OSI and TCP/IP Models

	OSI	TCP/IP
7	Application	Application
6	Presentation	
5	Session	
4	Transport	Transport
3	Network	Internet
2	Data Link	Network Access
1	Physical	

OSI and TCP/IP Models - PDU

	OSI	TCP/IP	Protocol Data Unit
7	Application	Application	Data
6	Presentation		
5	Session		
4	Transport	Transport	Segments
3	Network	Internet	Packets
2	Data Link	Network Access	Frames
1	Physical		Bits

OSI and TCP/IP Models - Devices

Layer	Devices
7	Layer 7 Firewall
6	
5	
4	Layer 4 Firewall
3	Router, Multilayer Switch, Wireless Router
2	Switch, Bridge, NIC, Wireless Access Point
1	Hub, NIC, Wireless Access Point

OSI and TCP/IP Models - Internet Protocol Sui

Layer	Internet Protocol Suite
7	HTTP, DNS, DHCP, FTP, Telnet, SSH, SMTP, POP, IMAP, NTP, SNMP, TLS/SSL, BGP, RIP, SIP
6	
5	
4	TCP, UDP
3	IPv4, IPv6, ICMP, ICMPv6, IPSec, OSPF, EIGRP
2	MAC, ARP, Ethernet 802.3, CDP, LLDP, HDLC, PPP, DSL, L2TP, 802.11, SONET/SDH
1	

7	Application	Application
6	Presentation	
5	Session	
4	Transport	Transport
3	Network	Internet
2	Data Link	Network Access
1	Physical	

- Applications, protocols and services that interface with the end user
- Data is formatted, converted, encrypted decrypted compressed and decompressed and sent or presented to the user (MIME types),
- Open, close and manage a session between end-user application processes (RPC)

7	Application	Application
6	Presentation	
5	Session	
4	Transport	Transport
3	Network	Internet
2	Data Link	Network Access
1	Physical	

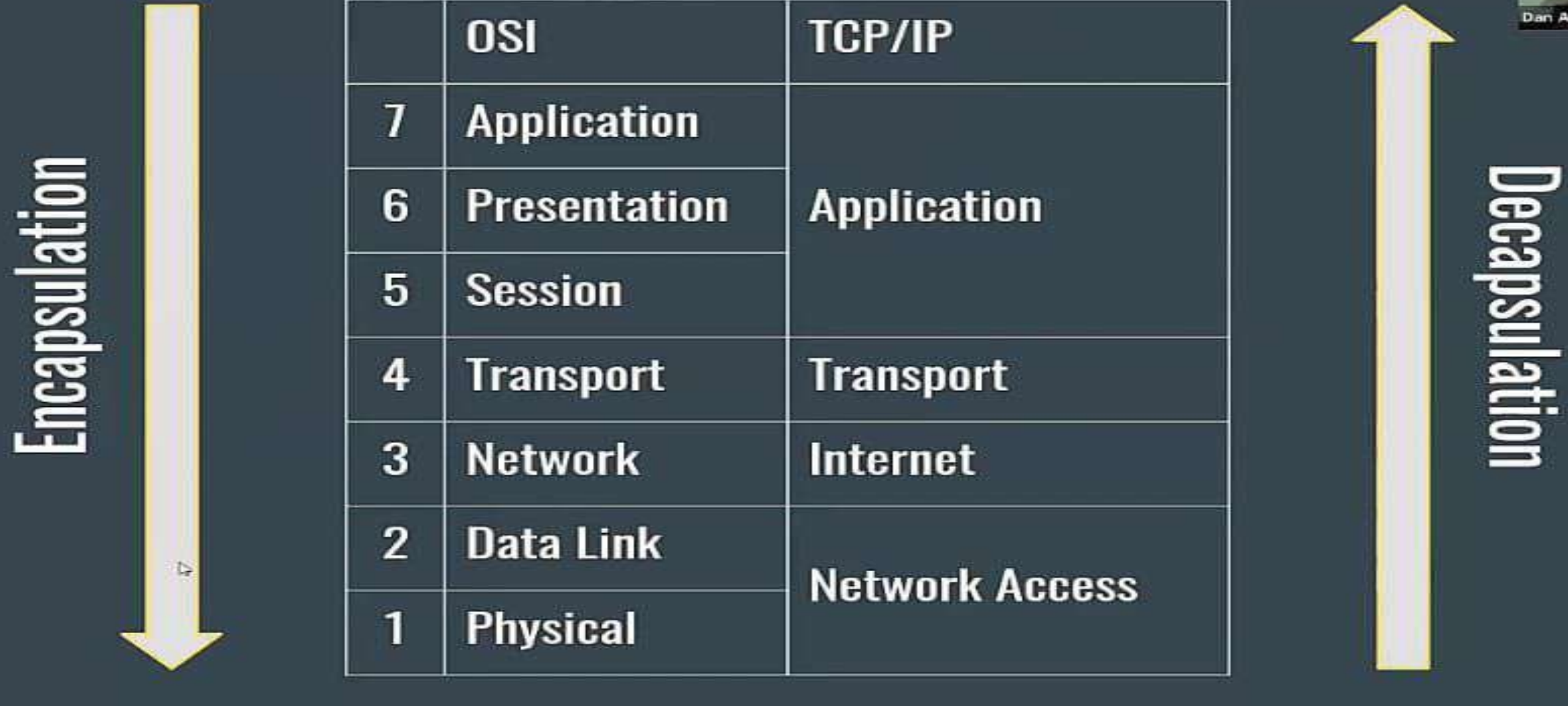
- Facilitates end-to-end communications between multiple applications simultaneously (ports)
- Reliable and unreliable end-to-end data transport and data stream services (TCP, UDP, SCTP)
- Connection oriented, connectionless communications, and data stream services(session establishment and termination)

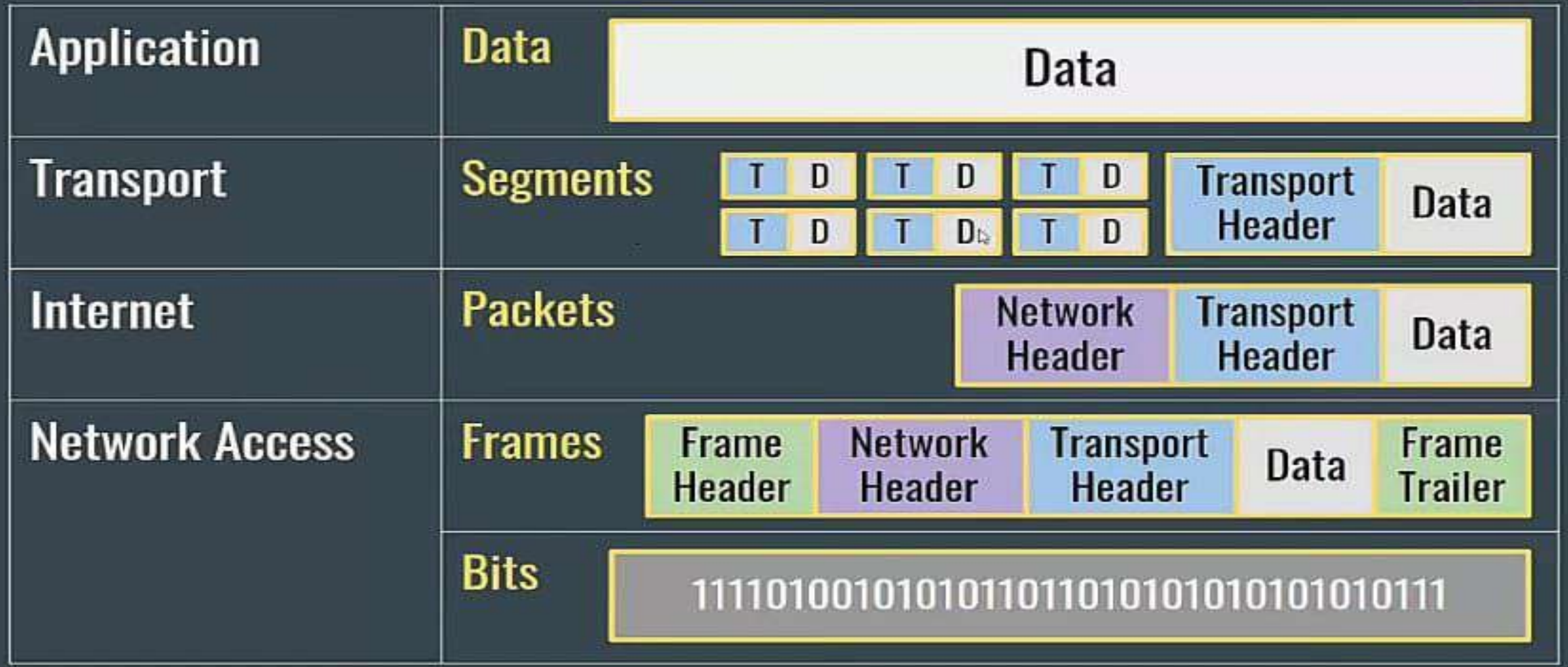
7	Application	Application
6	Presentation	
5	Session	
4	Transport	Transport
3	Network	Internet
2	Data Link	Network Access
1	Physical	

- Provide host addressing (IP)
- Choose the best path to the destination network (Routing)
- Switch packets out of the correct interface (Forwarding)
- Maintain quality of service (QoS)
- Connectionless end-to-end networking

7	Application	Application
6	Presentation	
5	Session	
4	Transport	Transport
3	Network	Internet
2	Data Link	Network Access
1	Physical	

- 2 sublayers:
  - Logical Link Control (LLC, 802.2)
    provides services to the upper layers
  - Media Access Control (MAC)
    defines how devices access the medium
    CSMA/CD, CSMA/CA, Token Passing
    Host addressing (MAC addressing)
- Layer 2 Framing
- Error Checking (CRC)


Encapsulation
Decapsulation
OSI
TCP/IP
7
Application
Application
6
Presentation
5
Session
4
Transport
Transport
3
Network
Internet
2
Data Link
Network Access
1
Physical


Application
Data
Data
Transport
Segments
T D
T D
T D
T D
T D
T D
Transport Header
Data
Internet
Packets
Network Header
Transport Header
Data
Network Access
Frames
Frame Header
Network Header
Transport Header
Data
Frame Trailer
Bits
1111010010101011011010101010101010111

Binary - 10111100

Base 2 = 0,1

powers of 2	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
place values	128	64	32	16	8	4	2	1
	1	0	1	1	1	1	0	0
decimal long form	128 + 32 + 16 + 8 + 4							
decimal conversion	188							

File Edit Format View Help

Network Layer

1. IP Internet Protocol
    - IPv4, IPv6, ICMP,
    - logical addressing (OSI Layer 3) ---as opposed to layer 2 physical addressing
    - End-to-end addressing,

from(PC) --- Router --- ISP-Cloud --- Router --- to(PC) ---- and back again

2. Routers ---- Data Plane, Control Plane, QoS, SDN Software Defined Networking
3. Routing ---- host routing table and default gateway, router's routing table
4. Configuring a router

IP

- IP packet header ---------- (IP header (transport header + Data))
- Connectionless ---------- no prior established connection at this layer
- Best Effort ---------- no reliability, no retransmission at this layer

File Edit Format View Help

IP

- IP packet header ---------- (IP header (transport header + Data))
- Connectionless ---------- no prior established connection at this layer
- Best Effort ---------- no reliability, no retransmission at this layer
- Media Independent ---------- works with fiber, copper, wireless, etc.
- IPv4 addressing
  - network address ---------- 192.168.3.0 (first address in the network)
  - broadcast address ---------- 192.168.3.255 (last address in the network)
  - host address ---------- 192.168.3.100
  - netmask ---------- 255.255.255.0 (defines the network)

    N N N H
  - default gateway ---------- 192.168.3.1 (gateway is the router on the network)
  - multicast address --------- 224.0.0.1 (used for sending to groups)

Routers

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Routers

==========

Make forwarding decisions at Layer 3 ---------- Using Layer 3 header information (dst ip address)

Determine the Best Path ---------- Using the routing table

Forward data ---------- Move packet from input interface to output interface

Hosts Computers

==========

also make forwarding decisions at layer 3

also have routing tables ---------- netstat -r

Use default gateway ---------- for unknown networks (route table - 0.0.0.0 0.0.0.0 gateway)

Logical Addressing

==========

192.168.44.211 --- IP address

255.255.255.0 --- subnet mask ---- /24, means 24 ones in the mask 11111111.11111111.11111111.0000000

N N N H

==========

192 168 44 0 --- network

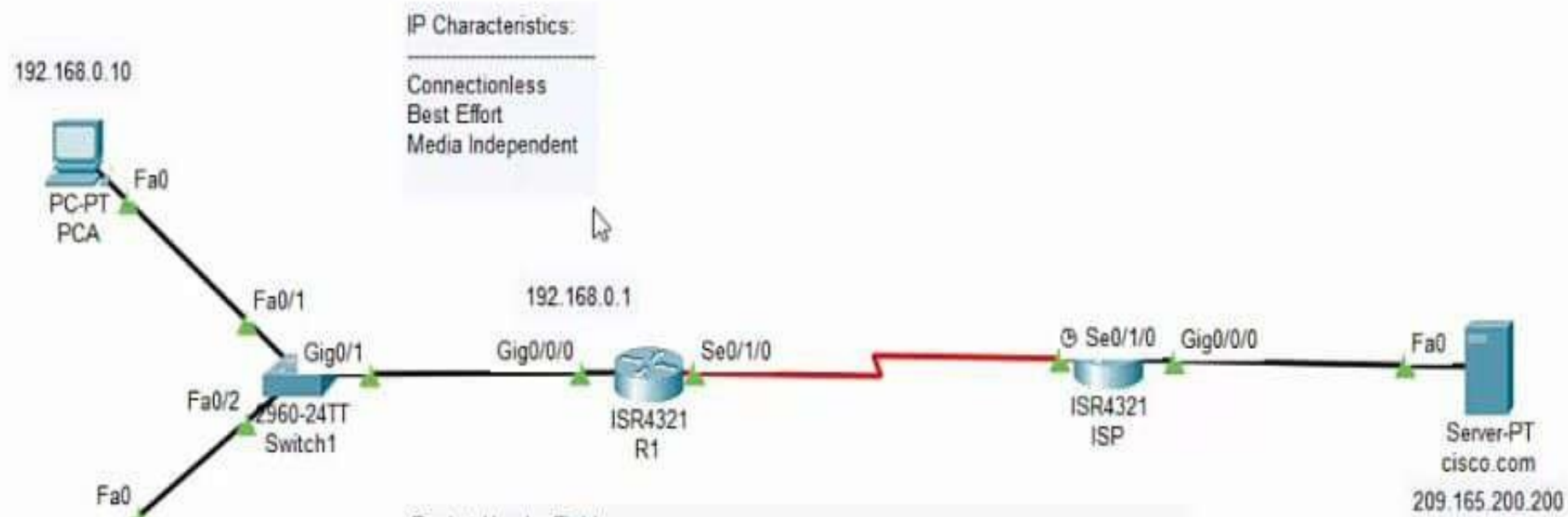
192 168 44 ? --- host

File Edit Format View Help

```
Logical Addressing
==========================
192.168.44.211  --- IP address
255.255.255.0   --- subnet mask     ---- /24, means 24 ones in the mask  11111111.11111111.1
 N   N   N  H
==================
192 168 44  0   --- network
192 168 44  ?   --- host
192 168 44 255  --- broadcast

Are the following addresses all on the same network? yes or no
192.168.44.111/24,
192.168.44.3/24,
192.168.44.252/24,
192.168.44.1/24

Are the following addresses all on the same network? yes or no
172.16.2.32/24,
172.16.2.6/24,
172.16.2.111/24,
172.16.20.167/24
```

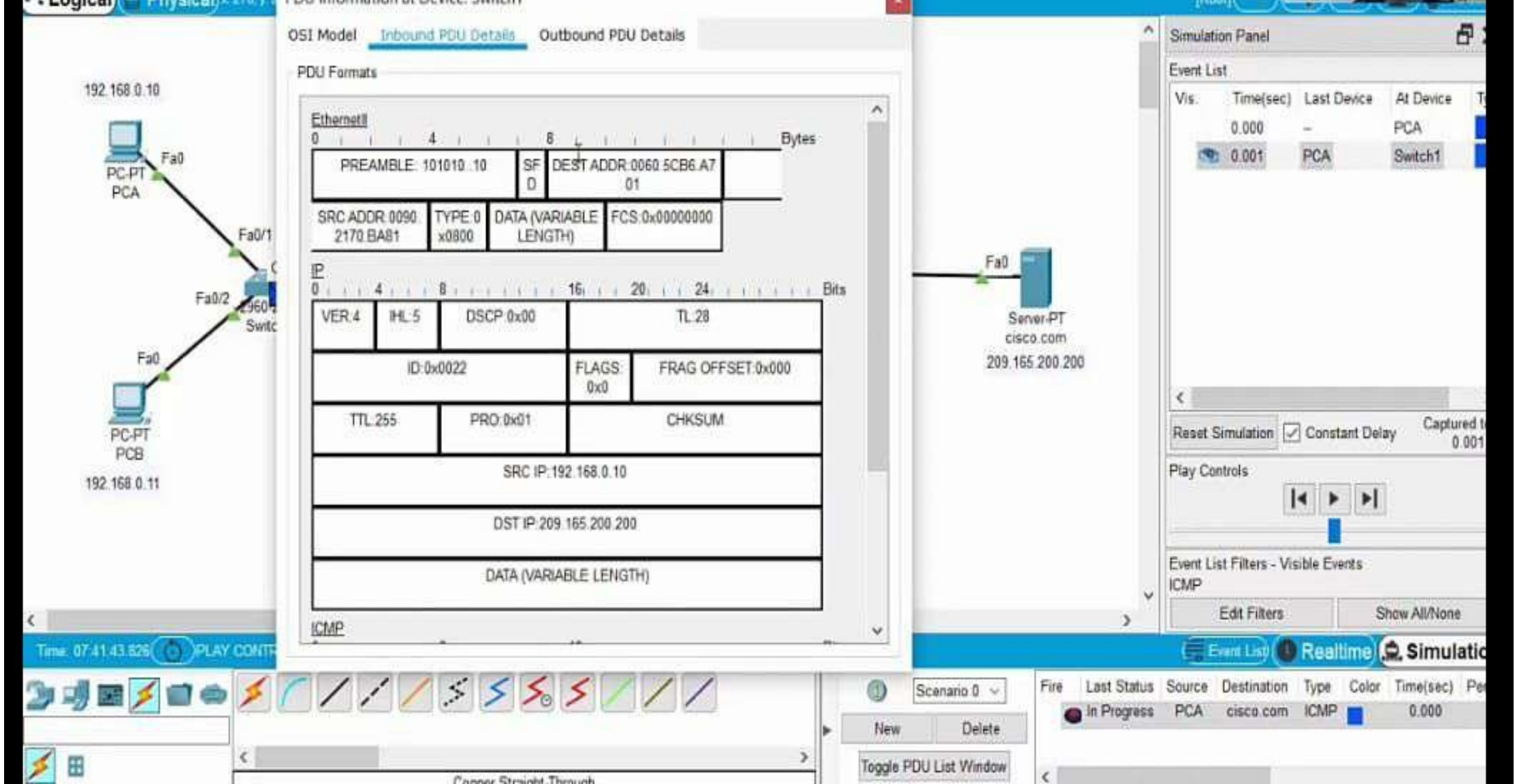


IP Characteristics:

Connectionless
Best Effort
Media Independent

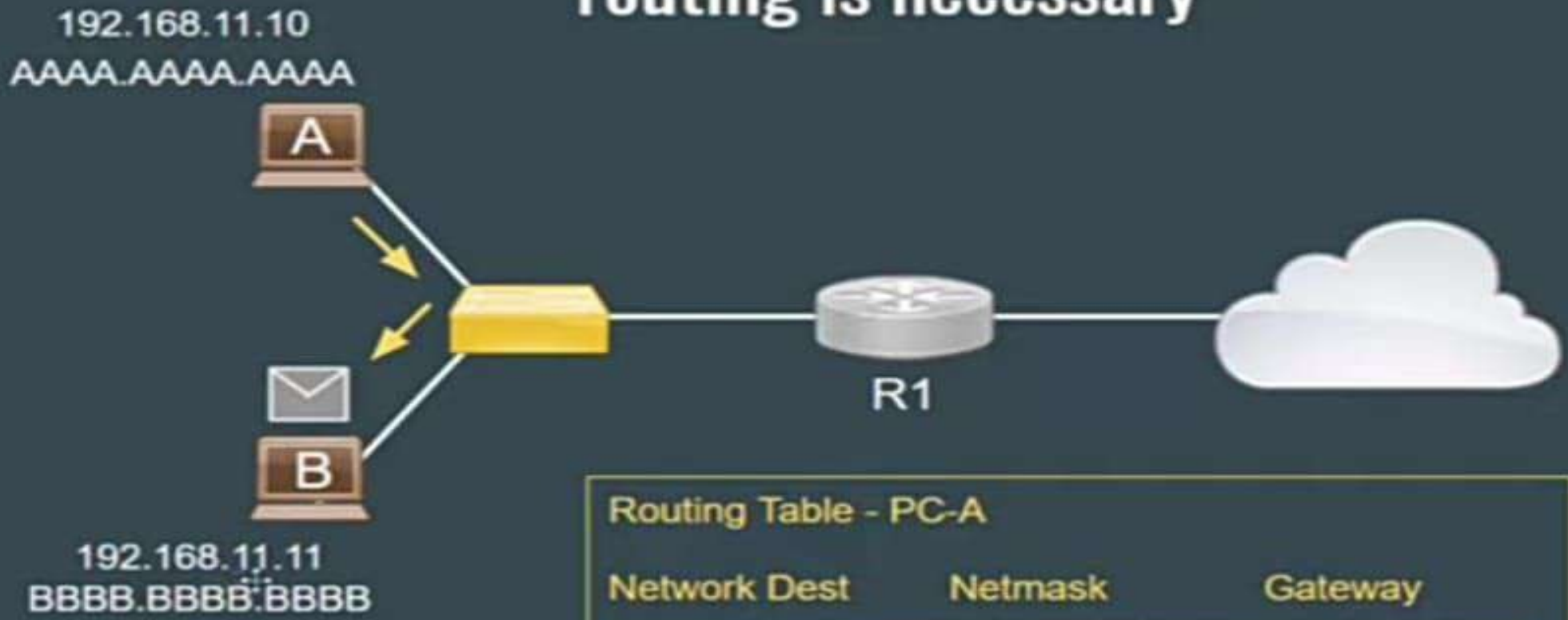
Packet Header Fields

Version	- IPv4 or IPv6
Internet Header Length	- network header and data
Differentiated Services	- QoS, Congestion Notification
Identification, Flag, Fragment Offset	- fragmentation
TTL	- how many hops a packet can travel, no infinite looping
Protocol	- upper layer protocol
Header Checksum	- error checking on the header
Source IP address	
Destination IP address	


OSI Model
Inbound PDU Details
Outbound PDU Details
PDU Formats
Ethernet II
0 4 8 Bytes
PREAMBLE: 101010 ..10
SF D
DEST ADDR:0060.5CB6.A701
SRC ADDR:0090.2170.BA81
TYPE:0x0800
DATA (VARIABLE LENGTH)
FCS:0x00000000
IP
0 4 8 16 20 24 Bits
VER:4
IHL:5
DSCP:0x00
TL:28
ID:0x0022
FLAGS:0x0
FRAG OFFSET:0x000
TTL:255
PRO:0x01
CHKSUM
SRC IP:192.168.0.10
DST IP:209.165.200.200
DATA (VARIABLE LENGTH)
ICMP
192.168.0.10
PC-PT PCA
Fa0
Fa0/1
Fa0/2
Fa0
PC-PT PCB
192.168.0.11
Fa0
Server-PT cisco.com
209.165.200.200
Simulation Panel
Event List
Vis. Time(sec) Last Device At Device
0.000 - PCA
0.001 PCA Switch1
Reset Simulation
Constant Delay
Play Controls
Event List Filters - Visible Events
ICMP
Edit Filters
Show All/None
Realtime
Fire Last Status Source Destination Type Color Time(sec)
In Progress PCA cisco.com ICMP 0.000
Scenario 0
New
Delete
Toggle PDU List Window

Type	Purpose	Example
Unicast	send to a single host	192.168.1.100
Multicast	send to a group of hosts	224.0.0.1
Broadcast	sending to every host	192.168.1.255
Loopback	send to self	127.0.0.1
Link-local	local link(subnet) only - not routable	169.254.0.0
Unspecified	unknown network - quad-zero	0.0.0.0
All-hosts broadcast	broadcast to all hosts on local link	255.255.255.255
Directed broadcast	broadcast to a specific network (remote)	192.168.2.255

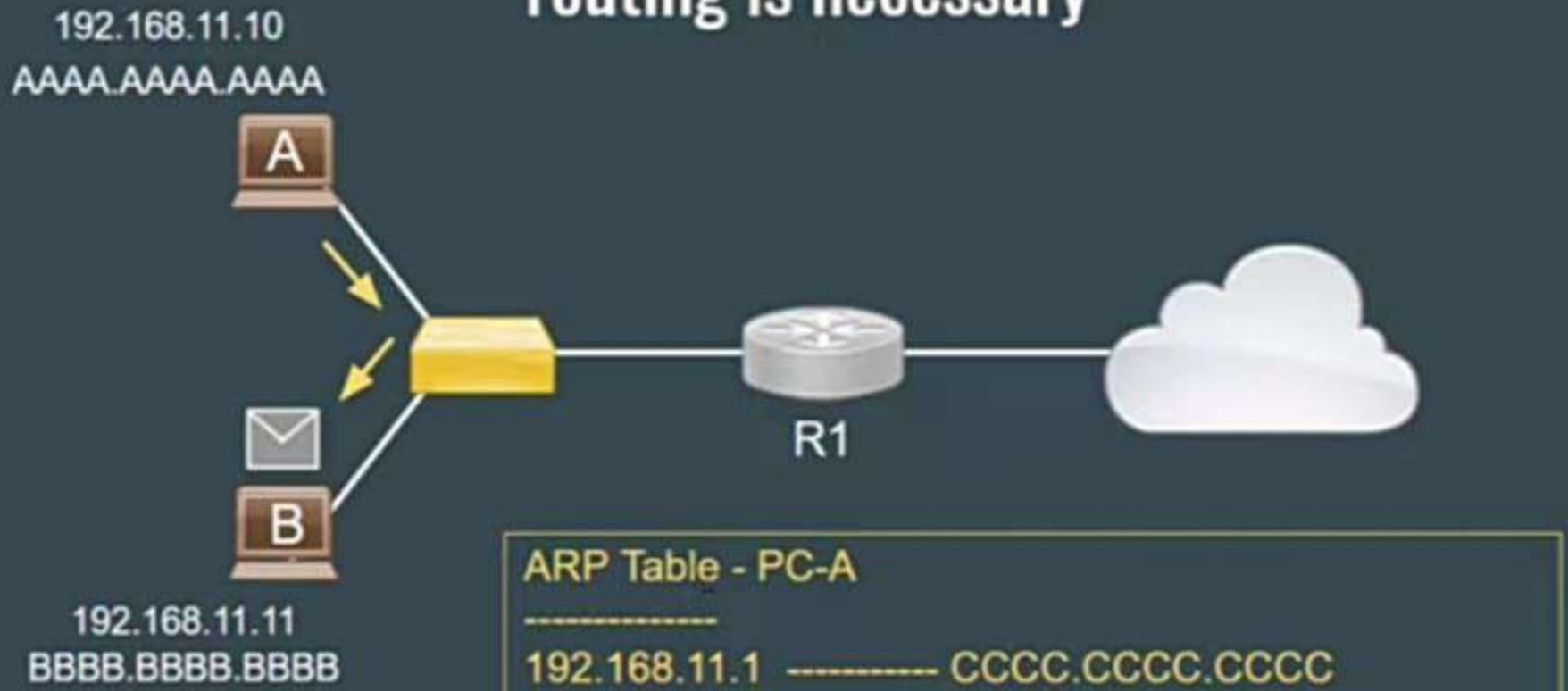
Communicating with hosts on the local network no routing is necessary



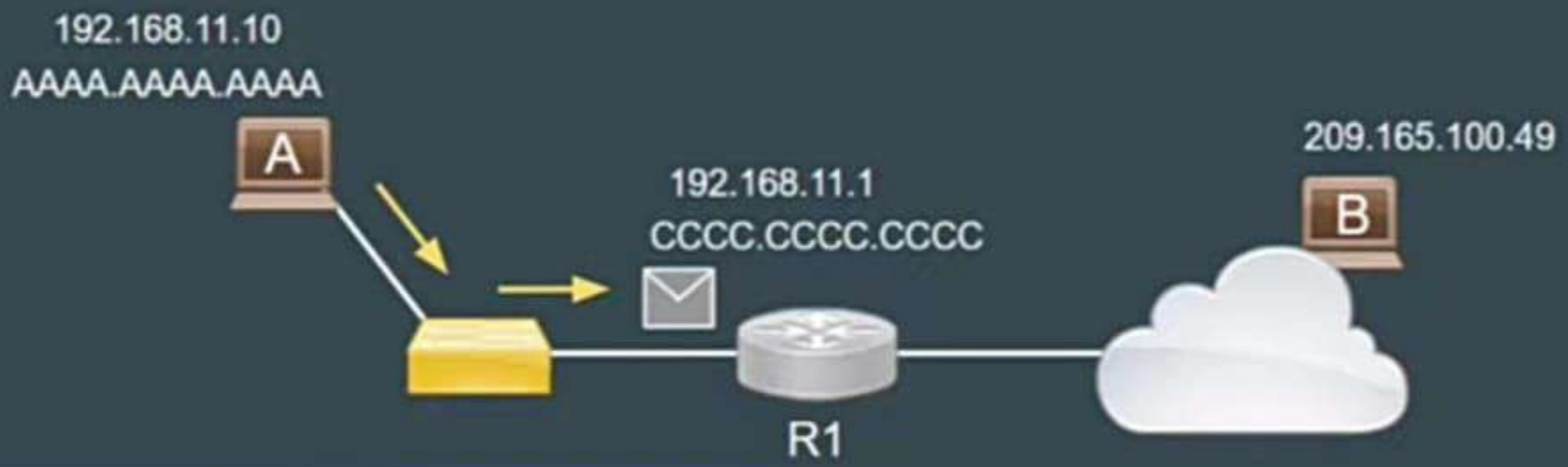
Routing Table - PC-A

Network Dest	Netmask	Gateway
0.0.0.0	0.0.0.0	192.168.11.1
192.168.11.0	255.255.255.0	On-link

Communicating with hosts on the local network no routing is necessary



To reach a remote network you need a default gateway



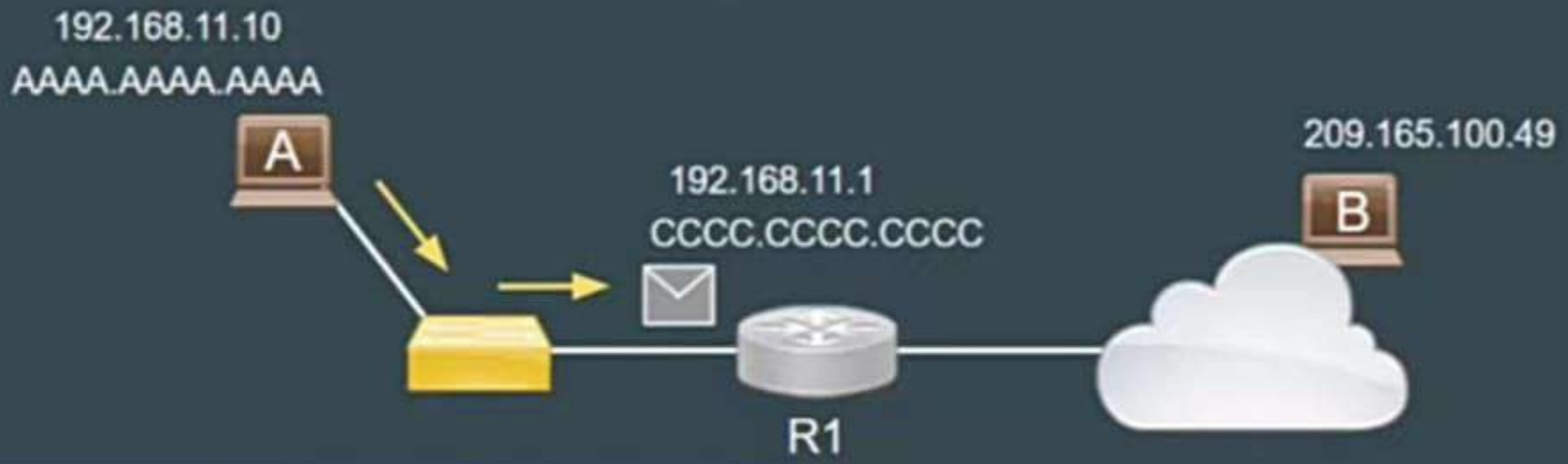
Routing Table - PC-A

Network Dest	Netmask		Gateway
0.0.0.0	0.0.0.0	-------	192.168.11.1
192.168.11.0	255.255.255.0	-------	On-link

ARP Table - PC-A

192.168.11.1	----------	CCCC.CCCC.CCCC
192.168.11.11	----------	BBBB.BBBB.BBBB

To reach a remote network you need a default gateway



Routing Table - PC-A

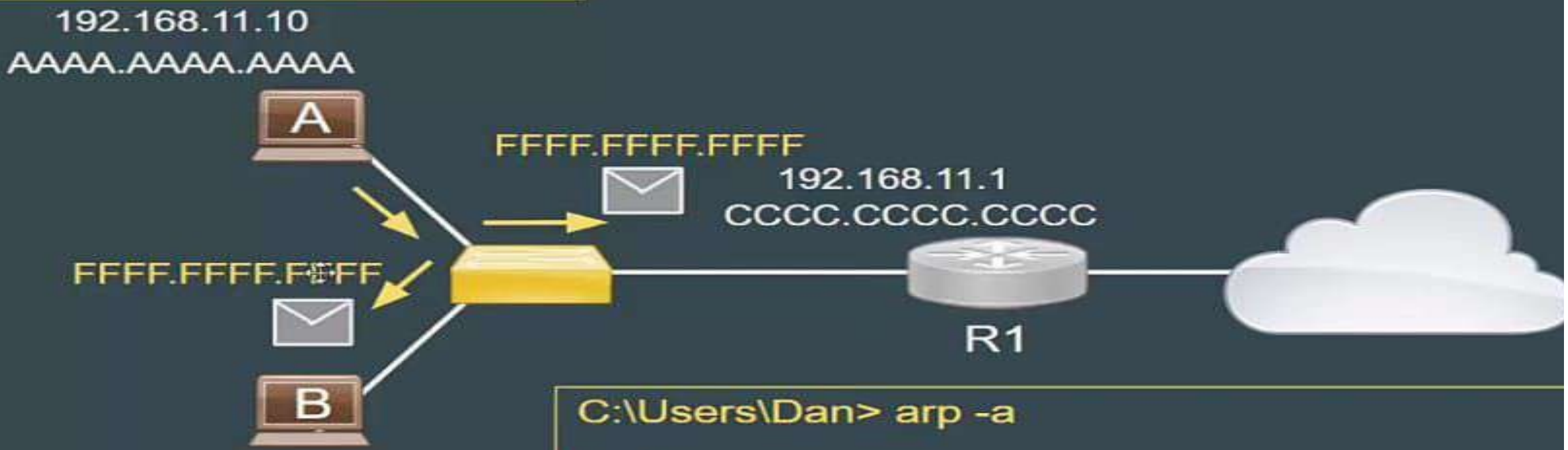
Network Dest	Netmask		Gateway
0.0.0.0	0.0.0.0	-------	192.168.11.1
192.168.11.0	255.255.255.0	-------	On-link

ARP Table - PC-A

192.168.11.1	----------	CCCC.CCCC.CCCC
192.168.11.11	----------	BBBB.BBBB.BBBB

PC-A sends an ARP reque

Who has the MAC address
for 192.168.11.11? Tell 192.168.11.10




```
C:\Users\Dan> arp -a

ARP Table - PC-A
------------
??????????? ---------  ??????
??????????? ---------  ??????
```

PC-B receives the ARP req

Who has the MAC address
for 192.168.11.11? Tell 192.168.11.10

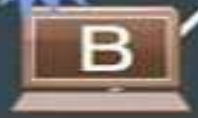
192.168.11.10
AAAA.AAAA.AAAA

This is not for me.
Discard

192.168.11.1
CCCC.CCCC.CCCC

R1

FFFF.FFFF.FFFF



192.168.11.11
BBBB.BBBB.BBBB

This is for me. I have it

```
C:\Users\Dan> arp -a

ARP Table - PC-A
------------
??????????? ---------  ??????
??????????? ---------  ??????
```

PC-B sends the ARP reply, and PC
the MAC address to its ARP ca

I will add the MAC address to my ARP cache

192.168.11.10
AAAA.AAAA.AAAA

192.168.11.11
BBBB.BBBB.BBBB

Here is my MAC address

C:\Users\Dan> arp -a

ARP Table - PC-A

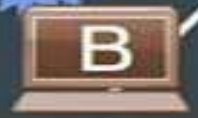
??????????? ---------- ??????
192.168.11.11 ---------- BBBB.BBBB.BBBB

PC-A can now send to PC-B

Now I can deliver an Ethernet Frame to BBBB.BBBB.BBBB

192.168.11.10
AAAA.AAAA.AAAA

Dst: BBBB.BBBB.BBBB



192.168.11.11
BBBB.BBBB.BBBB

192.168.11.1
CCCC.CCCC.CCCC

R1

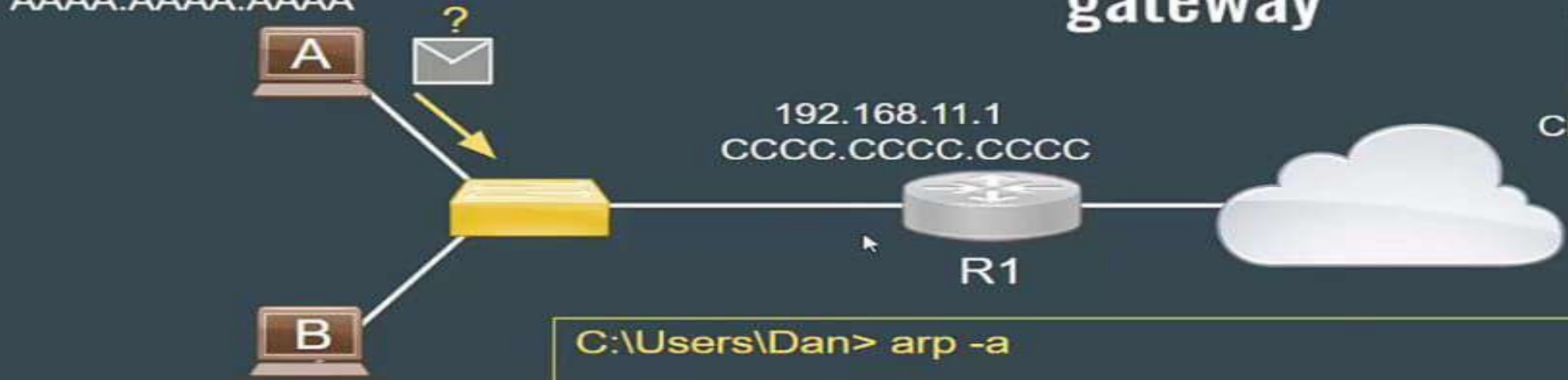
C:\Users\Dan> arp -a

ARP Table - PC-A

192.168.11.1 ---------- ??????
192.168.11.11 ---------- BBBB.BBBB.BBBB

I want to go to Cisco.com, but I need the MAC address of the default gateway to get there

PC-A wants to go to cisco.com b not have the MAC address of the gateway




```
C:\Users\Dan> arp -a

ARP Table - PC-A
-------------
192.168.11.1  ----------  ??????
192.168.11.11 ----------  BBBB.BBBB.BBBB
```

R1 receives the ARP reque

Who has the MAC address for 192.168.11.1? Tell 192.168.11.10

This is not for me. Drop

C:\Users\Dan> arp -a

ARP Table - PC-A

192.168.11.1 ---------- ??????

192.168.11.11 ---------- BBBB.BBBB.BBBB

PC-A can now send to Cisco.com
way of R1 the default gatewa

Now I can deliver a an Ethernet Frame to CCCC.CCCC.CCCC

192.168.11.10
AAAA.AAAA.AAAA

192.168.11.11
BBBB.BBBB.BBBB

```
C:\Users\Dan> arp -a

ARP Table - PC-A
-------------
192.168.11.1  ----------  CCCC.CCCC.CCCC
192.168.11.11 ----------  BBBB.BBBB.BBBB
```

IPv4 address	192.168.50.112 /24
Address in binary	11000000.1010100.00110010.01110000
Netmask in binary	11111111.11111111.11111111.00000000

IPv4 address with mask	192.168.50.112 /24
subnet mask	255.255.255.0
network and host portions	N . N . N . H
network and host	192.168.50.112

subnet mask in binary	11111111.11111111.11111111.00000000

/24 means 24 binary ones for the network and 8 zeros left for the hosts

IPv4 address	192.168.50.112 /24
subnet mask	255.255.255.0
network and host portions	N . N . N . H
network address (first address)	192.168.50.0
broadcast address (last address)	192.168.50.255

Minus the network and broadcast address leaves 1-254 addresses for the hosts

IPv4 address	172.16.40.201 /16
subnet mask	255.255.0.0
network and host portions	N .N .H .H
network address (first address)	172.16.0.0
broadcast address (last address)	172.16.255.255

Minus the network and broadcast address leaves 172.16.0.1 through 172.16.255.254 addresses for the hosts (65,536 hosts -2)

IPv4 address	192.168.50.112
subnet mask	255.255.255.0
IPv4 address (binary)	11000000.10101000.00110010.01110000
subnet mask (binary)	11111111.11111111.11111111.00000000
Logical AND (A ^ B)	TTFFFFFF.TFTFTFFF.FFTTFFTF.FFFFFFFF
Network address	11000000.10101000.00110010.00000000

Network address	192.	168.	50.	0

Subnetting divides one network into smaller netw

192.168.50.0 /24 = 1 network of 256 hosts (minus the network and the broadcast a

or

/25 (255.255.255.128) = 2 subnets of 128 hosts (minus 2)

or

/26 (255.255.255.192) = 4 subnets of 64 hosts (minus 2)

or

/27 (255.255.255.224) = 8 subnets of 32 hosts (minus 2)

or

/28 (255.255.255.240) = 16 subnets of 16 hosts (minus 2)

Subnetting divides one network into smaller networks

192.168.50.0 /24 = 11111111.11111111.11111111.00000000 1 network of 256 hosts (minus 2)

or 2 subnets

/25 = 11111111.11111111.11111111.10000000 2^7 = 128 hosts (minus 2)

or 4 subnets

/26 = 11111111.11111111.11111111.11000000 2^6 = 64 hosts (minus 2)

or 8 subnets

/27 = 11111111.11111111.11111111.11100000 2^5 = 32 hosts (minus 2)

or 16 subnets

Subnetting divides one network into smaller netwo

1 network of 256 hosts (minus 2)	192.168.50.0	/24	255.255.255.0
or 2 subnets of 128 hosts (minus 2)	192.168.50.0	/25	255.255.255.128
	192.168.50.128	/25	255.255.255.128
or 4 subnets of 64 hosts (minus 2)	192.168.50.0	/26	255.255.255.192
	192.168.50.64	/26	"
	192.168.50.128	/26	"
	192.168.50.192	/26	"
or 8 subnets of 32 hosts (minus 2)	192.168.50.0	/27	255.255.255.224
	192.168.50.32	/27	"
	192.168.50.64	/27	"
	192.168.50.96	/27	"
	192.168.50.128	/27	"
	192.168.50.160	/27	"
	192.168.50.192	/27	"
	192.168.50.224	/27	"

IP datagram format

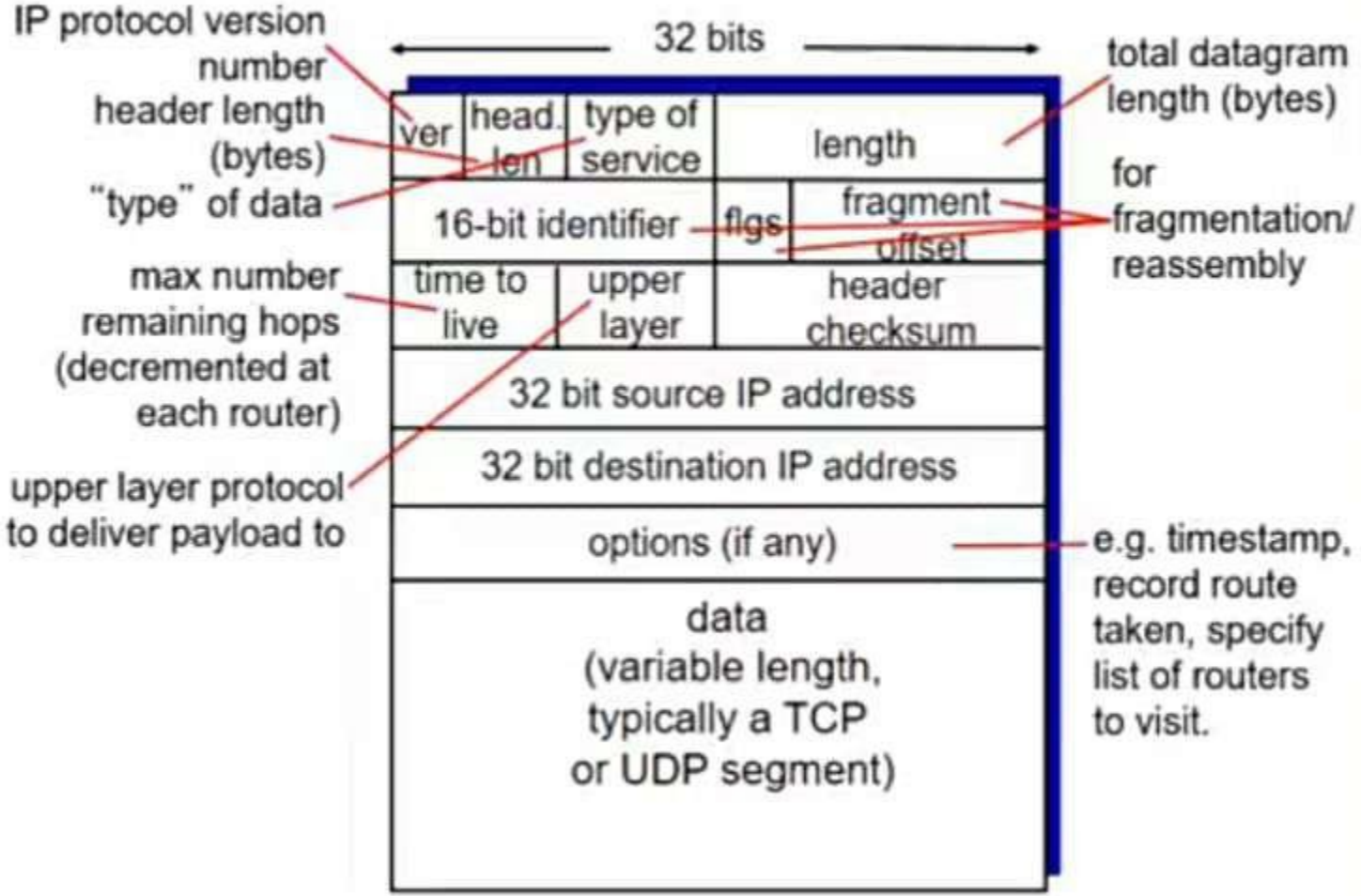


Figure 4.13