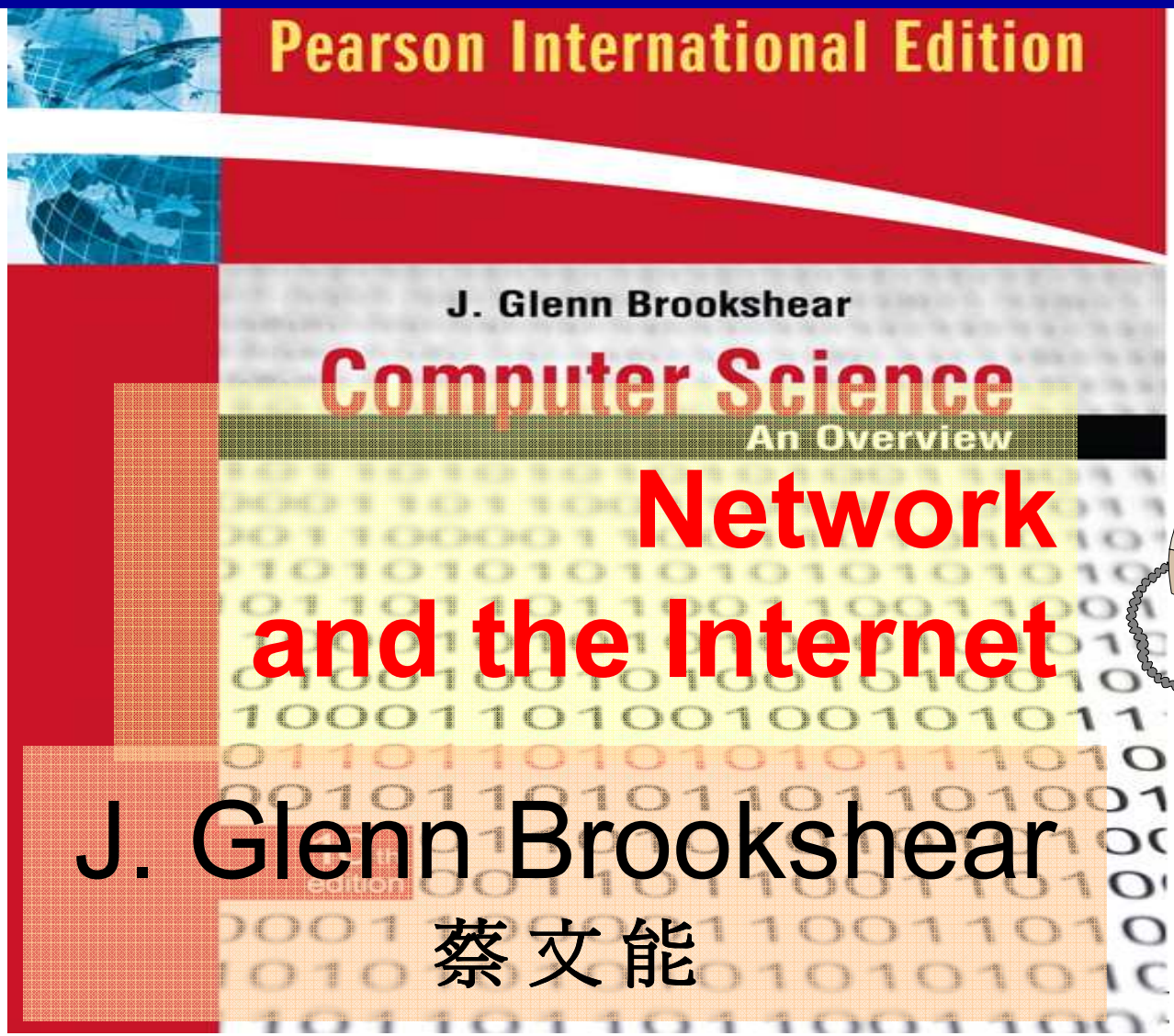
Chapter 4

Part B



Network and the Internet

J. Glenn Brookshear
蔡文能

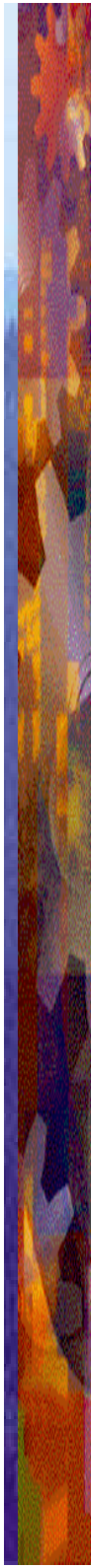
Agenda

4.1 Network Fundamentals
4.2 The Internet
4.3 The World Wide Web

} Part A

4.4 Network Protocols
4.5 Security

} Part B



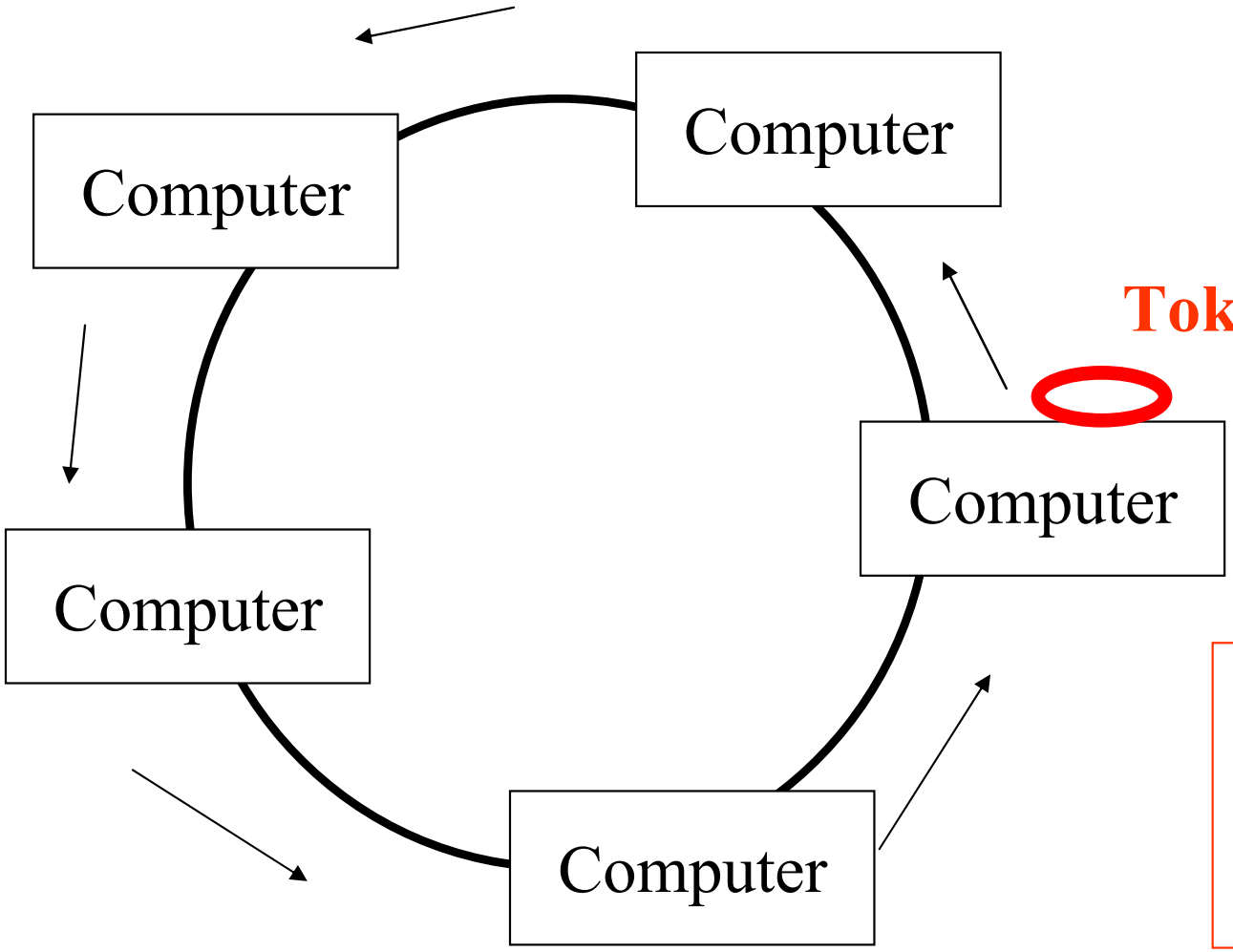
Network Protocols

- Rules that govern the communication between different components within a computer system
- Rules Obeyed by All Parties
- Network protocols define the details of each activity
  - Delegate the right (privilege) to transmit message
  - Address messages
  - Package and unpack messages
- Examples of Link layer protocol
  - Token ring protocol
  - CSMA/CD (for Ethernet)
  - CSMA/CA (for Wireless)

Token Ring Protocol (1/2)

- Popular in networks based on the ring topology
- All machines transmit message in a common direction
- **Token**, a unique **bit pattern** is passed around the ring
- Possession of the token gives a machine the authority to transmit its own messages
- Without the token, a machine is only allowed to forward messages
- Token is forwarded to next machine when a message has completed its cycle along the ring

Token Ring Protocol (2/2)

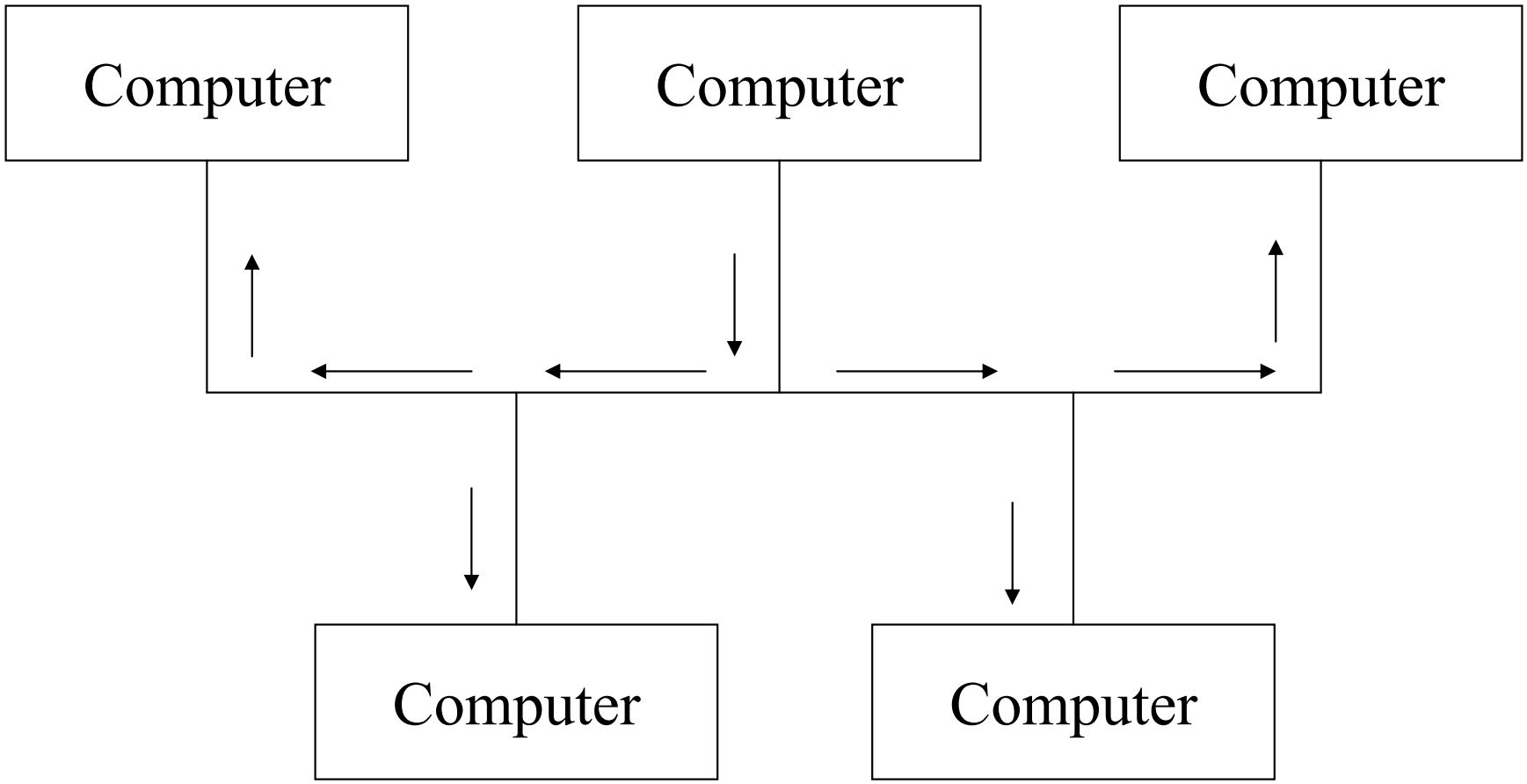


What if the **token** is missing?

CSMA/CD Protocol (1/2)

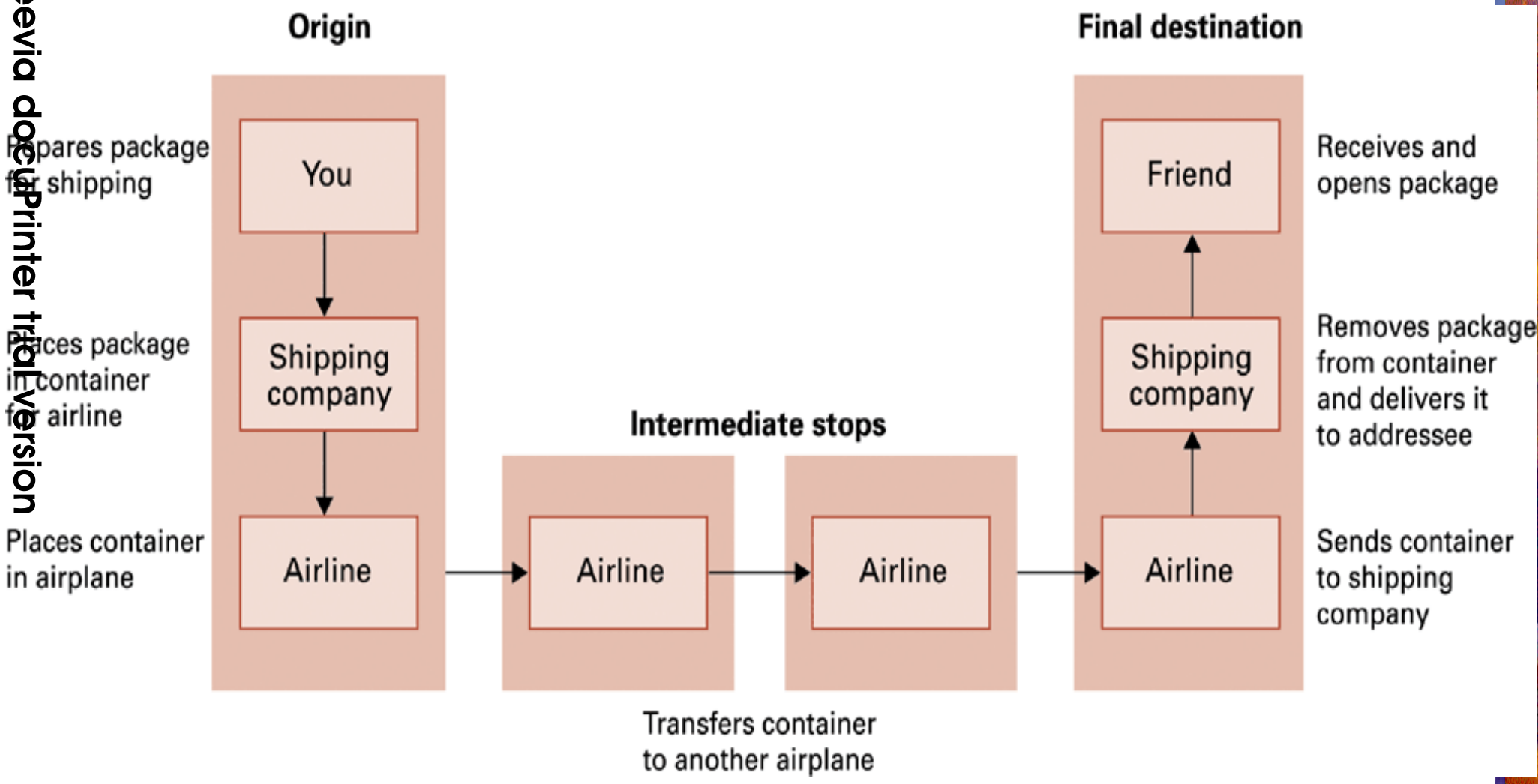
- **C**arrier **S**ense, **M**ultiple **A**ccess with **C**ollision **D**etection
- Popular in Ethernet
- Each message is broadcasted on the **bus**
- Each machine monitors all messages but keeps only those addressed to itself
- Wait until the bus is silent to transmit a message
- When collision occurs, both machine pause for a brief **random period of time** before trying again

CSMA/CD Protocol (2/2)

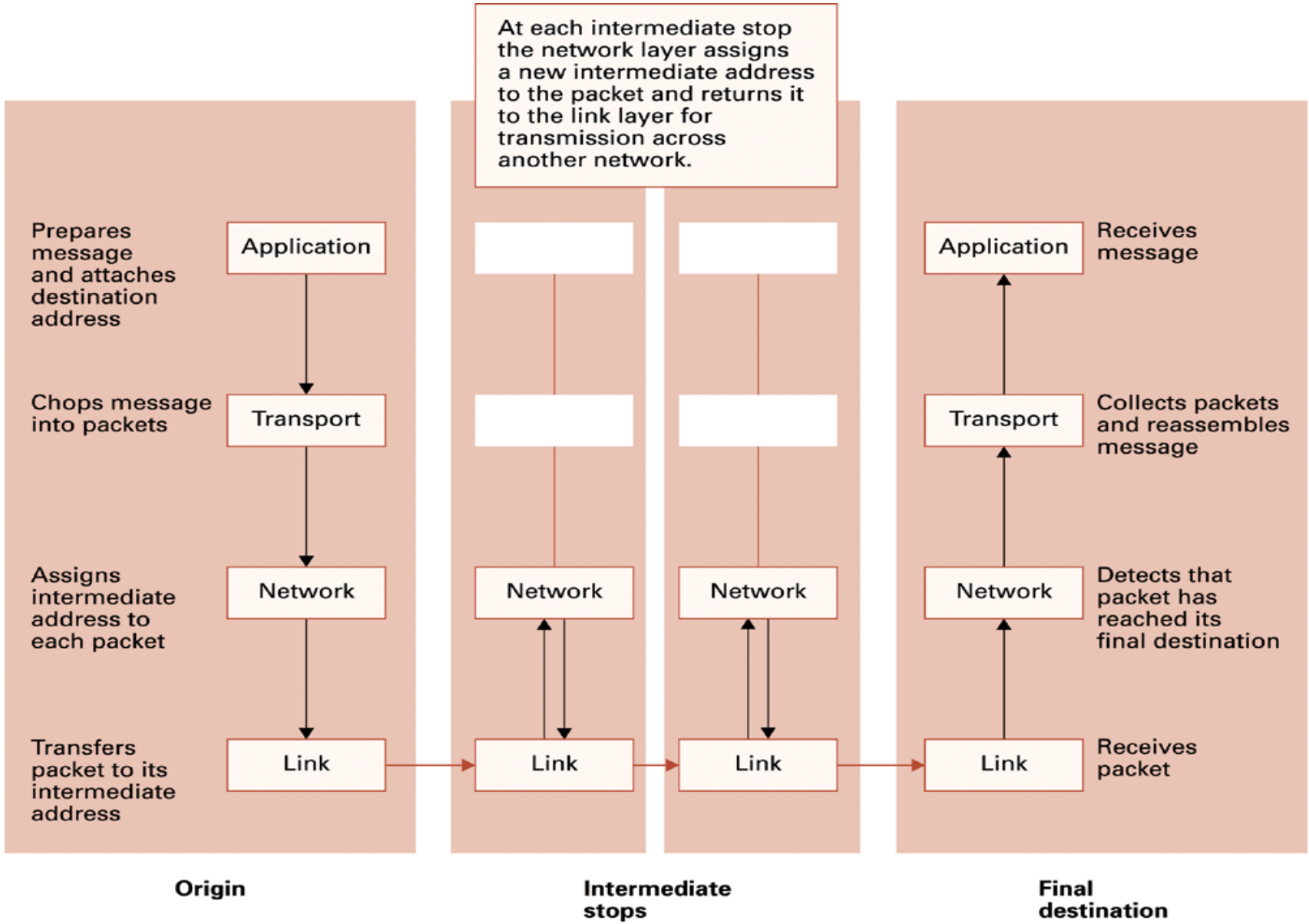


CSMA/CD: **C**arrier **S**ense, **M**ultiple **A**ccess with **C**ollision **D**etection

Package-Shipping by Air

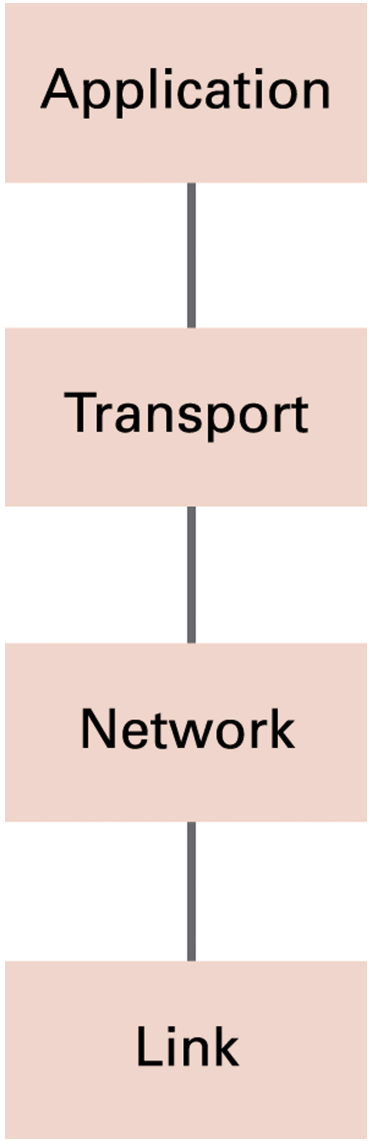


Message-Shipping by Internet



TCP/IP 4 Layers

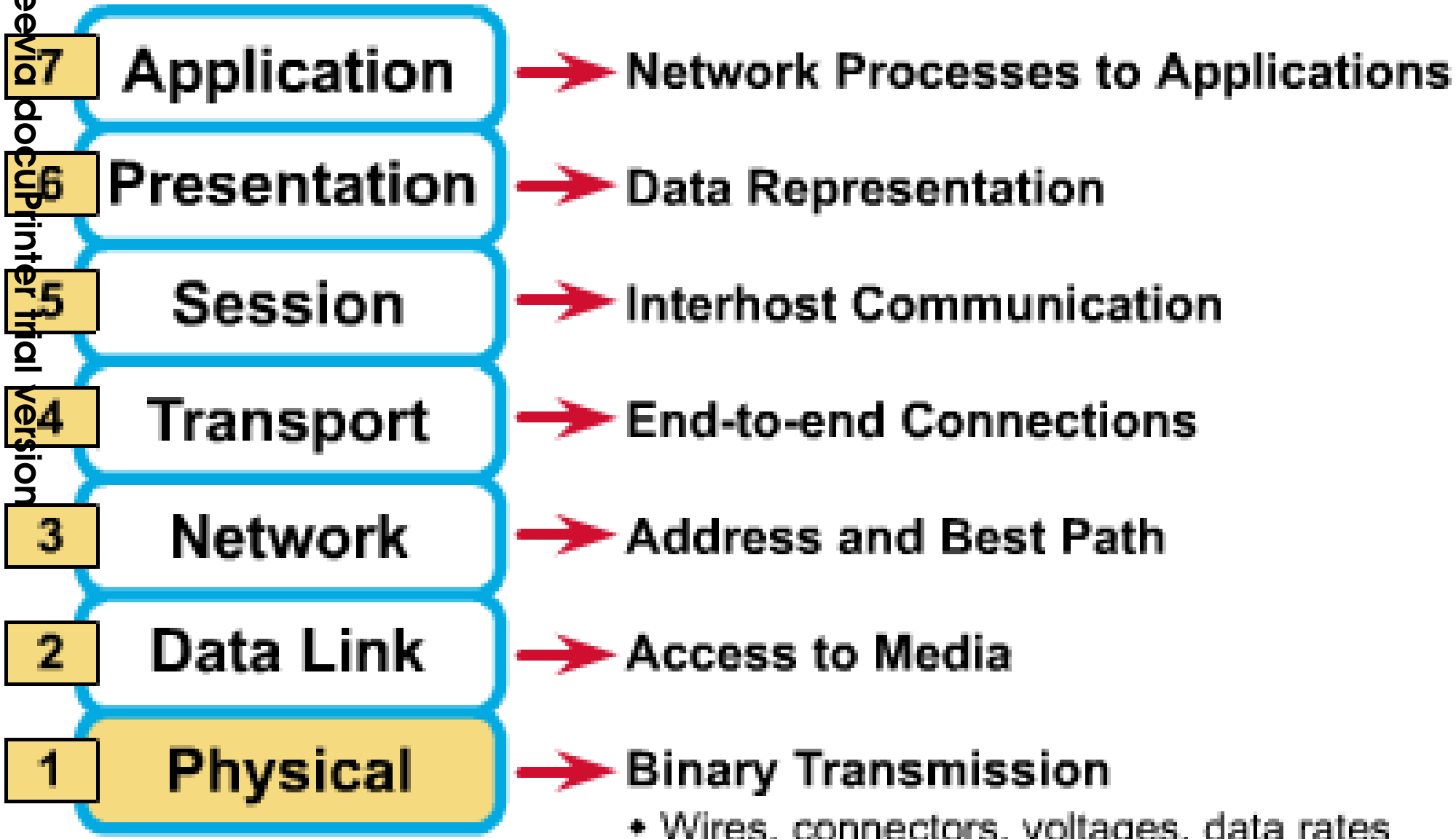
- Application layer (Layer 4)
  - HTTP, FTP, Telnet
- Transport layer (Layer 3)
  - TCP, UDP
- Network layer (Layer 2)
  - Routing
- Link layer (Layer 1) (MAC layer)
  - Token ring or Ethernet



MAC: Media Access Control

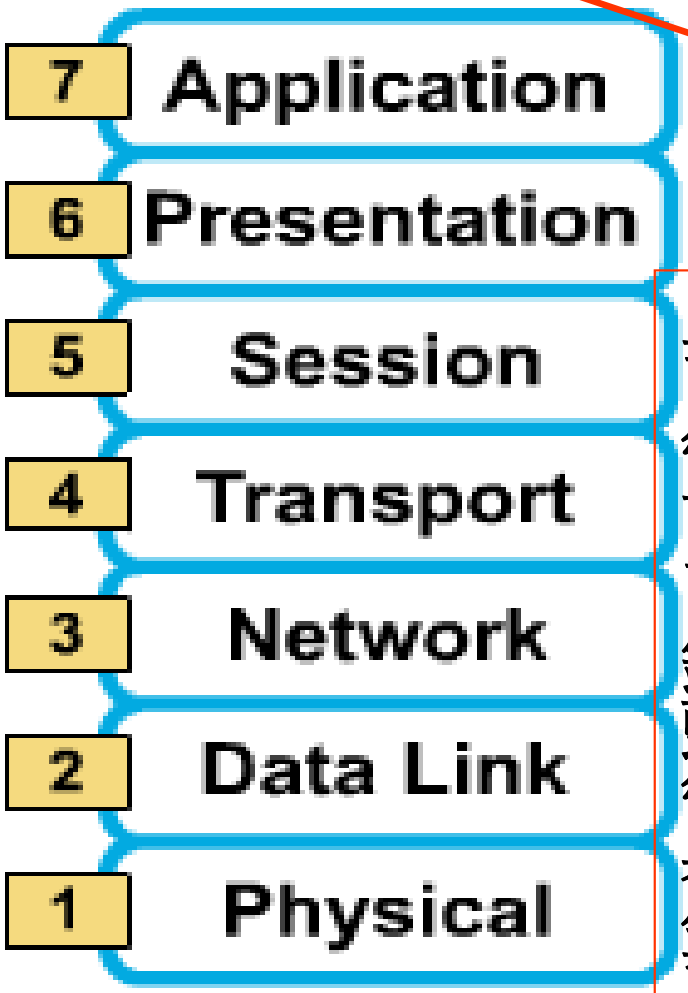
The 7 Layers of the OSI Model

OSI : Open System Interconnection



Why a Layered Network Model?

OSI 7-Layer Reference Model



分層負責; 分工合作

上司管下司鋤頭管畚箕

- Reduces complexity
- Standardizes interfaces
- Facilitates modular engineering
- Ensures interoperable technology
- Accelerates evolution
- Simplifies teaching and learning

•It prevents changes in one layer from affecting the other layers, so that they can develop more quickly.

OSI

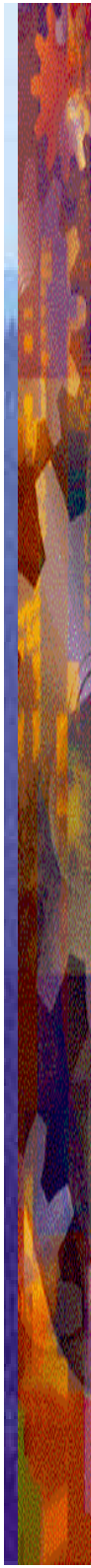
ISO

Proposed by International Organization for Standardization (ISO)

Layers for Receiving Messages

- Roughly that of reversing the task performed by their counterparts at the message's origin
- Strips off the outer wrapping placed by their counterparts and hands the underlying packets to its upper layer

- 分工合作, 分層負責



Physical Layer (實體層)

- 實體層：定義網路媒介的型態、連接器的型態、以及通訊訊號的型態

- Defines the **electrical, mechanical, procedural, and functional** specifications for activating, maintaining, and deactivating the physical link between end systems
  - Voltage levels, timing of voltage changes, physical data rates, maximum transmission distances, physical connectors, and other
- Think of signals and media

tsaiwn@csie.nctu.edu.tw

Data Link Layer (資料連結層)

- **Layer 2** creates data frames to send to Layer 1
- On receiving side, takes raw data from Layer 1 and packages into data frames
  - Data frame is basic unit for network traffic on the wire
  - Ethernet frame on Ethernet (IEEE 802.3)
- Performs Cyclic Redundancy Check (CRC) to verify data integrity
- Detects errors and discards frames containing errors
- PDU (*Protocol Data Units*)at Layer 2 is called a frame
- The software component that operates at this layer is the NIC driver; the hardware components that operate here include the NIC (網路卡) and switches (交換器)

OSI 7-Layer 的第二層相當於 TCP/IP 的第一層

又稱 MAC Layer (Media Access Control)

TCP/IP 網路通訊協定
de facto Standard (業界標準)

- TCP/IP network model

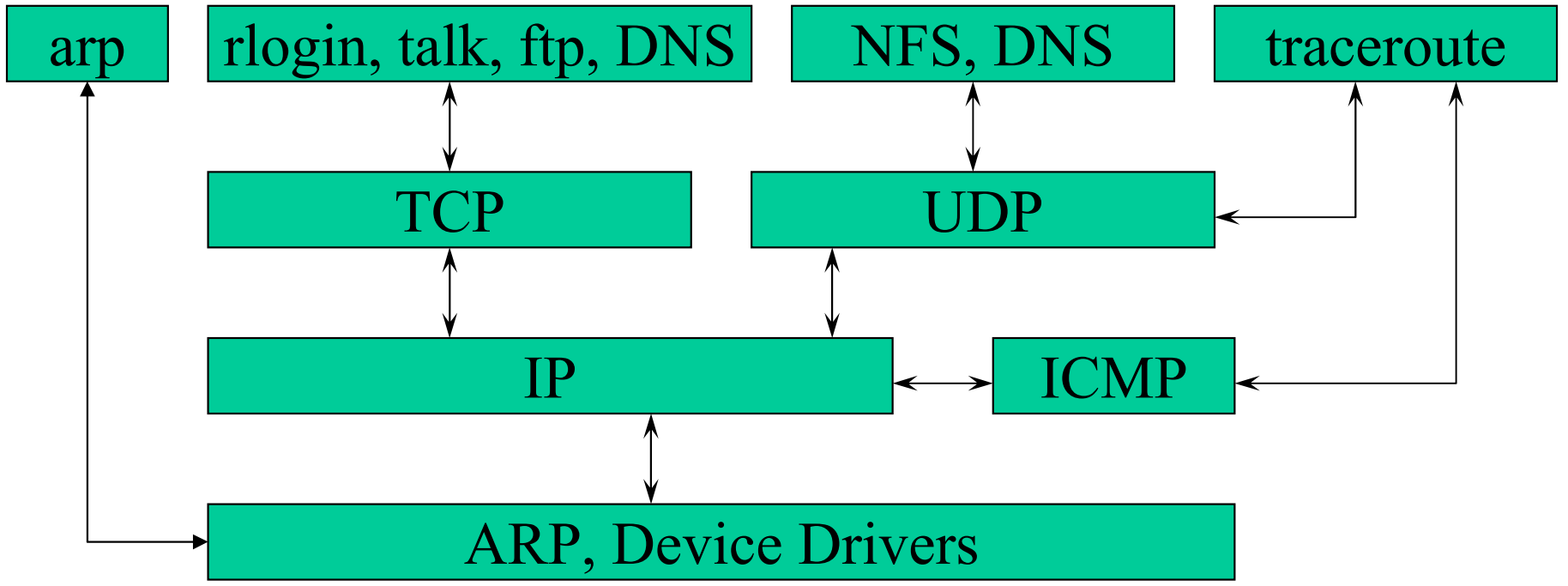
Layer	Function
Application	End-user application programs
Transport	Communication among programs on a net (TCP/UDP)
Network	Basic communication, addressing, and routing (IP, ICMP)
Link(Data Link)	Network hardware and device drivers(ARP, RARP)

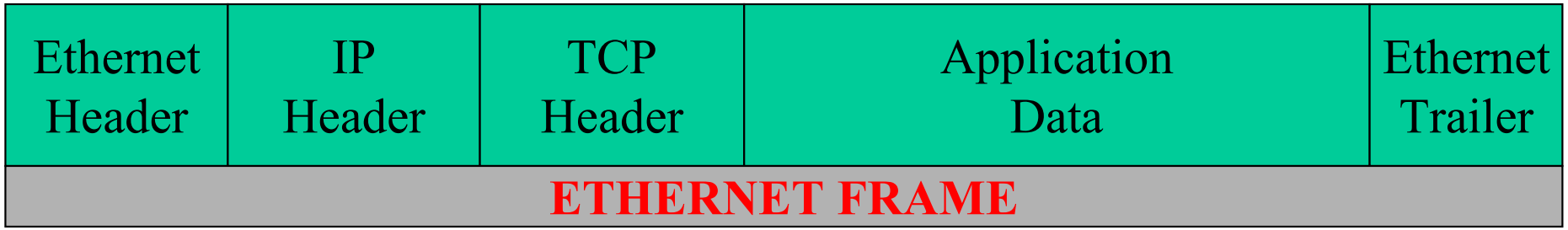
4.應用層，3.傳輸層(Transport Layer)，2.網路層，1.鏈結層(Link Layer)

Developed in the US for the Department of Defense ARPAnet system and has become a de facto standard used by many vendors.

TCP/IP網路通訊協定

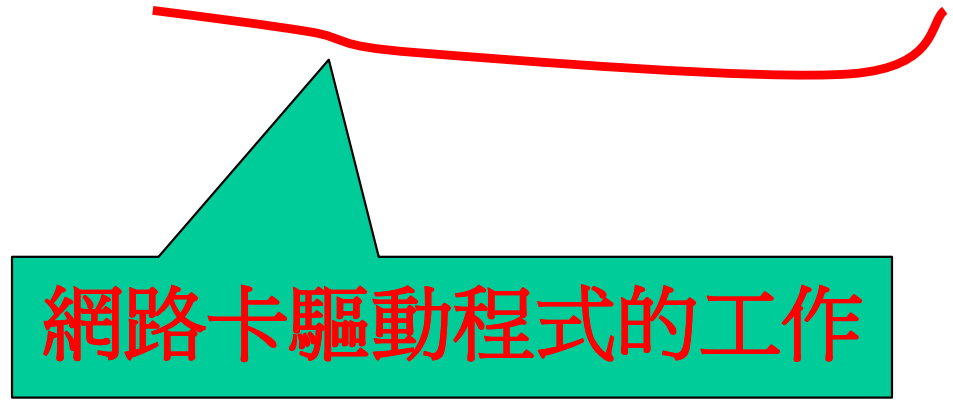
Layer





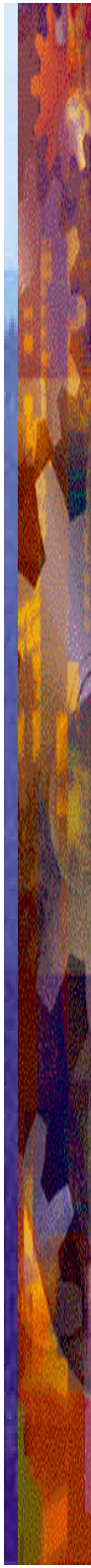
Example using TCP/IP

- ccsun2: talk mfchang@ccsun2.csie.nctu.edu.tw
- 如何查出 ccsun2 的 IP address ?
  - 查 /etc/hosts 或
  - 問 DNS 伺服器
- 每次如何把打的字送到對方機器?
  - TCP ➔ IP ➔ [ARP] ➔ Ether frame ➔ bit stream



Application Layer (Layer 4)

- Consists of software units that must communicate with each other across the internet
  - File Transfer Protocol (FTP)
  - Simple Mail Transfer Protocol (SMTP)
  - Telnet
  - Web browser (HTTP)



Transport Layer (Layer 3)

- Divides long messages into segments of a size compatible with the underlying layer
- Adds sequence numbers to these segments
- Attaches destination address to each segment
- The segment becomes a packet

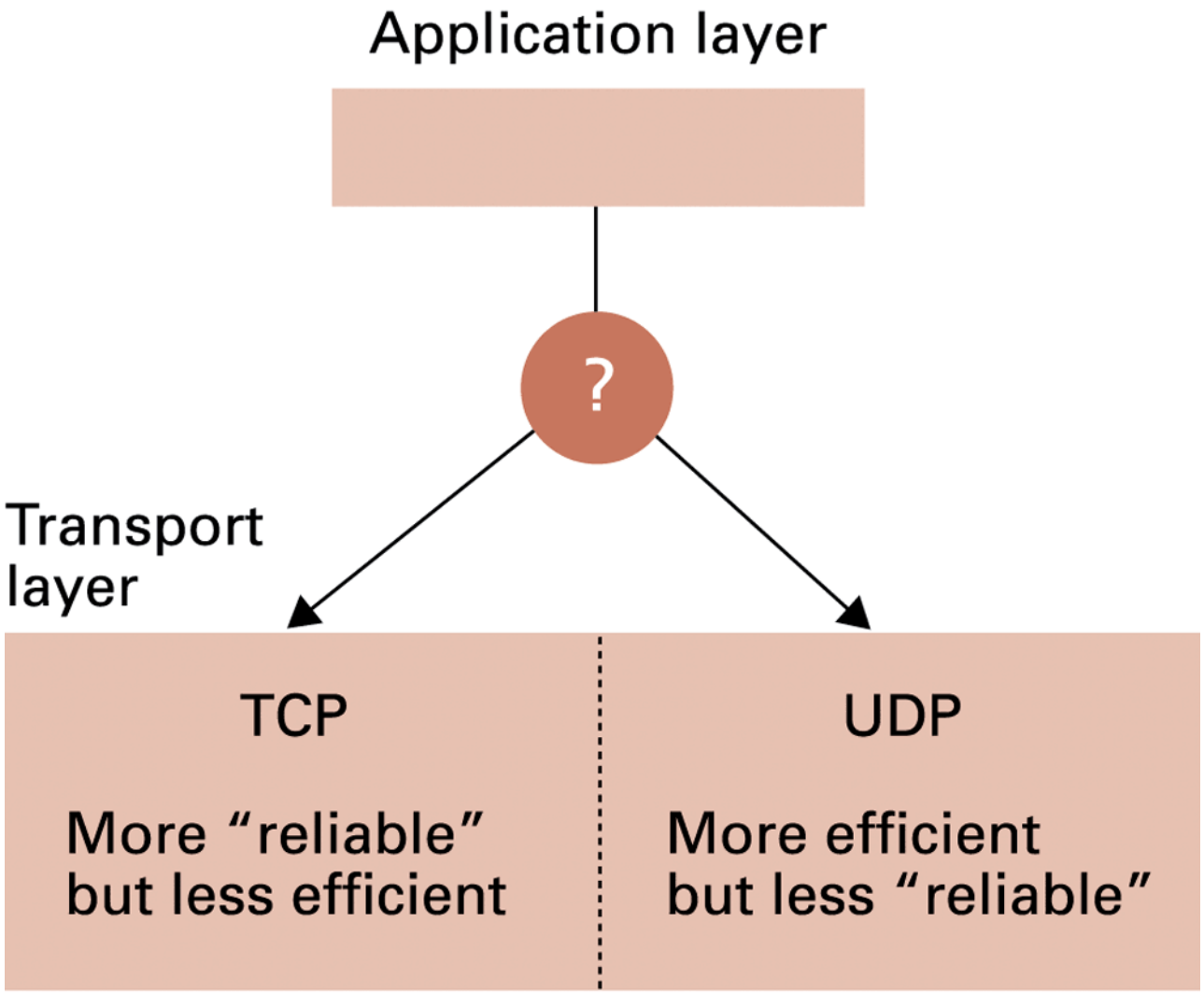
TCP segment vs. UDP datagram

Transport Layer (傳輸層; 運輸層)

- The transport layer involves two protocols - Transmission Control Protocol (***TCP***) and ***User Datagram Protocol (UDP)***
  - *TCP*
    - *Connection oriented (就是雙方要先講好)*
    - *Header 至少 20 octets*
  - *UDP header*
    - *Connectionless*
    - *Header 固定 8 octets*

Octet : 指 8 bits 的 Byte; 因一Byte 可能 6bits, 7bits, 8bits

Choosing between TCP and UDP



TCP Connections

- 3-way handshaking is required to establish virtual connection before sending any message
- Before sending a message, a transport layer sends its own message to the transport layer at the destination telling that a message is about to be sent
- It then waits for this message to be acknowledged before starting to send the application layer's message
- Use acknowledgement and packet retransmissions to confirm that all packets are successfully transferred to the destination

UDP Connections ?

Network Layer (Layer 2; IP Layer)

- Determine intermediate router address for each packet if necessary
- Append intermediate or ultimate destination address to each packet

- **Also know as Layer 3 in OSI 7-layer Reference Model**
- Also known as **IP Layer**
- A LAN connects to a WAN via a **Router**

Network Layer(網路層)=IP Layer (cont.)

- There is only one network protocol - **I**nternet **P**rotocol, or **IP**
- The **network** access layer(網路存取層), refers to the particular LAN or WAN technology that is being used
- IP header: 填入 **12 octets** 重要資訊(含TTL, protocol)接著雙方 IP,再接著 options (if any), 再來是 IP data, 最後有 32-bit 的 CRC 檢查值

Octet : 指 8 bits 的 Byte; 因一Byte 可能 6bits, 7bits, 8bits

Link Layer (Layer 1) (MAC Layer)

- Deals with the communication details particular to the individual networks in which the machine resides
- Translates the Internet addresses appearing outside of the packets into the appropriate local addressing system
- Add these translated addresses to the packet
- Example:
  - Ethernet: **CSMA/CD** Carrier Sense, Multiple Access with Collision Detection
  - Token ring: one-way communication around ring network

Ethernet is the most popular medium access control protocol.

MAC

- **M**edium **A**ccess **C**ontrol
- The class of protocols that handle medium access problems
- Example
  - Ethernet (IEEE 802.3)
  - Wireless LAN (IEEE 802.11)
  - Bluetooth (IEEE 802.15)
  - WiMAX (IEEE 802.16) (Broadband Wireless Access Standards)

啥是 802.??
Next slides

Ethernet is the most popular medium access control protocol.

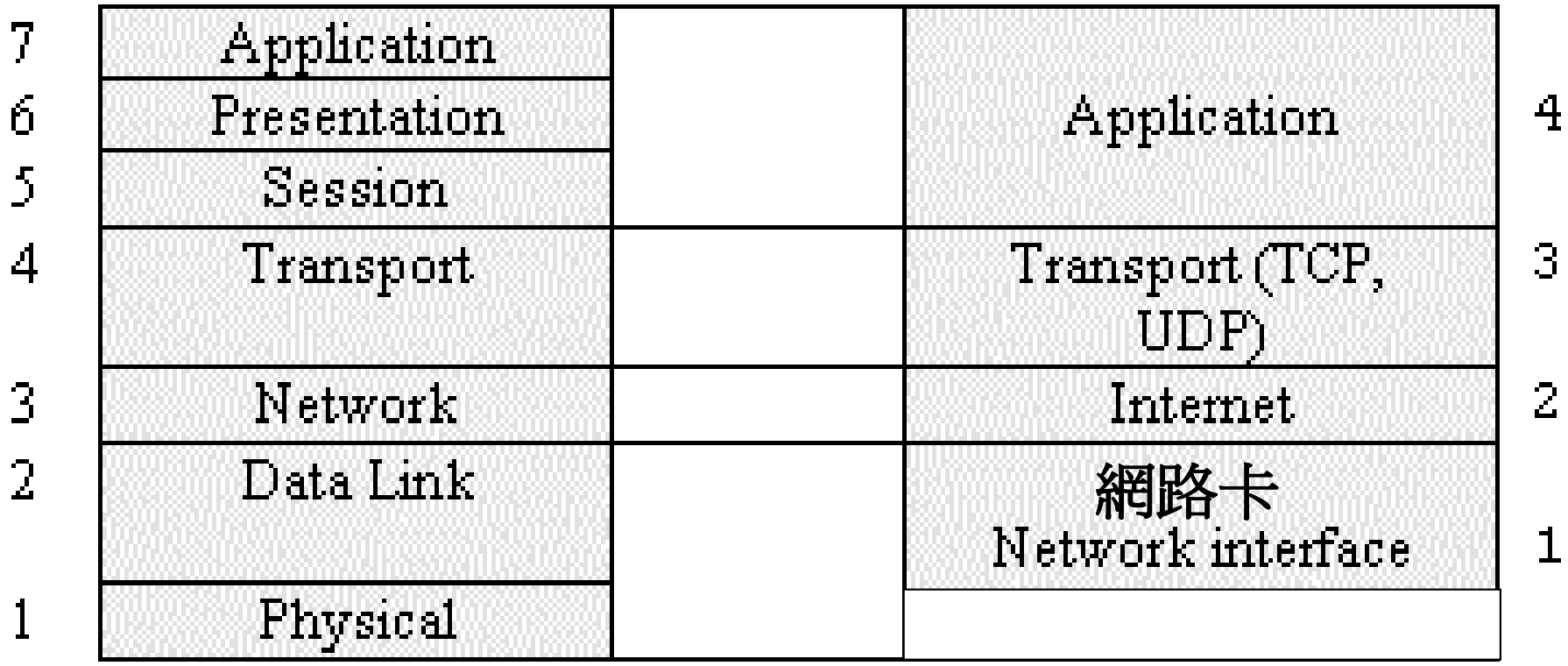
TCP/IP Protocol Suite

- Application Layer : FTP, HTTP, SMTP, Telnet, …
- Transport Layer
  - TCP (Transmission Control Protocol)
    - Transport layer
    - Establish connection before sending data
    - Reliable protocol
  - UDP (User Diagram Protocol)
    - Transport layer
    - Connectionless
    - Unreliable protocol
- IP (Internet Protocol)
  - Network layer
  - Handles hop count (Hop count = 經過幾個 Router)

OSI Reference Model vs TCP/IP Model

OSI 7-Layer

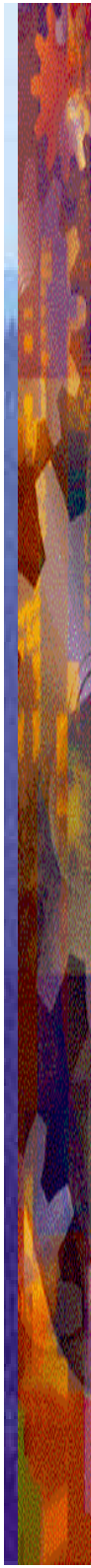
TCP/IP



TCP/IP 沒有定義實體層(physical layer)

Similarities

- Both have layers
- Both have application layers, though they include very different services
- Both have comparable transport and network layers
- **Packet-switched** (not circuit-switched) technology is assumed
- **Networking professionals need to know both**



Differences

TCP/IP combines the presentation and session layer issues into its application layer

TCP/IP combines the OSI data link and physical layers into one layer (或說 **TCP/IP 沒有定義實體層**)

TCP/IP appears simpler because it has fewer layers

TCP/IP protocols are the standards around which the Internet developed, so the TCP/IP model gains credibility just because of its protocols. In contrast, typically networks aren't built on the OSI protocol, even though the OSI model is used as a **guide**.

CSMA/CD

802.3 or Ethernet

Carrier Sense Multiple Access with Collision Detection

- *Carrier Sense*: can tell when another host is transmitting
- *Multiple Access*: many hosts on 1 wire
- *Collision Detection*: can tell when another host transmits at the same time.

http://en.wikipedia.org/wiki/Carrier_sense_multiple_access_with_collision_detection

The Mechanisms of CSMA/CD

- Each computer listens on the Ethernet
  - If not sensing data on the carrier, OK to send its own data **(Carrier Sense, Multiple Access)**
  - If sensing data on the carrier, check whether the data is addressed for itself
- In case of simultaneous transmissions, (collisions) **(Collision Detection)**
  - The computer waits a **random period** of time before re-send
  - **Exponential back-off (**binary back-off**)**

CSMA/CD: Carrier Sense, Multiple Access with Collision Detection

Ethernet - IEEE 802.3 (1/2)

- **Hub** (集線器)– **bus** topology
  - Collision : **CSMA/CD**
  - 10Mbps shared, 100Mbps shared
  - Cheap
- **Switch** (交換器)– **star topology**
  - No collision (送第一次仍會廣播,之後記住MAC)
  - 100Mbps each; 1Gbps each for Gbit Switch
  - Expensive for Gbit Switch at now (2005)

其實 Ethernet 與 IEEE 802.3 並非完全一樣

Ethernet - IEEE 802.3 (2/2)

- **Ethernet** developed by Xerox in mid 1970s
- Basic ideas from AlohaNet packet radio project
- Ethernet standardized by Xerox, DEC, Intel in 1978
- IEEE later standardized as 802.3 - at **MAC layer differs in one header field from Ethernet**
- 10, 100, 1000 Mbps(802.3ab 1000BaseT at 1999, 802.3z Gigabit Ethernet at 1998)
- 10 Gbps (**802.3ae 10Gbps** at 2002)

http://www.ieee802.org/3/
http://www.ieee802.org/3/

Ethernet Technology

Origin: Xerox in 1970

Standard: Xerox, Intel and Digital in 1978.

IEEE standard number: 802.3

Maximum distance: 500m

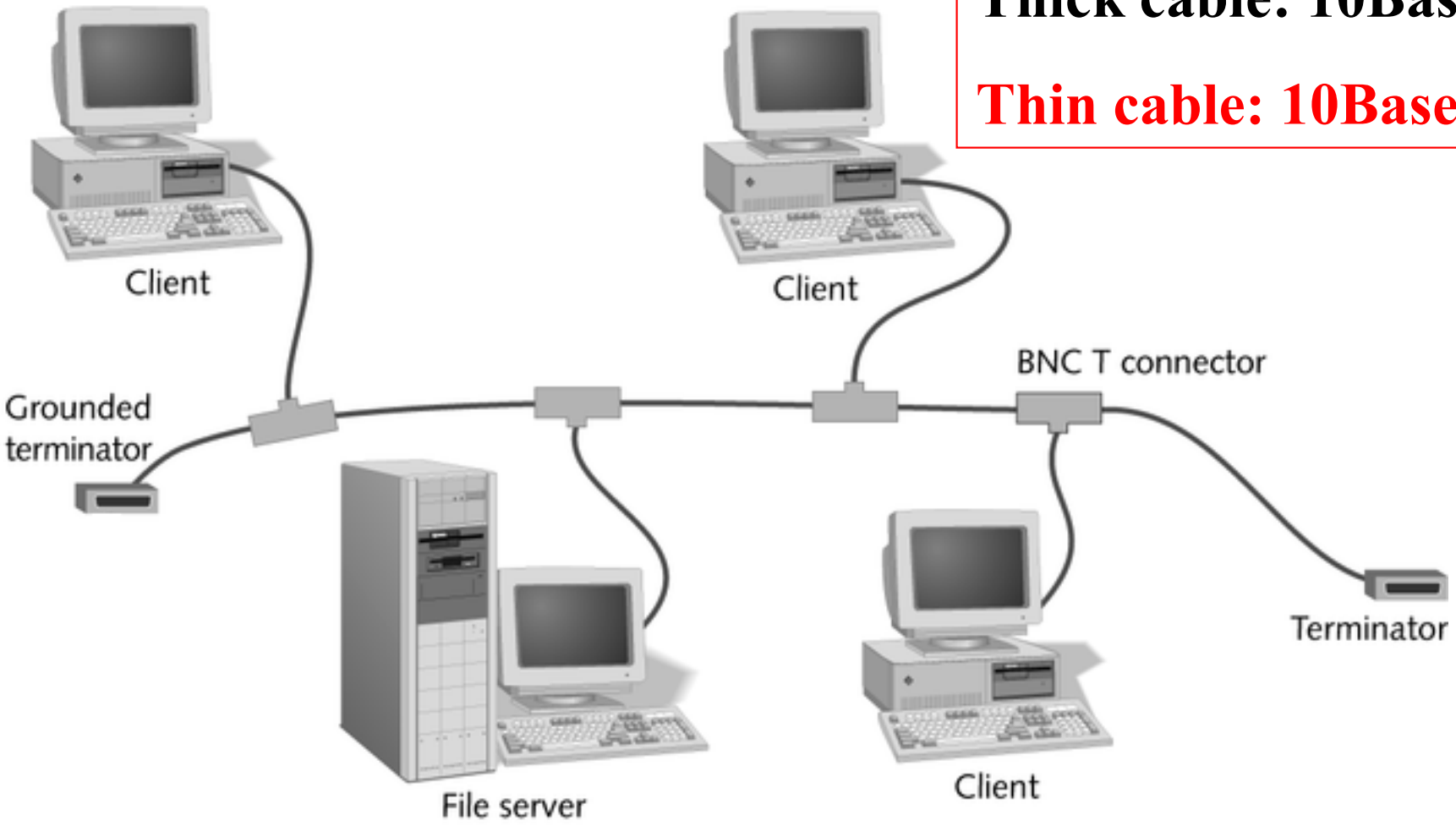
Items / Types	Max. Distance	Connector	Line
Thick Ethernet	500m	AUI	10 Base 5
Thin Ethernet	185m	BNC	10 Base 2
Twisted-Pair Ethernet	100m	RJ-45	10 Base T 100Base T 1000Base T

10Base2 Network

長度不可超過185公尺

Thick cable: 10Base 5

Thin cable: 10Base2

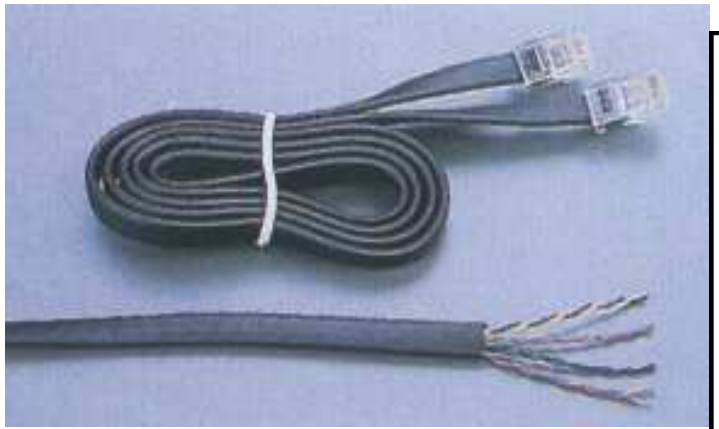


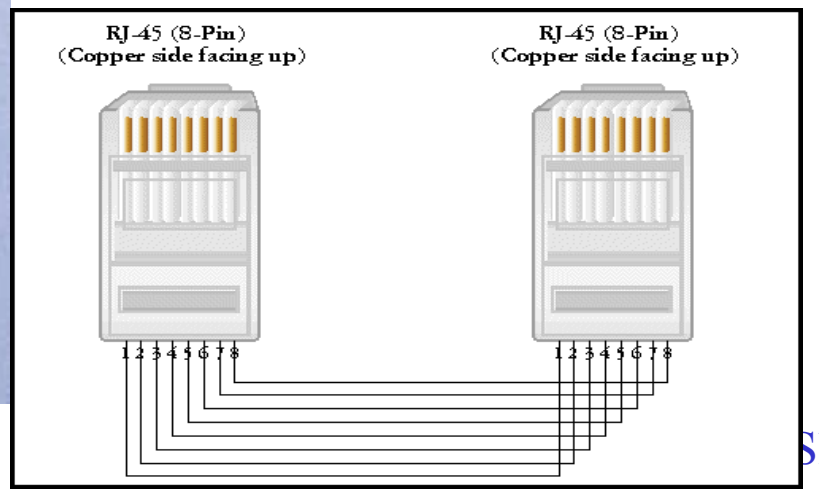
Coaxial cable (同軸電纜)

10BaseT, 100BaseT, 1000Base T

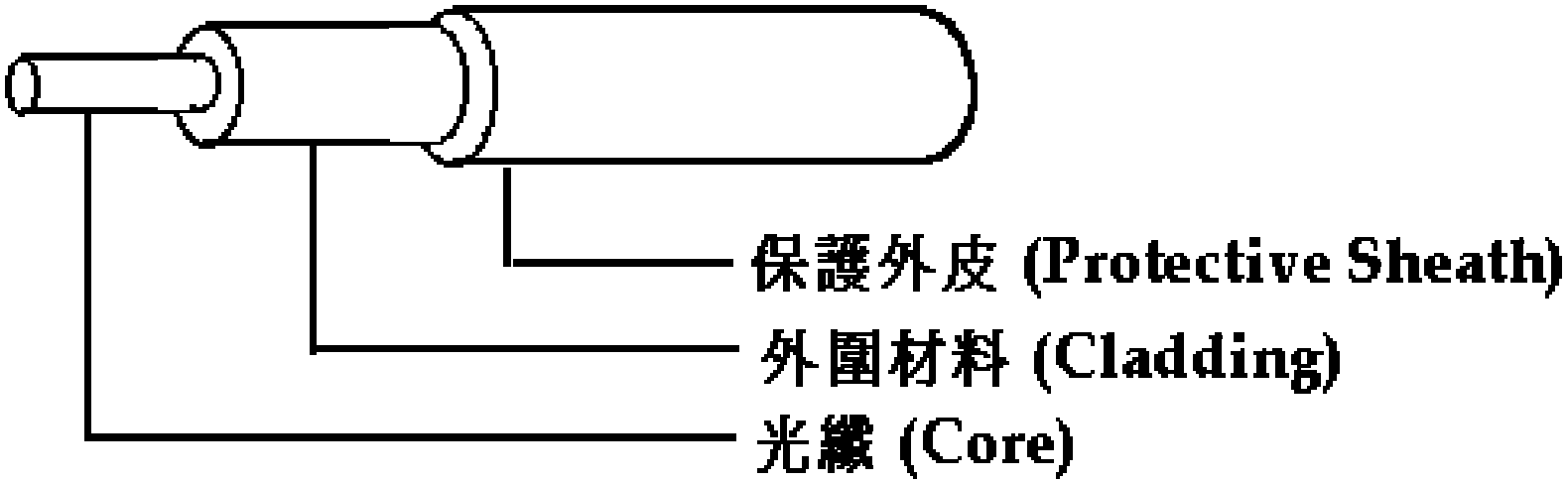
- This is the current and most widely used method of hooking Ethernet devices together
- This layout requires a central hub and wiring in a star pattern using Cat 5 Unshielded Twisted Pair wiring (UTP)
- The wiring is terminated using RJ45 connectors

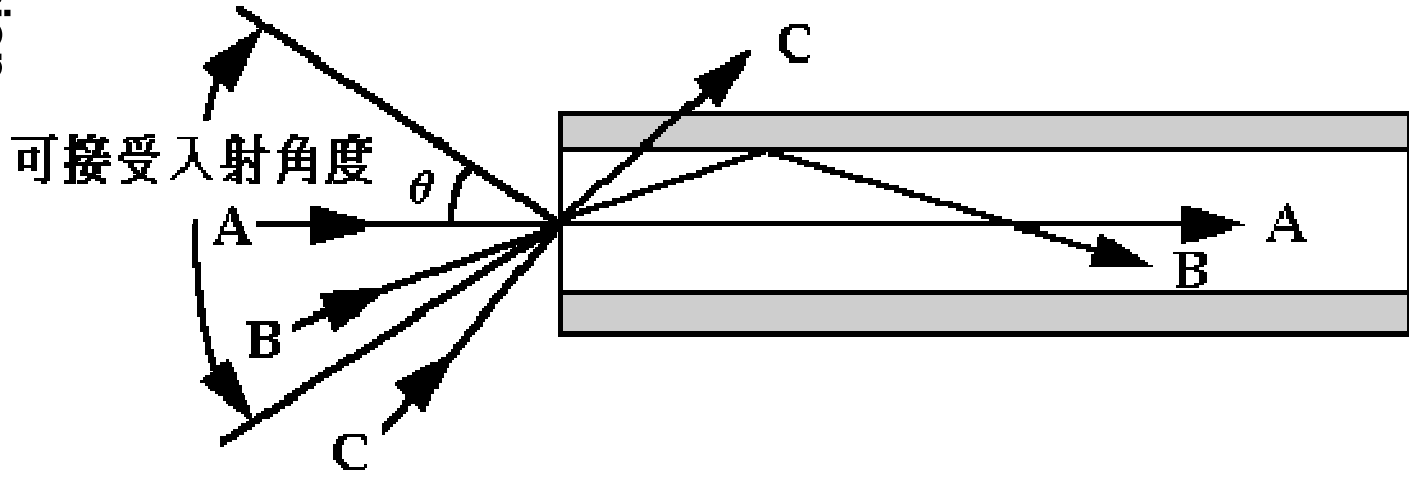
Twisted-pair
(雙絞線)





Fiber optical cable (光纖)





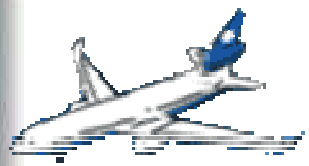
IEEE 802 Family ： 802.3? 802.11?

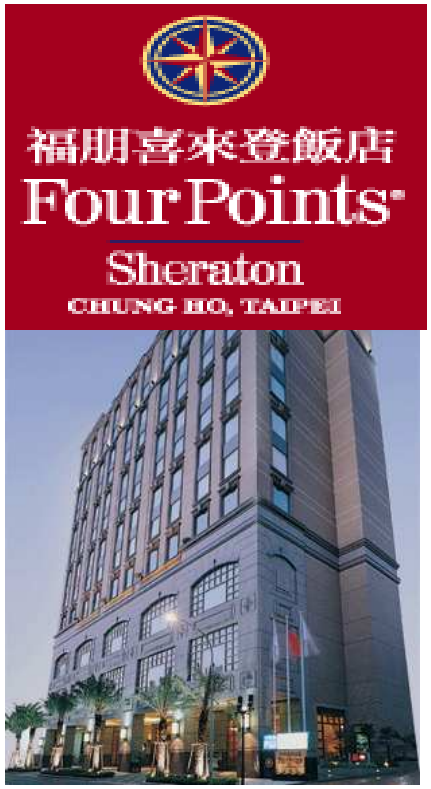
- 802.1 → 高層介面、網路互連
- 802.2 → 邏輯鏈結控制 (LLC = *Logical Link Control*)
- **802.3 → CSMA/CD 乙太網路**(Carrier-Sense Multiple Access with Collision Detection)
- 802.4 → 權杖匯流排 (Token bus) 網路，或稱記號匯流排網路
- 802.5 → 權杖環 (Token ring) 網路，也有人稱**記號環網路**
- 802.6 → 都會網路 (MAN，Metropolitan Area Network)
- 802.7 → 寬頻區域網路 (Broadband LAN)
- 802.8 → 光纖區域網路 (Fiber Optic LAN)
- 802.9 → 多媒體傳輸 (Multimedia traffic)，整合聲音與網路資料
- 802.10→ 網路保全 (Security)
- **802.11→ 無線網路 (Wireless Network)**
- 802.12→ 需求優先存取***Demand Priority***區域網路 (100BaseVG-AnyLAN)
- 802.14→ 有線電視通訊網
- **802.1x→ Port Based Network Access Control (Authentication)**

802.11 or WiFi

Wireless: Intended Use
Any Time Any Where
隨時隨地都可上網遨遊

- Wireless Internet access inside hotel lobbies, conference rooms, etc.

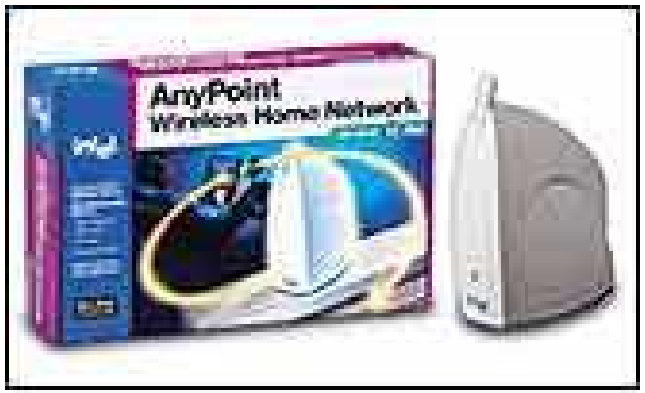




← Wireless at the Airport

- Wireless with your Latte?

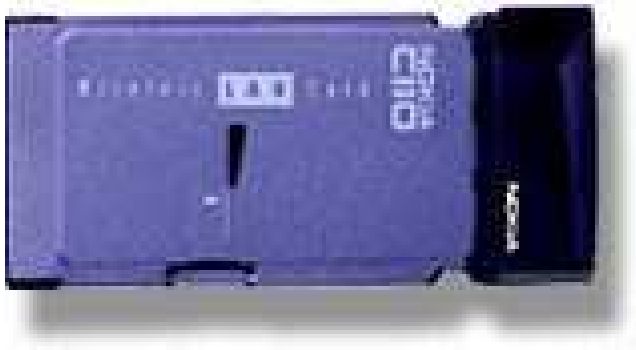
- Wireless home networking →



AnyPoint Wireless Home Network

802.11 or WiFi

Wireless LAN (Wi-Fi)



CSMA/CA

***C**arrier **S**ense **M**ultiple **A**ccess with **C**ollision **A**voidence*

- Wi-Fi 是與 Ethernet 相容的**無線**通信協定
- Wi-Fi技術代號是**IEEE 802.11**，也叫做 Wireless LAN
- 適用範圍在 50 到 150 公尺之間，
  Transmission rate 可到 11Mbps (802.11b)
  甚至到 50Mbps (802.11g, 802.11a)

http://en.wikipedia.org/wiki/Carrier_sense_multiple_access_with_collision_avoidence

Differences between IEEE 802.11?

	IEEE 802.11	IEEE 802.11b	IEEE 802.11a	IEEE 802.11g
Frequency	2.4G Hz	2.4G Hz	5 G Hz	2.4G Hz
Transmission Rate	1~2 Mbps	1~11Mbps	6~54 Mbps	22~54Mbps
Modulation Technique	FHSS/DSSS	FHSS/DSSS	OFDM	PBCC-22 + CCK-OFDM

IEEE 802.11 Work Groups (1/3)

http://grouper.ieee.org/groups/802/11/QuickGuide_IEEE_802_WG_and_Activities.htm

Group	Label	Description	Status
IEEE 802.11 Working Group	WG	The Working Group is comprised of all of the Task Groups together	
Task Group	TG	The committee(s) that are tasked by the WG as the author(s) of the Standard or subsequent Amendments	
MAC Task Group	MAC	develop one common MAC for Wireless Local Area Networks	IEEE Std. 802.11-1997
PHY Task Group	PHY	three PHY's for Wireless Local Area Networks (WLANs) applications, using Infrared (IR), 2.4 GHz Frequency Hopping Spread Spectrum (FHSS), and 2.4 GHz Direct Sequence Spread Spectrum (DSSS)	IEEE Std. 802.11-1997
Task Group a	TGa	develop a PHY to operate in the newly allocated **UNII band**	IEEE Std. 802.11a-1999

IEEE 802.11 Work Group(2/3)

Group	Label	Description	Status
Task Group b	TGb	develop a standard for a higher rate PHY in the **2.4GHz band**	IEEE Std. 802.11b-1999
Task Group b-cor1	TGb-Cor1	correct deficiencies in the MIB definition of 802.11b	Ongoing
Task Group c	TGc	add a subclause under 2.5 Support of the Internal Sub-Layer Service by specific MAC Procedures to cover bridge operation with IEEE 802.11 MACs	Part of IEEE 802.1D
Task Group d	TGd	define the physical layer requirements	Ongoing
Task Group e	TGe	Enhance the 802.11 Medium Access Control (MAC) to improve and manage Quality of Service, provide classes of service, and enhanced security and authentication mechanisms	Ongoing

IEEE 802.11 Work Group(3/3)

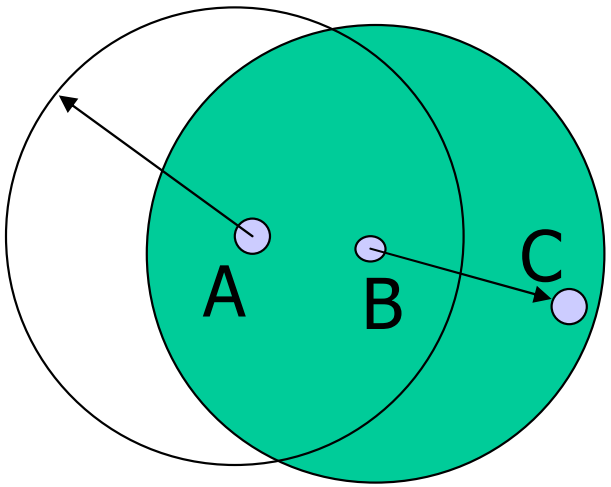
Group	Label	Description	Status
Task Group f	TGf	develop recommended practices for an Inter-Access Point Protocol (IAPP) which provides the necessary capabilities to achieve multi-vendor Access Point interoperability	Ongoing
Task Group g	TGg	**develop a higher speed(s) PHY extension to the 802.11b standard**	Ongoing
Task Group h	TGh	Enhance the 802.11 Medium Access Control (MAC) standard and 802.11a High Speed Physical Layer (PHY) in the 5GHz Band	Ongoing
Task Group i	TGi	Enhance the 802.11 Medium Access Control (MAC) to **enhance security and authentication mechanisms**	Ongoing
Study Group	SG	Investigates the interest of placing something in the Standard	

IEEE 802.11 (Wireless Ethernet)

802.11 or WiFi

- CSMA/CA
- Why can't we use regular Ethernet for wireless?
  - Ethernet: A sees B, B sees C, → A sees C
  - Wireless: Hidden node problem

    A sees B, B sees C, yet A does not see C



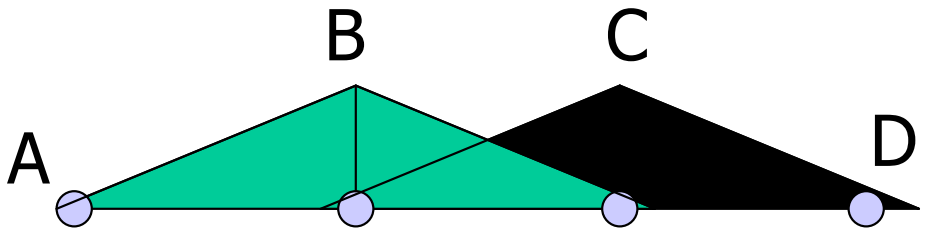
CSMA/CA

***C**arrier **S**ense **M**ultiple **A**ccess*
*with **C**ollision **A**voidence*

IEEE 802.11 (Wireless Ethernet) vs. Ethernet

802.11 or WiFi

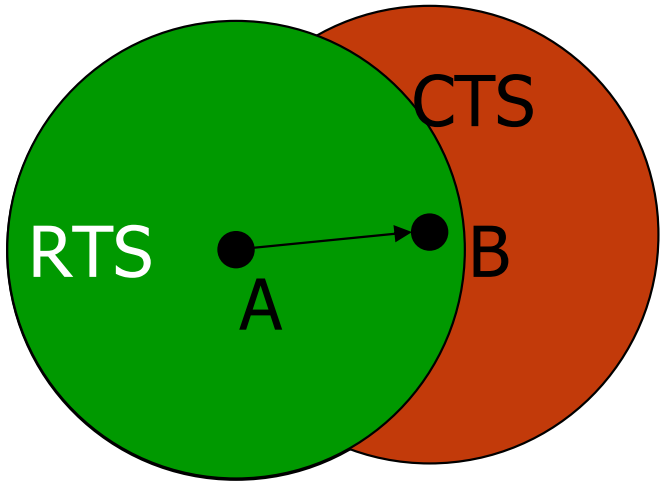
- Why can't we use regular Ethernet for wireless?
  - Ethernet: B sees C, C sees D → B & C can't send together
  - Wireless: B can send to A while C sends to D



802.11 transmission Protocol

802.11 or WiFi

- Sender A sends Request-to-Send (RTS)
- Receiver B sends Clear-to-Send (CTS)
  - Nodes who hear **CTS cannot** transmit concurrently with A (red region)
  - **Nodes who hear RTS but not CTS can transmit (green region)**
- Sender A sends data frame
- Receiver B sends ACK
- Nodes who hear the ACK can now transmit



http://en.wikipedia.org/wiki/Carrier_sense_multiple_access_with_collision_avoidence

802.11 Collision Resolution

MAC Layer：CSMA/CA

- Two senders might send RTS at the same time
- Collision will occur corrupting the data
- No CTS will follow
- Senders will time-out waiting for CTS and retry with exponential backoff

Carrier Sense Multiple Access /Collision Avoidance

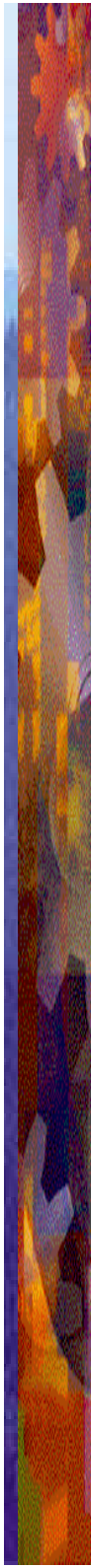
RTS: Request-to-Send

CTS: Clear-to-Send

Status of IEEE 802.11i

http://grouper.ieee.org/groups/802/11/Reports/tgi_update.htm

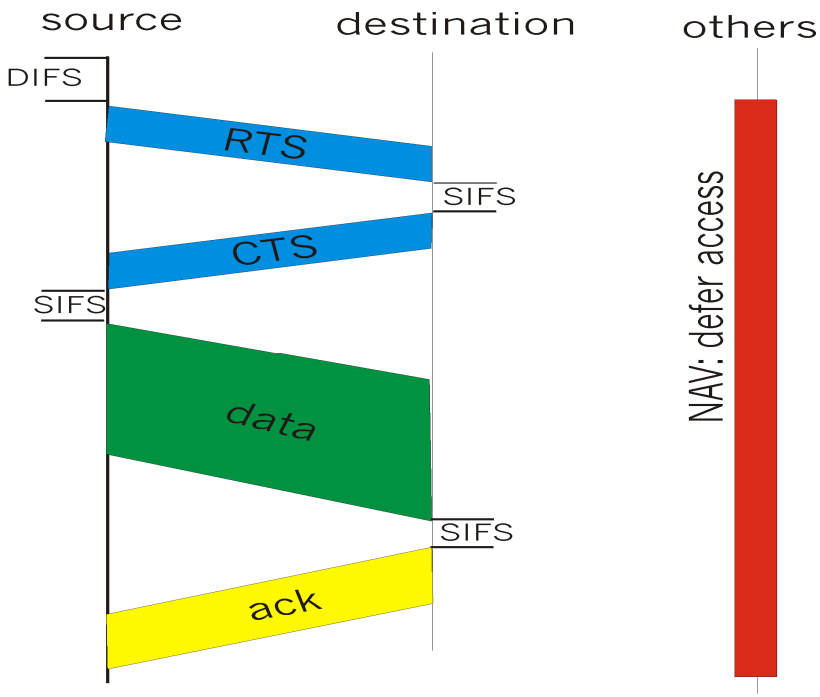
- 2002/2 – preparing TGi draft
- Used to improve the **network security**
- WEP2 – Increases IV spaces to 128Bits.
- Kerberos
- **802.1X Authentication**



Collision Avoidance: RTS-CTS exchange

802.11 or WiFi

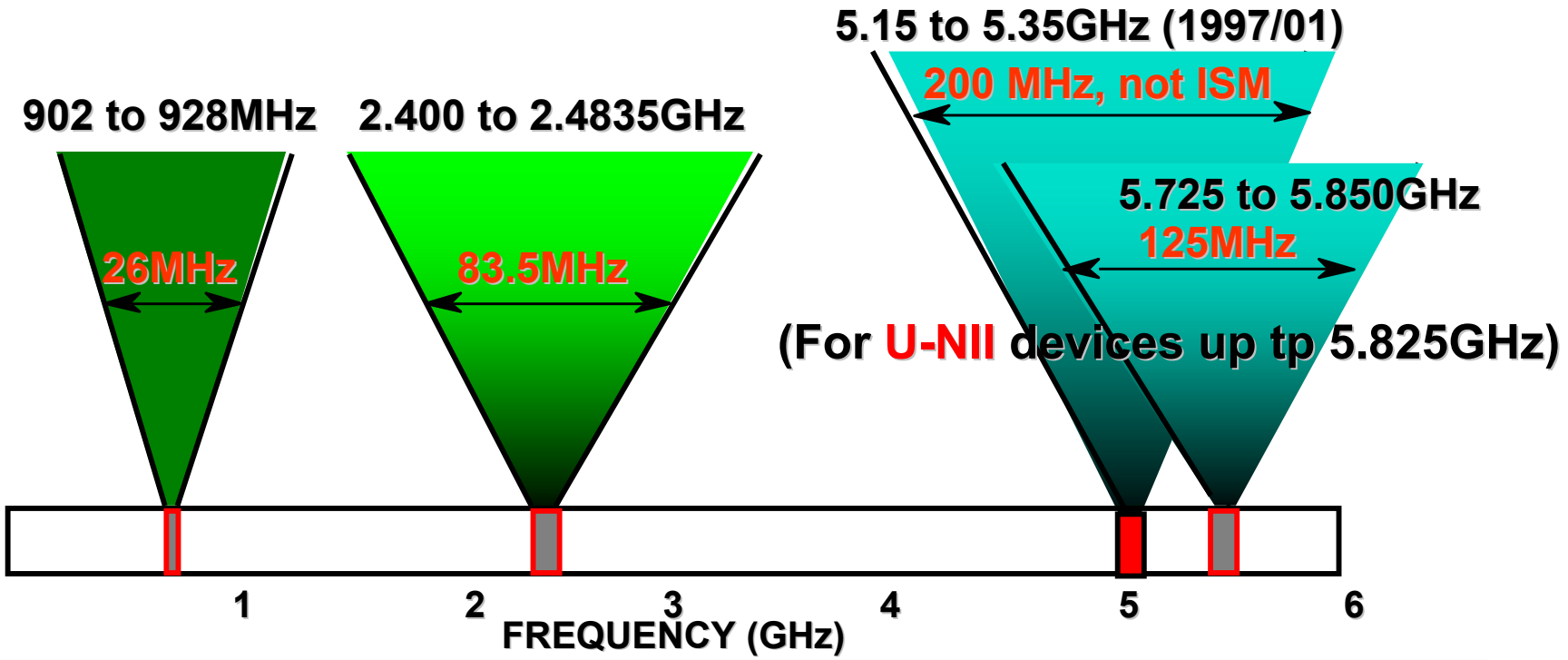
- **CTS "freezes" stations within range of receiver (but possibly hidden from transmitter); this prevents collisions by hidden station during data**
- **RTS and CTS are very short: collisions during data phase are thus very unlikely (the end result is similar to Collision Detection)**



Note: IEEE 802.11 allows CSMA, CSMA/CA and "polling" from AP

Industrial, Scientific and Medical (ISM) Bands

http://www.fcc.gov/Bureaus/Engineering_Technology/Orders/1997/fcc97005.pdf



- UNLICENSED OPERATION GOVERNED BY FCC DOCUMENT 15.247, PART 15
- SPREAD SPECTRUM ALLOWED TO MINIMIZE INTERFERENCE
- 2.4GHz ISM BAND
  - More Bandwidth to Support Higher Data Rates and Number of Channels
  - Available Worldwide
  - Good Balance of Equipment Performance and Cost Compared with 5.725GHz Band
  - IEEE 802.11 Global WLAN Standard

UNII band : Unlicensed National Information Infrastructure band

AP96358 3-4

Channel allocation for 802.11b

每channel佔22MHz, 但只隔5MHz

Ch1: 2.401 ~ **2.412GHz** ~ 2.423GHz

Ch2: 2.406 ~ **2.417GHz** ~ 2.428GHz

Ch3: 2.411 ~ **2.422GHz** ~ 2.433GHz

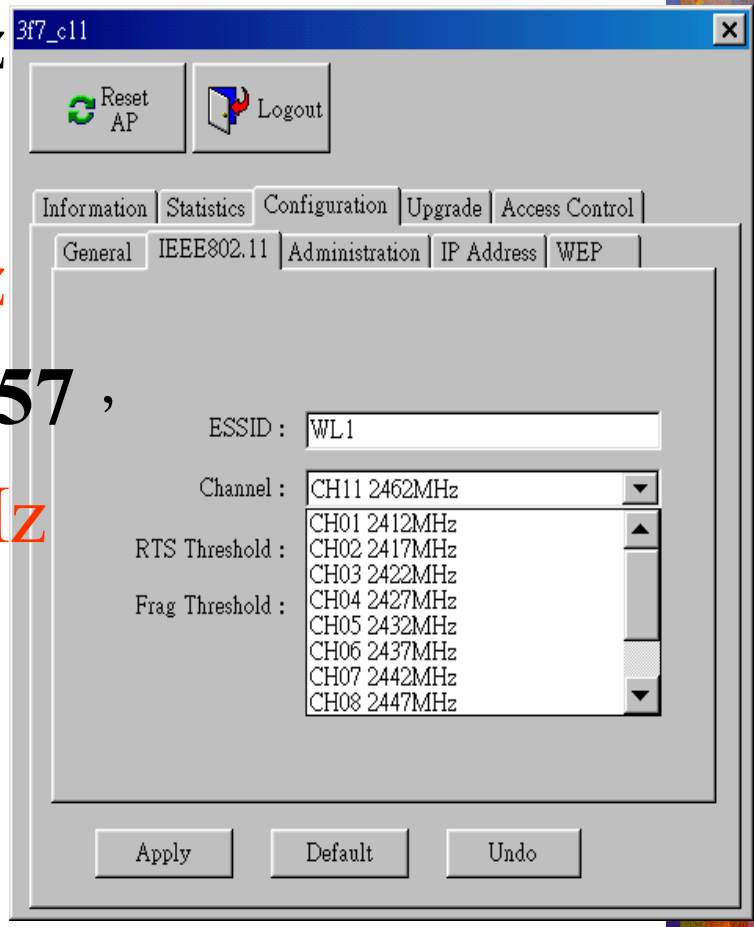
2.427GHz， **2.432GHz**

Ch6: 2.426 ~ **2.437GHz** ~ 2.448GHz

2.442， **2.447**， **2.452**， **2.457**，

- Ch11: 2.451 ~ **2.462GHz** ~ 2.473GHz

歐洲 ~ ch 13, 日本 ~ ch14



tsaiwn@csie.nctu.edu.tw

The Frequencies of Various Wireless Media

Ultraviolet : 0.75P ~30PHz ; 10nm ~ 400nm
Infrared light : 1T~430THz; 0.7~300micrometers

Frequency (H_z)

10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}

X rays, gamma rays
Ultraviolet light
Visible light
Infrared light

紫外線

紅外線

Millimeter waves

Microwaves
UHF television
VHF television
VHF TV (high band)
FM radio
VHF TV (low band)
Short-wave radio
AM radio

毫米波

Very Low Frequency

微波

極超高頻 SHF Super High Frequency, 頻率範圍 3GHz~30GHz.

超高頻 UHF Ultra High Frequency, 頻率範圍 300MHz~3000MHz.

極高頻 VHF Very High Frequency, 頻率範圍 30MHz~300MHz.

高頻HF High Frequency, 頻率範圍 3MHz~30MHz.

Electromagnetic Spectrum

waveLength * frequency = Light Speed = 299,792,458 m/second ($3*10^8$米/秒)

- γ =Gamma rays
- HX = Hard X-Rays
- SX = Soft X-Rays
- EUV = Extreme UltraViolet
- NUV = Near UltraViolet
- NIR = Near Infrared
- MIR = Mid Infrared
- FIR = Far Infrared
- EHF= Extremely High Freq.
- SHF= Super High Freq.
- UHF= Ultra High Freq.
- VHF= Very High Freq
- High / Medium / Low Freq.
- VLF= Very Low Frequency
- VF/ULF= Voice Frequency
- SLF= Super Low Frequency
- ELF= Extremely low freq.

FREQUENCY	WAVELENGTH	ENERGY
300 EHz	1 pm	1.24 MeV
30 EHz	10 pm	124 keV
3 EHz	100 pm	12.4 keV
300 PHz	1 nm	1.24 keV
30 PHz	10 nm	124 eV
3 PHz	100 nm	12.4 eV
300 THz	1 μm	1.24 eV
30 THz	10 μm	124 meV
3 THz	100 μm	12.4 meV
300 GHz	1 mm	1.24 meV
30 GHz	1 cm	124 μeV
3 GHz	1 dm	12.4 μeV
300 MHz	1 m	1.24 μeV
30 MHz	10 m	124 neV
3 MHz	100 m	12.4 neV
300 kHz	1 km	1.24 neV
30 kHz	10 km	124 peV
3 kHz	100 km	12.4 peV
300 Hz	1 Mm	1.24 peV
30 Hz	10 Mm	124 feV
3 Hz	100 Mm	12.4 feV

Source: http://en.wikipedia.org

Channel assignment

802.11 or WiFi

三樓

Ch11

Ch 1

Ch6

二樓

Ch6

Ch11

Ch 1

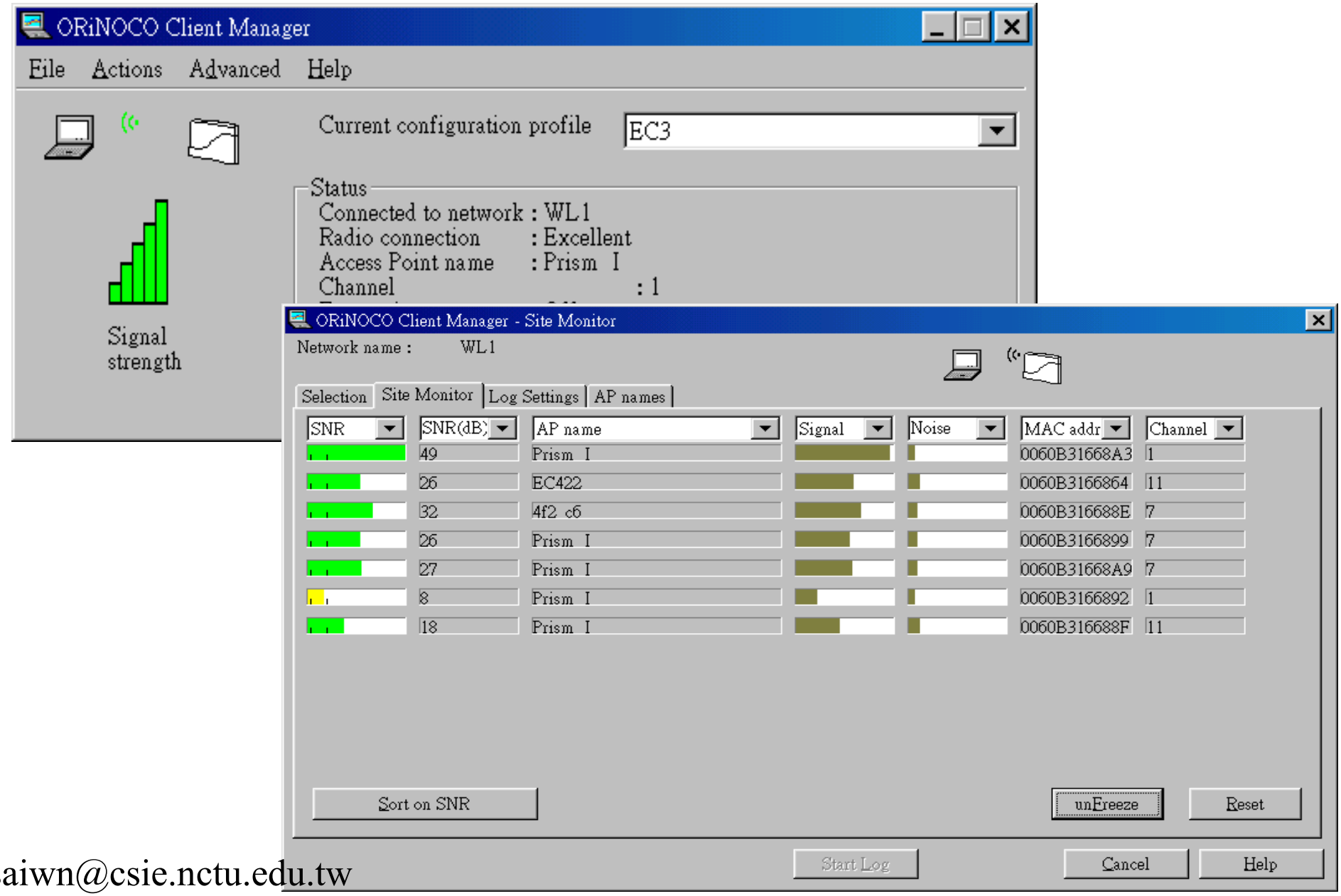
一樓

Ch 1

Ch6

Ch11

Wireless Signal /Noise Ratio (S/N Ratio)

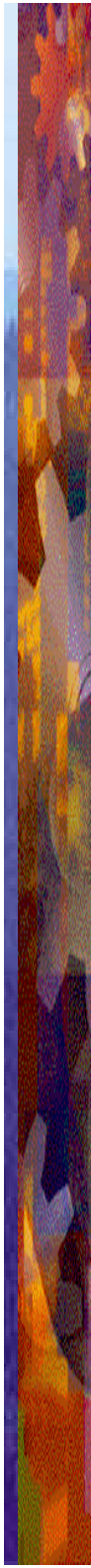


tsaiwn@csie.nctu.edu.tw

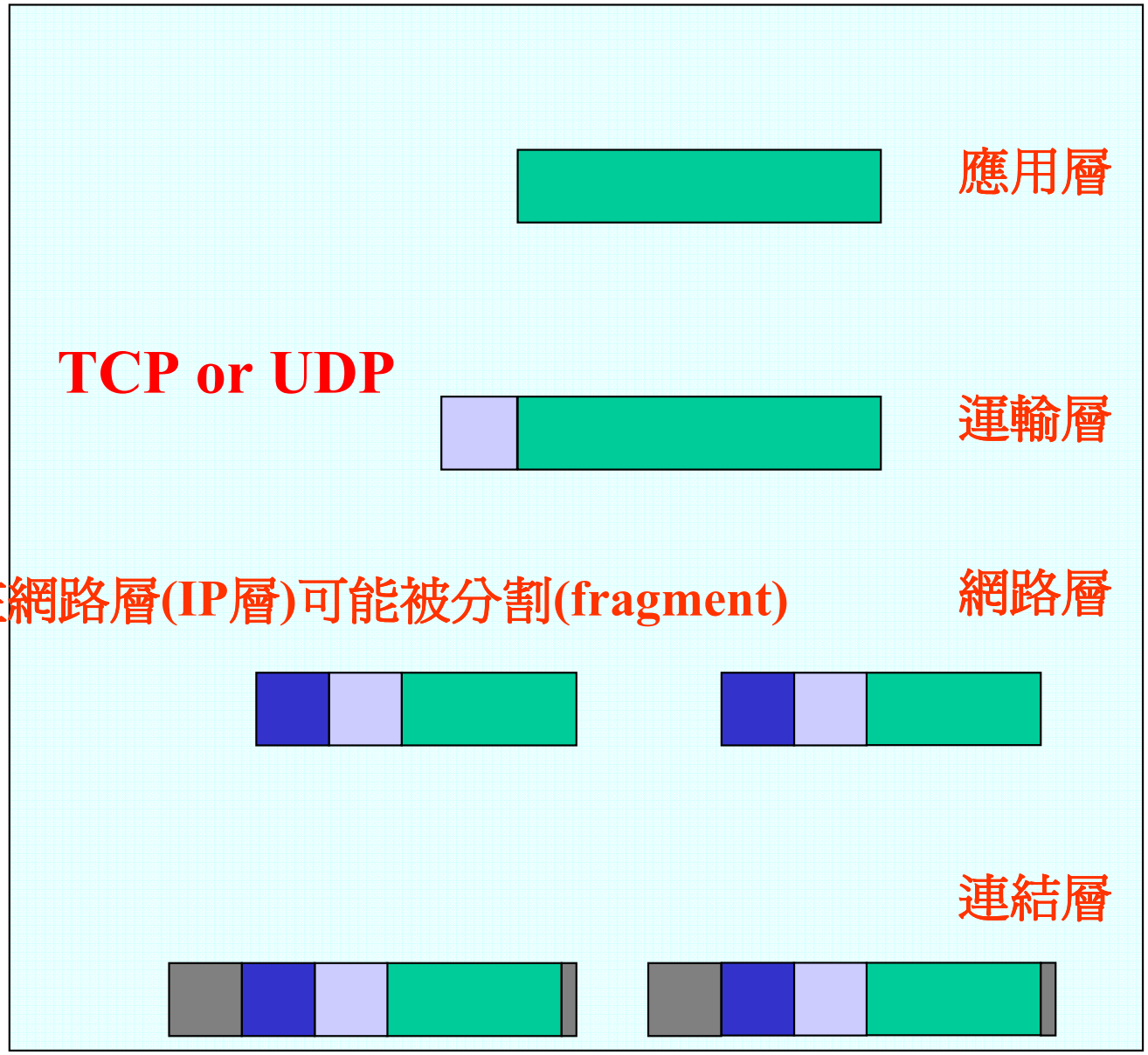
Layers for Receiving Messages

- Roughly that of reversing the task performed by their counterparts at the message's origin
- Strips off the outer wrapping placed by their counterparts and hands the underlying packets to its upper layer

- 分工合作, 分層負責



Wrapping up Messages in TCP/IP



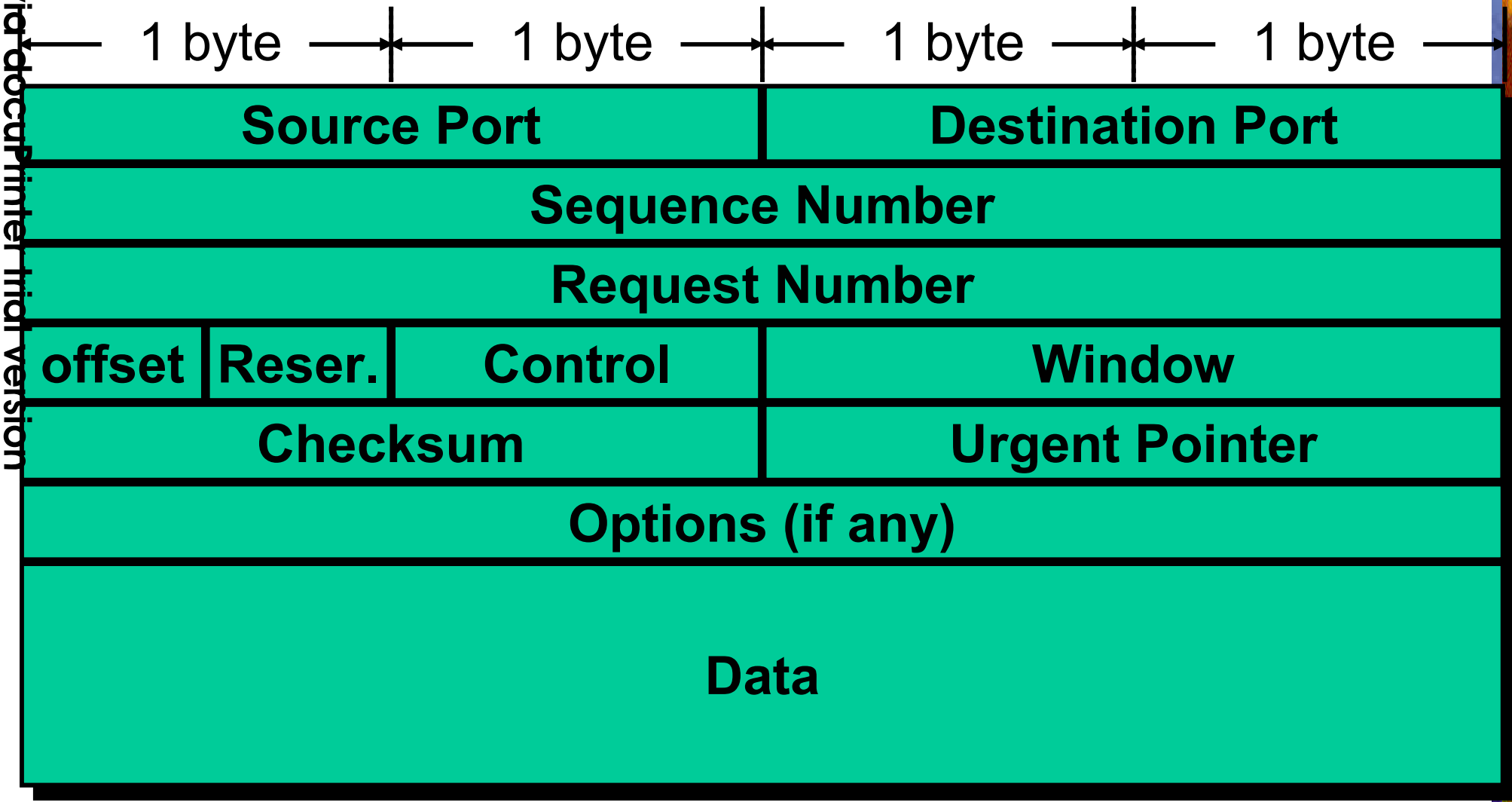
Application Layer

Transport Layer

Network Layer

Link Layer

TCP Segment Format



UDP (User Datagram Protocol)

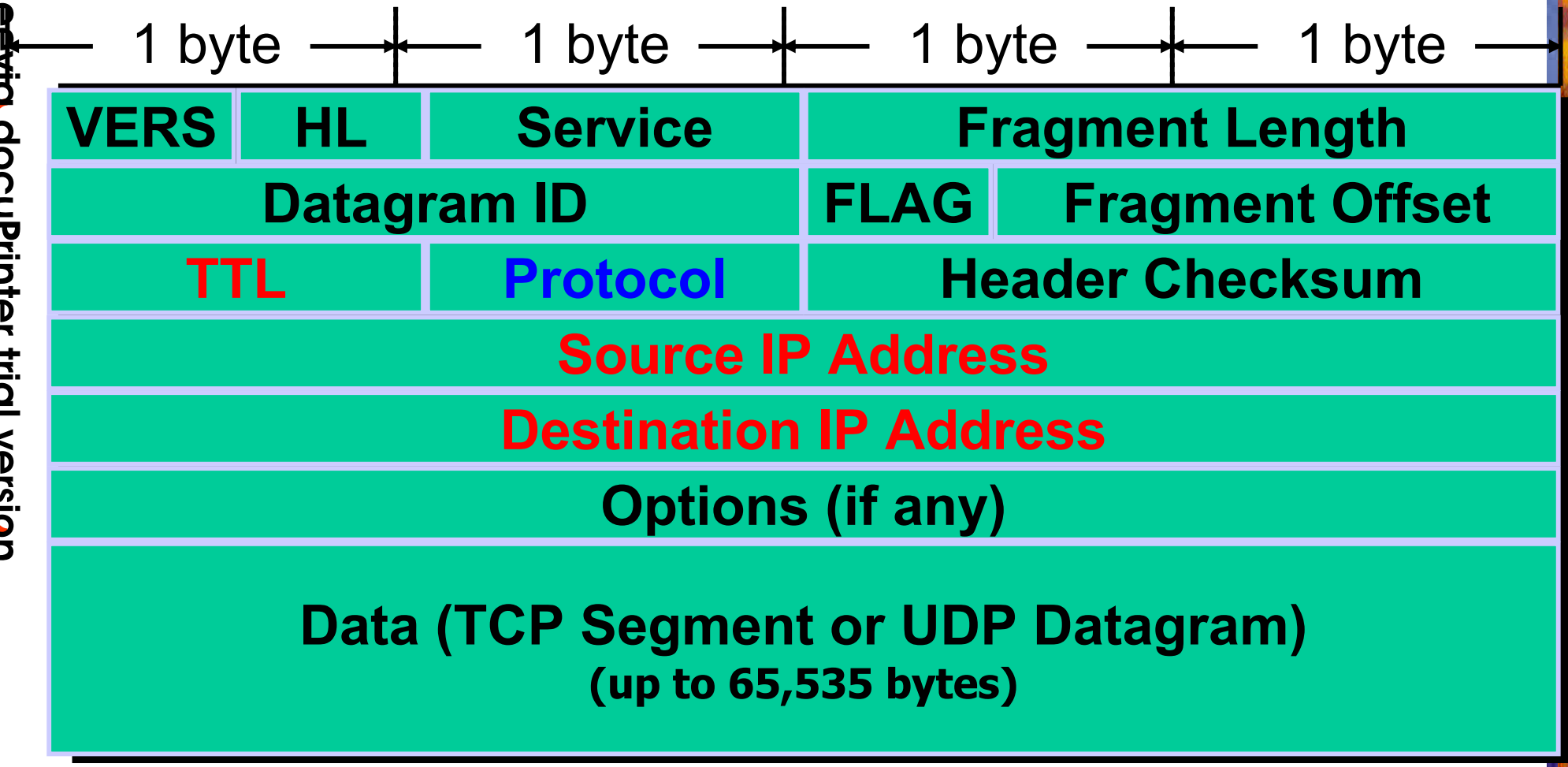
Datagram Delivery
Connectionless
Unreliable
Minimal

- UDP is a transport layer protocol
  - communication between processes
- UDP uses IP to deliver **datagrams** to the right host.

UDP **Datagram** Format

Source Port	Destination Port
Length	Checksum
Data	

IP Datagram (Frame type = 0x0800)



IP datagram is encapsulated in an Ethernet frame

Ethernet Frame Structure

Octet 就是 8-bit 的 Byte

網路卡

Sending **adapter** encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame :

Preamble	*Destination Address*	*Source Address*	*Frame Type*	*Frame Data*	*CRC*
8 octets	6 octets	6 octets	2 octets	46-1500 octets	4 octets

先填對方的 MAC address

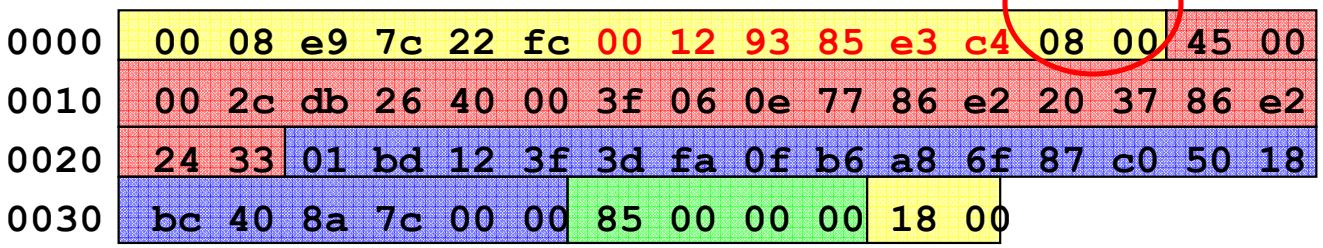
(0800 表示 IP datagram)

Preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern **10101011**
- used to synchronize receiver, sender clock rates

Ether Frame Protocol Headers

Frame type = **0x0800** = **IP Datagram**



Ethernet header:

Dest addr: **00 08 e9 7c 22 fc**

Src addr: **00 12 93 85 e3 c4**

frame type: **08 00**

IP Header:
src addr: 134.226.36.55
dest addr: 134.226.36.51

TCP Header:
src port: 445
dest port: 4671

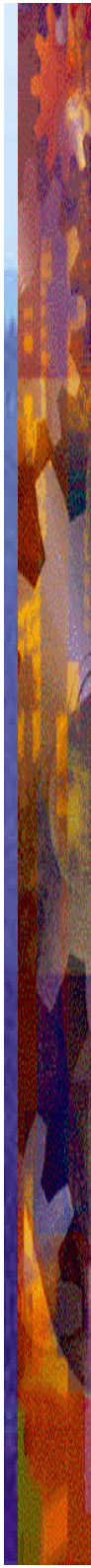
NetBios Information

Header Information (56 bytes)

Payload (4 bytes)

Network traffic (packet) analyzer

- WireShark (EtherReal)
- Kismet
- Tcpdump (and Libpcap)
- Cain and Abel
- Ettercap
- Dsniff
- NetStumbler
- Sniffer / NetXray (Sniffer Pro)



IP Datagram 分類 (看**protocol** byte)

```
Ip      0  IP # internet protocol, pseudo protocol number
icmp  1  ICMP # internet control message protocol
Igmp  2  IGMP # Internet Group Management
ggp    3 GGP # gateway-gateway protocol
ipencap 4 IP-ENCAP # IP encapsulated in IP (officially ``IP")
st      5  ST # ST datagram mode
Tcp   6  TCP # transmission control protocol
egp  8  EGP # exterior gateway protocol
pup 12  PUP # PARC universal packet protocol
udp 17  UDP # user datagram protocol
hmp 20  HMP # host monitoring protocol
xns-idp 22  XNS-IDP # Xerox NS IDP
rdp   27 RDP # "reliable datagram" protocol
iso-tp4 29  ISO-TP4 # ISO Transport Protocol class 4
xtp  36  XTP # Xpress Tranfer Protocol
ddp 37  DDP # Datagram Delivery Protocol
idpr-cmtp 39 IDPR-CMTP # IDPR Control Message Transport
rspf  73 RSPF #Radio Shortest Path First.
vmtp  81 VMTP # Versatile Message Transport
ospf  89 OSPFIGP # Open Shortest Path First IGP
ipip   94 IPIP # Yet Another IP encapsulation
encap 98 ENCAP # Yet Another IP encapsulation
```

IP: Internet Protocol

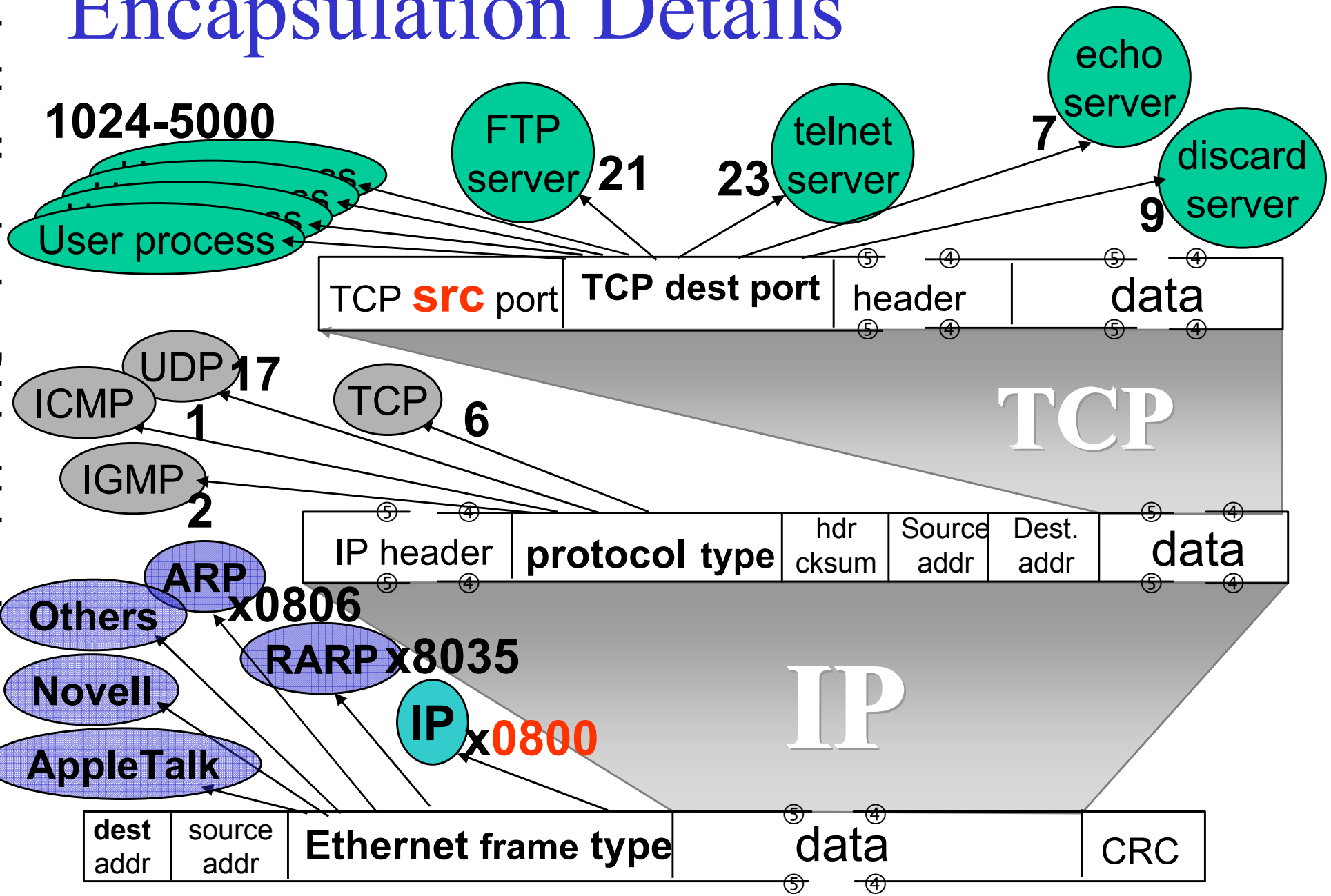
- IP Header: 20 ~ 60 bytes
  - Frame type = **0x0800**
  - TOS, identification, flags, TTL, **protocol**, options, …
- IP Routing
  - routing table
- Subnetting, CIDR, and netmask
- Private IP addresses
  - 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16
- Related Commands:
  - ifconfig, netstat, route
    - **netstat –r**
    - **route print**

Classless Inter-Domain Routing

什麼意思?

試一試以上這些 command

Encapsulation Details



(Ethernet Frame types in hex, others in decimal)

ARP: Address Resolution Protocol

- ARP (RFC826): frame type = **0x0806**
- ARP cache

```
% arp -a
ccsun1 (140.113.209.101) at 0:40:45:0:4:38
ccsun2 (140.113.209.102) at 0:40:45:0:7:4
? (140.113.209.203) at (incomplete)
e3rtn-209 (140.113.209.254) at 0:20:9c:8:e9:d
```

- ARP packet format: 28 bytes
  - hardware addr type/size, protocol addr type/size
  - op field (1, 2, 3, 4)
- Proxy ARP ?
- Gratuitous ARP ?

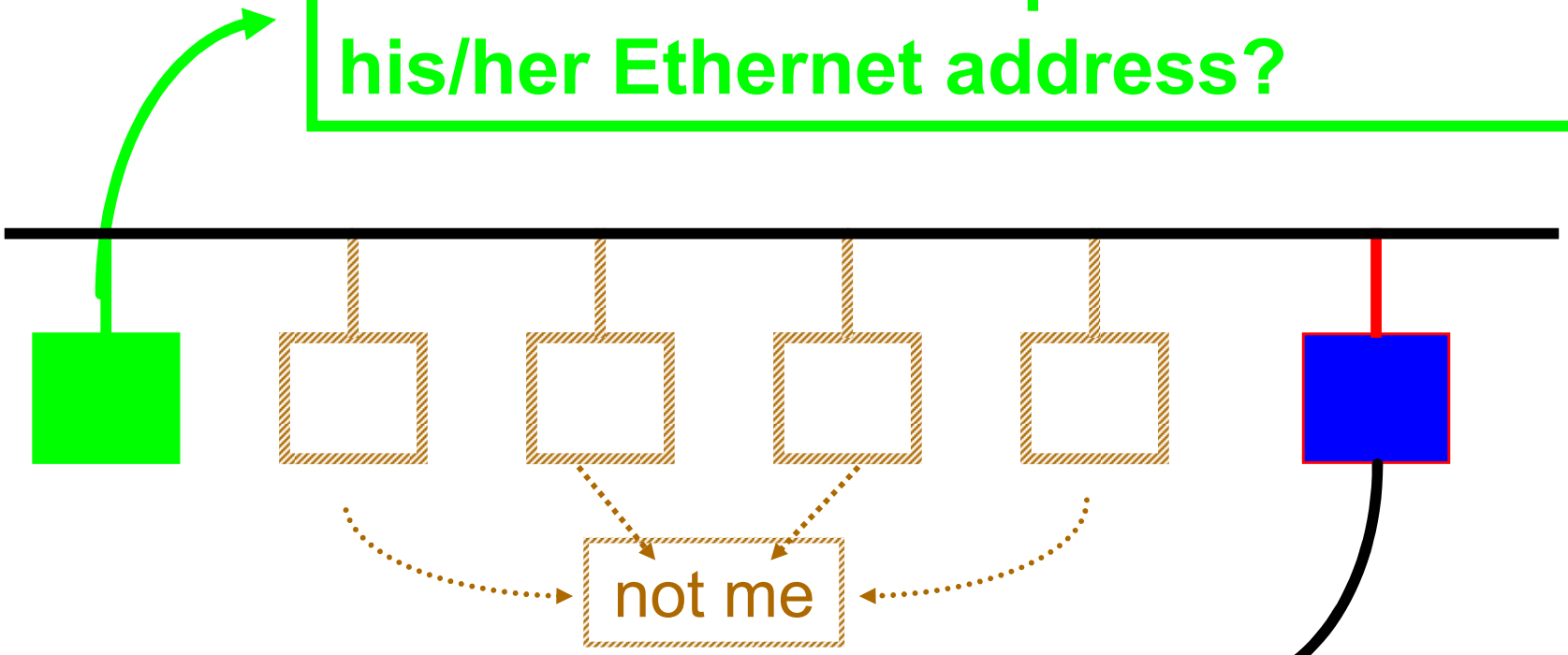
tcpdump -ntex arp

RARP: Reverse ARP

- RARP (RFC903): frame type = **0x8035**
  - For diskless system
- rarpd, /etc/ethers
- RARP server design
  - System dependent and complex
  - RARP servers as user processes
    - Must have some way of sending and receiving ethernet frames
  - Multiple RARP servers per network
    - Network traffic
    - Collision rate

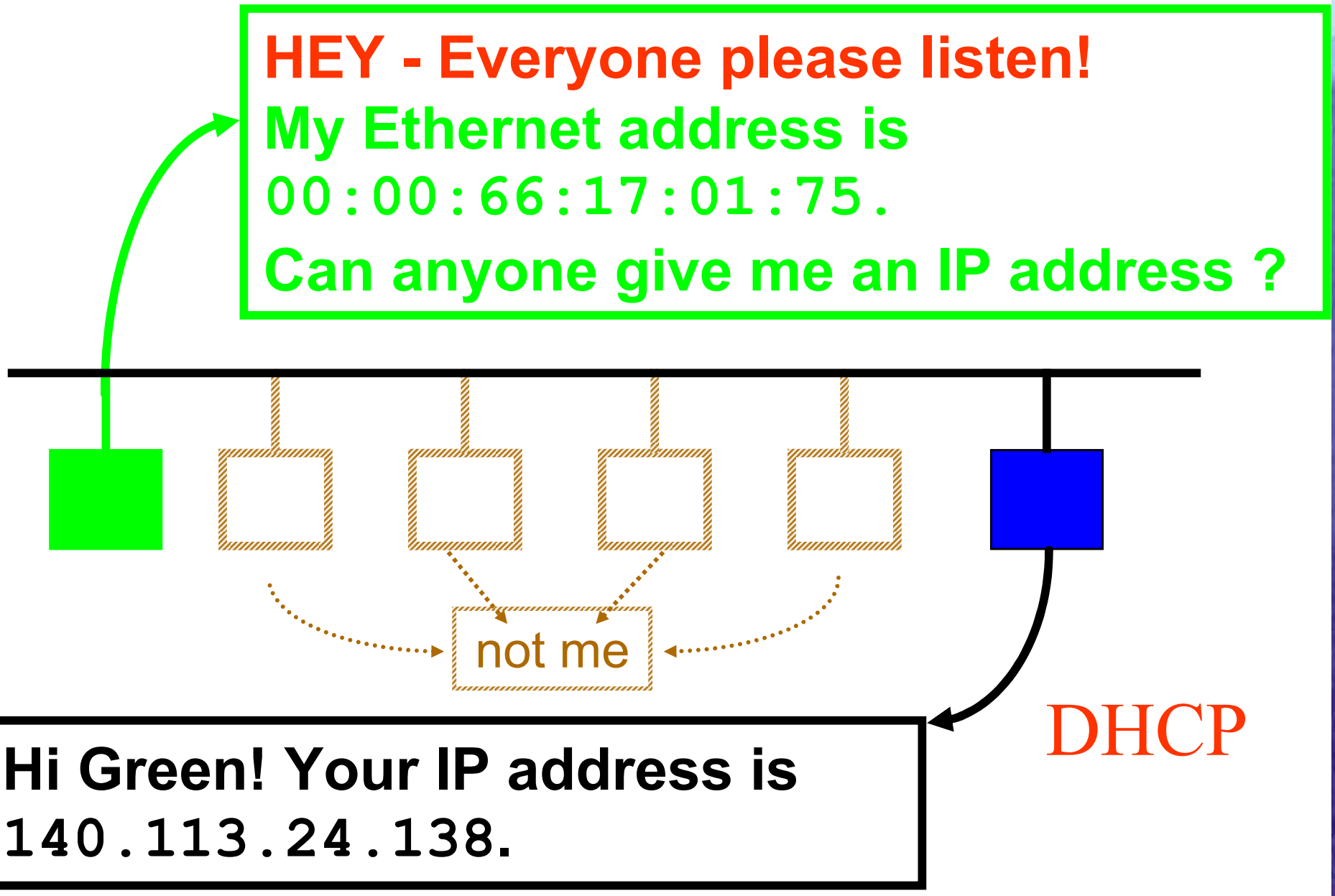
ARP conversation

HEY - Everyone please listen!
Will `140.113.1.5` please send me his/her Ethernet address?



Hi Green! I'm 140.113.1.5, and my Ethernet address is `00:0D:15:35:02:C3`

RARP conversation

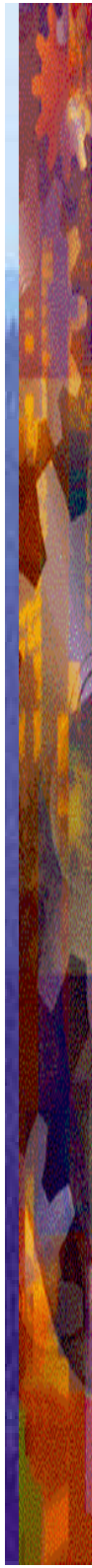


ICMP: Internet Control Message Protocol

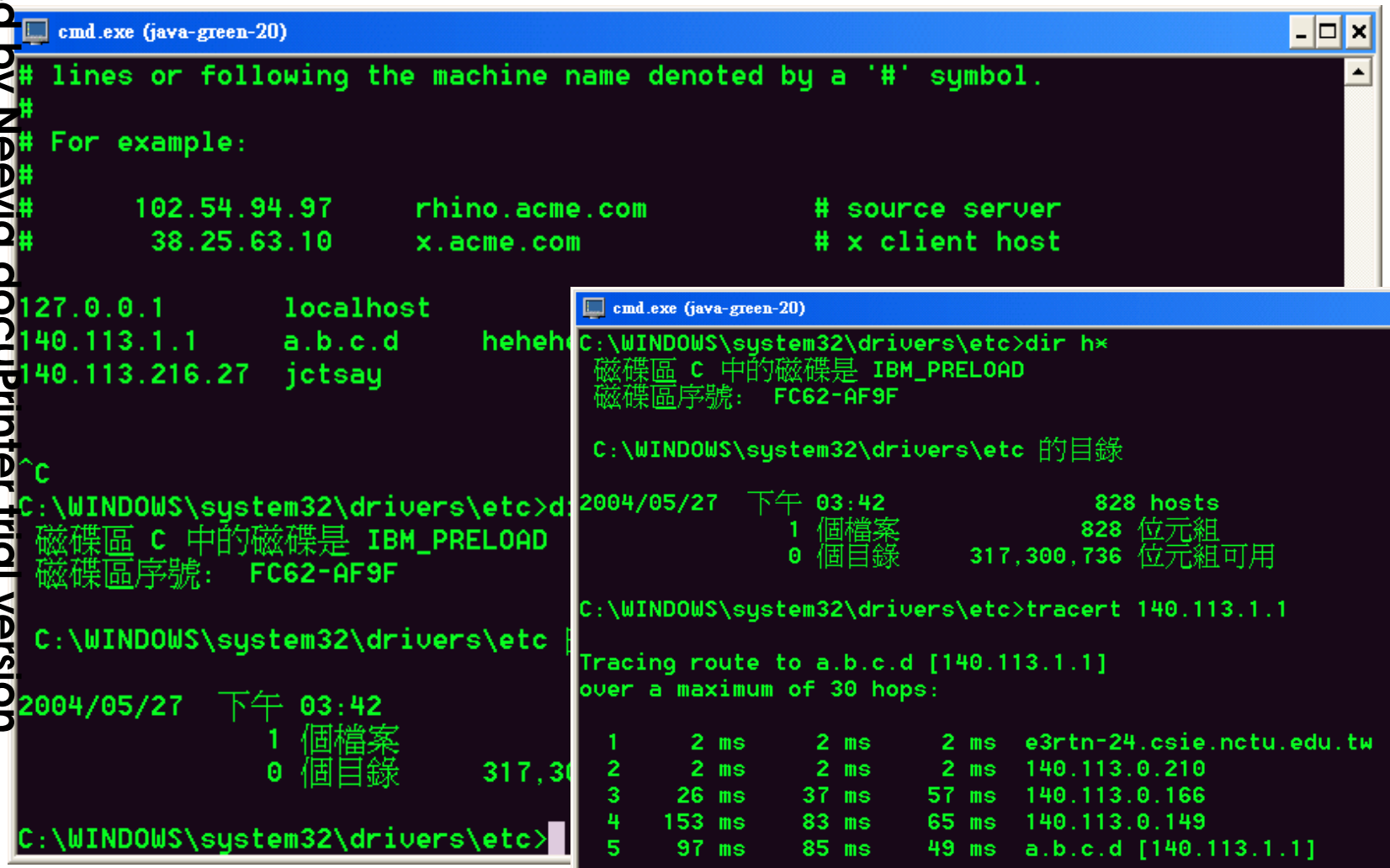
- ICMP message format
  - 15 types and various codes for each type
- An ICMP error message always contains
  - IP header
  - the first 8 bytes of the IP datagram
- An ICMP error message is never generated in respond to
  - An ICMP error message
  - A datagram destined to an IP multicast/broadcast message
  - A link-layer broadcast message
  - A fragment other than the first
  - A datagram whose source address does not define a single host

ICMP (cont.)

- ICMP Types:
  - ICMP Address Mask Request and Reply (type 17, 18)
    - Subnet mask
  - ICMP Timestamp Request and Reply (type 13, 14)
    - orig timestamp, recv timestamp, xmit timstamp
    - Calculating the clock difference
  - ICMP Destination Unreachable (type 3, code 0~15)
    - Network unreachable (code 0)
    - Host unreachable (code 1)
    - Port unreachable (code 3)
    - Source route failed (code 5)



tracert （traceroute)（或也有系統用 tr）



利用封包中的 **TTL**

tracert 140.113.1.1

Public vs. Private IP (公共 IP與私有 IP) 1/2

- ✓ 公共 **IP(Public IP)**
  - 當我們要將網路連上 Intetnet 的時候，我們必須先註冊好 Net ID，如果該 ID 已經被使用了，您就必須選用另外的 ID 了。負責 Internet IP 註冊的機構叫做 InterNIC (Network Information Center)，他們的網路位址是 http://www.internic.net。不過，實際上的運作，一般機構或個人是不太可能直接從 InterNIC 上註冊 IP 的，而是經您的 ISP 分配下來。這些經過合法授權使用的 IP ，我們稱之爲 **公共 IP(Public IP)** 。
- ✓ 私有IP位址 (Private IP address)
  - ➢ 由於 Internet 的爆炸性成長，IP 的位址越來越少，而且在很多機構裡，也不是所有機器都有必要使用註冊的 IP 位址。於是，我們就在 A、B、C 這三個class裡面，各劃出一些位址範圍保留給私有位址所用，它們分別是：
    - **10.0.0.0 - 10.255.255.255 (Class A)**
    - **172.16.0.0 - 172.31.255.255 (Class B)**
    - **192.168.0.0 - 192.168.255.255 (Class C)**
  - ➢ 這些無需註冊就能自由使用的 IP ，我們稱之爲 **私有 IP(Private IP)**。

Public vs. Private IP (公共 IP與私有 IP) 2/2

✓ Private IP 之封包在網路上的限制

- 10.0.0.0 - 10.255.255.255 (Class A)
- 172.16.0.0 - 172.31.255.255 (Class B)
- 192.168.0.0 - 192.168.255.255 (Class C)

- 當您使用這些private位址的時候，當然是有所限制的：
  - ➢ 私有位址的路由資訊不能對外散播
  - ➢ 使用私有位址作爲來源或目的位址的封包，不能透過 Internet 來轉送
  - ➢ 關於私有位址的參考紀錄，只能限於內部網路使用

✓ 正是由於這些限制，當我們使用這些私有位址來設定網路的時候，就無需擔心會和其它也使用相同位址的網路衝突。

✓ 那這些使用 private IP 的電腦如何與外界機器溝通?

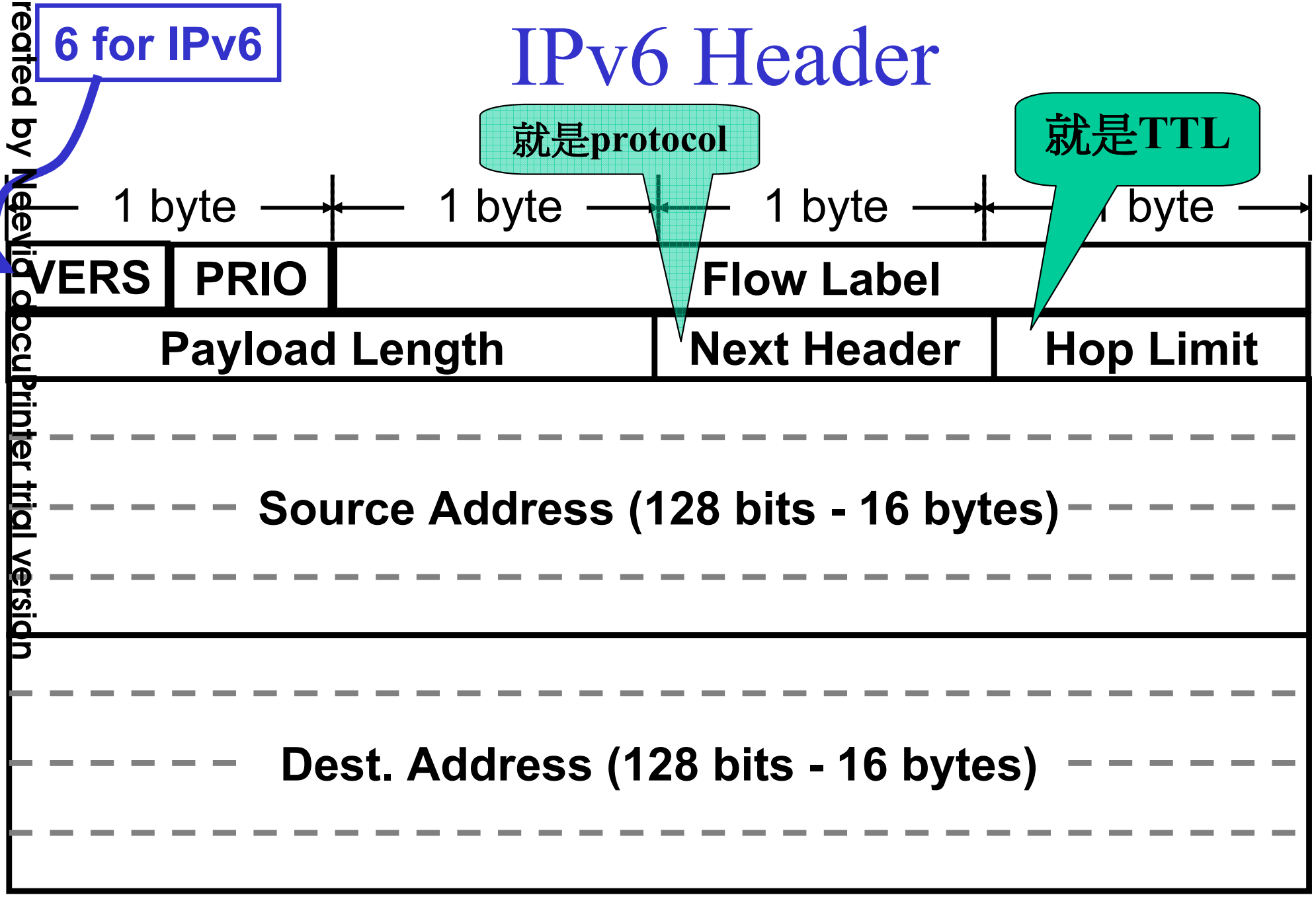
➢ NAT --- Network Address Translation

NAT？ 寬頻分享器?

IPv6 (IPng =下 一 代 IPnext generation)

- 1992 年 6 月 IETF發 啓 IPng提 議 徵 文
- 1995 年 1 月 RFC 1752, "The Recommendation for the IPNext Generation Protocol"
- **IPv6 實 驗 網 路(6Bone)**
  - 爲 了 在 Internet 上 推 廣 IPv6 的 一 個 全 球 性 IPv6 測 試 平 臺
  - 1997 年 6月 開 始 運 作

IPv6 Header



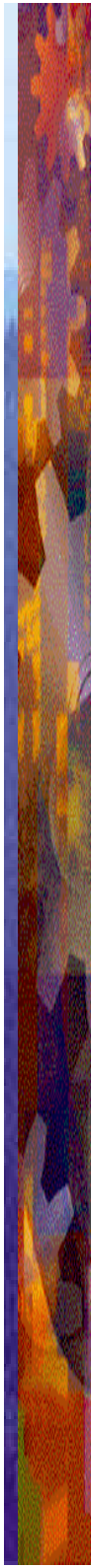
Determining the Application that Should Accept the Message

- Assign unique **port numbers** to various application units
- Require that an application sending a message append the appropriate port number to the message's address
- Some universally accepted **port** numbers
  - HTTP server: 80
  - FTP server: 21
  - Telnet server: 23

WAN

- **W**ide **A**rea **N**etwork
- A large number (usually) of connected computers spreading across a wide area

- Connecting LANs
  - A LAN connects to a WAN via a router
- Irregular

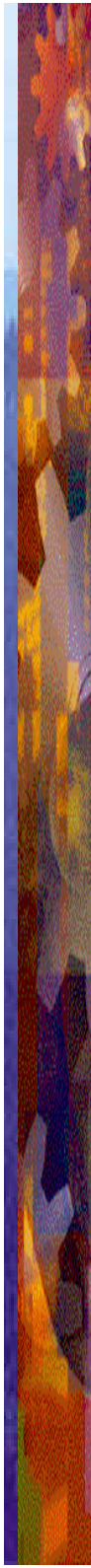


Routing

– How to get the data to go where you want them to be?

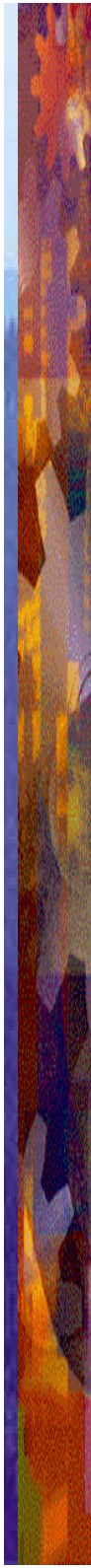
Router 路由器

– Finding a route from the source to the destination



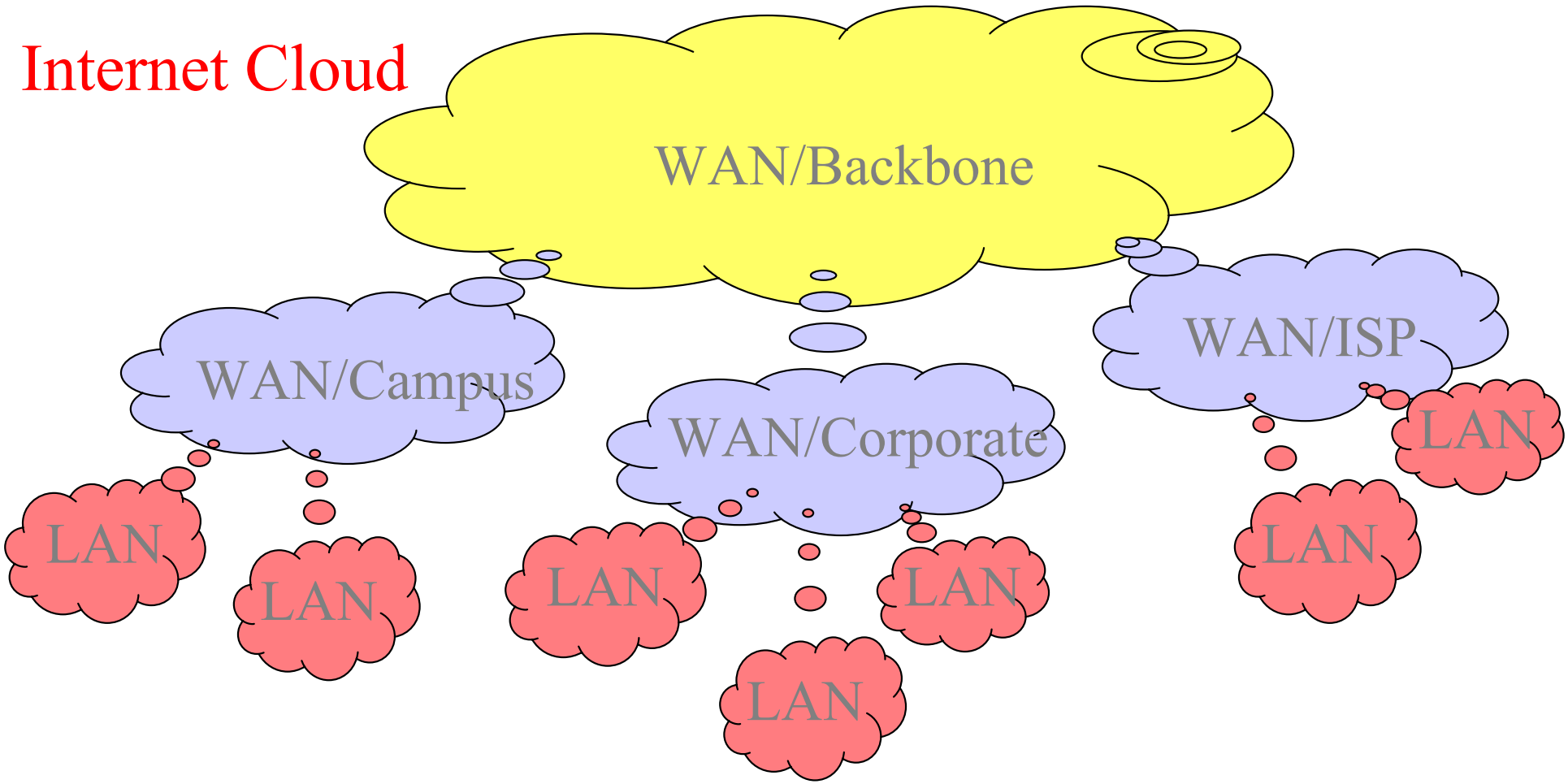
IP Routing (IP 封包繞送)

- Internet Protocol Routing
- The class of protocols that handle routing problems
- Example
  - RIP (IETF RFC 1058)
  - BGP (IETF RFC 1771)
  - **OSPF (IETF RFC 2328)**



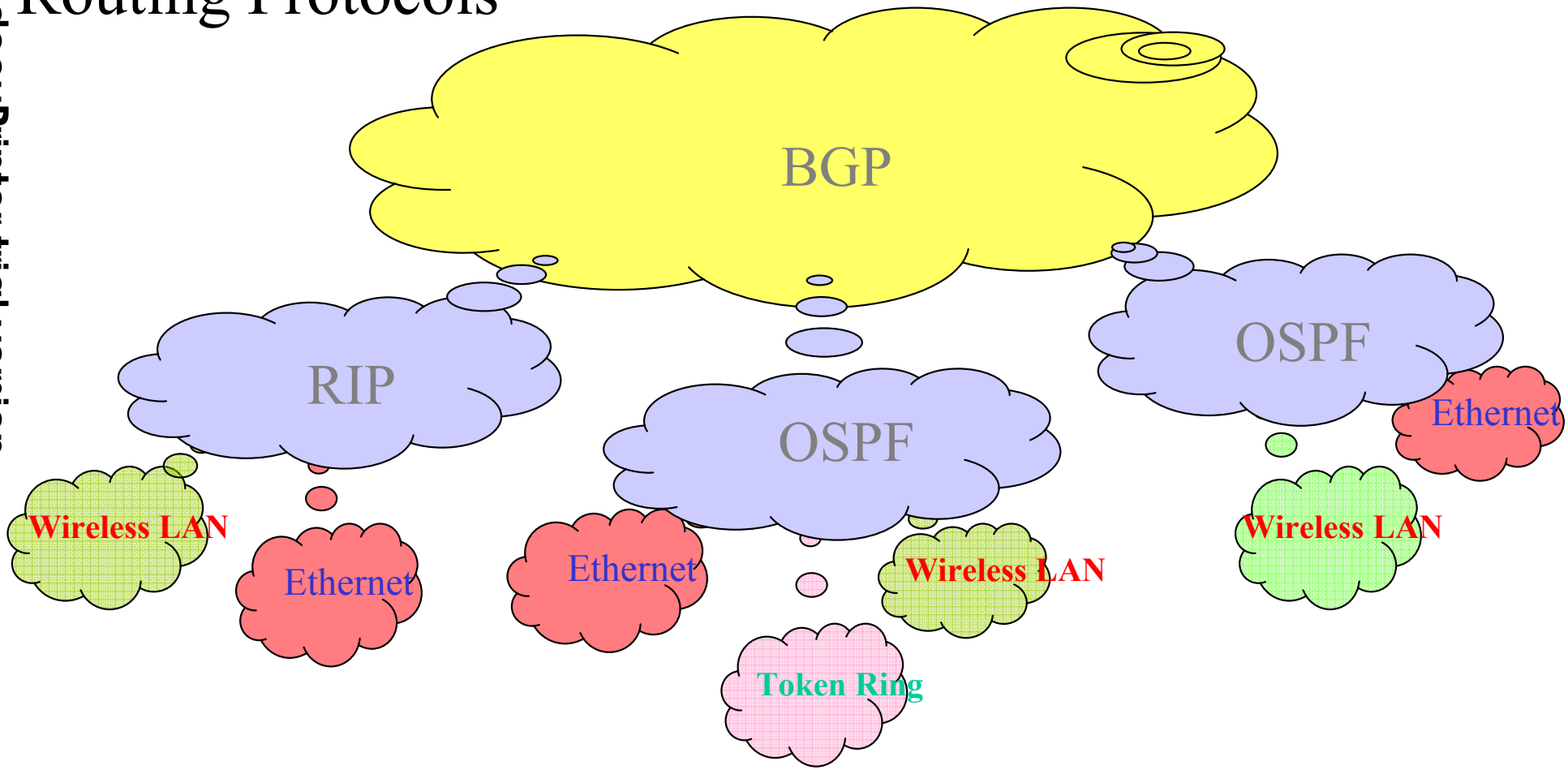
Internet – **Structural** View

Internet Cloud



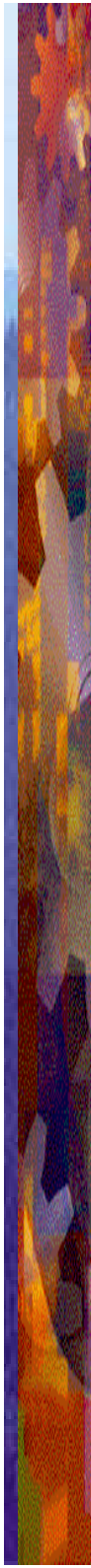
Internet - **Protocol** View

Routing Protocols



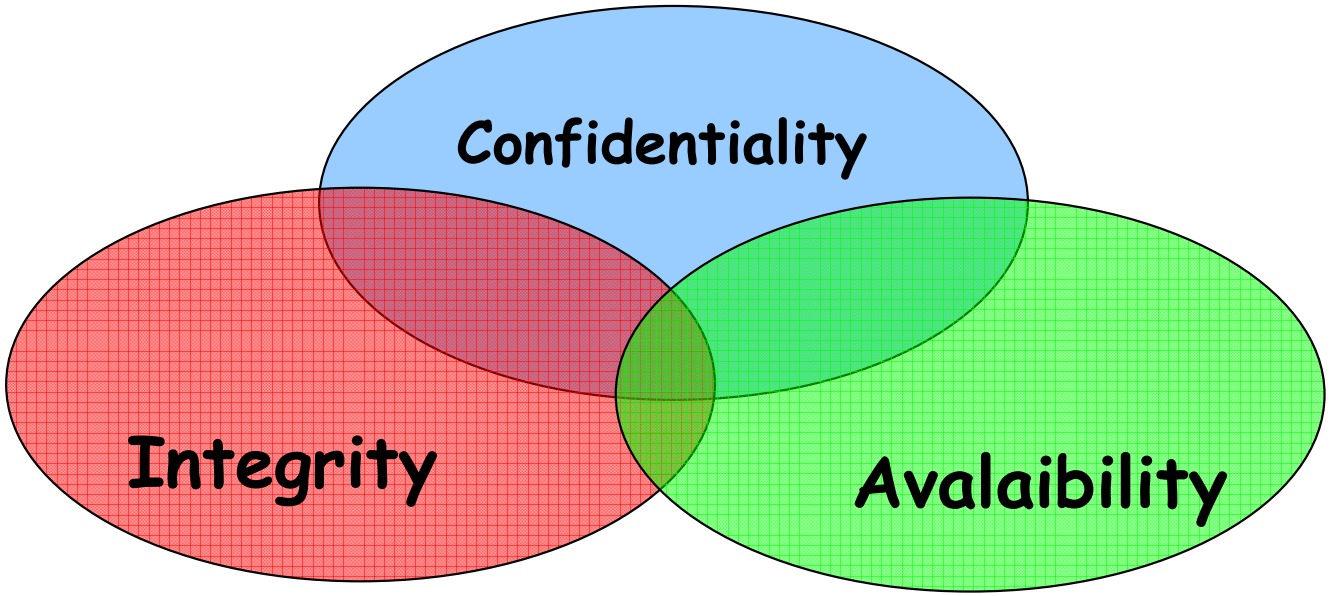
Agenda

- 4.1 Network Fundamentals
- 4.2 The Internet
- 4.3 The World Wide Web
- 4.4 Network Protocols
- 4.5 Network Security



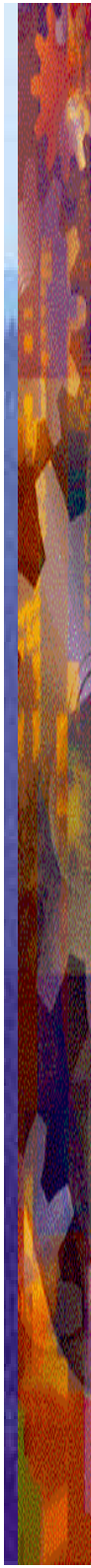
Network security

- Privacy of communication
  - Public-key encryption
- Integrity of machine exposed to internet
  - Attacks: viruses, worms, and intrusion
  - Defense: Anti-virus, Firewall, IDS/IPS

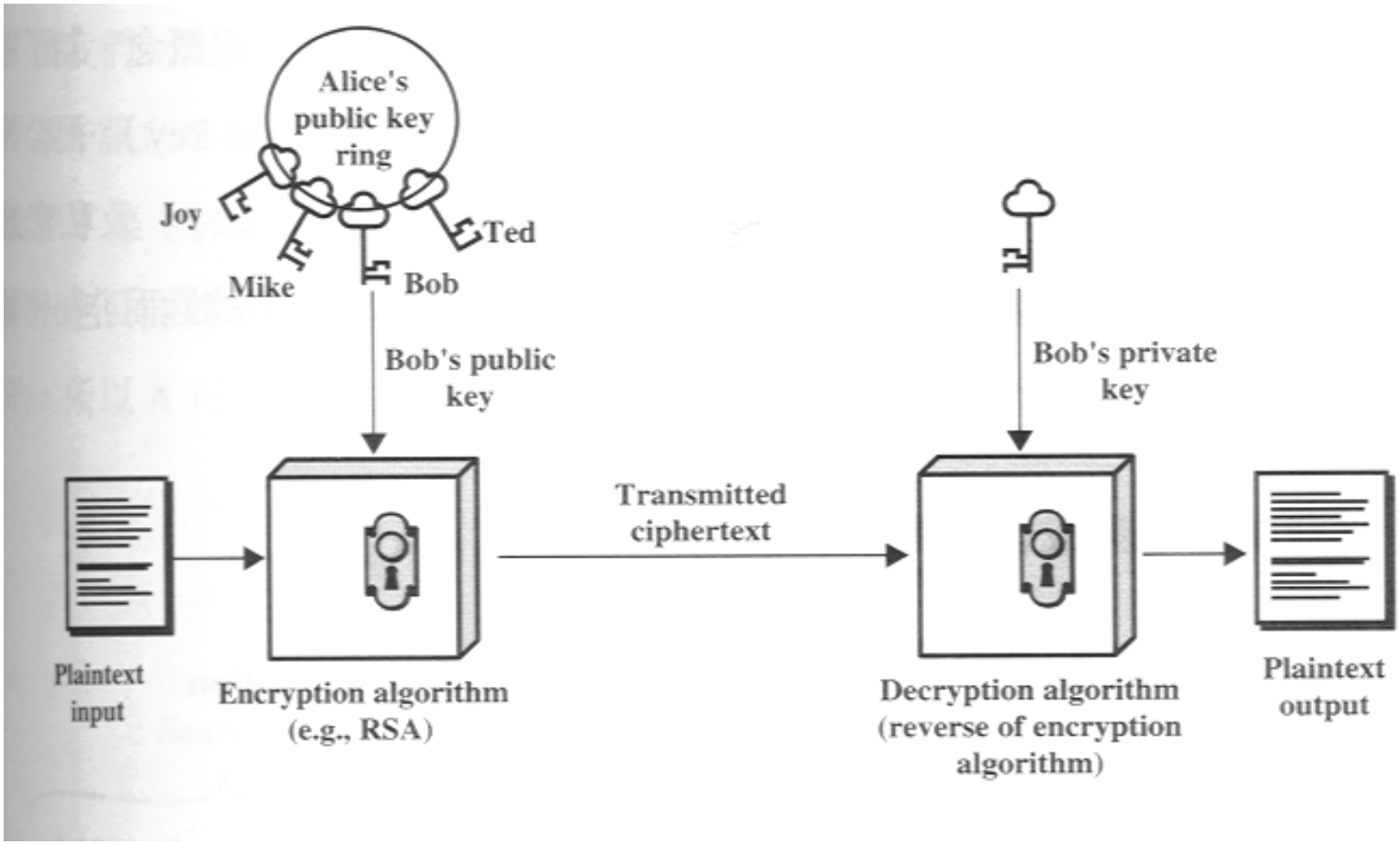


Public-Key Encryption (1/2)

- Public key is used to encode messages and is known by all people authorized to generate messages
- Private key is required to decode messages and is known by only the person who is to receive messages

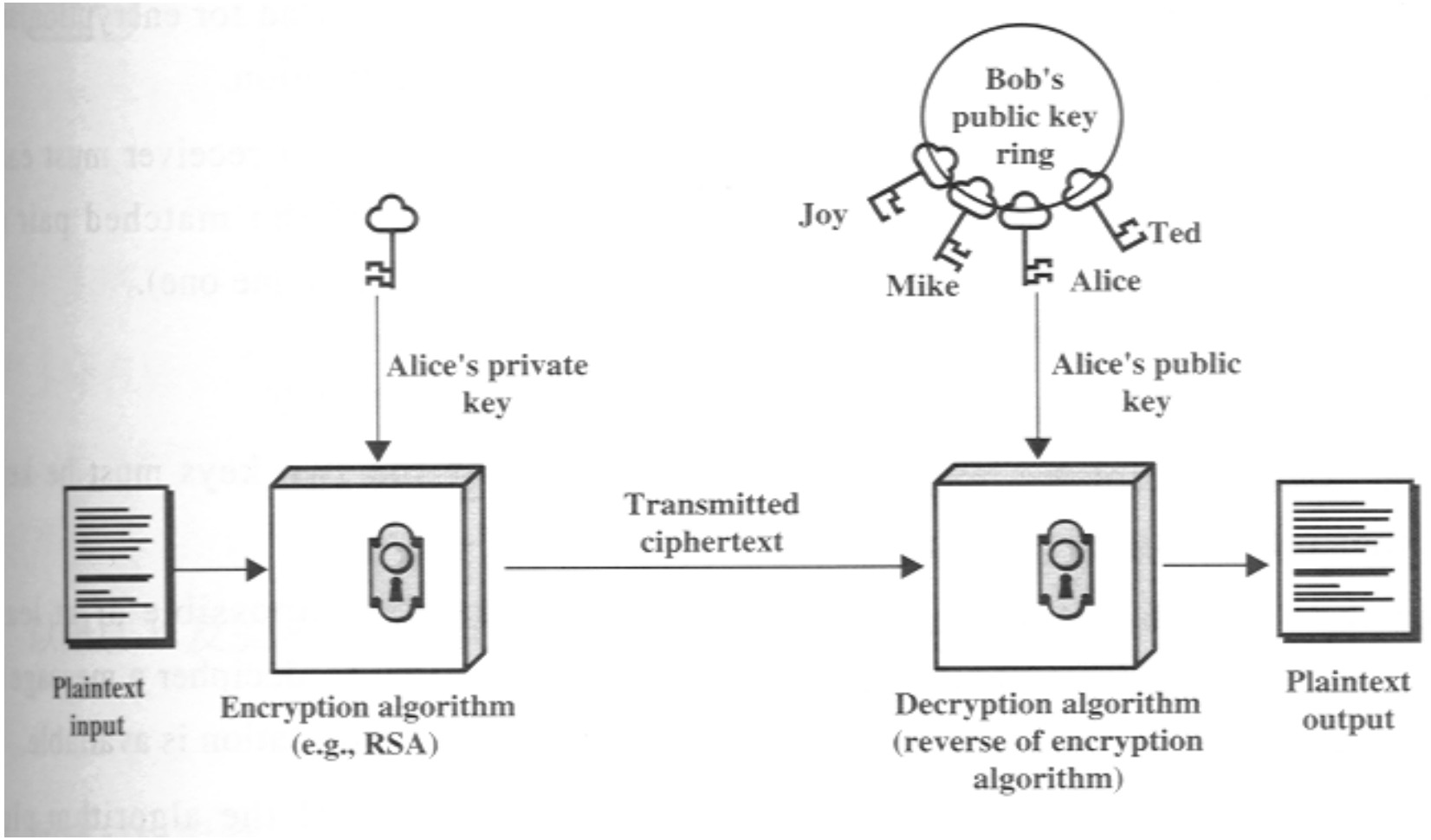


Public-Key Encryption (2/2)



Source: William Stallings

Digital Signature 數位簽章 for Authentication



Source: William Stallings

Public-Key Cryptographic Algorithms

- **RSA** and **Diffie-Hellman**
- **RSA** - Ron **R**ives, Adi **S**hamir and Len **A**dleman at MIT, in 1977.
  - RSA is a **block cipher**
  - The most widely implemented
- **Diffie-Hellman** in 1976
  - Echange a secret key securely
  - Compute discrete logarithms

一次切取一區塊(例64Bytes)來加解密

Block cipher vs. Stream cipher

The RSA Algorithm – Key Generation

1977

1. Select p,q — p and q both prime
2. Calculate $n = p \times q$
3. Calculate $\Phi(n) = (p-1)(q-1)$
4. Select integer e — $\gcd(\Phi(n), e) = 1; 1 < e < \Phi(n)$
5. Calculate d — $d = e^{-1} \bmod \Phi(n)$
6. Public Key — KU = {e,n}
7. Private key — KR = {d,n}

Example of RSA Algorithm (1/2)

1. Select p,q $p=7,\ q=17$
2. Calculate $n = p \times q = 7 \times 17 = 119$
3. Calculate $\Phi(n) = (p-1)(q-1) = 96$
4. Select integer $e=5$ $\gcd(\Phi(n), e) = 1;\ 1 < e < \Phi(n)$
5. Calculate $d = 77$ $d = e^{-1} \bmod \Phi(n)$
6. Public Key $KU = \{e,n\} = \{5, 119\}$
7. Private key $KR = \{d,n\} = \{77, 119\}$

因爲 **77 x 5 = 385 = 4 x 96 + 1**

Example of RSA Algorithm (2/2)

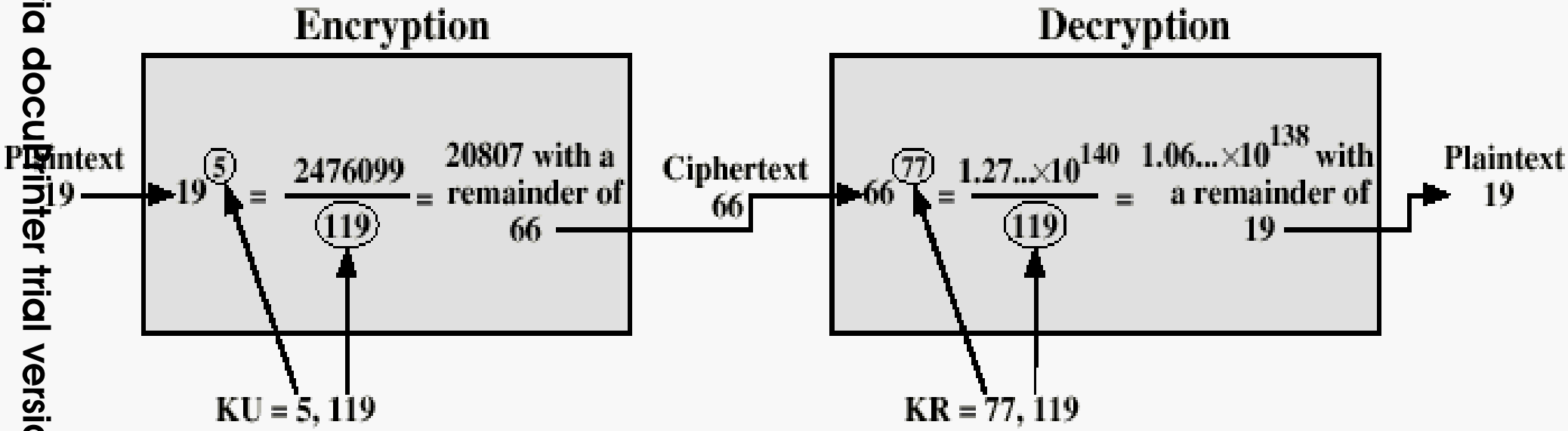
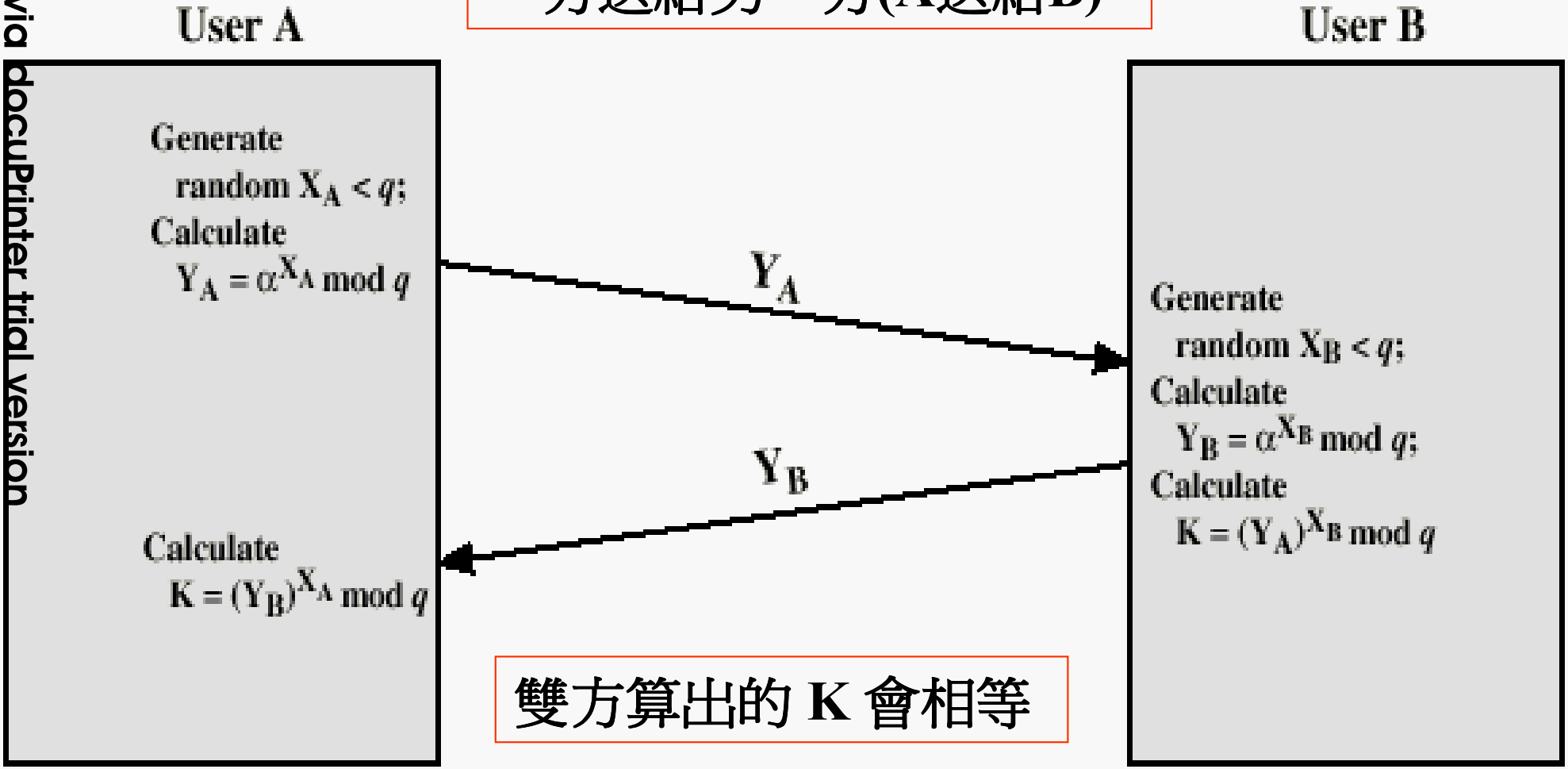


Figure 3.9 Example of RSA Algorithm

Diffie-Hellman Key Echange

1976

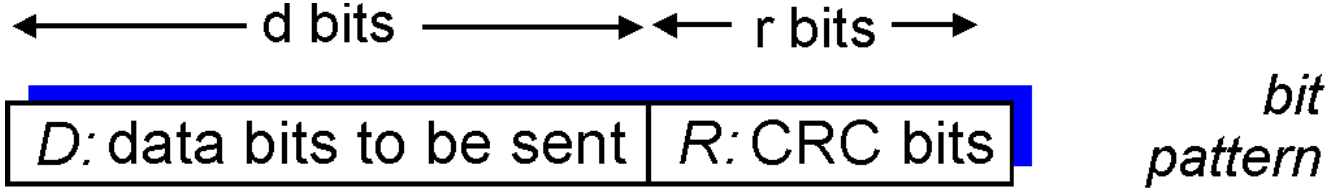
α 和 q 是雙方先約好或由一方送給另一方(A送給B)



雙方算出的 K 會相等

Checksumming: Cyclic Redundancy Check(CRC)

- view data bits, D, as a binary number
- choose r+1 bit pattern (generator), G
- goal: choose r CRC bits, R, such that
  - <D,R> exactly divisible by G (modulo 2)
  - receiver knows G, divides <D,R> by G. If non-zero remainder: error detected!
  - can detect all burst errors less than r+1 bits
- widely used in practice (ATM, HDCL)



$D * 2^r$ XOR R

mathematical formula

CRC Example

Want:

$D \cdot 2^r$ XOR R = nG

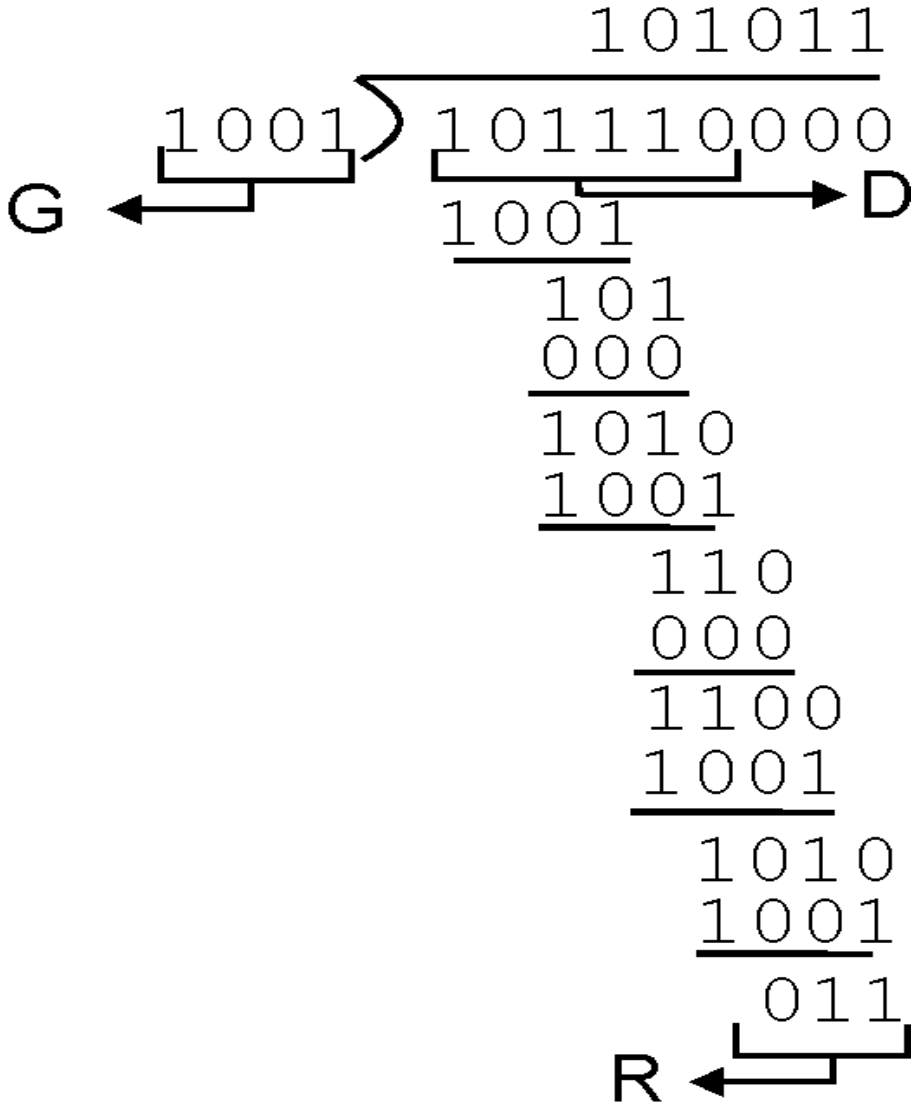
equivalently:

$D \cdot 2^r$ = nG XOR R

equivalently:

if we divide $D \cdot 2^r$ by G, want remainder R

$$R = \text{remainder}\left[\frac{D \cdot 2^r}{G}\right]$$



Security Attacks

- **Interruption**: This is an attack on availability
- **Interception**: This is an attack on confidentiality
- **Modification**: This is an attack on integrity
- **Fabrication**: This is an attack on authenticity

Denial of Service (DoS) 簡介

- DoS : 阻絕服務攻擊 --- 讓大家都不能用!
- 攻擊對象 :

  連上Internet 的網路和裝置
- 目的 :

  讓被攻擊的網路伺服器因忙碌著回應不合法的存取要求或拒絕合法使用者的存取，導致 :

  ➔ 伺服器無法正常運作

  ➔ 使用者無法再存取網路資源

DoS 攻擊型態

- 皆是利用 TCP/IP 相關的漏洞，讓網路充滿了垃圾封包，攻擊型態包含:
  - 利用主機系統 TCP/IP **程式漏洞**，例如 :
    - Ping of Death
    - Teardrop
  - 利用 TCP/IP **協定規格本身的漏洞**，例如 :
    - SYN Flood
    - LAND
  - Smurf 攻擊

DoS攻擊型態 – Ping of Death

Ping 呼伊死

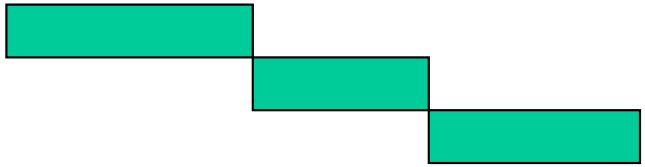
- 方式：
  - 利用"ping"這支工具程式來產生超過 IP 協定所能允許的最大封包 (>65535 bytes based on RFC-791)。
  - 當這封包送到沒有檢查功能的系統，則可能發生系統當機
  - 或者是因爲過長的封包會被切成可接受長度的片段(fragments)再逐一傳送至遠端電腦，再將這些片段組合還原成完整封包，但此舉有時會造成對方電腦Buffer overflow而當機或重開。

DoS攻擊型態 – Land attack

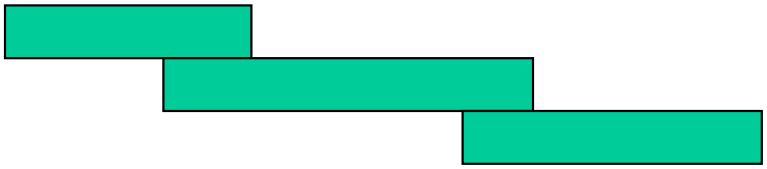
- 原理：
  - 傳輸層在 three way handshake 過程中，每一步都有一組：(**來源**位址，**來源埠號**，目的位址，目的埠號)
  - 來源位址與目的位址可以相同
  - 當來源位址與目的位址不同，來源埠號與目的埠號相同也是可以
  - **當來源位址與目的位址相同，同時來源埠號與目的埠號也相同 ？？？**
- 攻擊方式：
  - 送出一連串偽造的封包，使得目的位址與來源位址都是受攻擊系統的位址，並且目的埠號與來源埠號也相同。
- Ex : land.c

DoS攻擊型態 – Teardrop

- 攻擊方式：
  - 利用IP封包重組的漏洞
  - 送出一對經過特別設計封包片段，使得這一對封包片段在目標電腦重新組合後，造成與原來資料不合的封包。
- 原理：
  - 網路層(Network layer)的IP(Internet Protocol)主要負責路由與資料包分割 (fragmentation)及重組(re-assembly)。



正常片段重組



異常片段重組

Example: teardrop.c

Malicious codes (Malware)

- Undesired code that might cause damage to your computer system
  - Virus
  - Worm
  - Trojan horse

http://en.wikipedia.org/wiki/Malware

http://en.wikipedia.org/wiki/Buffer_overflow

http://en.wikipedia.org/wiki/Stack_buffer_overflow

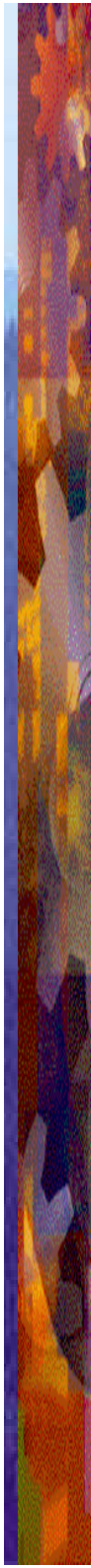
Viruses

- Program segment that attaches itself to other programs in the computer system
- When executed the virus may perform malicious acts that are readily noticeable or merely search for other programs to which it can attach copies of itself
- If an infected program is transferred to a new machine, the virus will begin to infect programs on the new machine as soon as it is executed

http://en.wikipedia.org/wiki/Computer_virus

http://en.wikipedia.org/wiki/**CIH**_(computer_virus)

參考: 趨勢科技網站http://www.trend.com.tw/



Worms

http://en.wikipedia.org/wiki/Computer_worm

- Autonomous program that **transfers itself through a network**, taking up residence in the machines and forwarding copies of itself through the network
- Can be designed merely to replicate themselves or to perform additional vandalism
- **蠕蟲**
  電腦蠕蟲病毒是一種惡意程式（或一組程式），可將本身的功能或程式碼透過網路散播到其他電腦。

Morris worm: 1988/11/02 by Robert Morris@Cornell Univ.

CodeRed : 2001/07/13 ; Nimda : 2001/09/18

http://en.wikipedia.org/wiki/Code_Red_(computer_worm)

Trojan Horse

- Propagation
  - A program that **does not replicate**
- Spreading model
  - Someone **emails** a Trojan Horse to you
  - You copy a program with embedded Trojan Horse
  - Visit a Web site contains Trojan Horse

http://en.wikipedia.org/wiki/Trojan_horse_(computing)

http://en.wikipedia.org/wiki/Trojan_Horse

Distinction between them

- **Virus**
  - Fast spreading within a system
- **Worm**
  - Fast spreading across systems
- **Trojan horse** vs. the other two
  - **No self-replication**

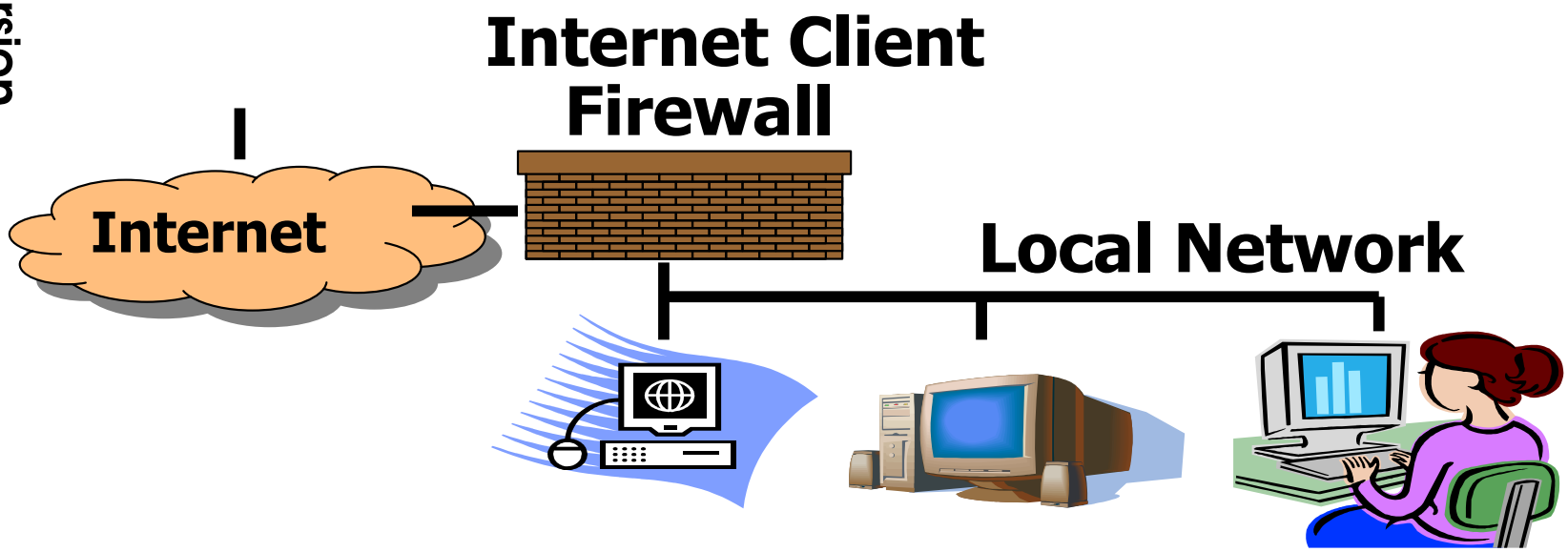
http://en.wikipedia.org/wiki/Computer_virus

http://en.wikipedia.org/wiki/Computer_worm

http://en.wikipedia.org/wiki/Trojan_horse_(computing)

Firewalls

- Filter the traffic entering or passing through a machine
- Examples
  - **Scan all incoming traffic and reject messages containing certain words**
  - **Reject all traffic from or to a given port number**
  - **Filter out all messages from certain IP addresses**
- Placed on **gateway** or individual machines



Thank You!

CHAPTER 4

Networking and the Internet

Part B

謝謝捧場

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