523353 – Computer Networks

Lecture 2 IPv4 Addressing

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Outline

มาตรฐาน

- Protocol Stack
- Internet structure
- History of the Internet
- IPv4 addressing

A Protocol

Protocol "layers"

แบ่งเป็น layer เพราะ
เทียบเสมือน layer ด้านล่าง

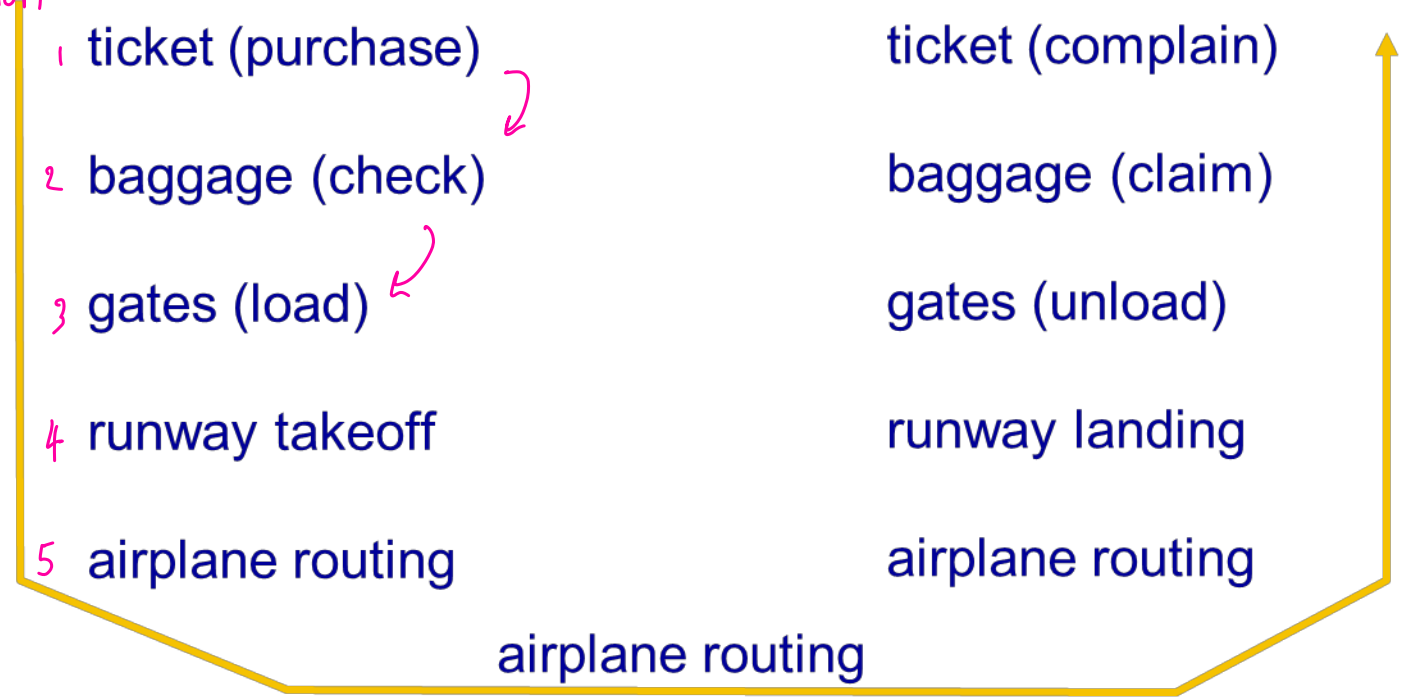
- *Networks are complex, with many "pieces":*

  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

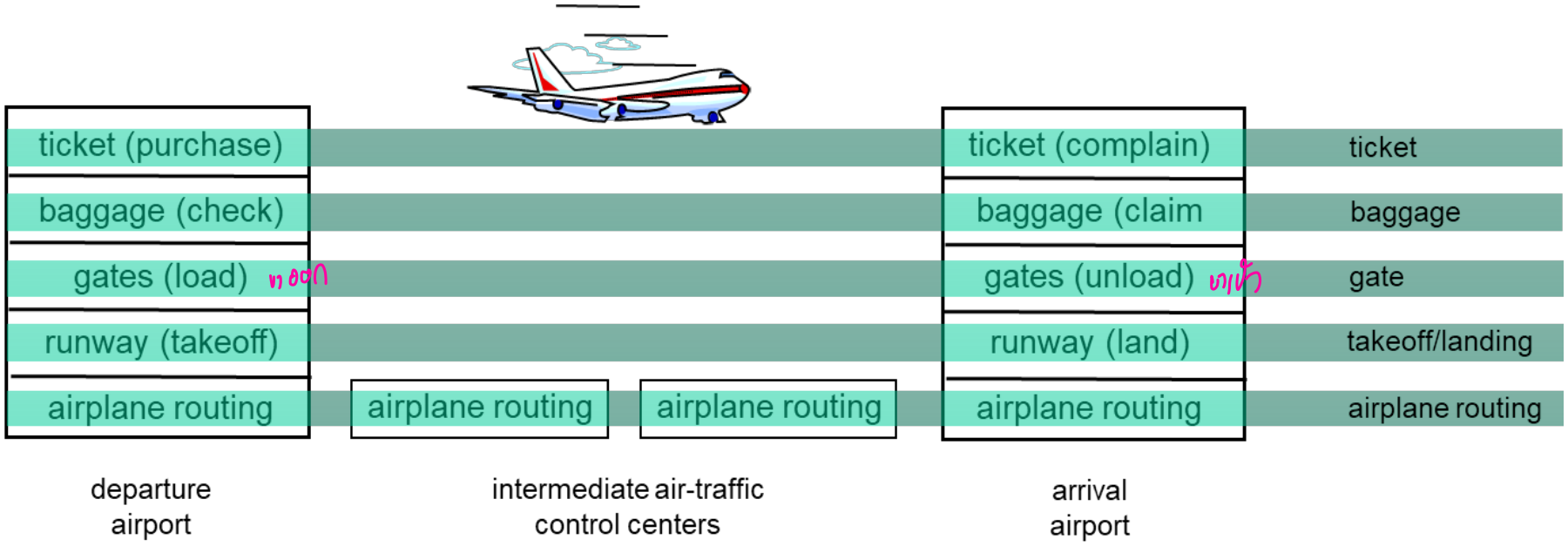
พวกอุปกรณ์
มันก็ทำงานอยู่ layer ต่างกัน

Organization of air travel

- a series of steps



Layering of airline functionality

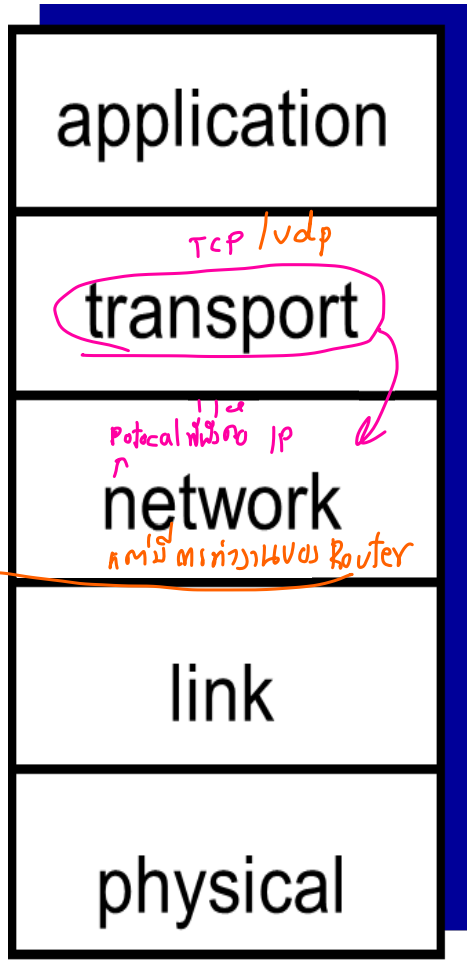


layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

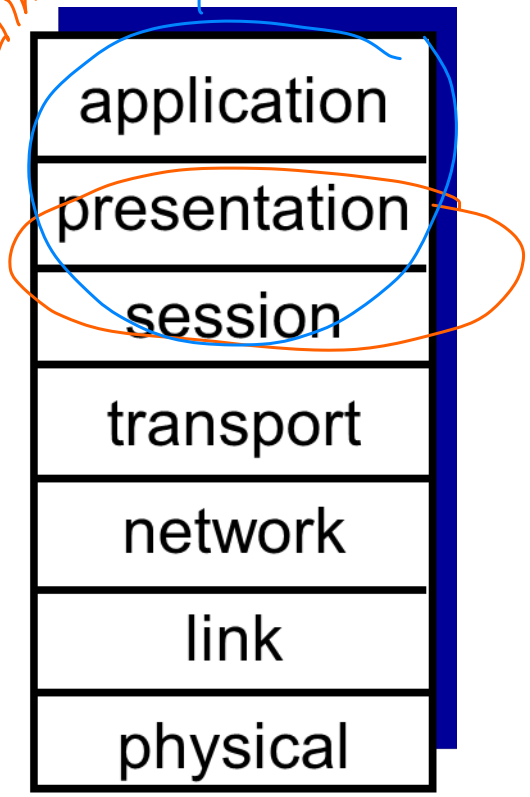
Internet protocol stack (TCP/IP Model)

- application: supporting network applications
  - FTP, SMTP, HTTP
- transport: process-process data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - Ethernet, 802.111 (WiFi), PPP
- physical: bits "on the wire"

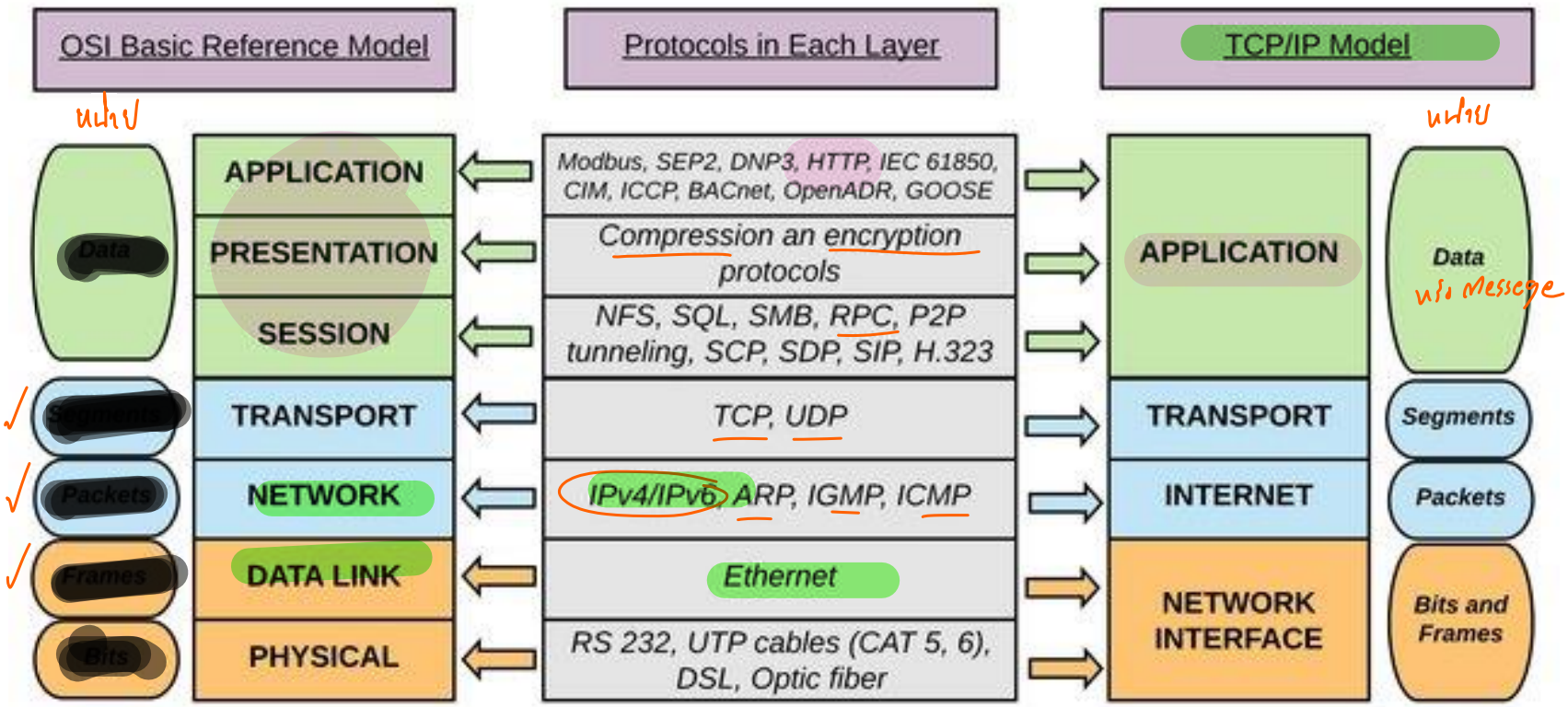


OSI reference model

- The International Standards Organization (ISO) developed the Open Systems Interconnection (OSI) model
- *presentation:* allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *session:* synchronization, checkpointing, recovery of data exchange
- Internet stack "missing" these layers!
  - these services, *if needed,* must be implemented in application

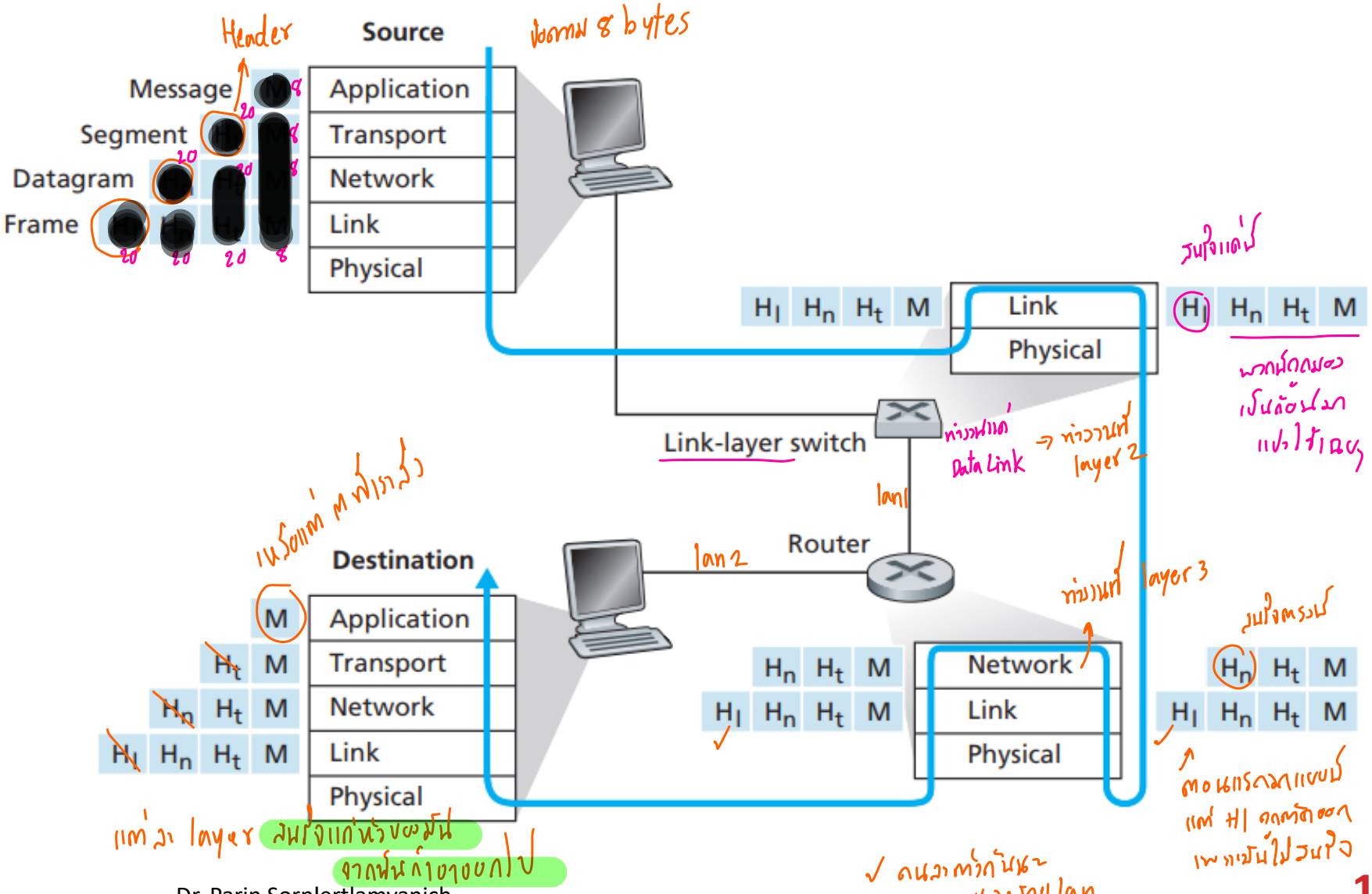


OSI model vs TCP/IP model

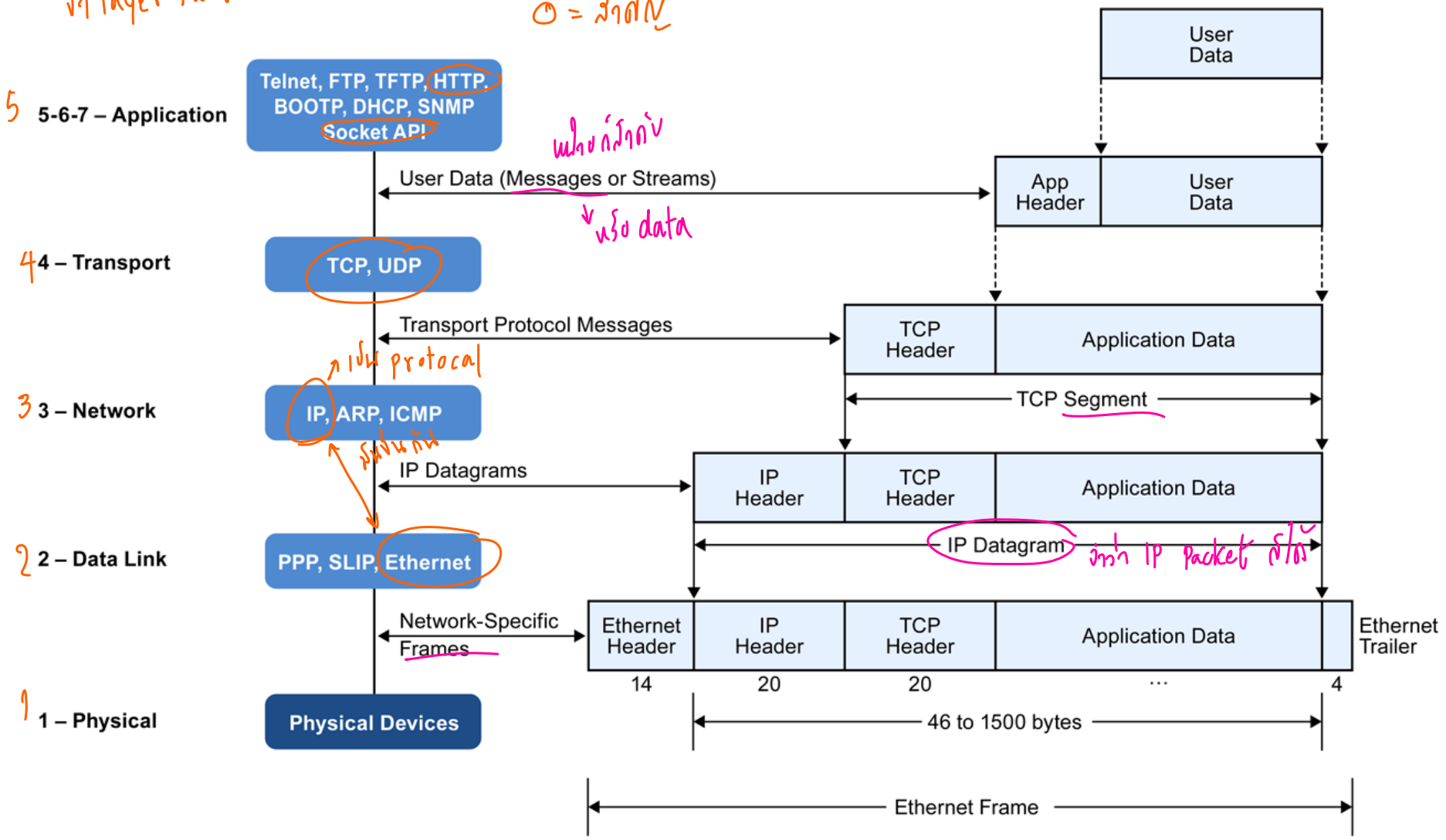


แต่ละ layer แม้ข้อความเหมือนกัน แต่ ค.ยาว ไม่เท่ากัน
เพราะ header

Data Encapsulation

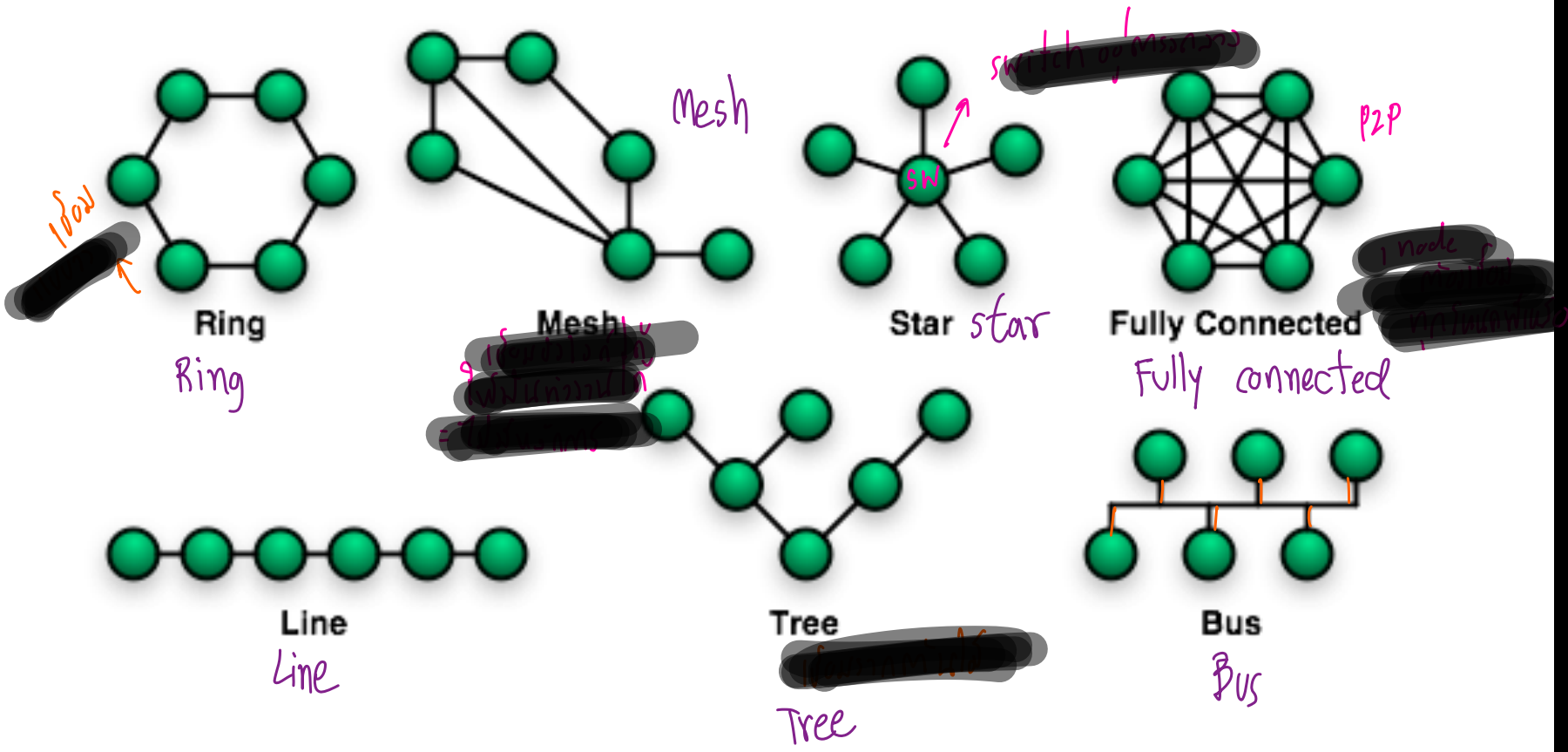


TCP/IP Model


5 5-6-7 – Application
Telnet, FTP, TFTP, HTTP, BOOTP, DHCP, SNMP Socket API
4 4 – Transport
TCP, UDP
3 3 – Network
IP, ARP, ICMP
2 2 – Data Link
PPP, SLIP, Ethernet
1 1 – Physical
Physical Devices
User Data (Messages or Streams)
Transport Protocol Messages
IP Datagrams
Network-Specific Frames
User Data
App Header
User Data
TCP Header
Application Data
TCP Segment
IP Header
TCP Header
Application Data
IP Datagram
Ethernet Header
IP Header
TCP Header
Application Data
Ethernet Trailer
14
20
20
...
4
46 to 1500 bytes
Ethernet Frame

Network Terminology

Physical Network Topology

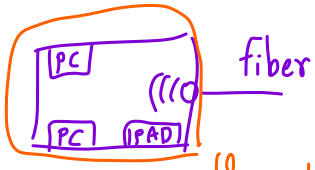


Source: http://en.wikipedia.org/wiki/Network_topology

Public Standards

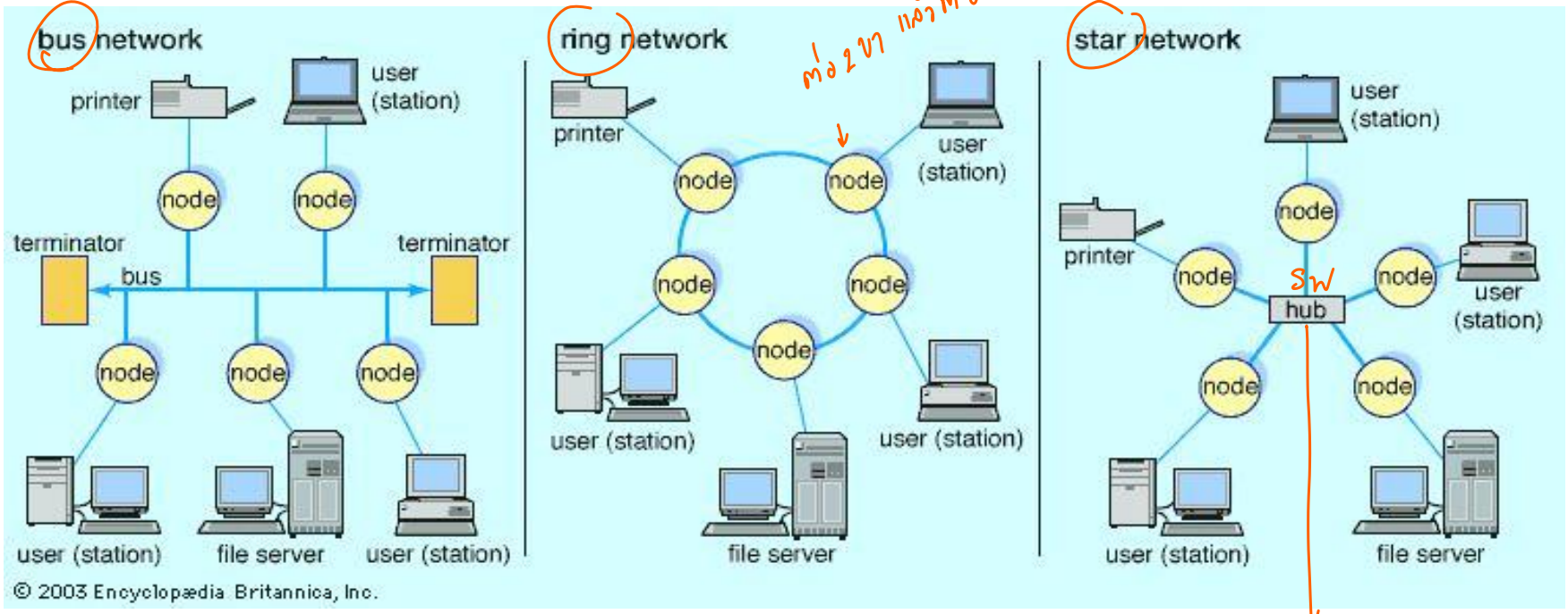
- IETF ธนาคารโลก
  - IPv4, IPv6, and Internet RFCs
- IEEE มาตรฐาน 46, 56
  - IEEE 802.3, IEEE 802.11, etc.
- ISO มาตรฐานต่างๆ
  - ISO 17799, ISO27001, etc.

Local Area Network (LAN)



- Operate within a limited geographical area
- Usually required high data rate transmission
- Control the network privately under local administration
- Provide full-time connectivity to local services
- Connect physically adjacent devices

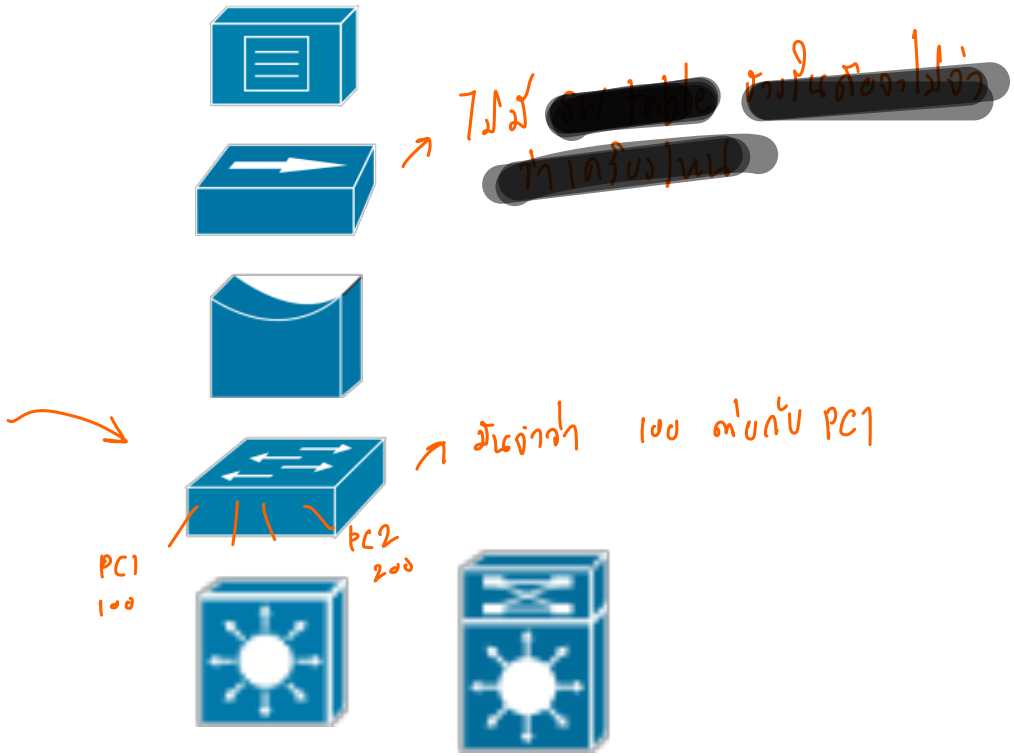
Local Area Network (LAN)



Source:
http://www.britannica.com/EBchecked/topic/345541/local-area-network-LAN

LAN Devices

- Repeater
- HUB
- Bridge
- Ethernet Switch
- Layer3 Switch



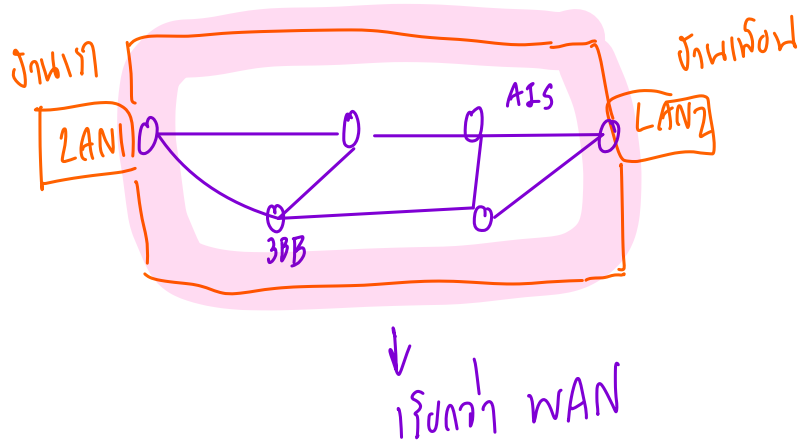
Wide Area Network (WAN)

ภูมิศาสตรแบบใหญ่

- Operate over a large geographical area
- Provide full-time and part-time connectivity
- Connect devices separated over wide, even global areas

เป็นได้ 2 แบบ

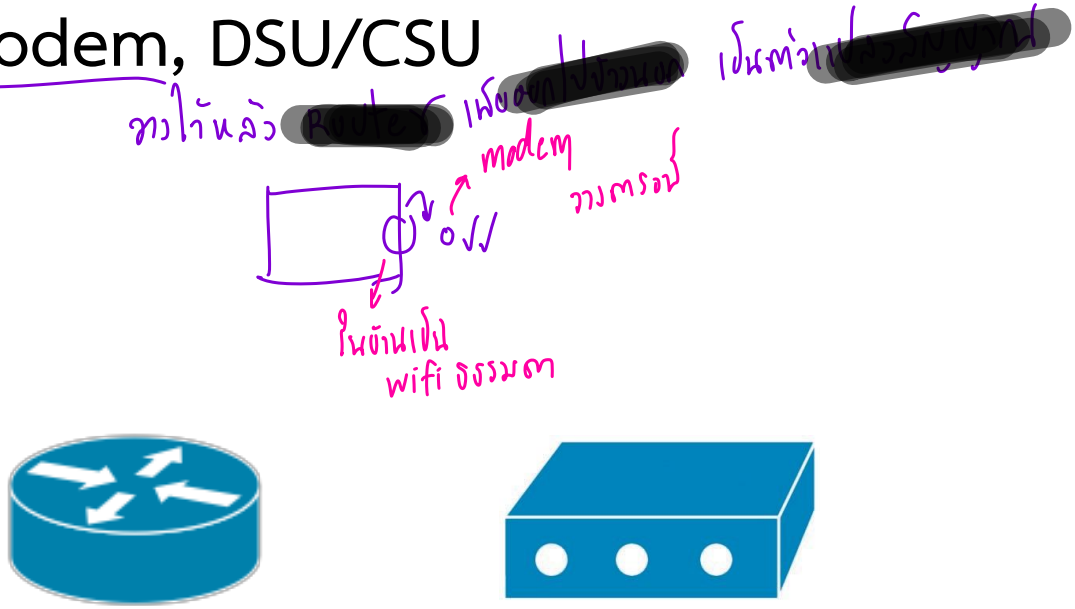
ไม่จำเป็นต้องต่อตลอดเวลา



เรียกว่า WAN

WAN Devices

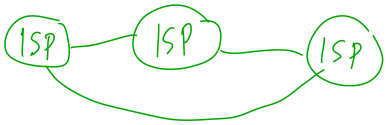
- Router
- Modem, DSU/CSU



Internet structure

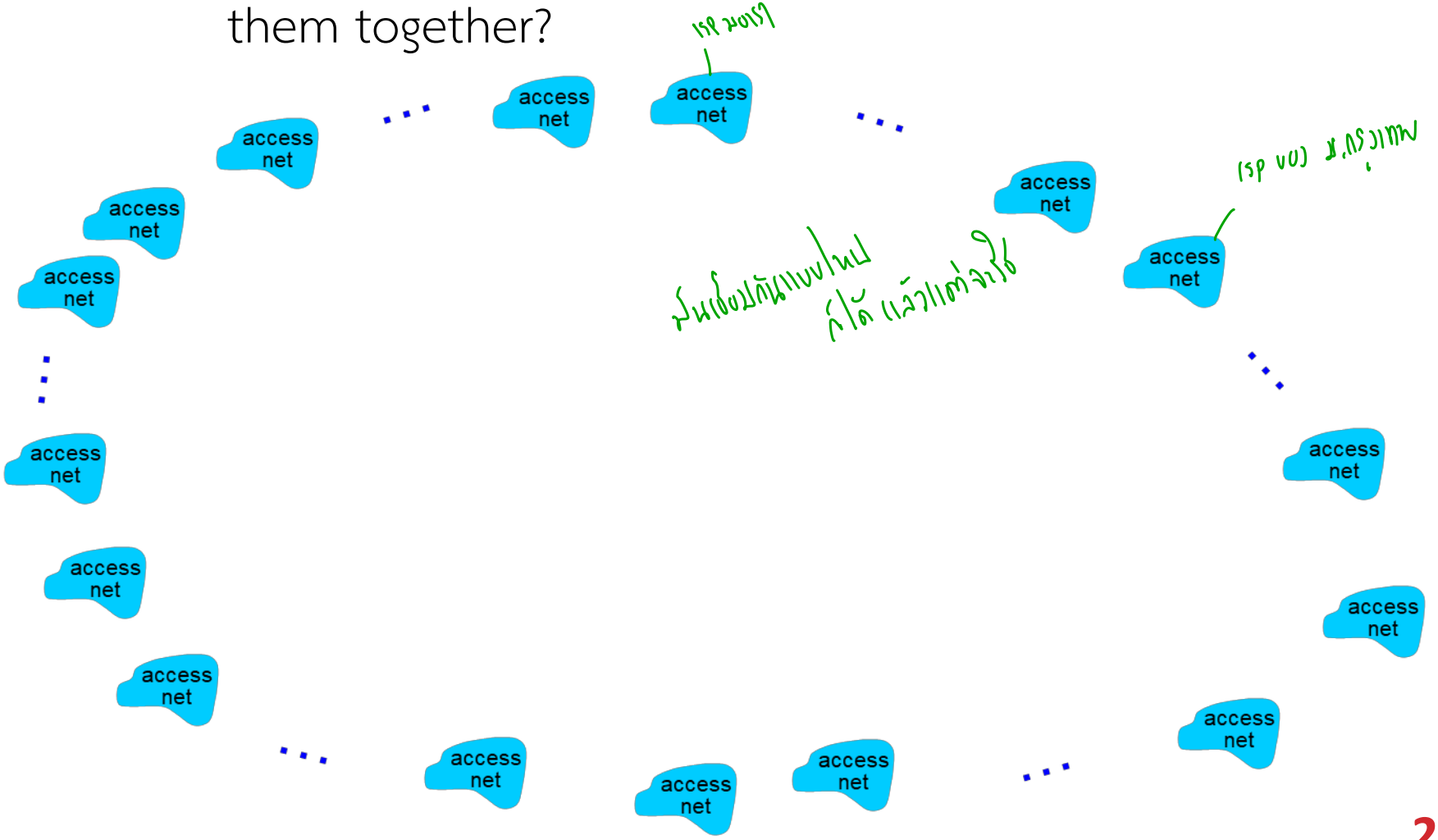
Internet structure: Network of networks

- End systems connect to Internet via access ISPs (Internet Service Providers)
  - residential, company and university ISPs
- Access ISPs in turn must be interconnected.
  - so that any two hosts can send packets to each other
- Resulting network of networks is very complex
  - evolution was driven by economics and national policies



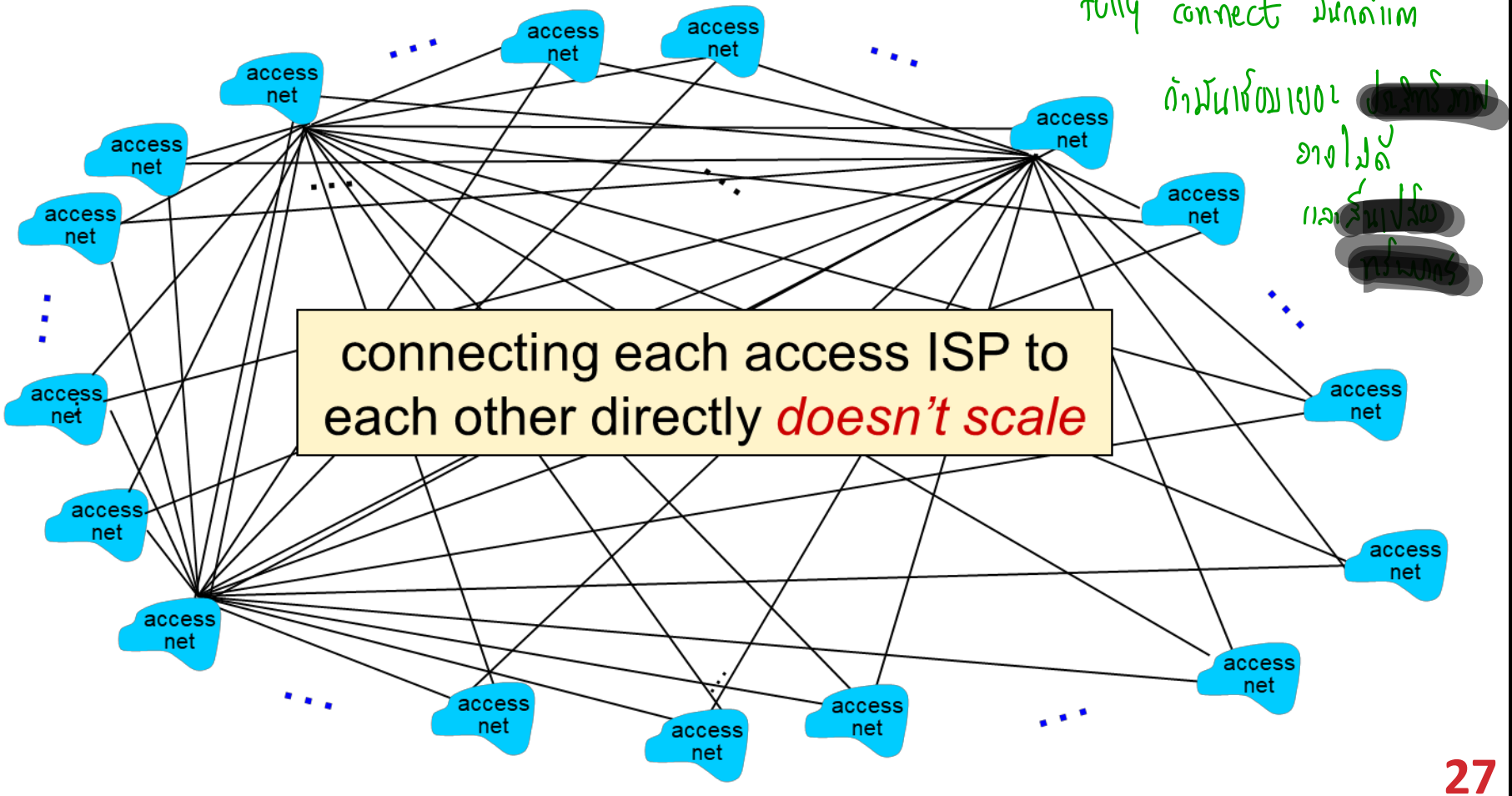
Internet structure: network of networks

- Given millions of access ISPs, how to connect them together?



Internet structure: network of networks

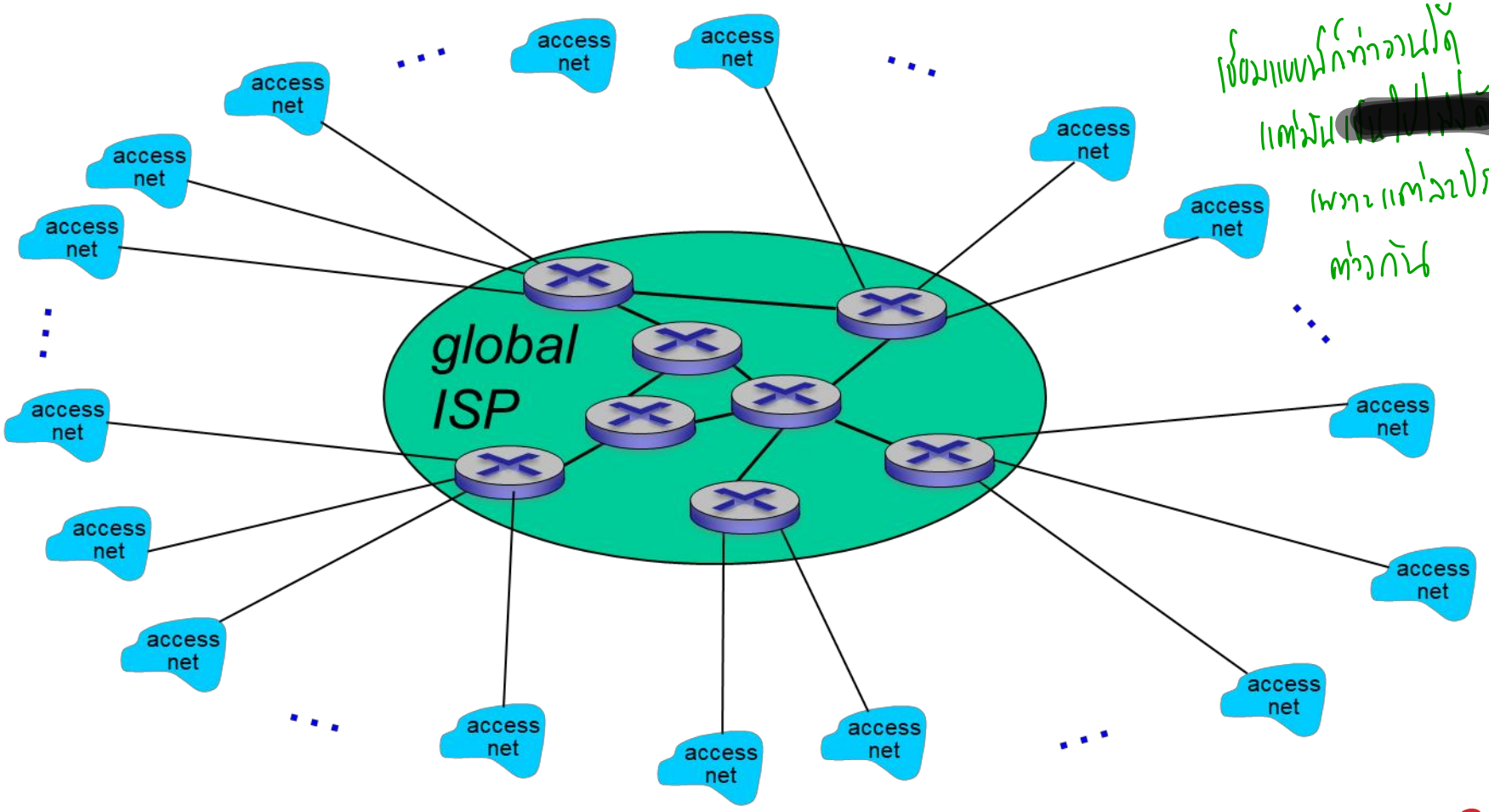
- Option: connect each access ISP to every other access ISP?



Internet structure: network of networks

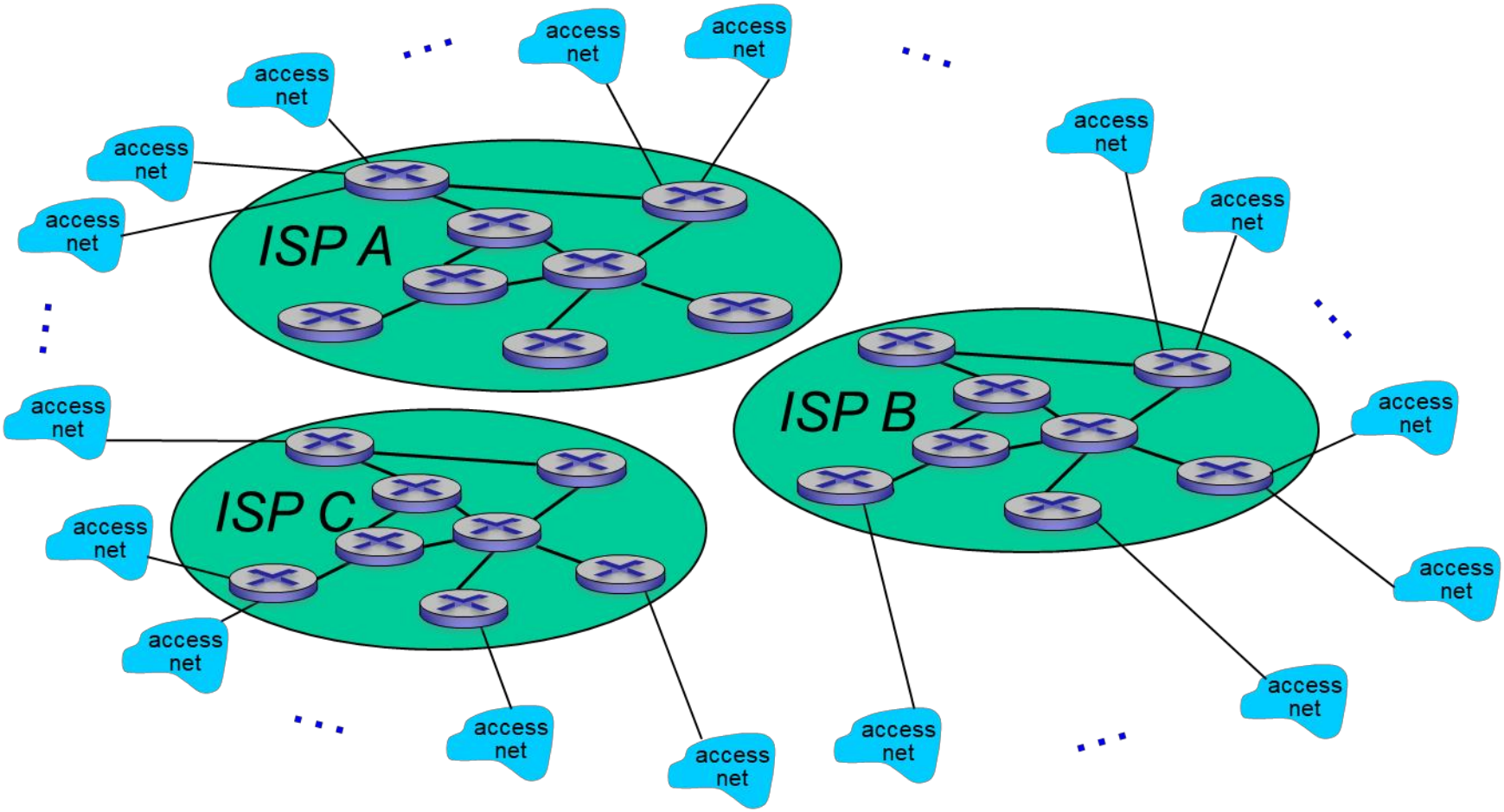
Option: connect each access ISP to one global transit ISP?

Customer and provider ISPs have economic agreement.



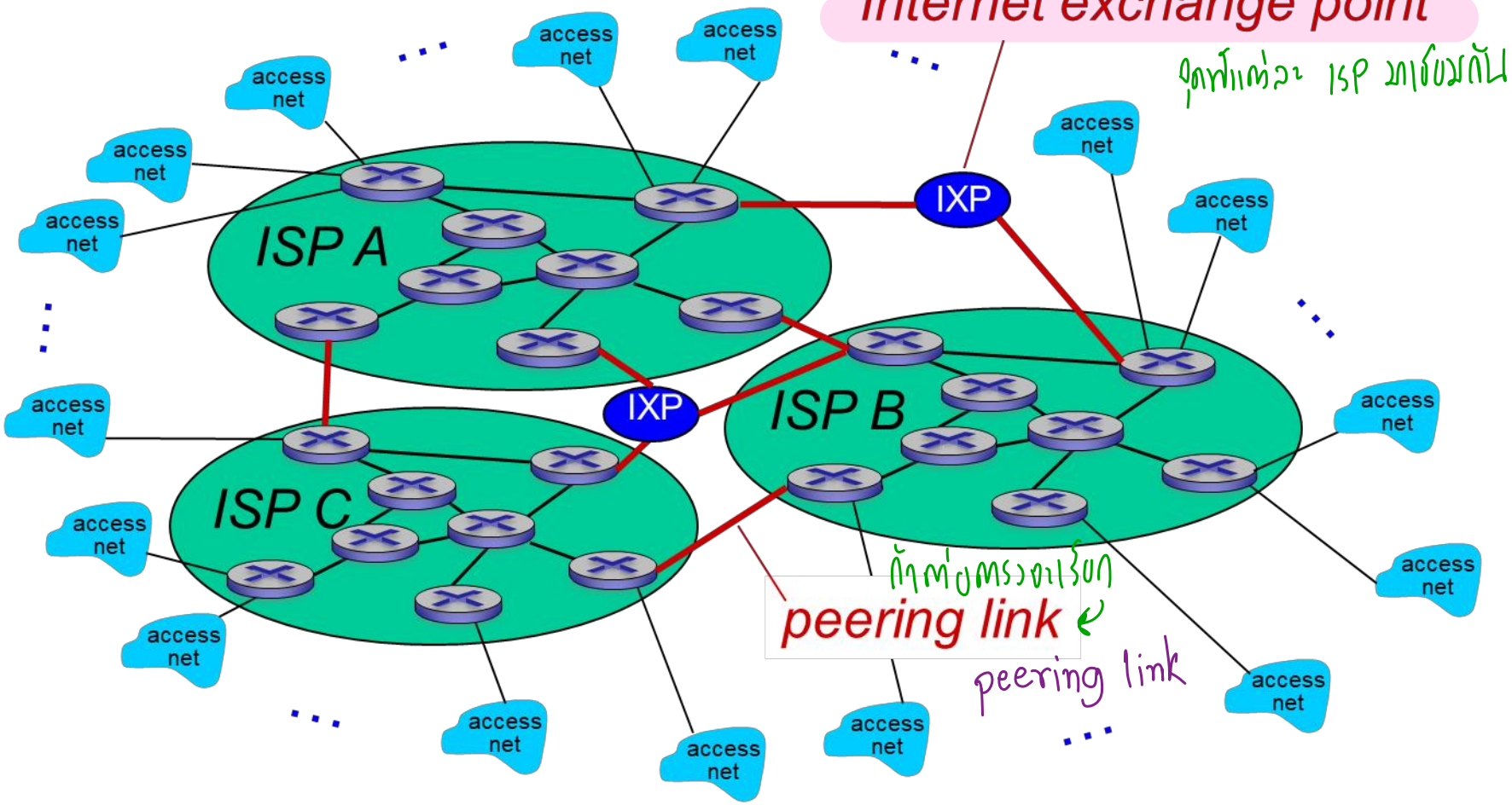
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors ....



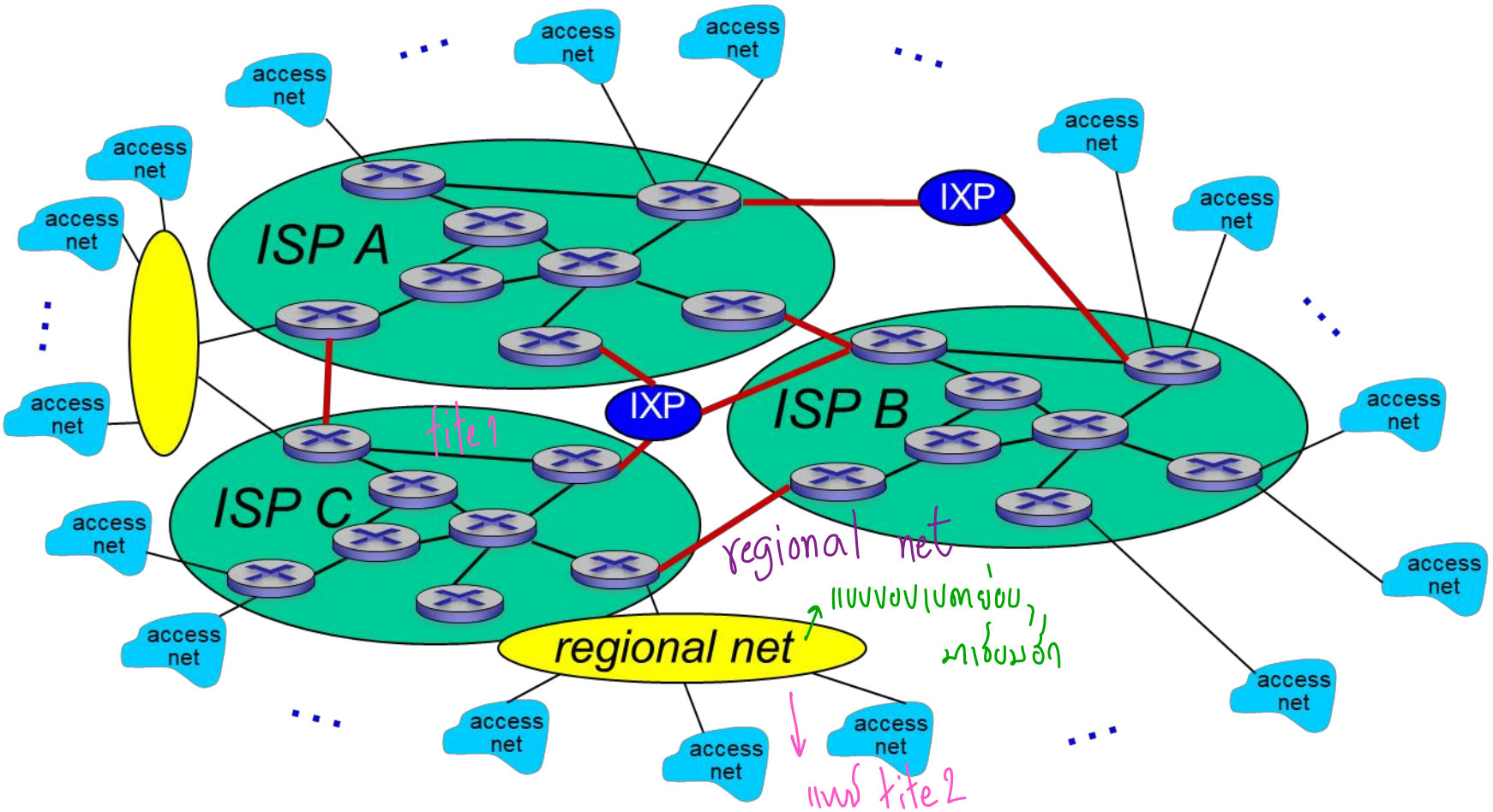
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors ....
which must be interconnected



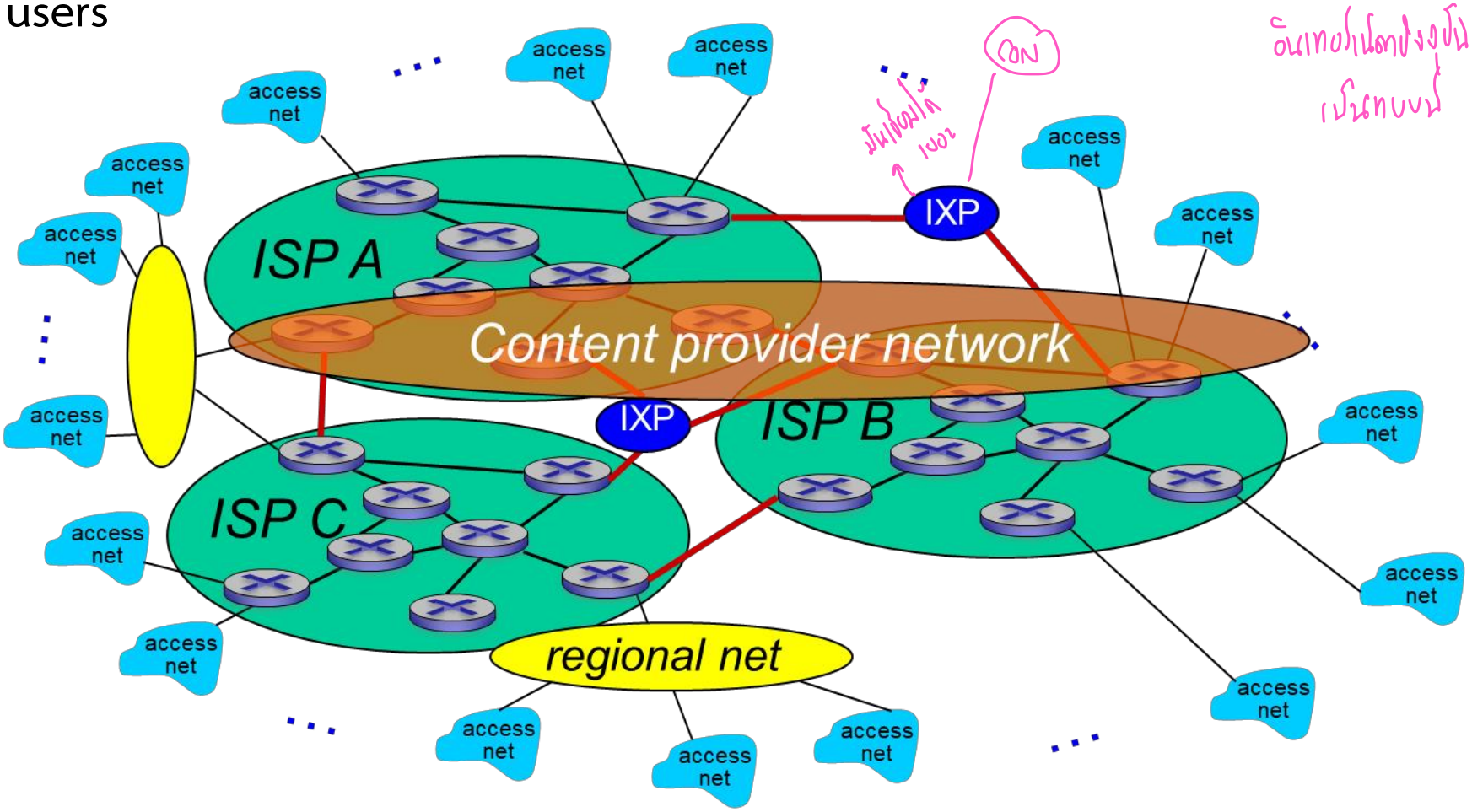
Internet structure: network of networks

... and regional networks may arise to connect access nets to ISPs

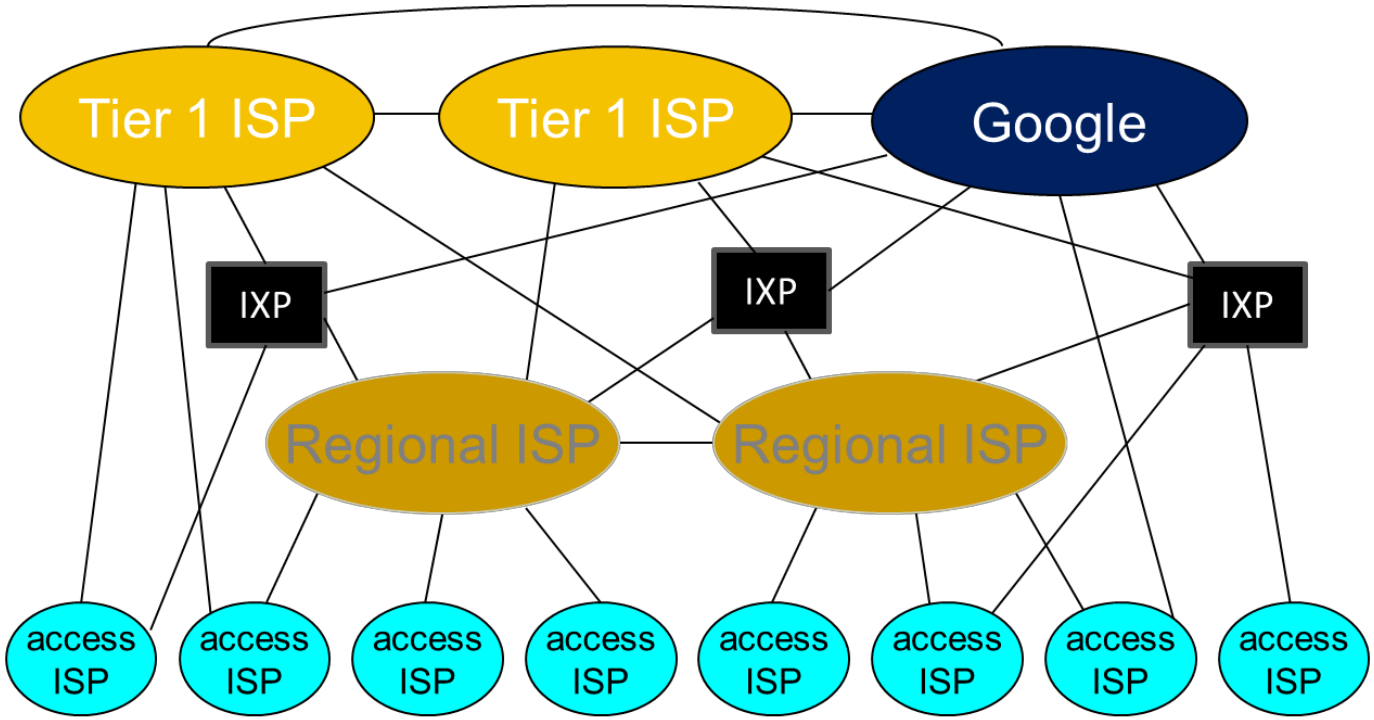


Internet structure: network of networks

... and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



Internet structure: network of networks



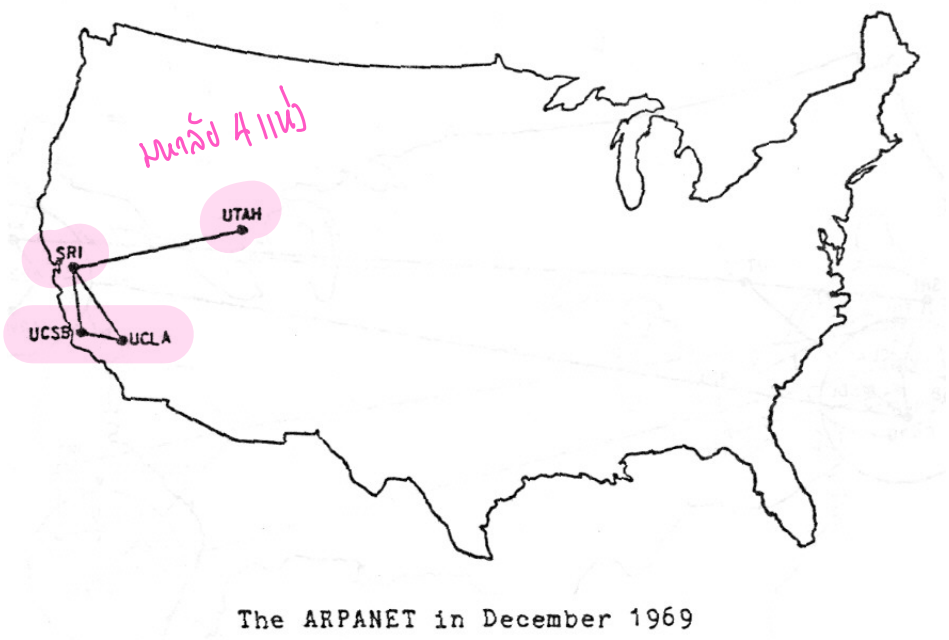
- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
  - content provider network (e.g., Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs

History of the Internet

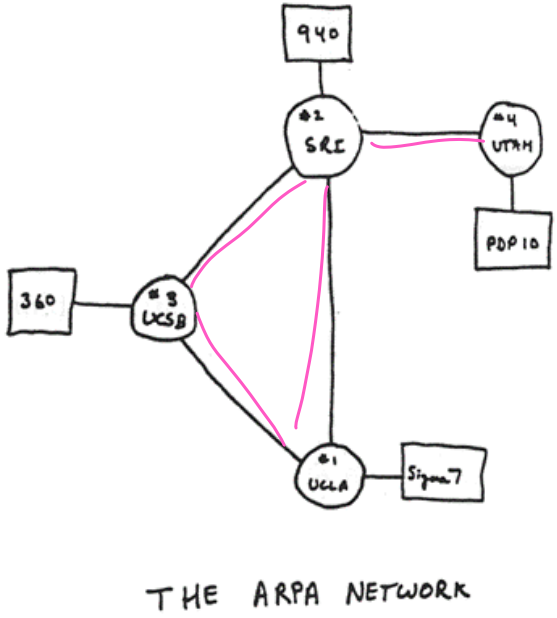
https://www.webfx.com/blog/web-design/the-history-of-the-internet-in-a-nutshell/

ARPANET

- 1969: first ARPANET node operational



The ARPANET in December 1969



THE ARPA NETWORK

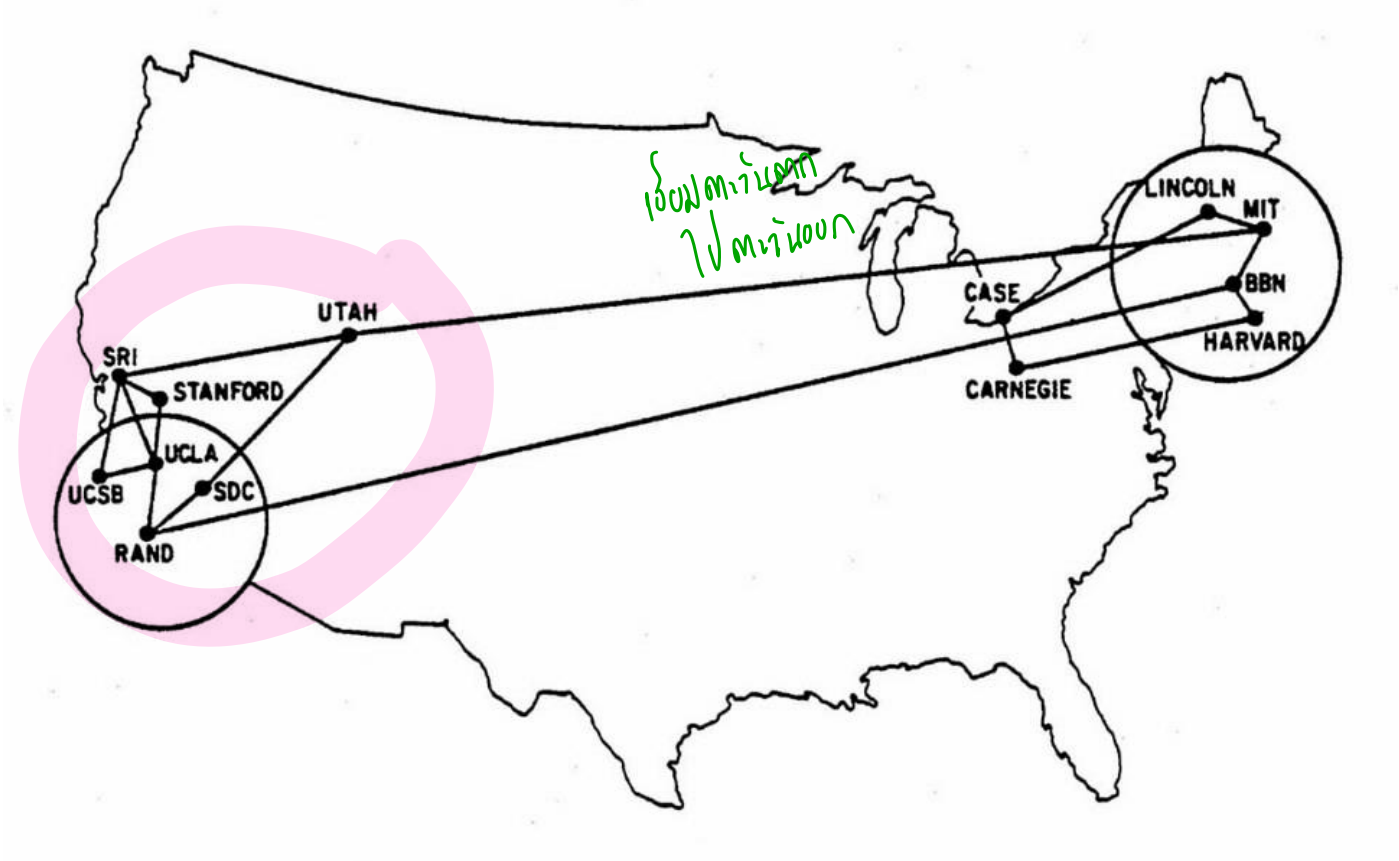
UCLA's Network Measurement Center, Stanford Research Institute (SRI), University of California-Santa Barbara and University of Utah

the first real network to run on packet switching technology

Source: http://cdn0.vox-cdn.com/assets/4463411/G69Dec.jpg

1970: ARPANET expands

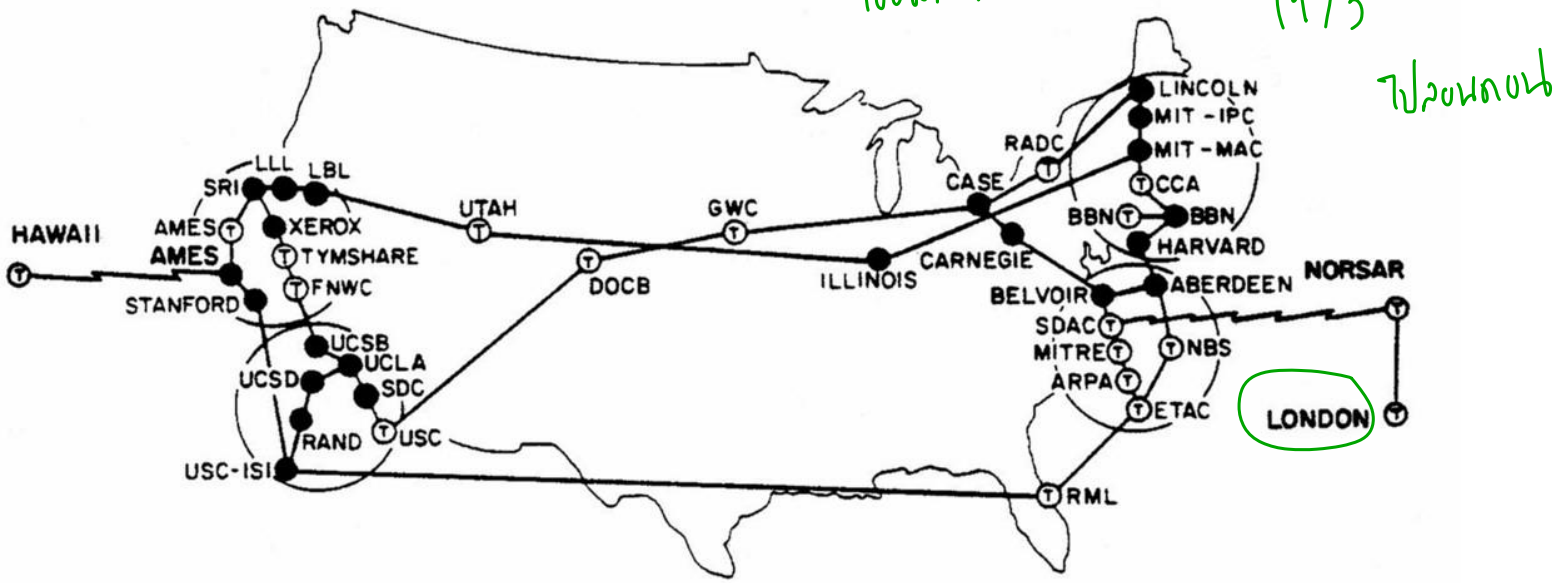
- An ARPANET network was established between Harvard, MIT, and BBN (the company that created the “interface message processor” computers used to connect to the network)



Source: http://cdn0.vox-cdn.com/assets/4463427/G70Dec.jpg

1973: ARPANET goes international

- Email was first developed in 1971 by Ray Tomlinson, who also made the decision to use the "@" symbol
- Arpanet made its first trans-Atlantic connection in 1973, with the University College of London. During the same year, email accounted for 75%

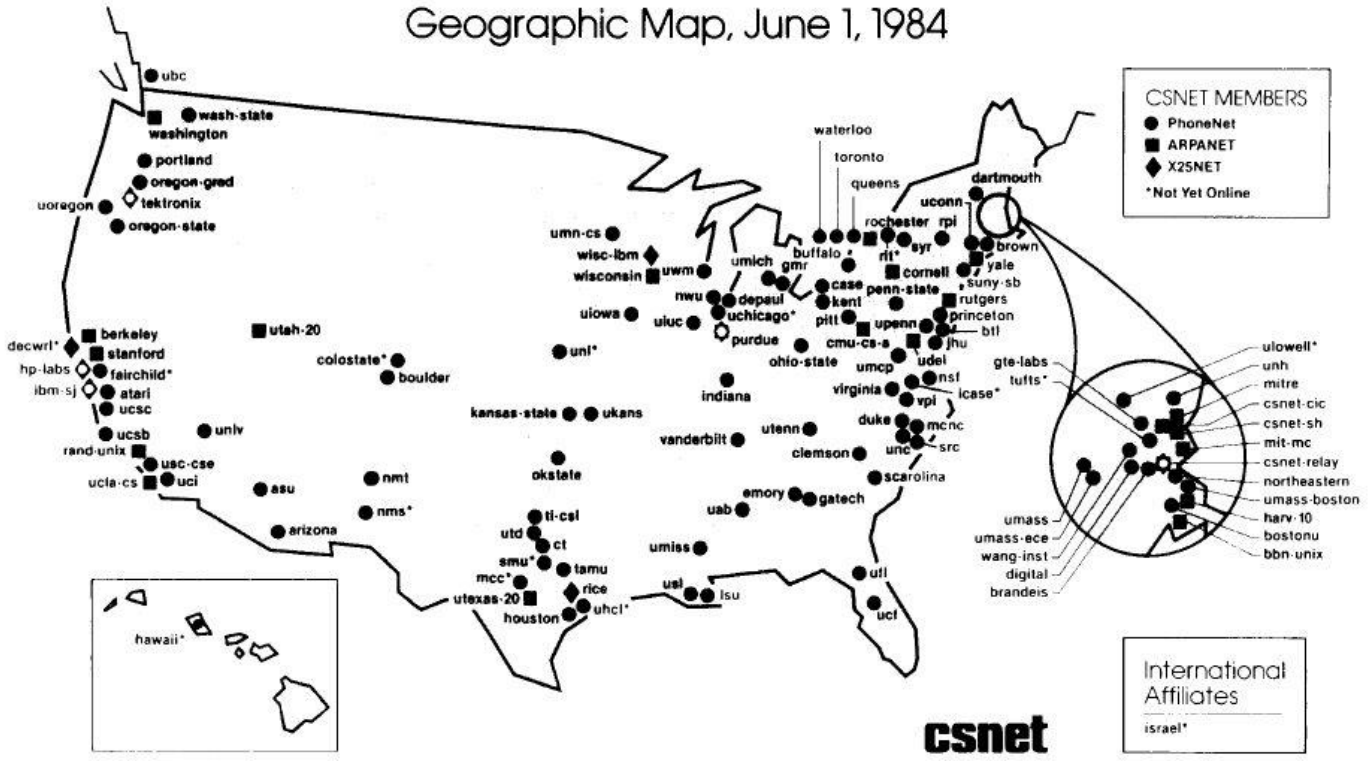


Source: http://cdn1.vox-cdn.com/assets/4463435/G73Sep.jpg

1983: TCP/IP protocols became the standard for the ARPANET

ปีของโปรโตคอลใหม่

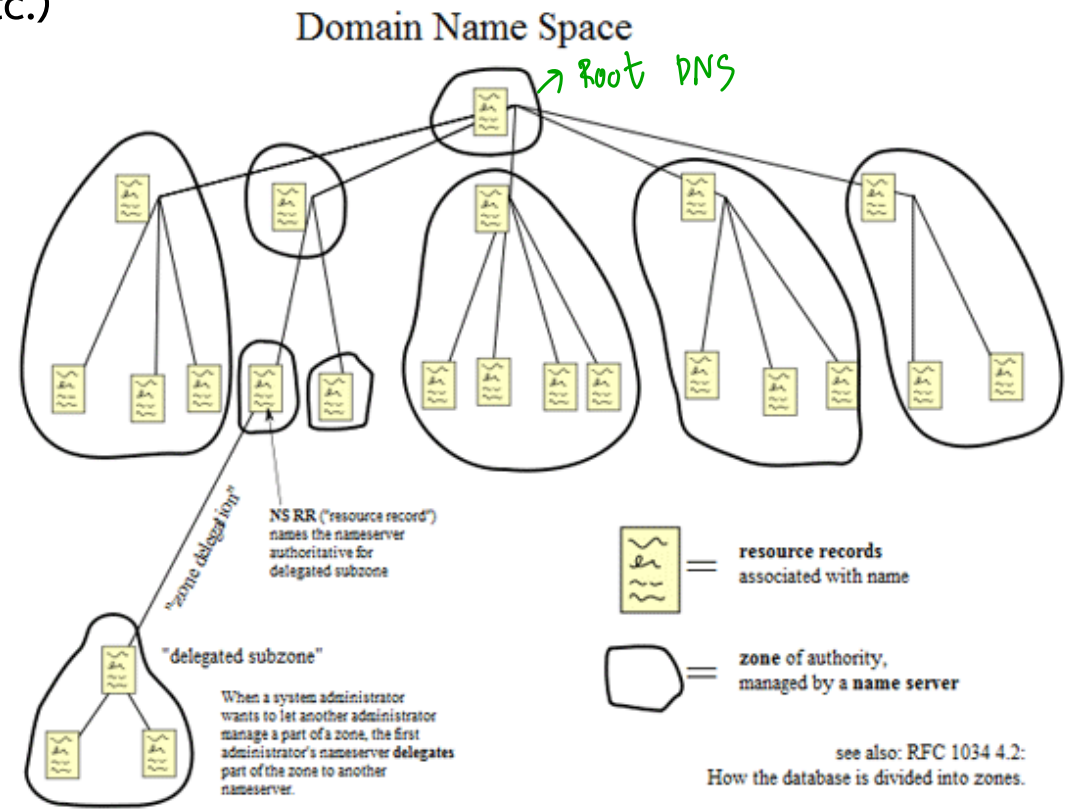
- To switch over to the TCP/IP protocols
- A few hundred computers were affected by the switch.



Source: http://cdn1.vox-cdn.com/assets/4463491/articlesdepot-info_20th-il-www_CNET-il.jpg

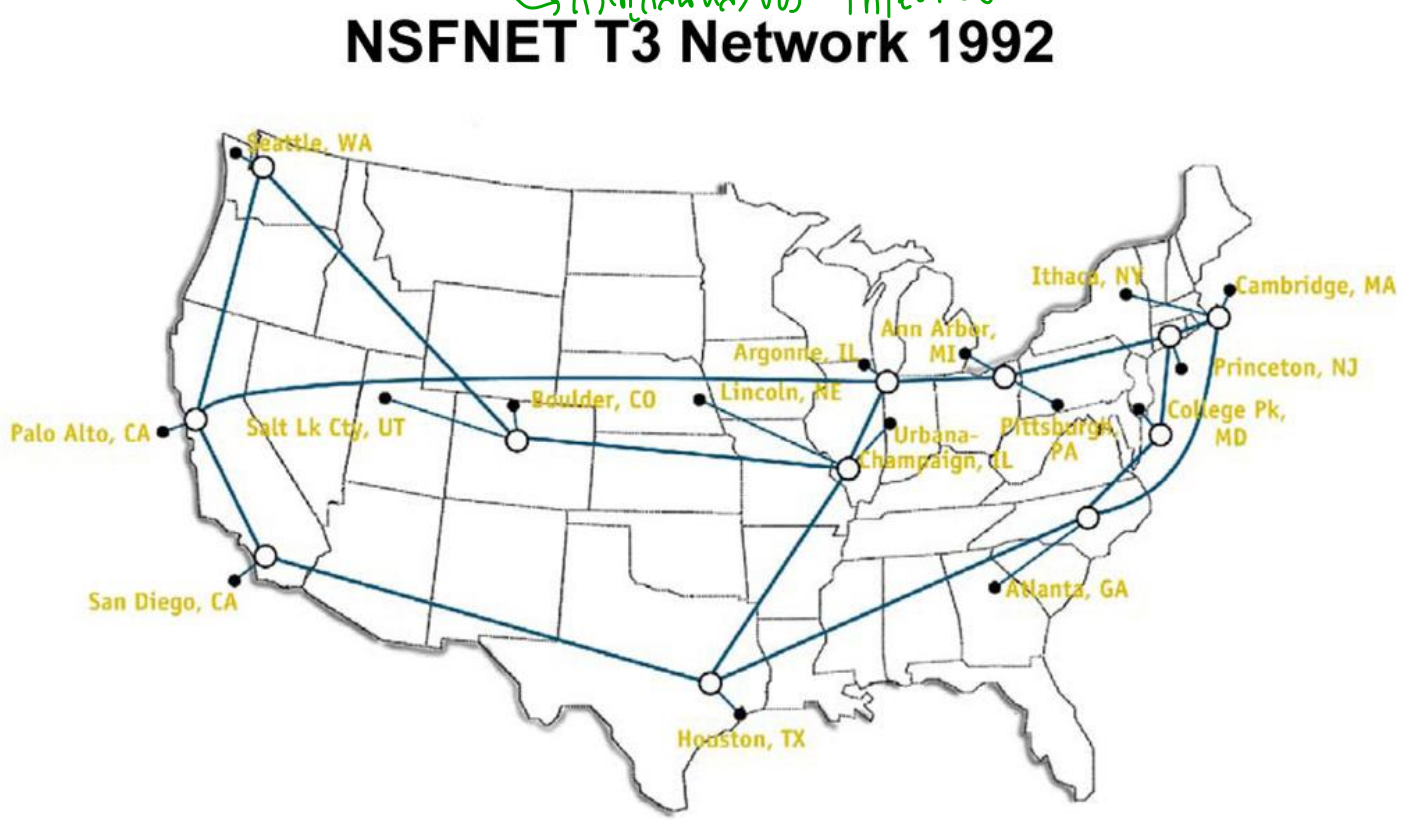
1984: Domain Name System (DNS)

- The domain name system was created in 1984 along with the first Domain Name Servers (DNS)
- In October 1984, RFC 920 was published to define a series of top-level domains (.com, .gov, .edu, etc.)



NSFNET: The first internet backbone

- From ARPANET to NSFNET (National Science Foundation Network)
- 45 Mbit/s (T-3) backbone มีงก์ → กระดูกสันหลังของ internet

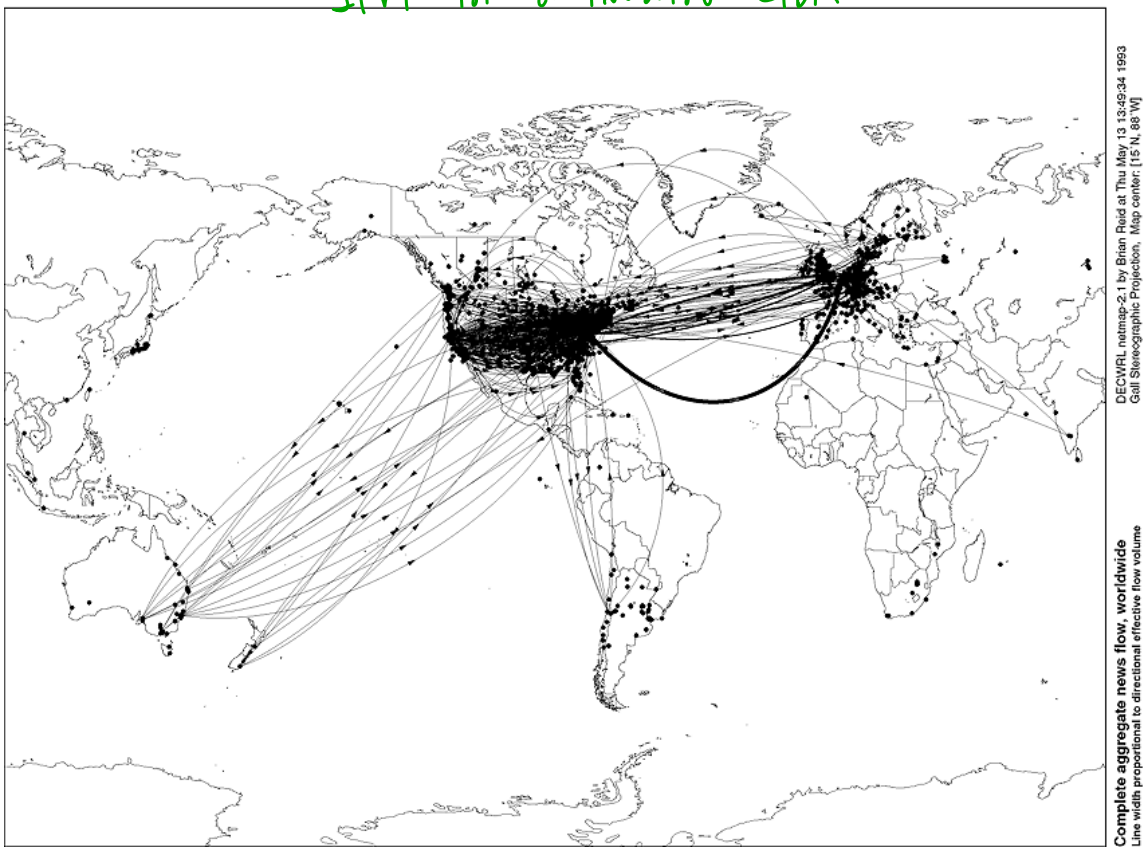


Source: http://cdn2.vox-cdn.com/assets/4463667/NSFNET-backbone-T3.png

1993: Global Internet Network

- In September 1993, CIDR (Classless Inter-Domain Routing) was introduced to slow the growth of routing tables and to help slow the exhaustion of IPv4 addresses

IPv4 เกิดปัญหาเลยมาใช้ CIDR

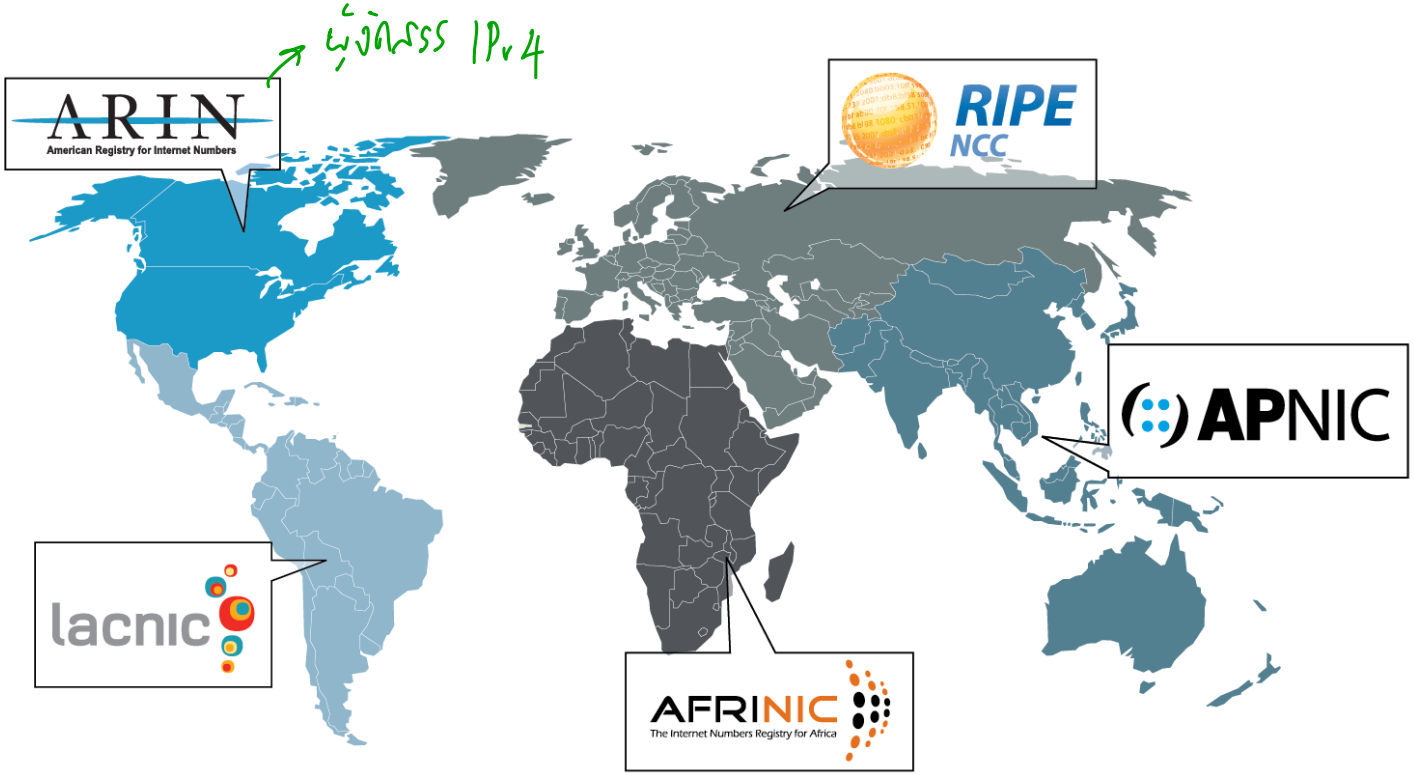


- APNIC (Asia-Pacific Network Information Centre) was formed to allocate address space in the Asia-Pacific region.

Source: http://cdn0.vox-cdn.com/assets/4463763/world_large.gif

Internet Registries

- In December 1997, ARIN (American Registry for Internet Numbers) formed as a nonprofit corporation. It provided IP registration and allocation in North America.
- In 2004, AFRINIC was incorporated as the internet registry for Africa.

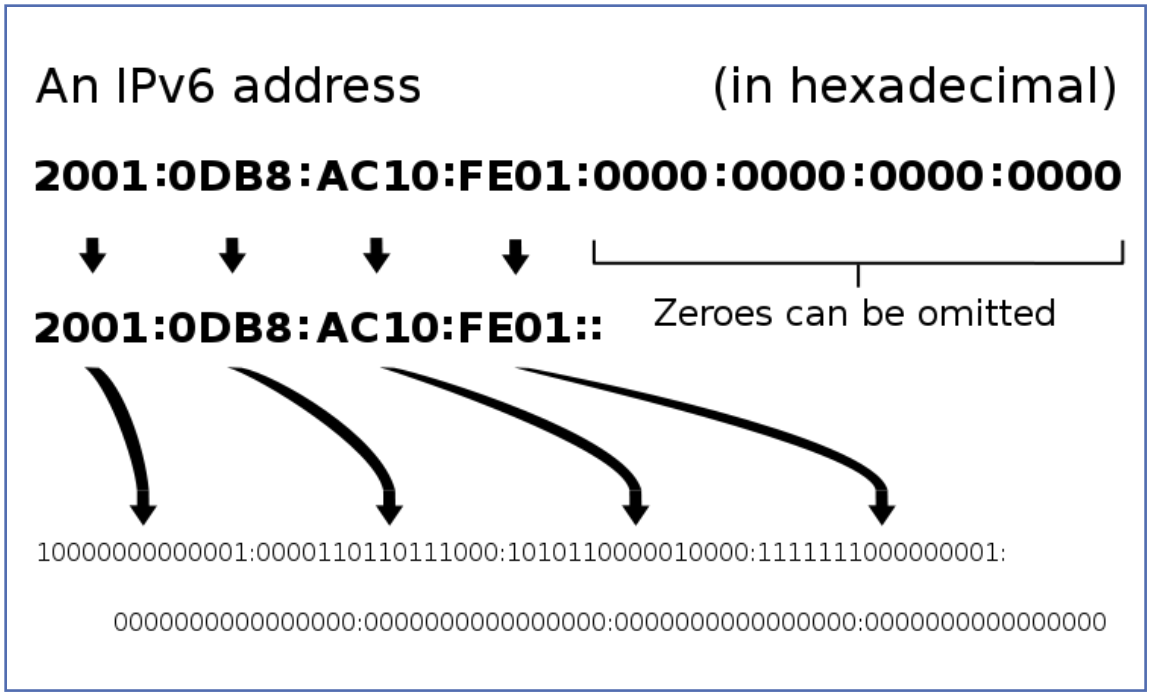


Source: http://cdn1.vox-cdn.com/assets/4463859/rirmap.png

IPv6 Address

IPv4 ไปพอ เพราะใช้ IPv6 แต่ก็ยังมาใช้ IPv4 อยู่

- In April 2011, APNIC was the first Regional Internet Registry (RIR) to exhaust its regional address pool, except for a small amount of address space reserved for the transition to IPv6.
- In January of 2015, native IPv6 utilization hit approximately 5% as measured by connectivity among Google users.

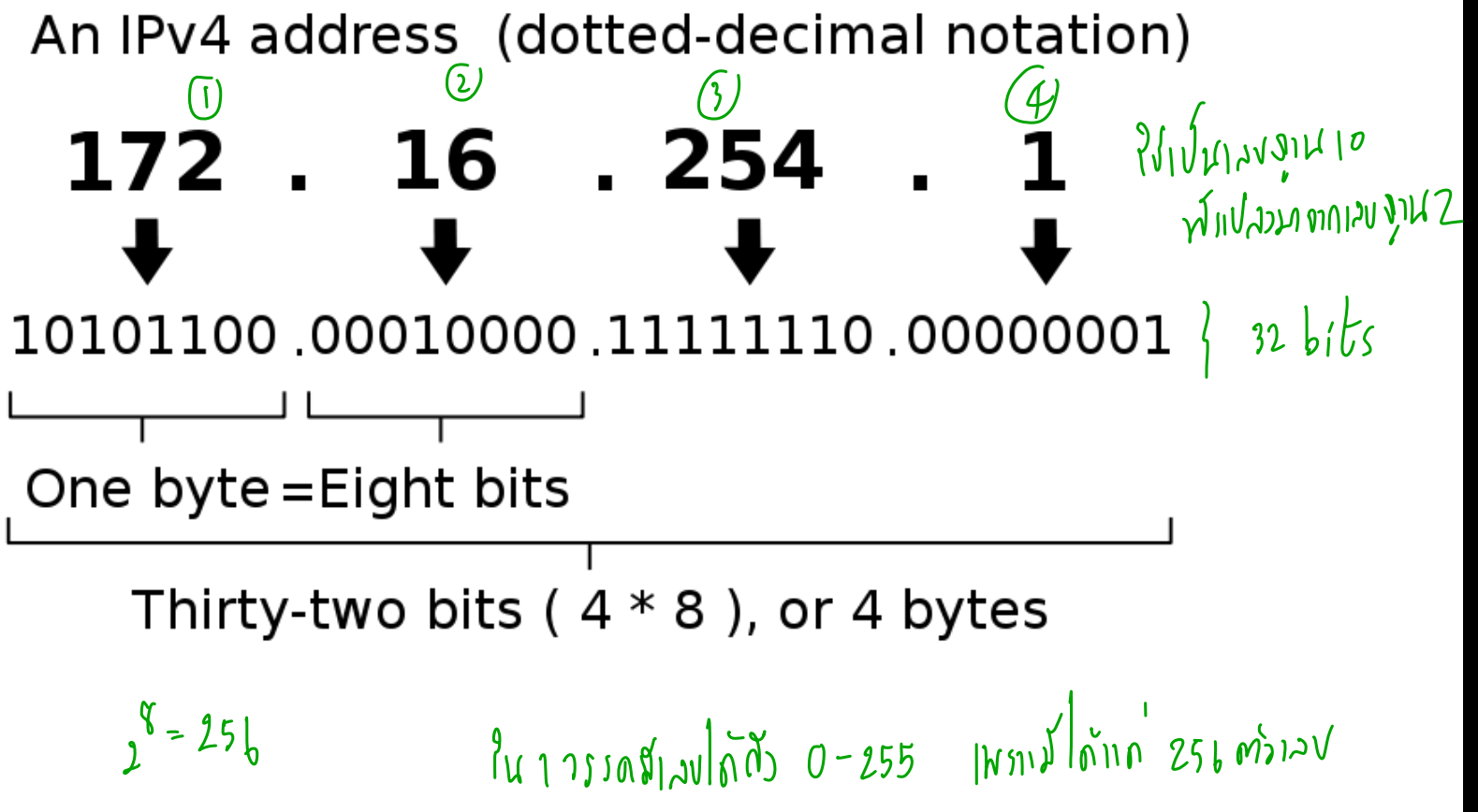


http://en.wikipedia.org/wiki/IPv6#mediaviewer/File:Ipv6_address_leading_zeros.svg

IPv4 addressing

IPv4 Address

แทนด้วย 4 จำนวน



① ② ③ ④

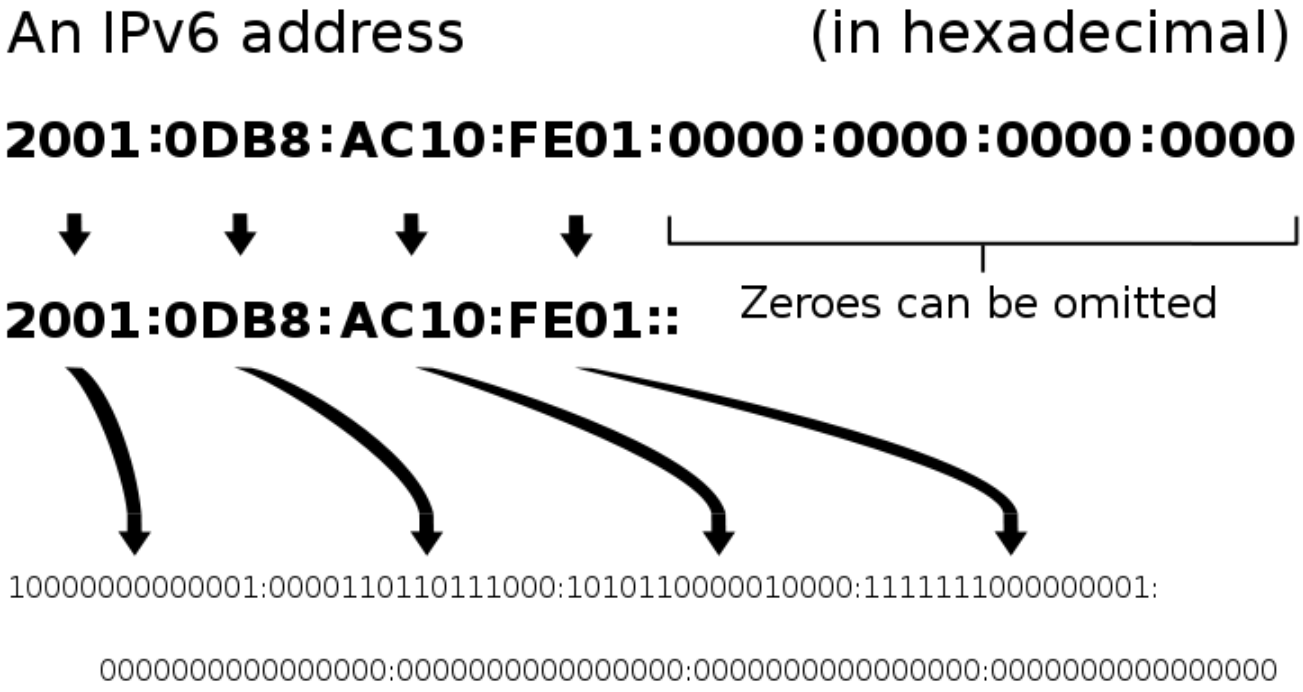
ปัญหาเลขฐานเอ
ฟังแปลงมาจากเลขฐาน 2

32 bits

$2^8 = 256$

ในแต่ละจำนวนมีค่าตั้งแต่ 0-255 เพราะมีได้ทั้งหมด 256 ตัวเลข

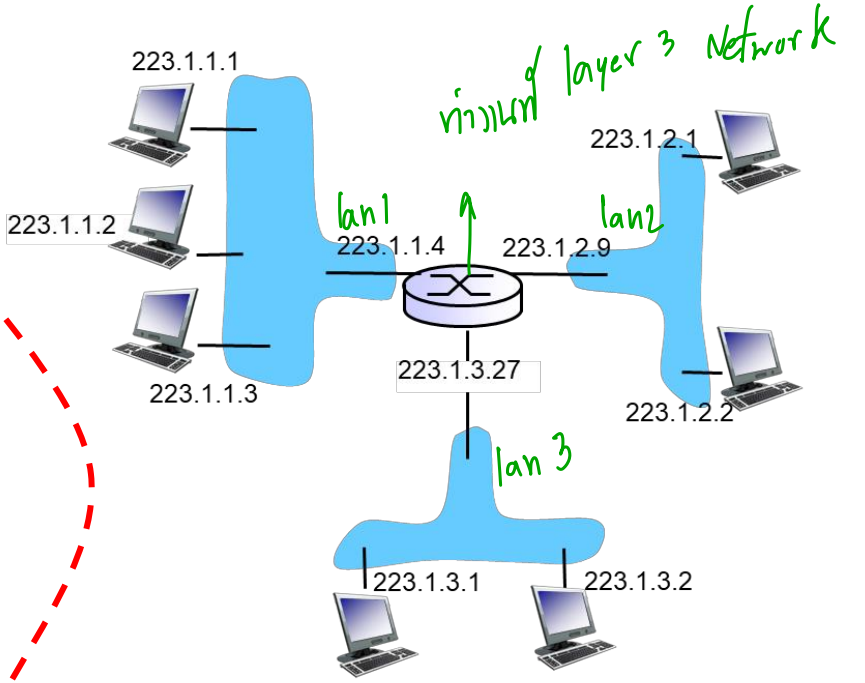
IPv6 Address



Source:
http://en.wikipedia.org/wiki/IPv6#mediaviewer/File:Ipv6_address_leading_zeros.svg

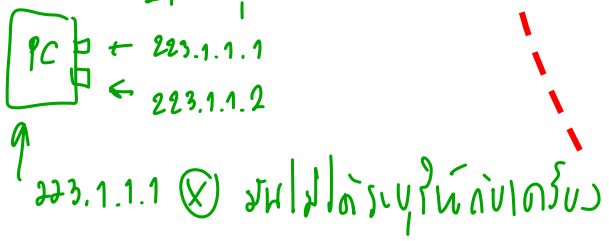
IP addressing: introduction

- ***IP address:*** 32-bit identifier for host, router *interface*
- ***Interface:*** connection between host/router and physical link
  - router's typically have multiple interfaces
  - host typically has one or two interfaces (e.g., wired Ethernet, wireless 802.11)
- *IP addresses associated with each interface*



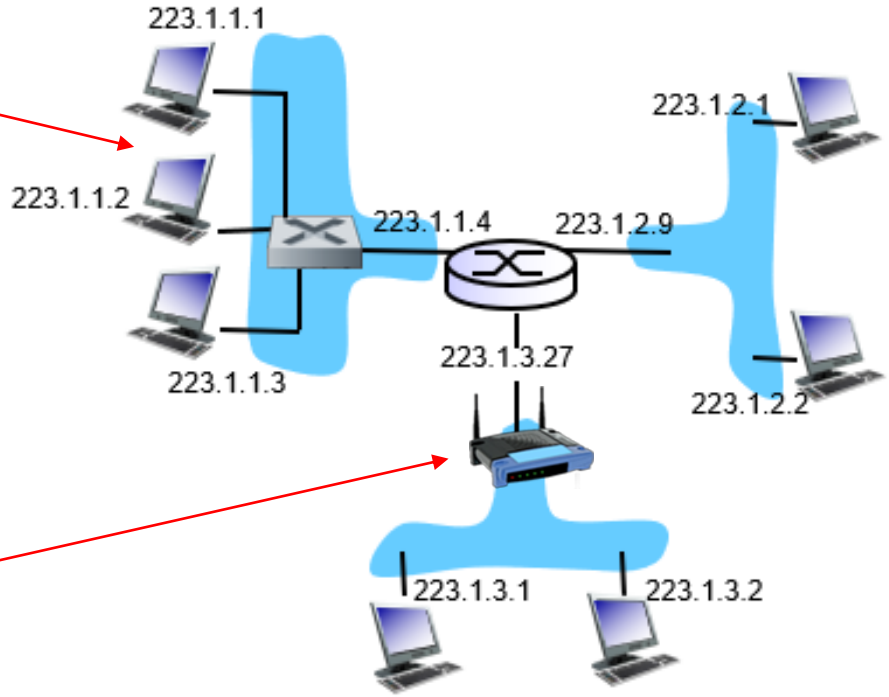
223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1



IP addressing: introduction

- *wired Ethernet interfaces connected by Ethernet switches*

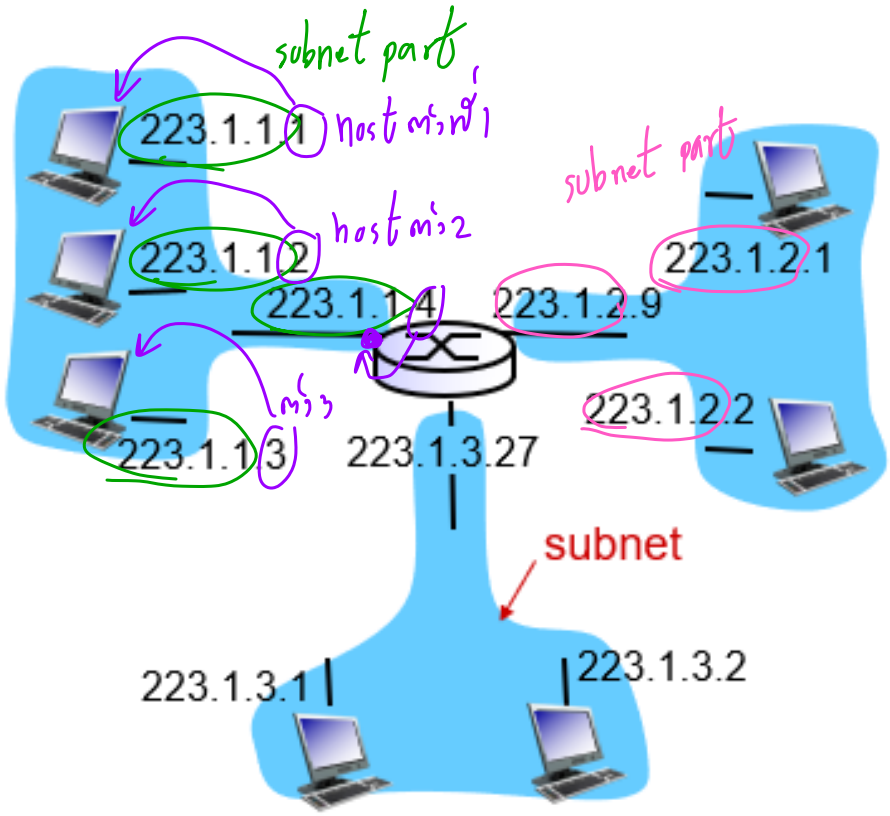


wireless WiFi interfaces connected by WiFi base station

Subnets

- IP address: มีองค์ประกอบ 2 ส่วน
  - subnet part - high order bits (ของทั้ง LAN1, LAN2, LAN3)
  - host part - low order bits

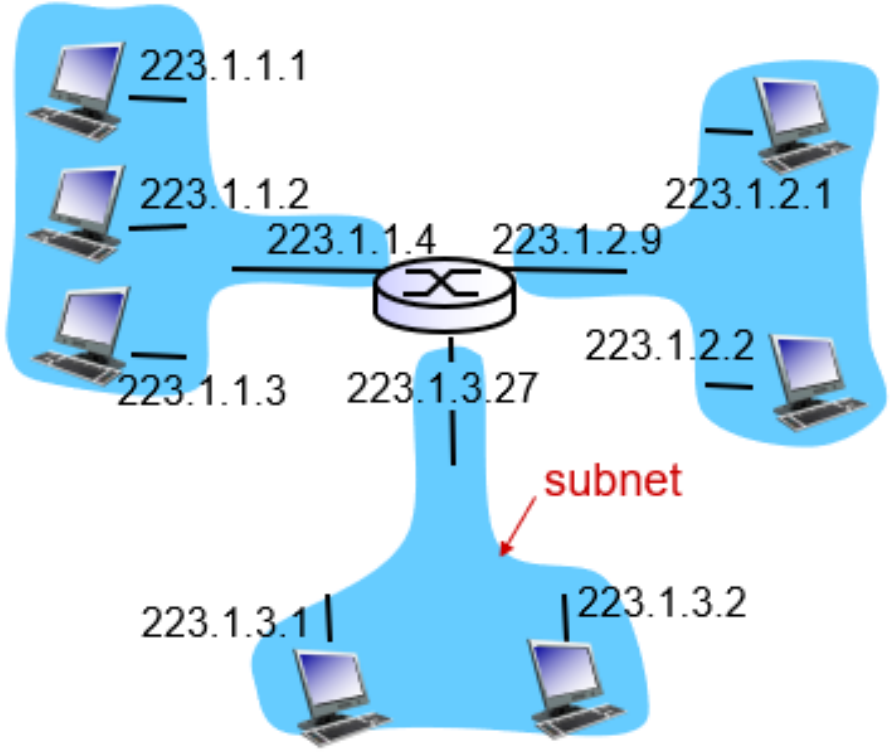
- What is a subnet ?
  - device interfaces with same subnet part of IP address
  - can physically reach each other without intervening router ไม่ผ่าน Router



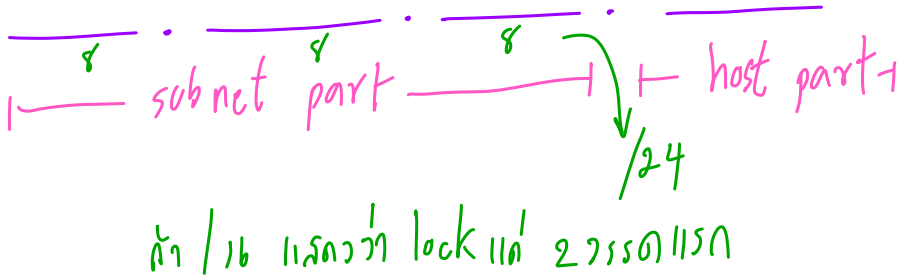
network consisting of 3 subnets

Subnets

- recipe
  - to determine the subnets, detach each interface from its host or router, creating islands of isolated networks
  - each isolated network is called a subnet

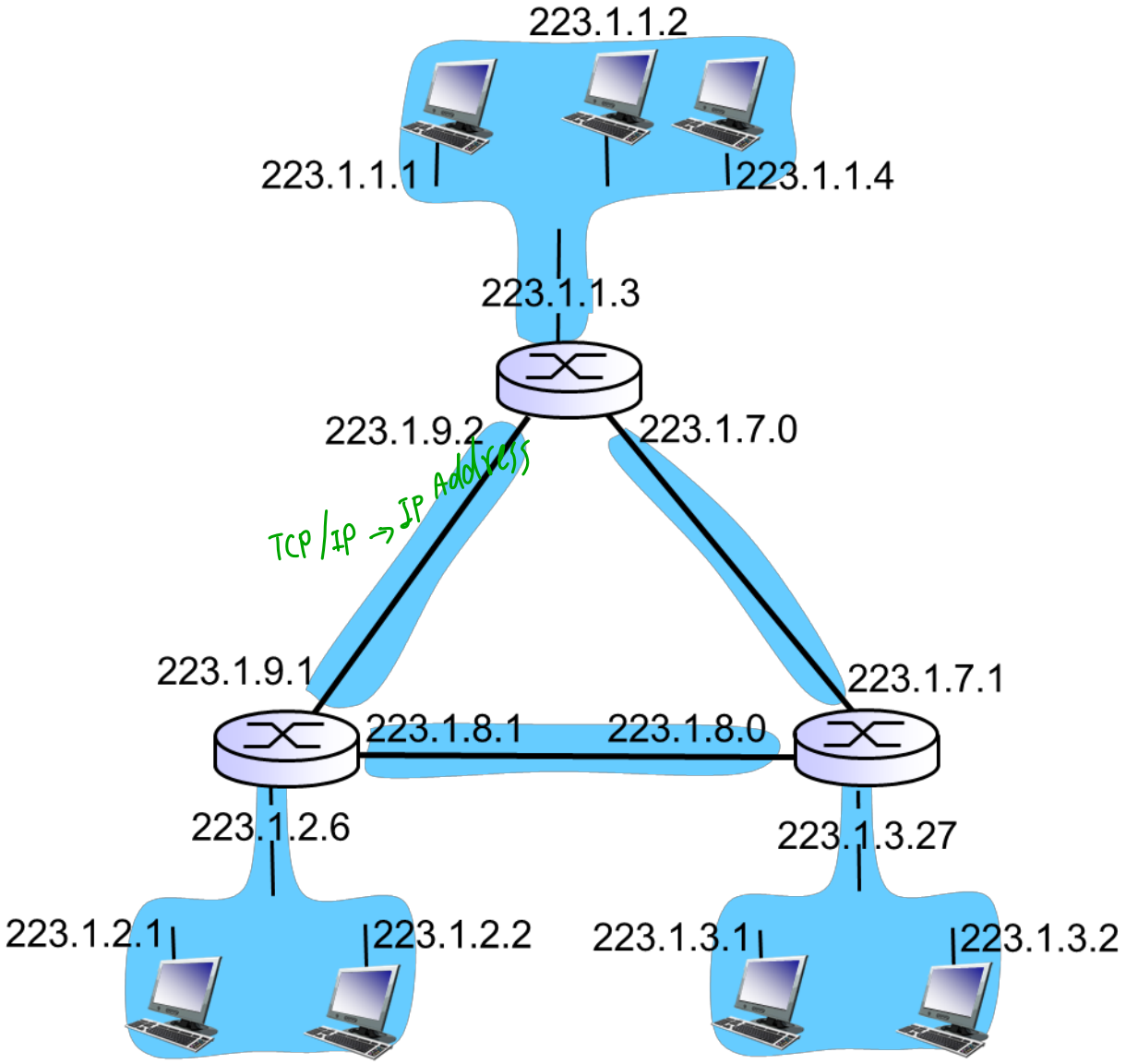


subnet mask: /24



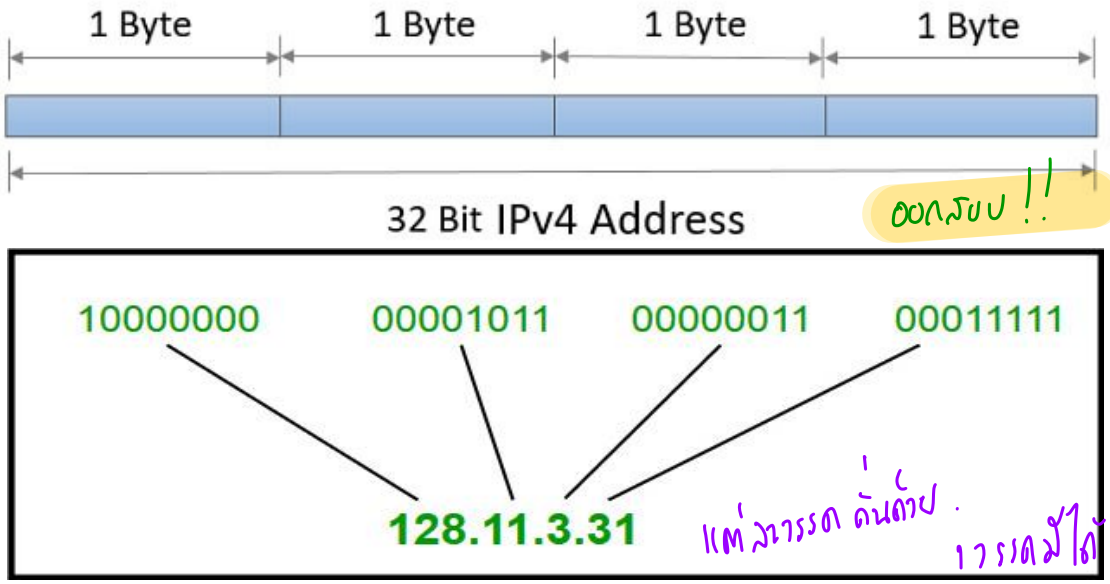
Subnets

how many?



IP Address Classes (Classful addressing)

แบ่งตามวรรค



ออกสอบ !!

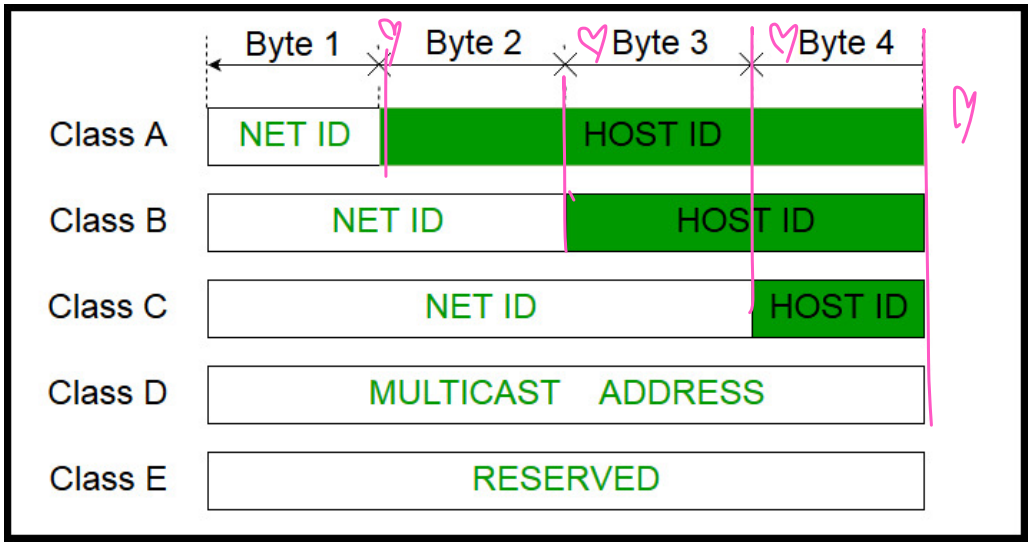
IPv4 มีทั้งหมดกี่บิต แต่ละวรรคมีกี่บิต

32 บิต 4 วรรค วรรคละ 8 บิต

แต่ละวรรค ตั้งต้น . วรรคมีได้ 256 ค่าคือ 0-255

IPv4 address is divided into two parts:

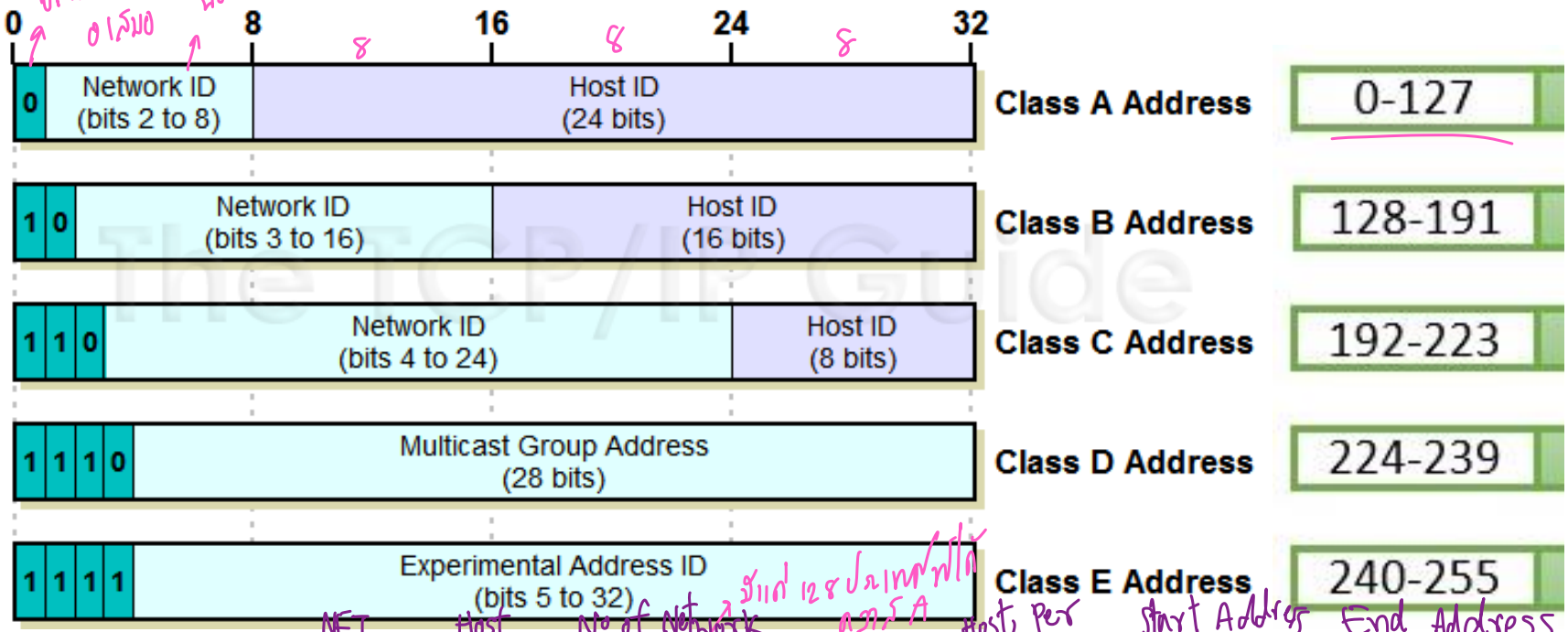
- Network ID subnet
- Host ID host part



https://www.geeksforgeeks.org/introduction-of-classful-ip-addressing/

https://knowledgeofthings.com/dividing-ip-addresses-part-i-classful-networking/

IP Address Classes (Classful addressing)



Class	HOB	NET ID Bits	Host ID Bits	No of Networks	Host Per Network	Start Address	End Address
Class A	0	8	24	2^7=128	2^{24}=16,777,216	0.0.0.0	127.255.255.255
Class B	10	16	16	2^{14}=16,384	2^{16}=65,536	128.0.0.0	191.255.255.255
Class C	110	24	8	2^{21}=2,097,152	2^8=256	192.0.0.0	223.255.255.255
Class D	1110	-	-	-	-	224.0.0.0	239.255.255.255
Class E	1111	-	-	-	-	240.0.0.0	255.255.255.255

Note: The class is determined by the first three bits of the prefix.

IP Address Range

Address Class	First Octet Value
A	1 - 126 (00000001 - 01111110)
B	128 - 191 (10000000 - 10111111)
C	192 - 223 (11000000 - 11011111)
D	224 - 239 (11100000 - 11101111)
E	240 - 255 (11110000 - 11111111)

class A ranges from 1.x.x.x – 126.x.x.x

class B ranges from 128.0.x.x – 191.255.x.x

class C ranges from 192.0.0.x – 223.255.255.x

***Note** that the address ranges of all addresses that begin with 0 and all addresses that begin with 127 are reserved.

- 0.X.X.X is reserved for default network
- 127.X.X.X is reserved for loopback

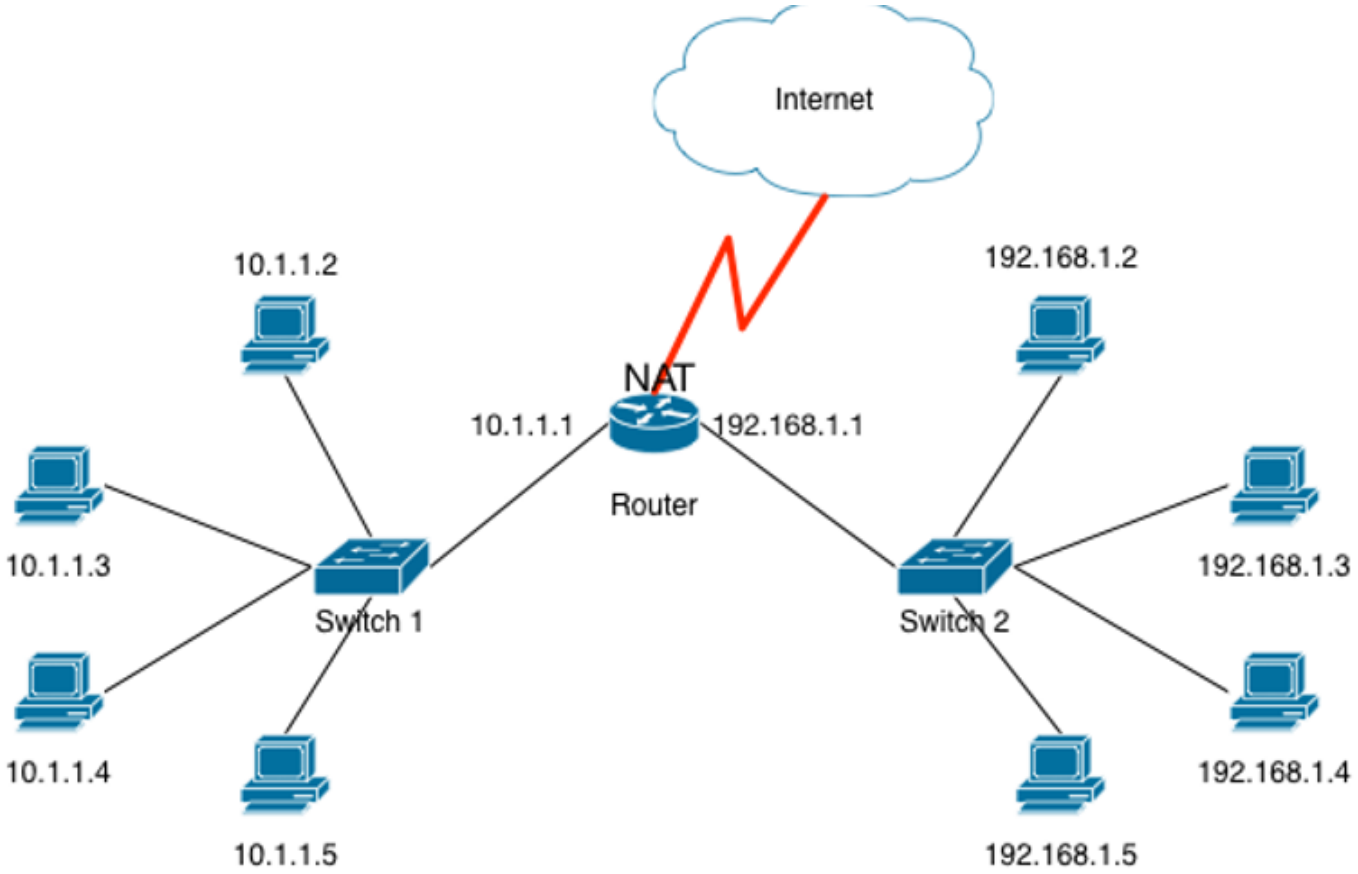
	Class A	Class B	Class C
First octet range	1–126	128–191	192–223
Valid network numbers	1.0.0.0–126.0.0.0	128.0.0.0–191.255.0.0	192.0.0.0–223.255.255.0
Total networks	$2^7 - 2 = 126$	$2^{14} = 16{,}384$	$2^{21} = 2{,}097{,}152$

Private IP Addresses (RFC1918)

Explaining in
Classless Addressing

RFC1918 name	IP address range	CIDR block
24-bit block	10.0.0.0 - 10.255.255.255	10.0.0.0/8
20-bit block	172.16.0.0 - 172.31.255.255	172.16.0.0/12
16-bit block	192.168.0.0 - 192.168.255.255	192.168.0.0/16

Using Private Addresses



NAT = Network Address Translation

NAT = Network Address Translation

Classless addressing

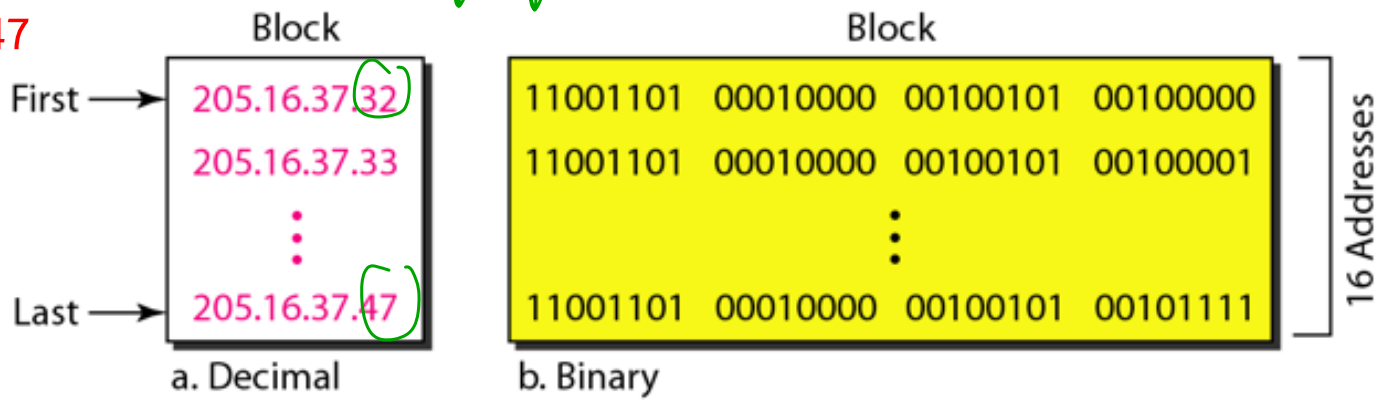
- In classful addressing, a large part of the available addresses were wasted

- Classful addressing is replaced with classless addressing (in 1993)
  - It is known as Classless Inter Domain Routing (CIDR)

- In IPv4 addressing, a block of addresses can be defined as x.y.z.t /n
  - in which x.y.z.t defines one of the addresses and the /n defines the mask (a slash followed by a number)

Classless addressing

- For small organization - 205.16.37.39/28
  - What is the first address in the block?
- 205.16.37.39/28 ① ทำเป็นเลขฐาน 2
  - 11001101 00010000 00100101 | 00100111
- If we set 32–28 rightmost bits to 0 (the first address)
  - 11001101 00010000 00100101 00100000
  - or 205.16.37.32
- the last address for the block -> set 32 – 28 rightmost bits to 1
  - 11001101 00010000 00100101 00101111
  - or 205.16.37.47



Network and Broadcast address

- In every network, there is 2 addresses used for Network and Broadcast addressing
  - Network and Broadcast address are not used for node addressing
- Network address is first address in the network
  - To identify network segment
- Broadcast address is the last address in the network
  - for addressing all the nodes in the network
  - Ex. PING broadcast address -> send PING to all nodes

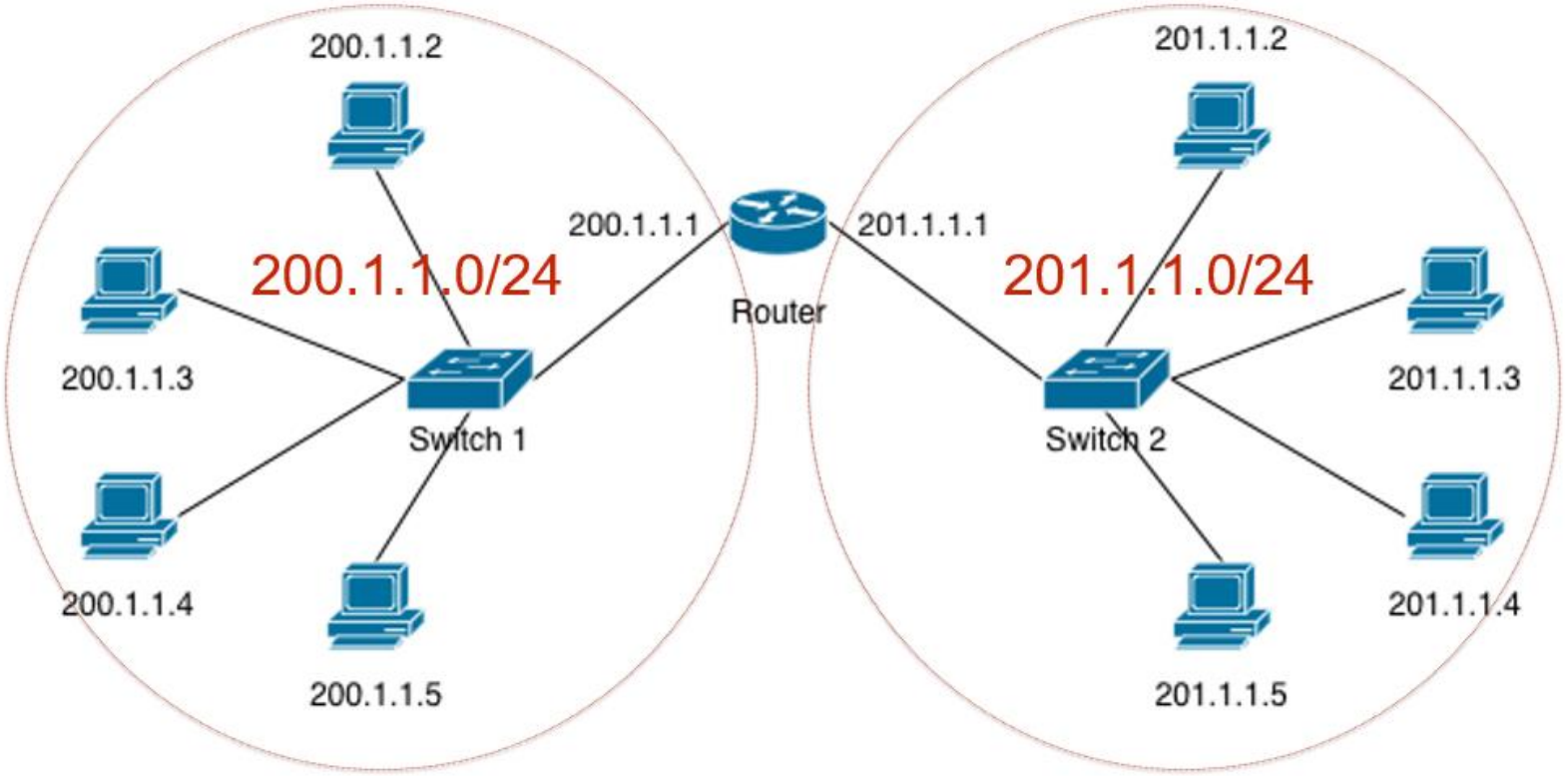
Network Addresses

132 . 123 . 0 . 0

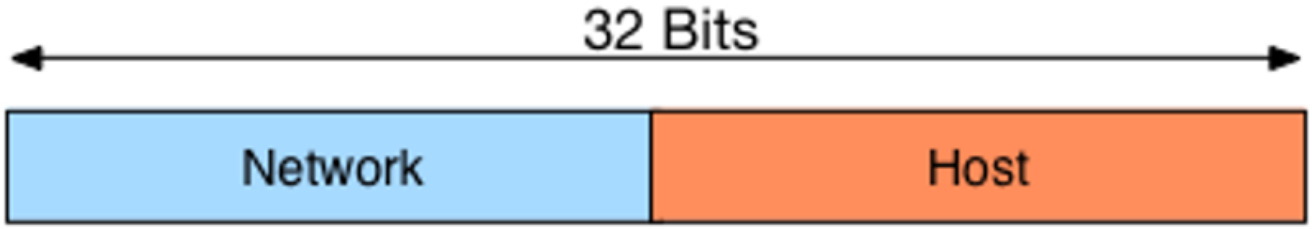
1000 0100 .0111 1011.0000 0000.0000 0000

Network Address ==> Host Bits = 0

Network Address



Broadcast Addresses

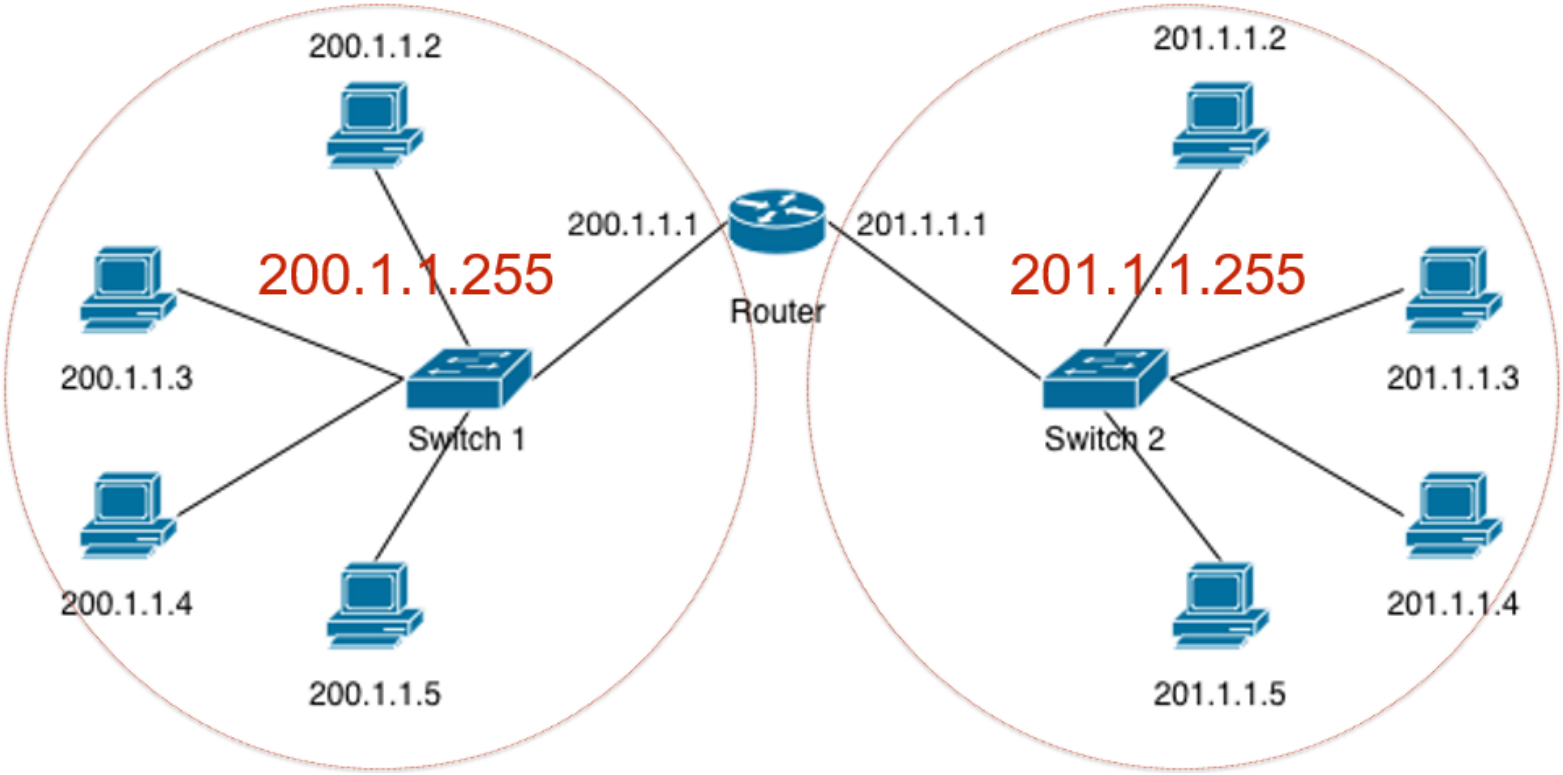


132 . 123 . 255 . 255

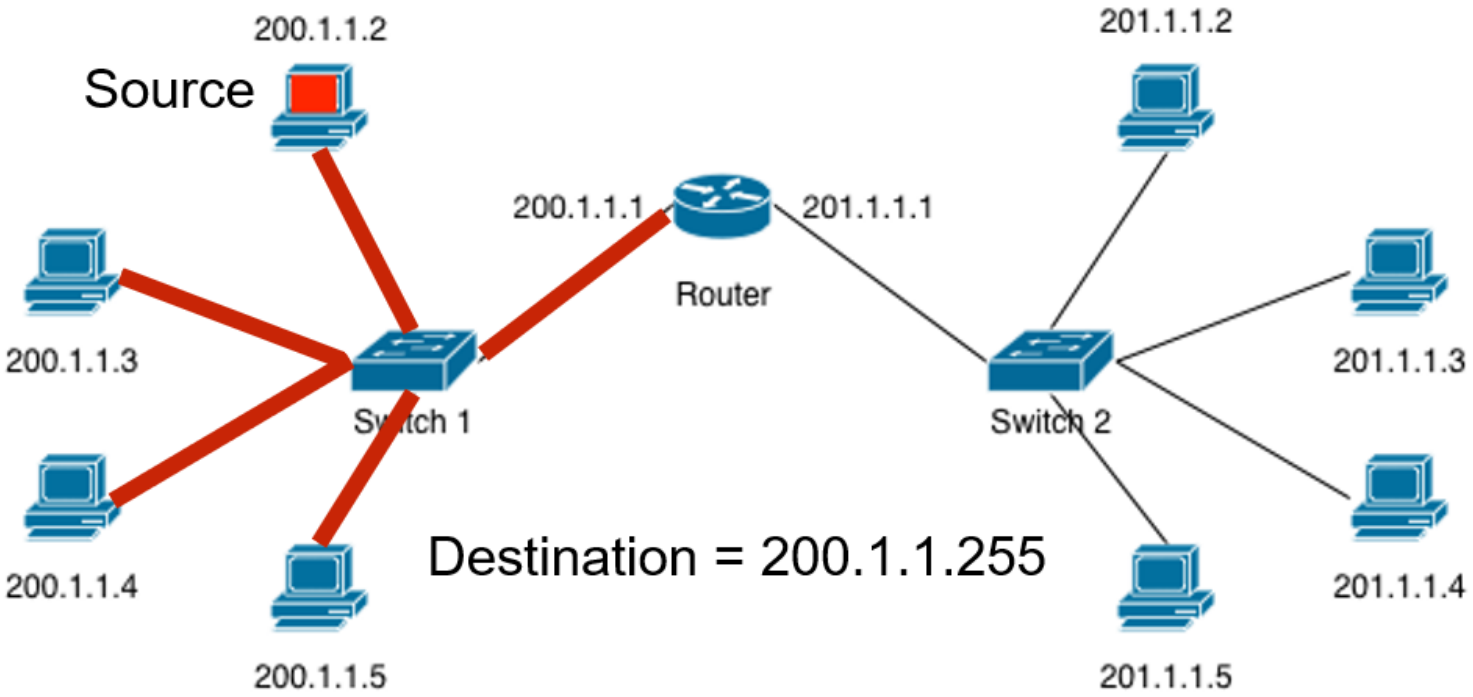
1000 0100 .0111 1011.1111 1111.1111 1111

Network Address ==> All Host Bits = 1

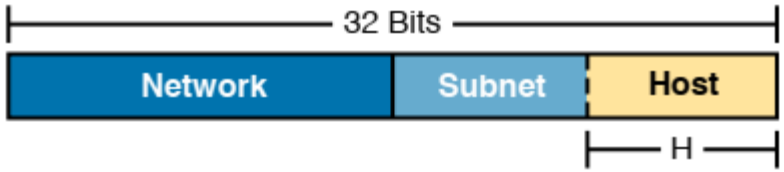
Broadcast Address



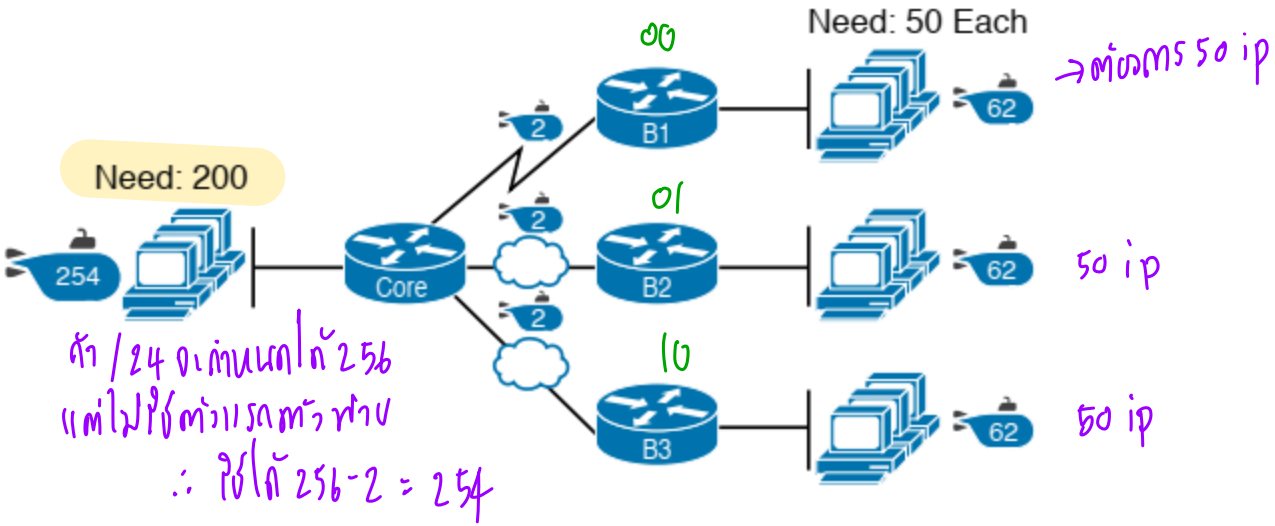
Broadcast Transmission



Subnetting



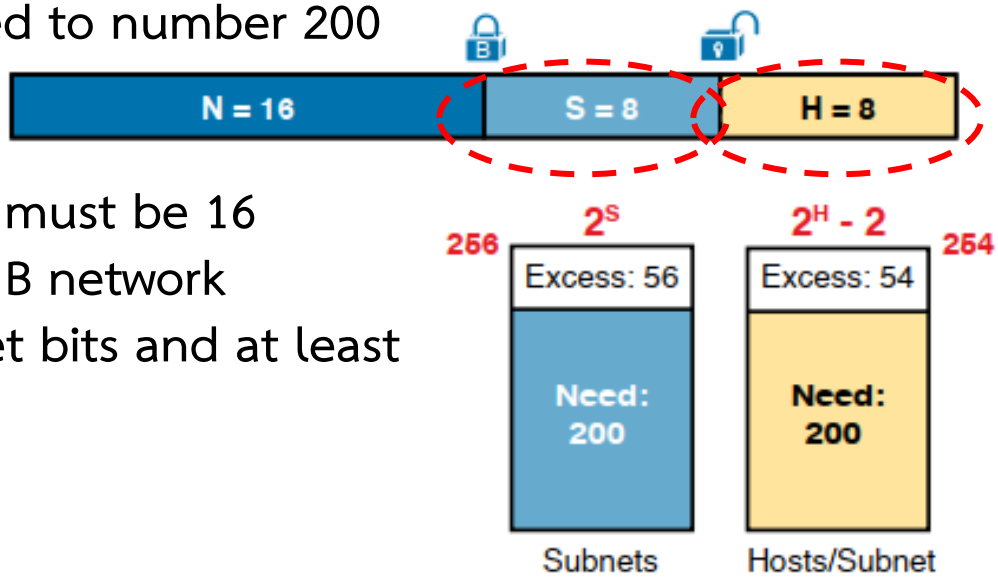
- The three-part structure of an IP address
- Different masks mean different numbers of host bits
  - and a different number of hosts in some subnets based on the $2^H - 2$



- The subnets on the right that need 50 IP addresses
- Subnets with 6 host bits, for $2^6 - 2 = 62$
  - available addresses per subnet

Example Design: 172.16.0.0, 200 Subnets, 200 Hosts

- Use private Class B network 172.16.0.0
- Plan for 200 subnets and Plan for 200 host per subnet
- How many subnet (S) bits do I need to number 200 subnets?
  - S = 7 is not large enough (2^7 = 128)
  - but S = 8 is enough (2^8 = 256). So, you need at least 8 subnet bits.
- How many host (H) bits do I need to number 200 hosts per subnet?
  - H = 8 is enough (2^8 – 2 = 254)
- The number of network bits (N) must be 16 because the design uses a Class B network
- the mask needs at least 8 subnet bits and at least 8 host bits



Reference

- CCNA 200-301 Official Cert Guide, Volume 1 (2019)
  - By Wendell Odom
- Computer Networking: A Top-Down Approach, Global Edition (2016)
  - By Keith Ross James Kurose

นางสาวณัฐชยา ผ่องกุศล B6226718

Classwork 2: IP Addressing (ส่งเป็น PDF ไฟล์)

ถ้า ISP ให้ block of addresses เริ่มที่ 192.177.0.0/16
จองวรรคที่ 3 สำหรับ subnet เช่น 192.177.0.x สำหรับบริษัทแรก

ต้องการแจกให้ 2 กลุ่ม
กลุ่ม 1 มีลูกค้า 6 บริษัท แต่ละบริษัทต้องการ 256 IP addresses
(256 addresses นับรวม Network and Broadcast address)
กลุ่ม 2 มีลูกค้า 4 บริษัท แต่ละบริษัทต้องการ 128 IP addresses
(128 addresses นับรวม Network and Broadcast address)

คำถาม?
1. ให้หาว่าในกลุ่ม 1 บริษัทแรก และบริษัทสุดท้ายตามลำดับจัดสรร IP address จะมี Network address และ Broadcast address คือเท่าไหร่
2. ให้หาว่าในกลุ่ม 2 บริษัทแรก และบริษัทสุดท้ายตามลำดับจัดสรร IP address จะมี Network address และ Broadcast address คือเท่าไหร่

1 ในกลุ่ม 1 บริษัทแรกจะมี Network address คือ 192.177.0.0
มี Broadcast address คือ 192.177.0.255

บริษัทสุดท้ายมี Network address คือ 192.177.5.0
มี Broadcast address คือ 192.177.5.255

2. ในกลุ่ม 2 บริษัทแรกจะมี Network address คือ 192.177.6.0
มี Broadcast address คือ 192.177.6.127

บริษัทสุดท้ายมี Network address คือ 192.177.9.0
มี Broadcast address คือ 192.177.9.127