Network Fundamentals

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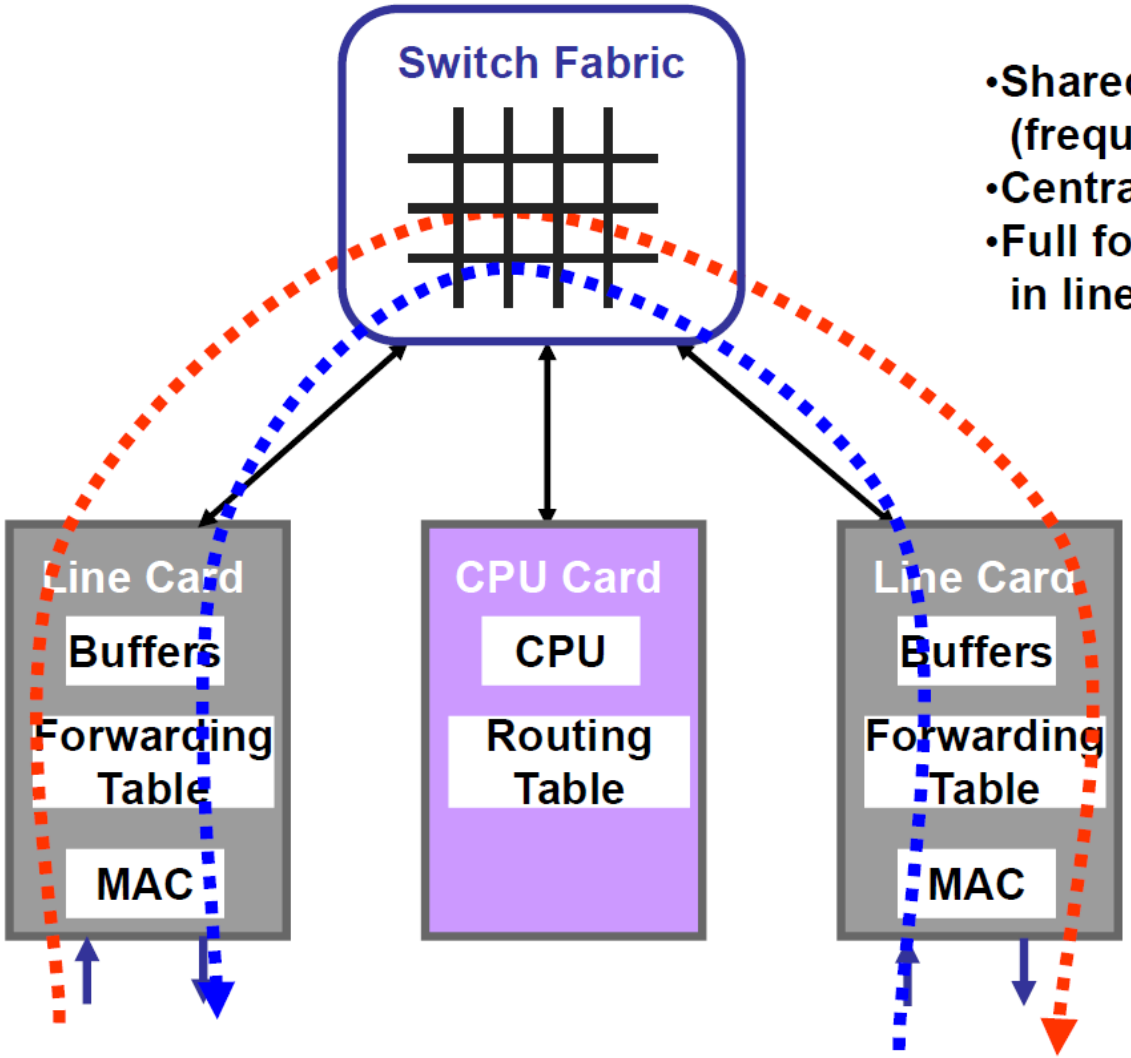
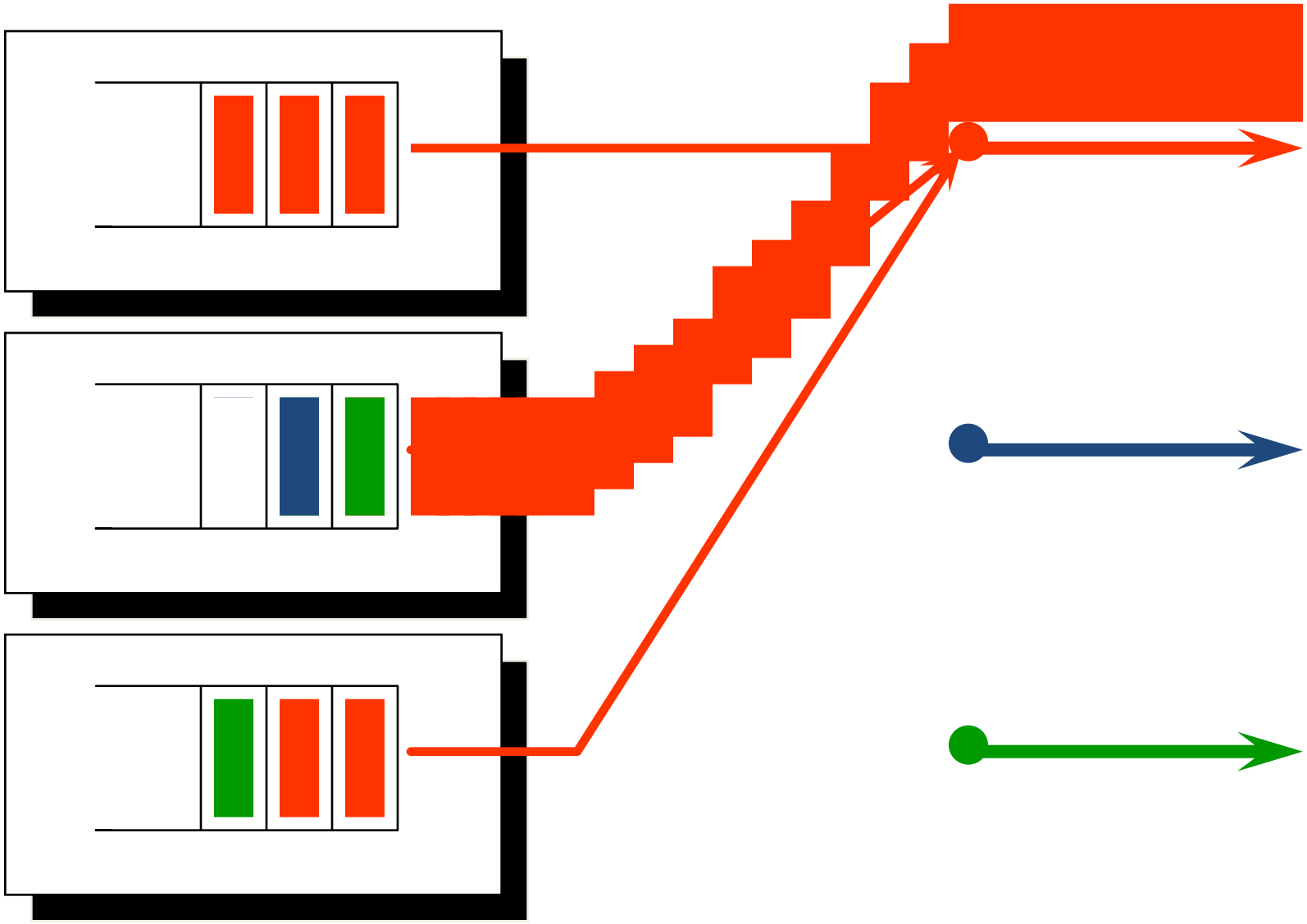
Recap: Third Generation Routers

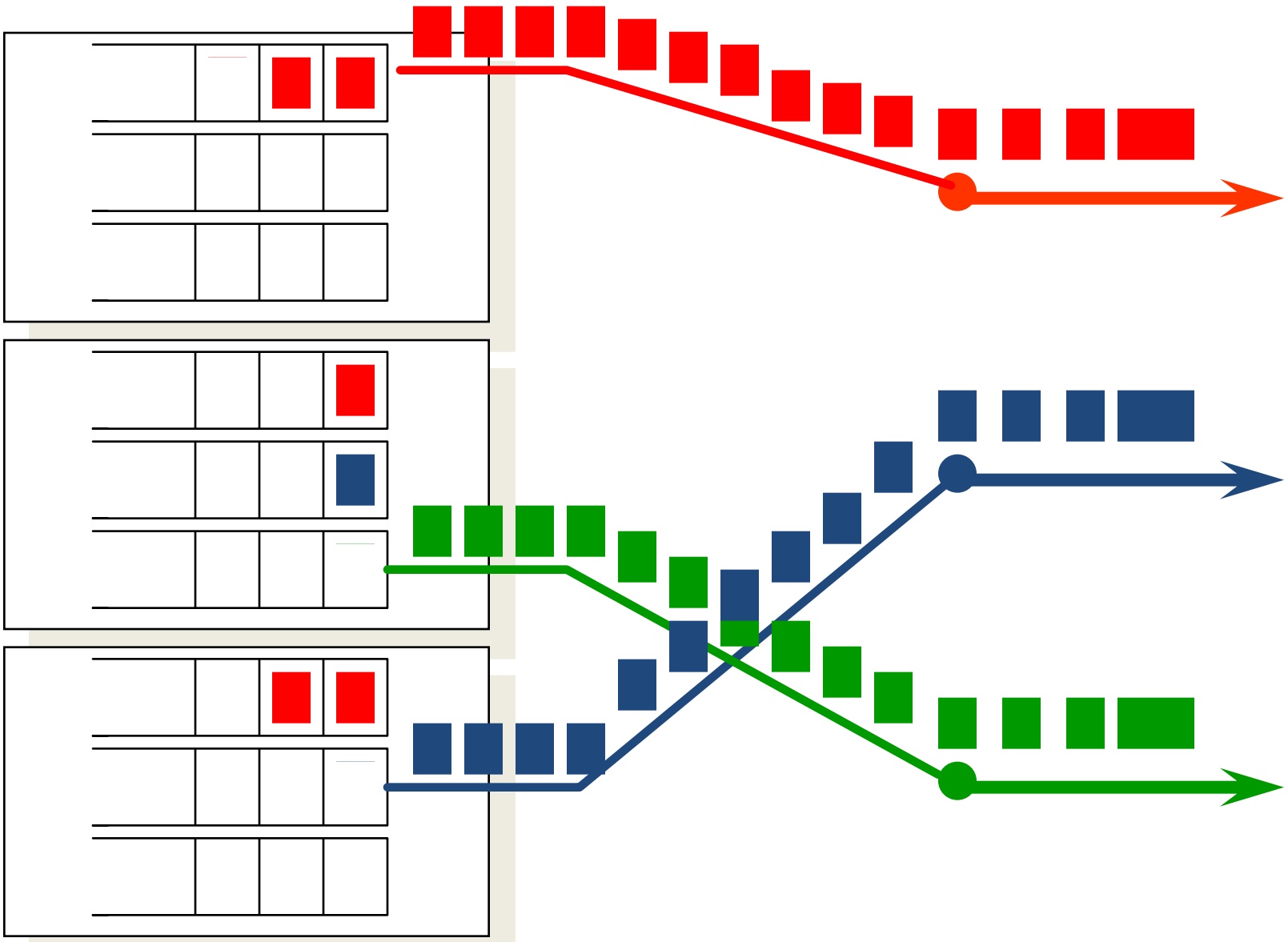


- Shared interconnect (frequently crossbar)
- Centralized scheduler
- Full forwarding table in line card

Recap: Head of Line Blocking

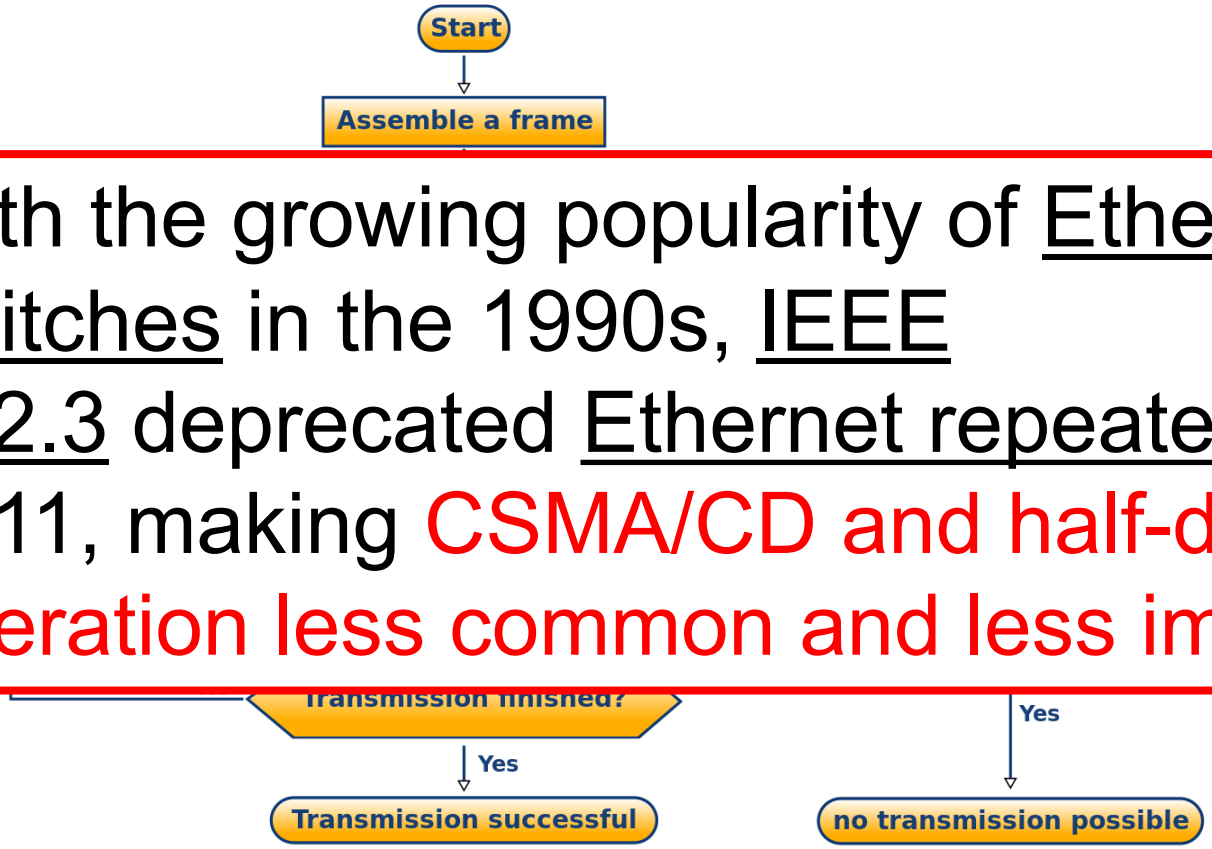


Recap: Virtual output queues



Question 1

Is CSMA/CD necessary?

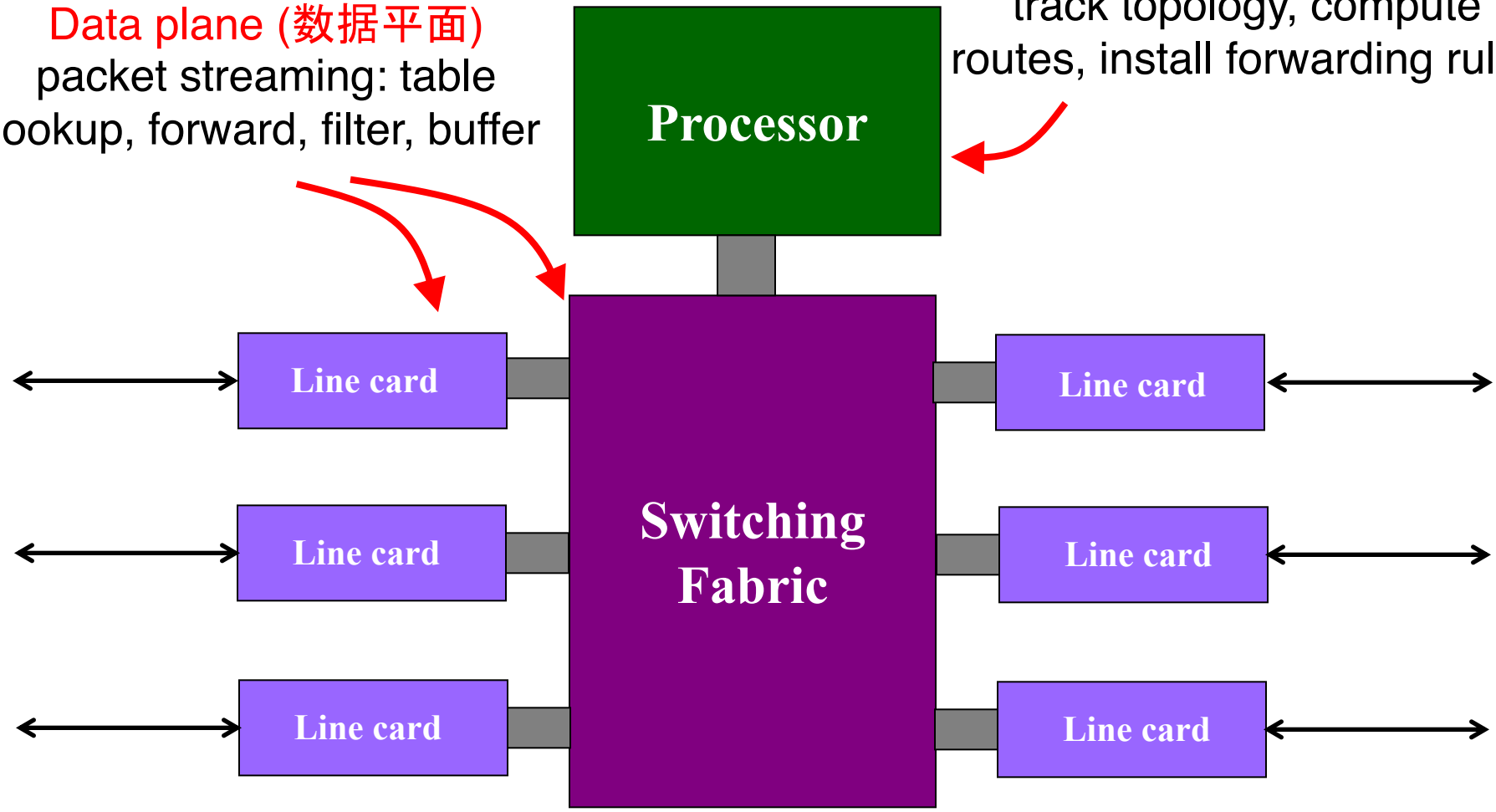


With the growing popularity of Ethernet switches in the 1990s, IEEE 802.3 deprecated Ethernet repeaters in 2011, making CSMA/CD and half-duplex operation less common and less important.

Recap: Control Plane vs. Data Plane

Control plane（控制平面）:
distributed algorithms:
track topology, compute
routes, install forwarding rules

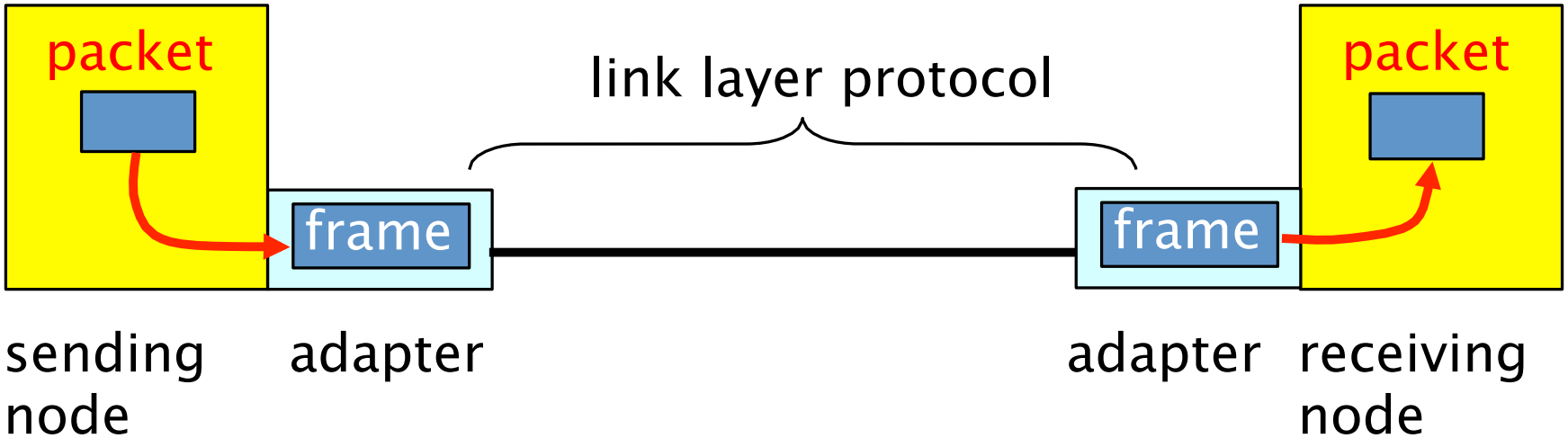
Data plane (数据平面)
packet streaming: table
lookup, forward, filter, buffer



Today

How do local computers communicate?

Switching


packet
link layer protocol
packet
frame
frame
sending node
adapter
adapter
receiving node

Switching

- MAC Address
  - 48bits identifying the other end of link
  - Globally Unique

34:36:3b:d2:8a:86

Switching

- MAC Address is Hierarchical

34:36:3b:d2:8a:86

Apple, Inc. 1 Infinite Loop
Cupertino CA 95014 US

see http://standards-oui.ieee.org/oui/oui.txt

Broadcast Address

- The address with all bits set to 1 identifies the broadcast address

`ff:ff:ff:ff:ff:ff`

enables to send a frame to *all* adapters on the link

What is My IP Address?

I want to send an IP packet to 192.168.1.10?

What destination MAC do I use?!

34:36:3b:d2:8a:10 ← Assigned by manufacture

192.168.1.9

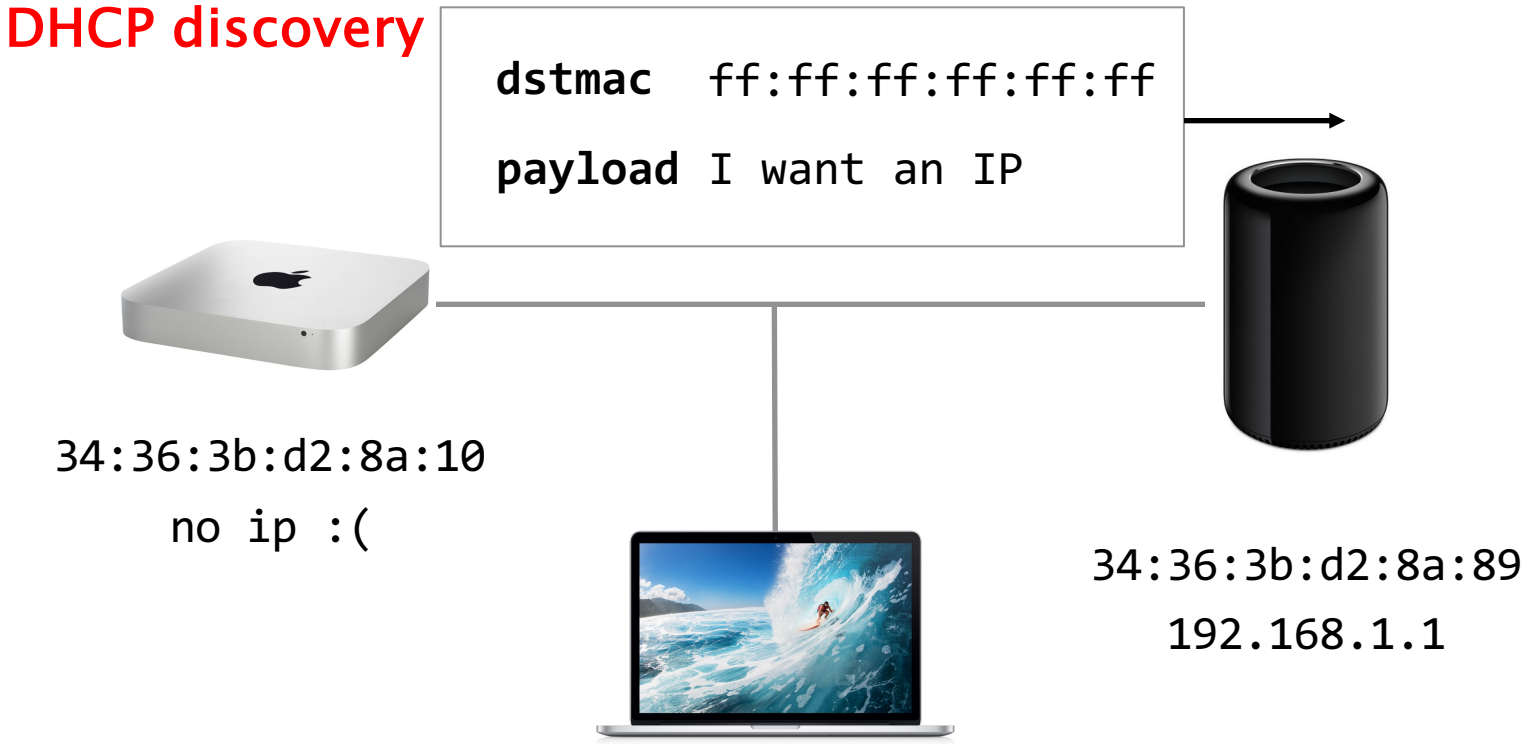
How do I know my IP address?

DHCP

Network adapters acquire an IP address using the Dynamic Host Configuration Protocol (DHCP)

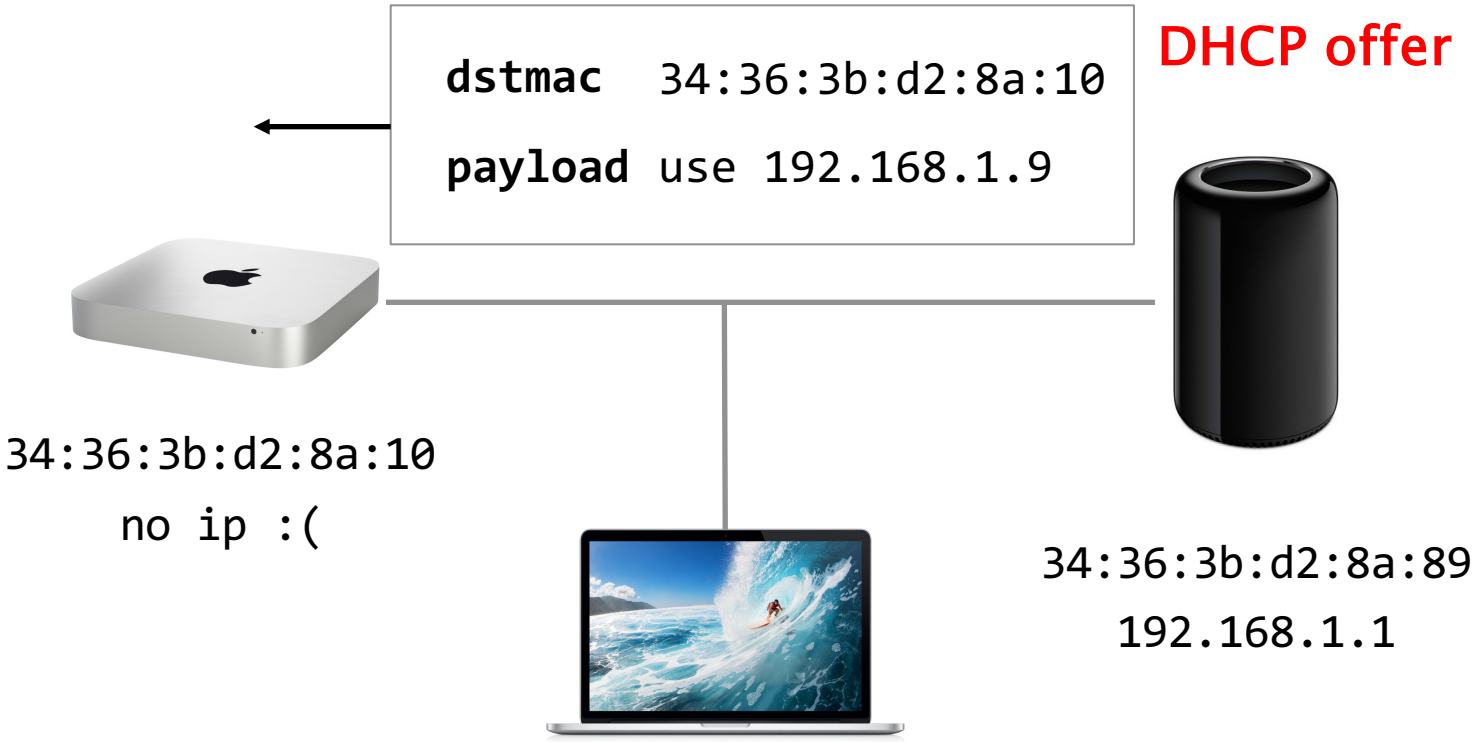
DHCP

Host sends an “IP request” to everyone on the link using the broadcast address



DHCP

DHCP server (if any) answers with an IP address



DHCP


34:36:3b:d2:8a:10
192.168.1.9
34:36:3b:d2:8a:89
192.168.1.1
34:36:3b:d2:8a:86
192.168.1.10

Address Resolution Protocol (ARP)

I want to send an IP packet to 192.168.1.10?

What destination MAC do I use?!

34:36:3b:d2:8a:10

192.168.1.9

Address Resolution Protocol (ARP)

ARP request

dstmac	ff:ff:ff:ff:ff:ff
payload	Who has 192.168.1.10?
	Tell 192.168.1.9

34:36:3b:d2:8a:10

192.168.1.9

34:36:3b:d2:8a:89

192.168.1.1

34:36:3b:d2:8a:86

192.168.1.10

Address Resolution Protocol (ARP)

34:36:3b:d2:8a:10

192.168.1.9

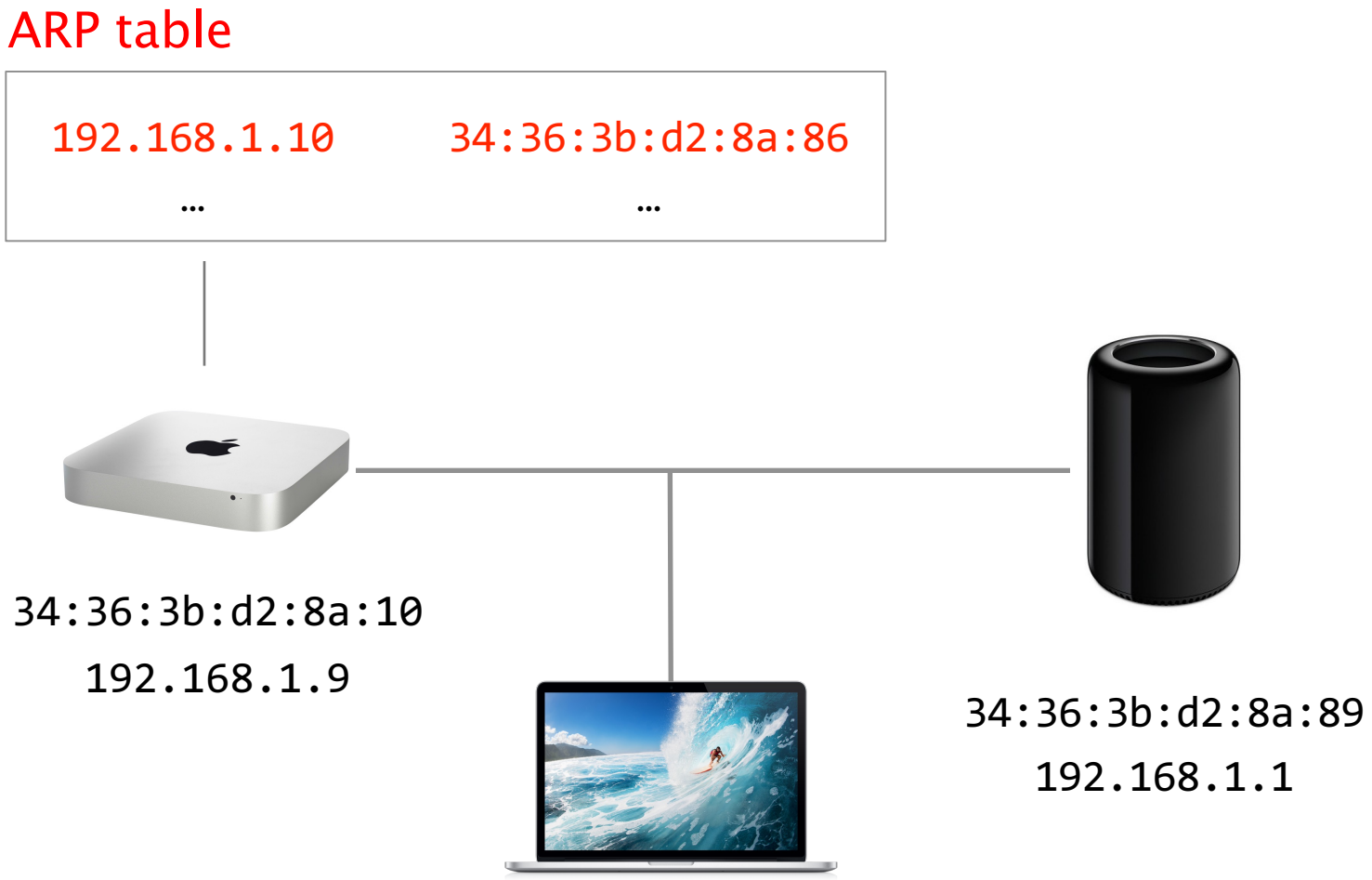
34:36:3b:d2:8a:86

192.168.1.10

ARP reply

dstmac	34:36:3b:d2:8a:10
payload	192.168.1.10 is at 34:36:3b:d2:8a:86

Address Resolution Protocol (ARP)

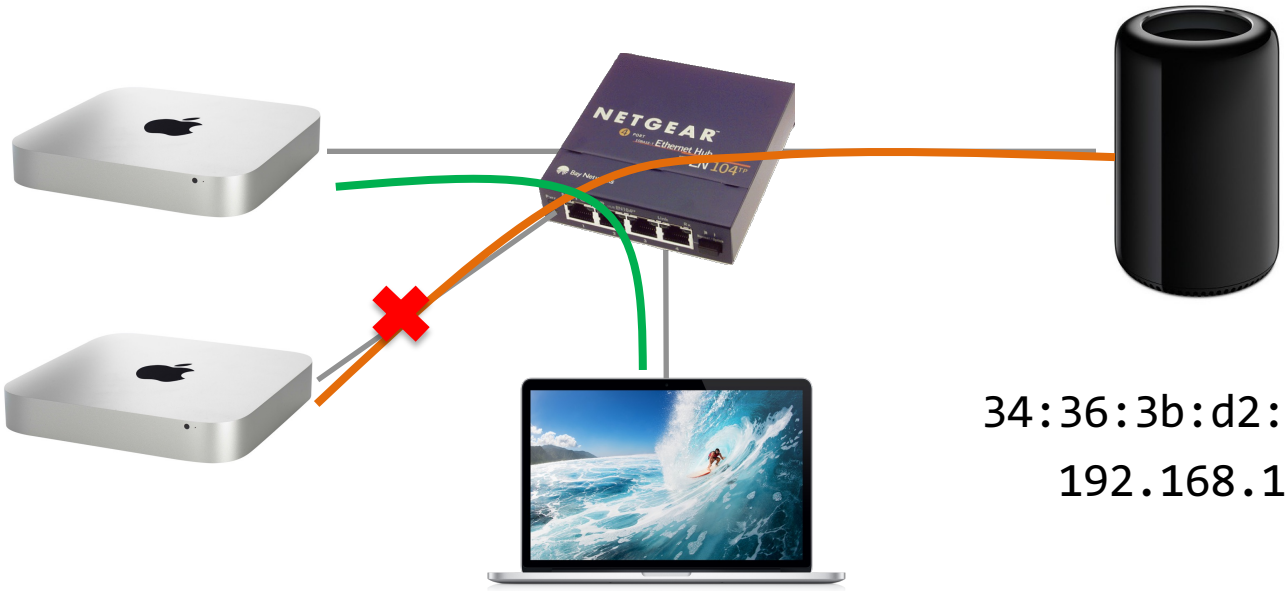


Ethernet Hub

Inefficient: each bit is sent everywhere

OBSOLETE

Ethernet hub
repeating bits from one port to all the other ones



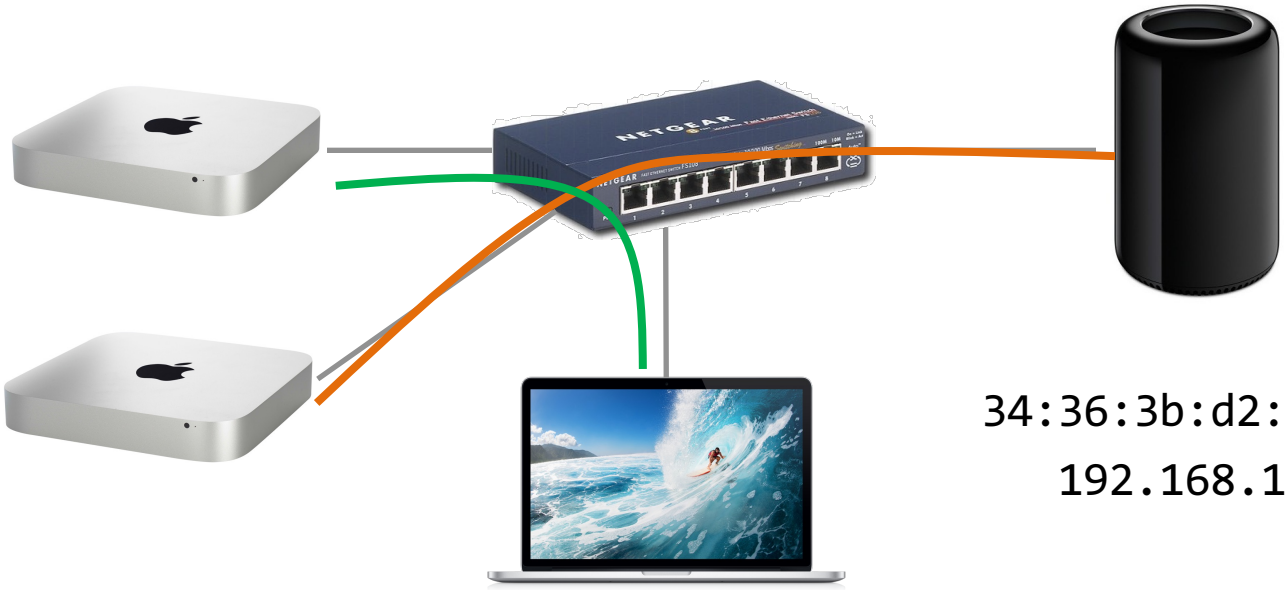
34:36:3b:d2:8a:89
192.168.1.1

34:36:3b:d2:8a:86
192.168.1.10

Ethernet Switch

efficient: communications between different hosts are isolated

Ethernet switch
repeating bits from one port to *the correct port*



34:36:3b:d2:8a:89

192.168.1.1

34:36:3b:d2:8a:86

192.168.1.10

Ethernet Switch

- Switch is a plug-and-play device （即插即用设备）

How does the switch
know the correct port?

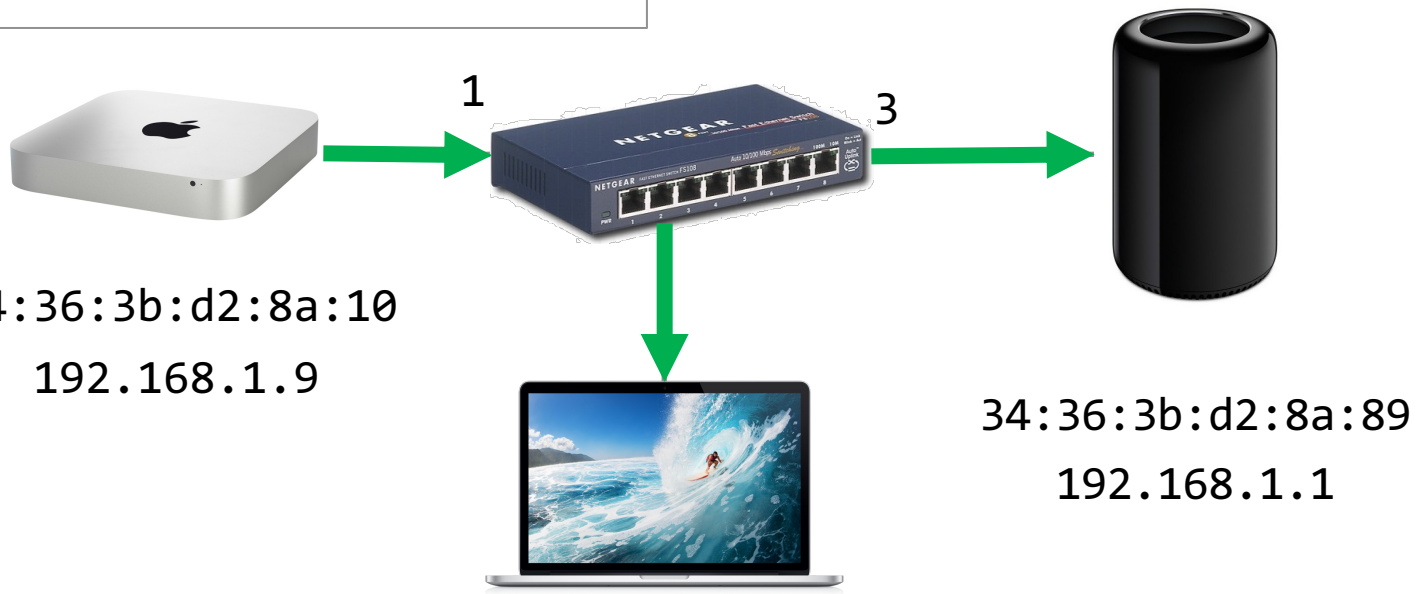
MAC Learning

ARP request

dstmac ff:ff:ff:ff:ff:ff

payload Who has 192.168.1.10?

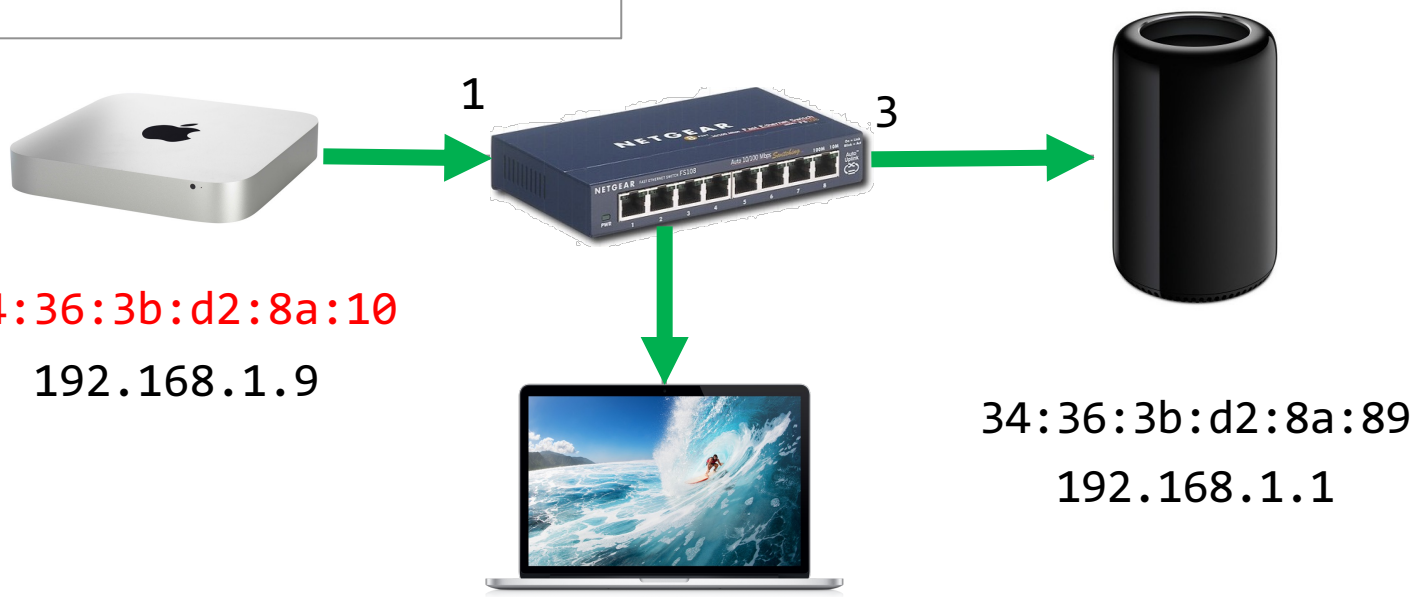
Tell 192.168.1.9



MAC Learning

MAC Table

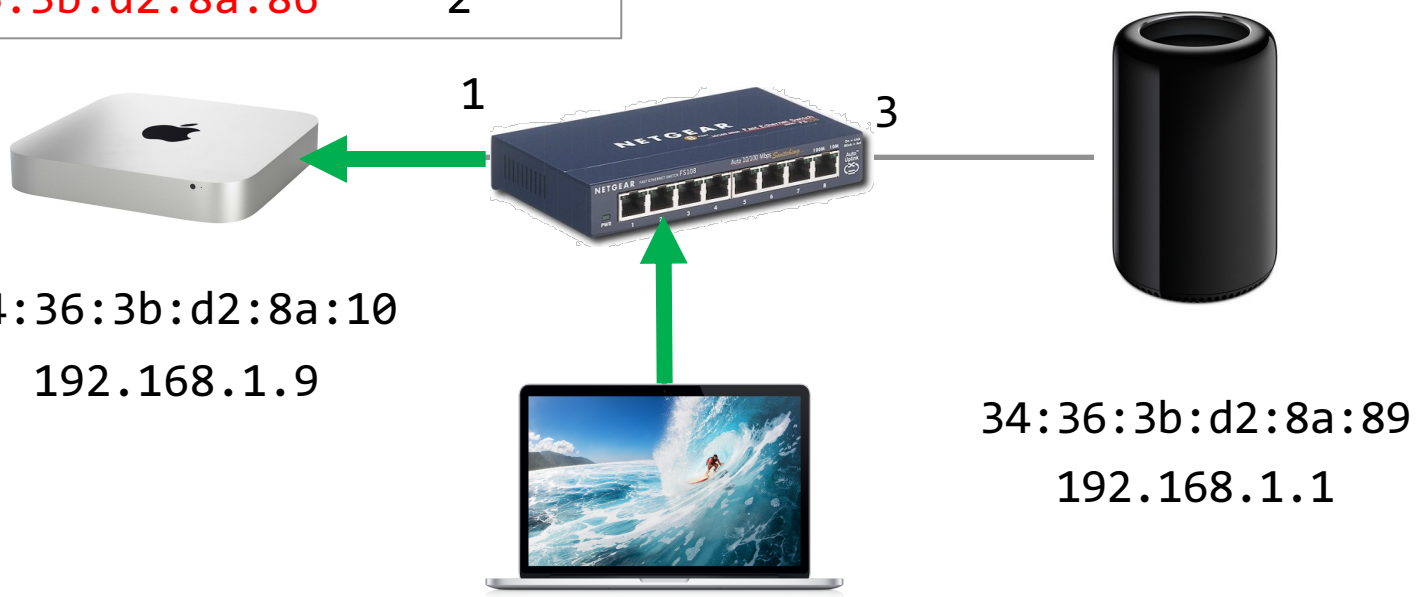
Dstmac	port
34:36:3b:d2:8a:10	1



MAC Learning

MAC Table

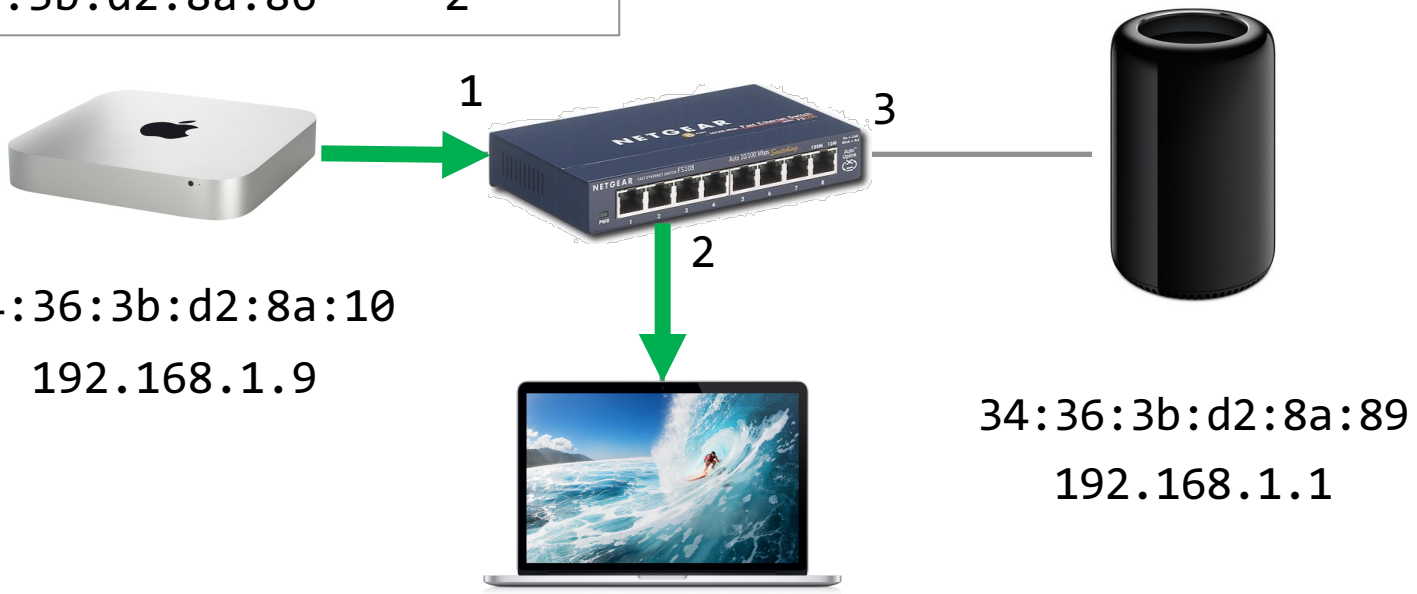
Dstmac	port
34:36:3b:d2:8a:10	1
34:36:3b:d2:8a:86	2



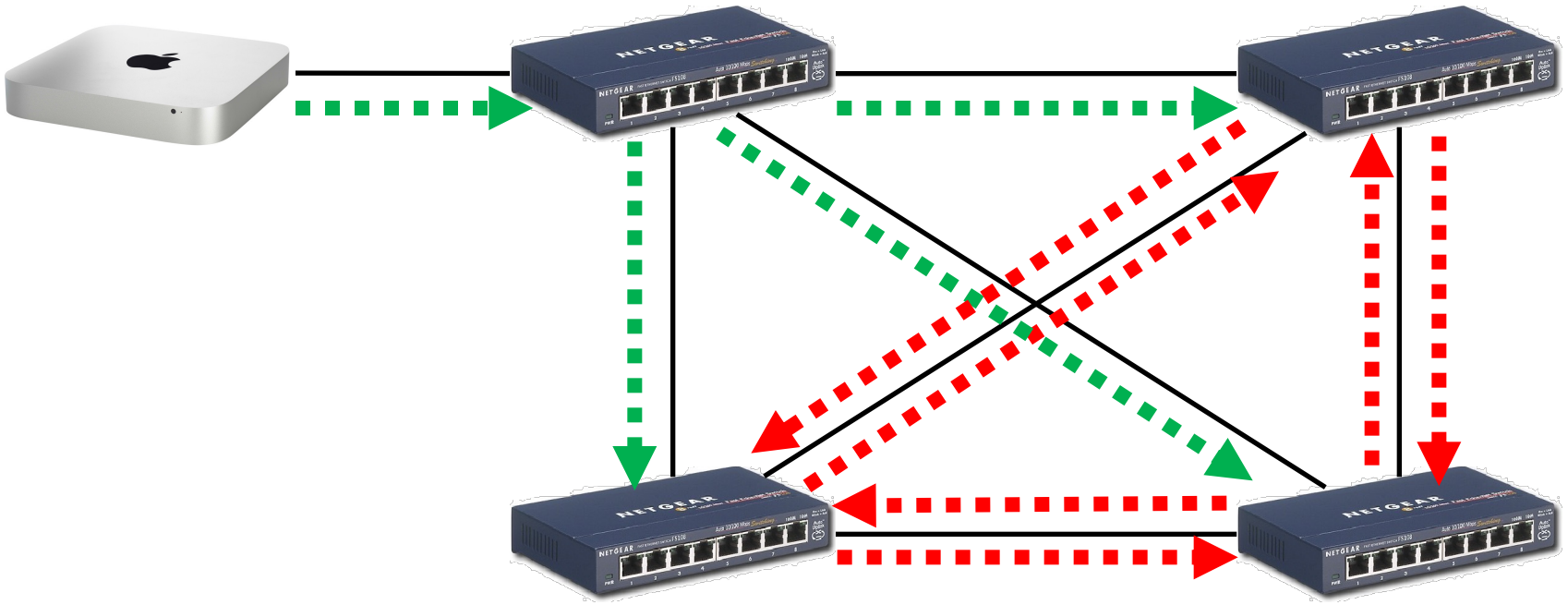
MAC Learning

MAC Table

Dstmac	port
34:36:3b:d2:8a:10	1
34:36:3b:d2:8a:86	2



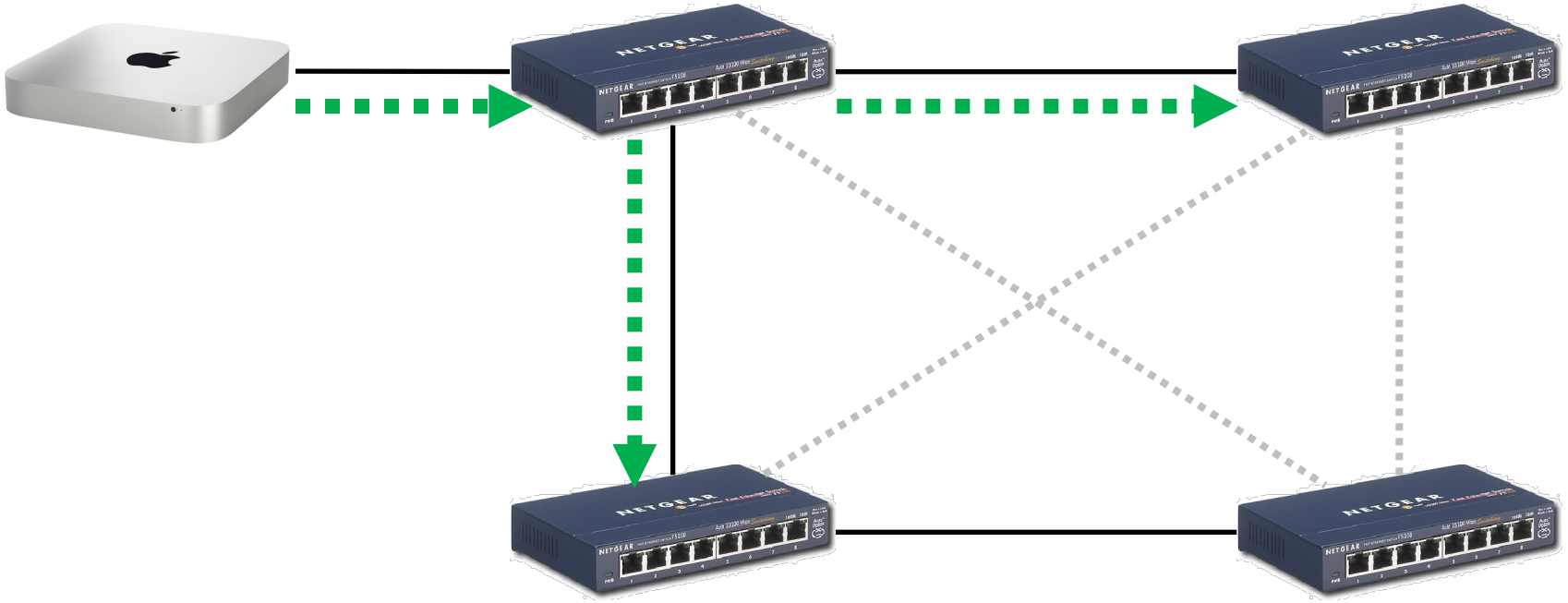
Broadcast Storm



Each frame leads to the creation of *at least two new frames!*

exponential increase, with no TTL to remove looping frames…

Spanning Tree Protocol (STP)



Run the spanning tree protocol to disable some ports, so that the topology becomes a tree (rather than a graph)

What you actually do

How can I know www.example.com
is at 192.168.1.10?

I want to visit
www.example.com

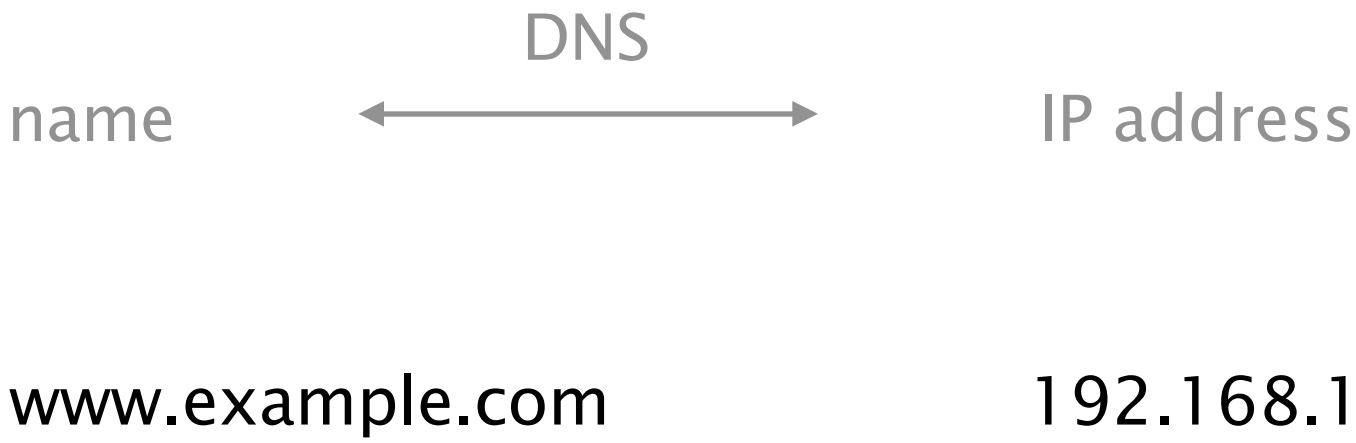
34:36:3b:d2:8a:10
192.168.1.9

34:36:3b:d2:8a:89
192.168.1.1

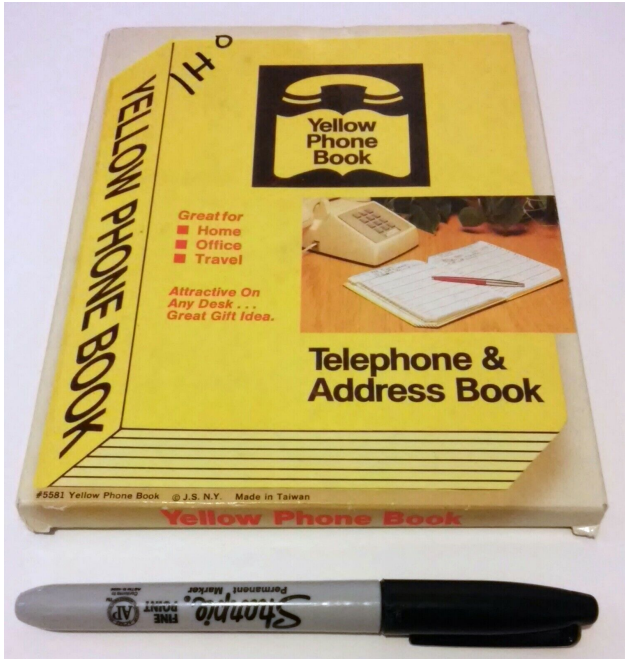
34:36:3b:d2:8a:86
192.168.1.10 ➡ **www.example.com**

Domain Name System (DNS)

- The DNS system is a distributed database which enables to resolve a name into an IP address

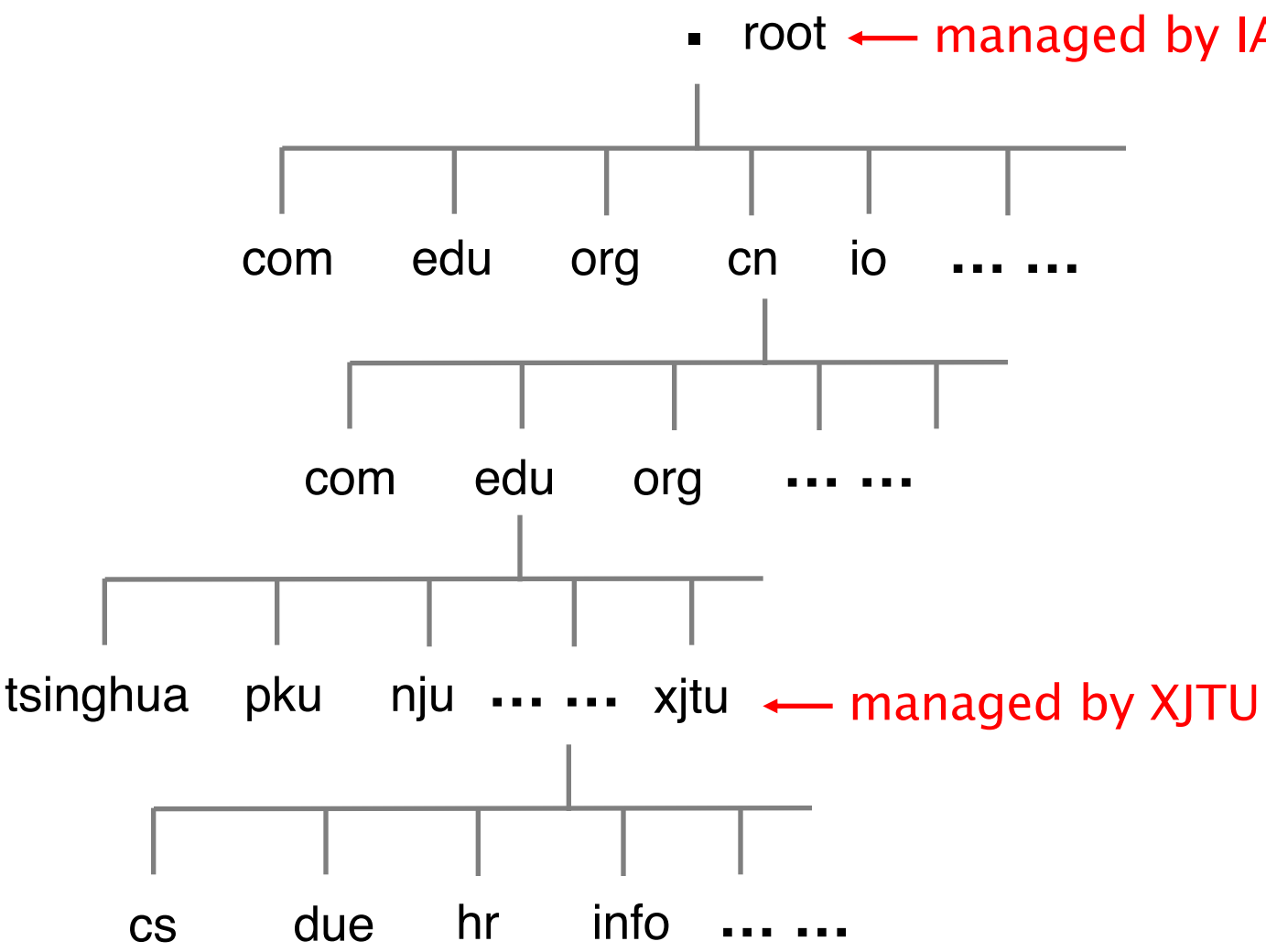


Domain Name System (DNS)



The Domain Name System (DNS) protocol is an important part of the web's infrastructure, serving as the Internet's phone book: every time you visit a website, your computer performs a DNS lookup.

Domain Name is Hierarchical



The Root

13 root servers across the world

a.	root-servers.net	VeriSign, Inc.
b.	root-servers.net	University of Southern California
c.	root-servers.net	Cogent Communications
d.	root-servers.net	University of Maryland
e.	root-servers.net	NASA
f.	root-servers.net	Internet Systems Consortium
g.	root-servers.net	US Department of Defense
h.	root-servers.net	US Army
i.	root-servers.net	Netnod
j.	root-servers.net	VeriSign, Inc.
k.	root-servers.net	RIPE NCC
l.	root-servers.net	ICANN
m.	root-servers.net	WIDE Project

DNS Server

- A DNS server stores Resource Records composed of a (name, value, type, TTL)

Records	Name	Value
A	hostname	IP address
NS	domain	DNS server name
MX	domain	Mail server name
CNAME	alias	canonical name
PTR	IP address	corresponding hostname

Using DIG to Resolve

- *dig* (domain information groper)

```
test@sdnexp:~$ dig

; <<>> DiG 9.11.3-1ubuntu1.15-Ubuntu <<>>
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 40301
;; flags: qr rd ra; QUERY: 1, ANSWER: 13, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 65494
;; QUESTION SECTION:
;.                              IN      NS

;; ANSWER SECTION:
.                       337324  IN      NS      j.root-servers.net.
.                       337324  IN      NS      d.root-servers.net.
.                       337324  IN      NS      e.root-servers.net.
.                       337324  IN      NS      f.root-servers.net.
.                       337324  IN      NS      h.root-servers.net.
.                       337324  IN      NS      l.root-servers.net.
.                       337324  IN      NS      g.root-servers.net.
.                       337324  IN      NS      c.root-servers.net.
.                       337324  IN      NS      m.root-servers.net.
.                       337324  IN      NS      k.root-servers.net.
.                       337324  IN      NS      b.root-servers.net.
.                       337324  IN      NS      a.root-servers.net.
.                       337324  IN      NS      i.root-servers.net.

;; Query time: 2 msec
;; SERVER: 127.0.0.53#53(127.0.0.53)
;; WHEN: Tue Feb 28 15:30:00 CST 2023
;; MSG SIZE  rcvd: 239
```

```
test@sdnexp:~$ dig www.baidu.com

; <<>> DiG 9.11.3-1ubuntu1.15-Ubuntu <<>> www.baidu.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 44151
;; flags: qr rd ra; QUERY: 1, ANSWER: 3, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 65494
;; QUESTION SECTION:
;www.baidu.com.                 IN      A

;; ANSWER SECTION:
www.baidu.com.          699     IN      CNAME   www.a.shifen.com.
www.a.shifen.com.       235     IN      A       182.61.200.7
www.a.shifen.com.       235     IN      A       182.61.200.6

;; Query time: 2 msec
;; SERVER: 127.0.0.53#53(127.0.0.53)
;; WHEN: Tue Feb 28 15:32:40 CST 2023
;; MSG SIZE  rcvd: 101
```

Internet

规范名字

What you actually do

DNS request

dstip 192.168.1.1

payload What is the IP address of www.example.com?

34:36:3b:d2:8a:10
192.168.1.9

34:36:3b:d2:8a:86
192.168.1.10
www.example.com

DNS Server
UDP Port 53

34:36:3b:d2:8a:89
192.168.1.1

What you actually do

DNS Reply

dstip 192.168.1.9

payload The IP for www.example.com is 192.168.1.10

DNS Server
UDP Port 53

34:36:3b:d2:8a:10
192.168.1.9

34:36:3b:d2:8a:89
192.168.1.1

34:36:3b:d2:8a:86
192.168.1.10
www.example.com

Public DNS Servers

DNS request

dstip 8.8.8.8

payload What is the IP address of www.baidu.com?

Google Public DNS

34:36:3b:d2:8a:10

192.168.1.9

34:36:3b:d2:8a:89

192.168.1.1

34:36:3b:d2:8a:86

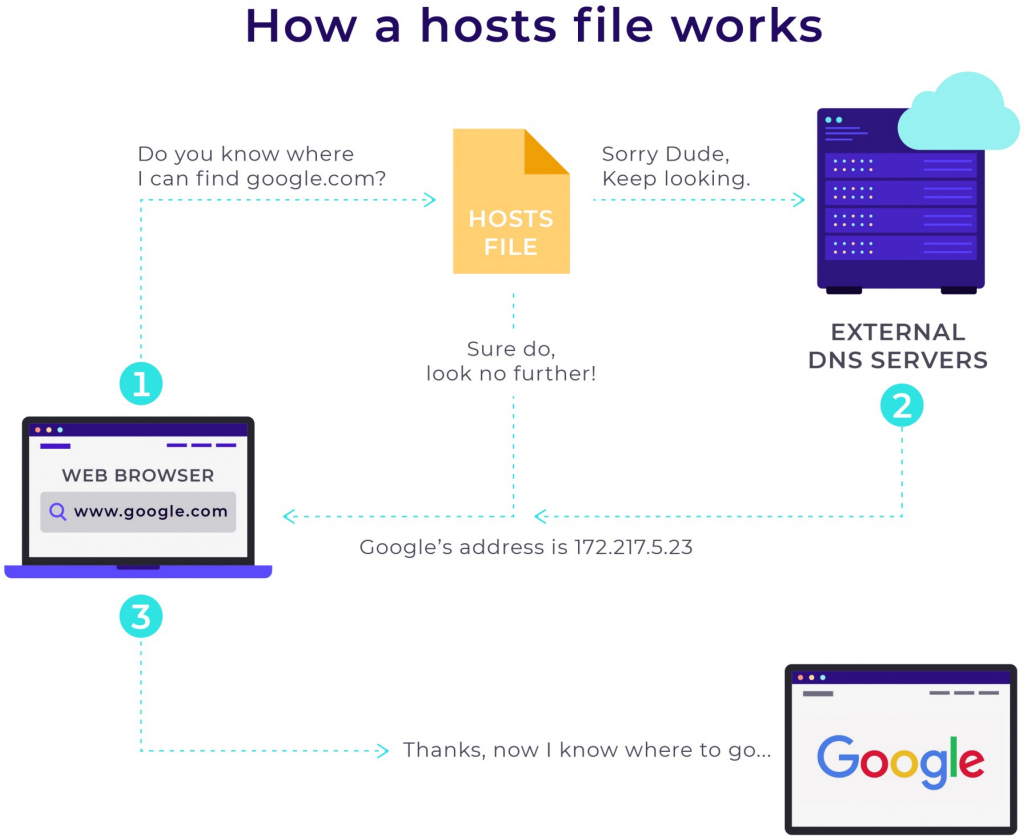
192.168.1.10

www.example.com

Public DNS Servers

- Cloudflare：1.1.1.1
- 阿里云：223.5.5.5
- 百度：180.76.76.76
- 腾讯：119.29.29.29

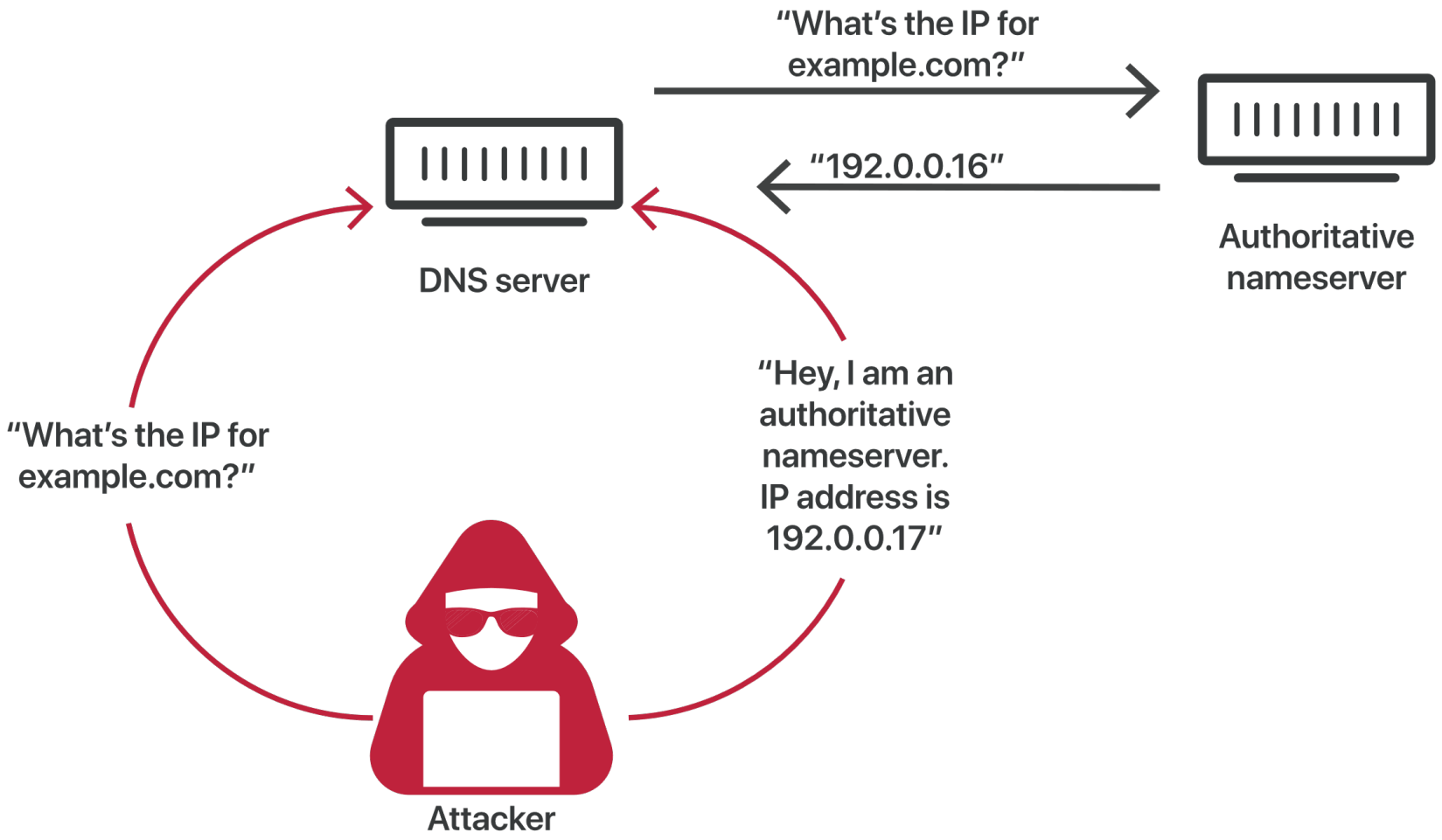
The hosts File



Host file takes priority over DNS

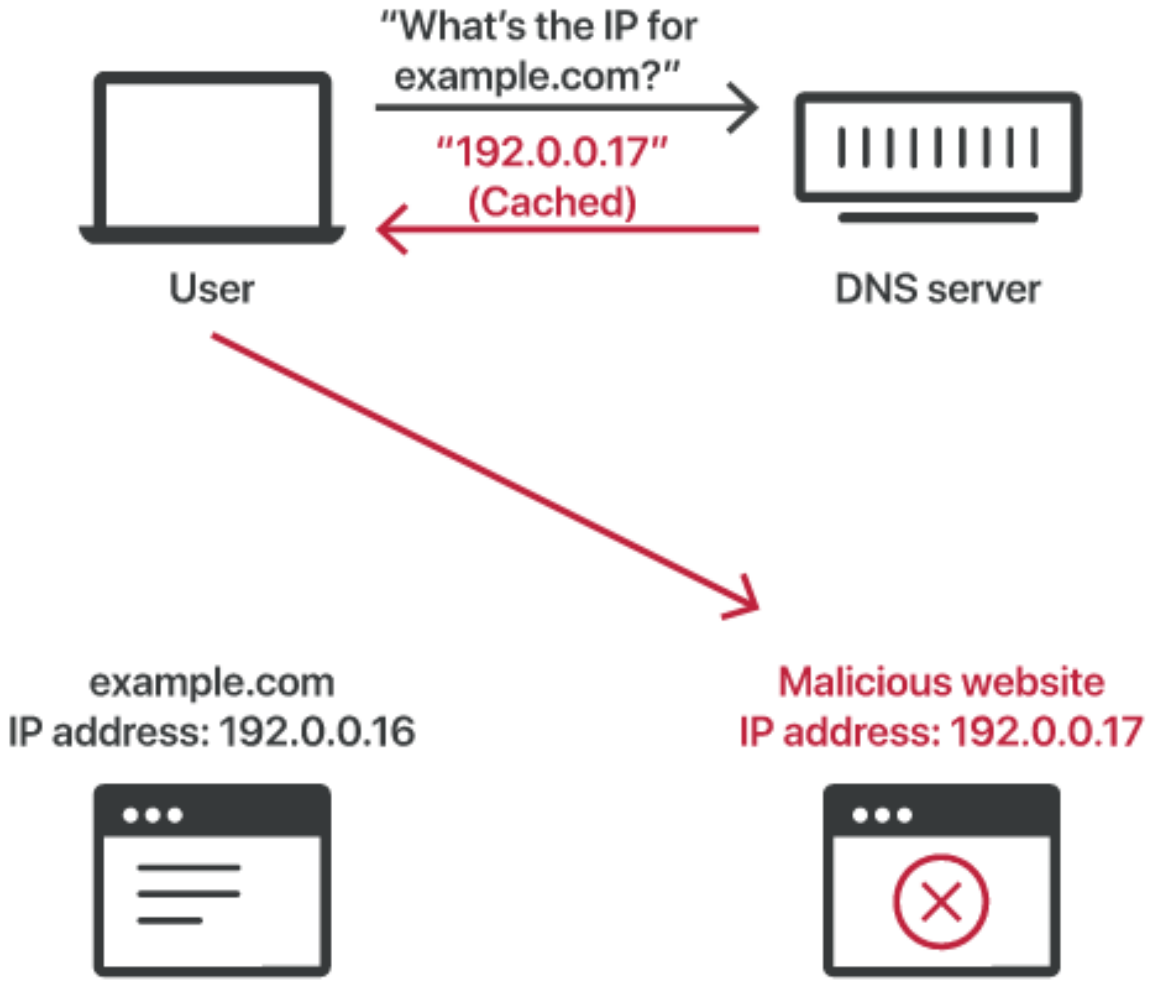
- How to modify it?
  - Linux/MacOS: /etc/hosts
  - Windows: c:\Windows\System32\Drivers\etc\hosts

DNS Cache Poisoning



https://www.cloudflare.com/zh-cn/learning/dns/dns-cache-poisoning/

DNS Cache Poisoning



https://www.cloudflare.com/zh-cn/learning/dns/dns-cache-poisoning/

DNS Cache Poisoning

How to Reach the Outside World

DNS request

dstip 8.8.8.8

payload What is the IP address of www.baidu.com?

34:36:3b:d2:8a:10

192.168.1.9

Subnet: 255.255.255.0

34:36:3b:d2:8a:89

192.168.1.1

34:36:3b:d2:8a:86

192.168.1.10

www.example.com

8.8.8.8 is not in the network

How to Reach the Outside World

DNS request

dstmac	34:36:3b:d2:8a:89
dstip	8.8.8.8
payload	What is the IP address of www.baidu.com?

34:36:3b:d2:8a:10

192.168.1.9

Subnet: 255.255.255.0

Default gateway: 192.168.1.1

34:36:3b:d2:8a:89

192.168.1.1

34:36:3b:d2:8a:86

192.168.1.10

www.example.com

How to Reach the Outside World

dstmac	??:??:??:??:??:??
dstip	8.8.8.8
payload	What is the IP address of www.baidu.com?

34:36:3b:d2:8a:10

192.168.1.9

Subnet: 255.255.255.0

Default gateway: 192.168.1.9

34:36:3b:d2:8a:89

192.168.1.1

34:36:3b:d2:8a:86

192.168.1.10

www.example.com