Networking Attacks

THE UNIVERSITY OF CHICAGO

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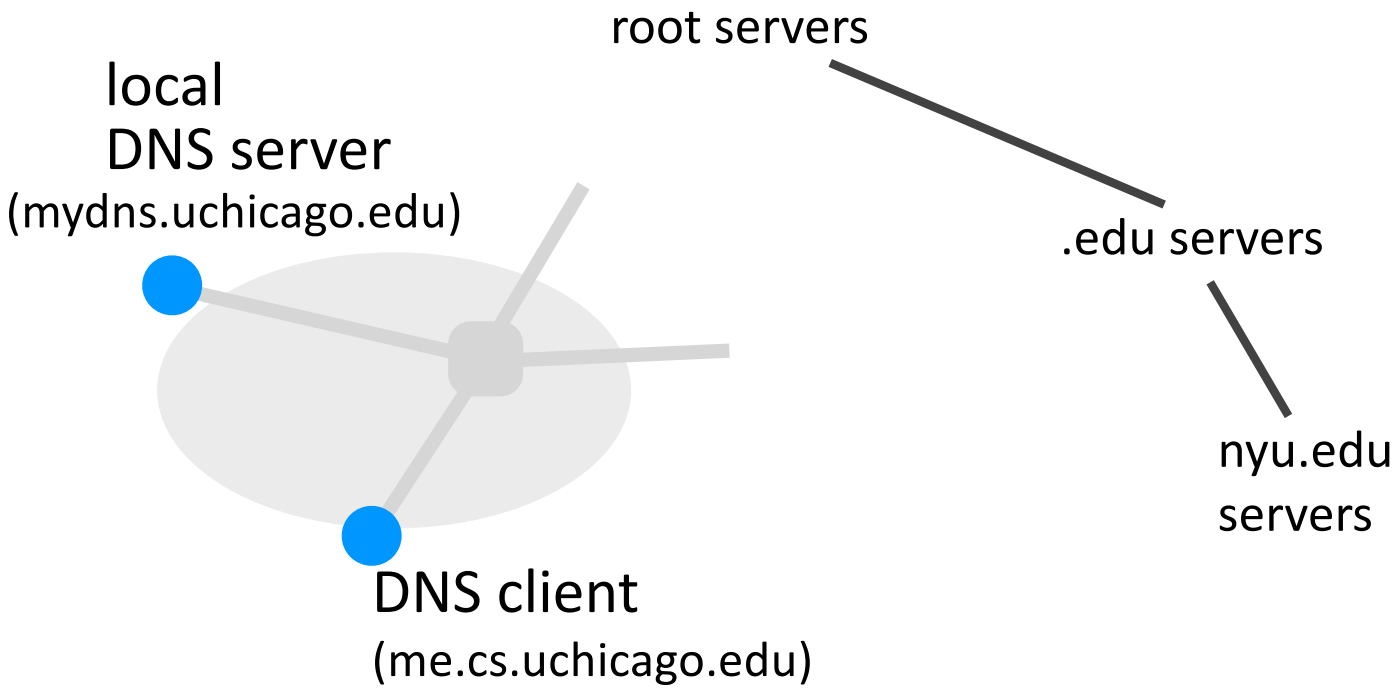
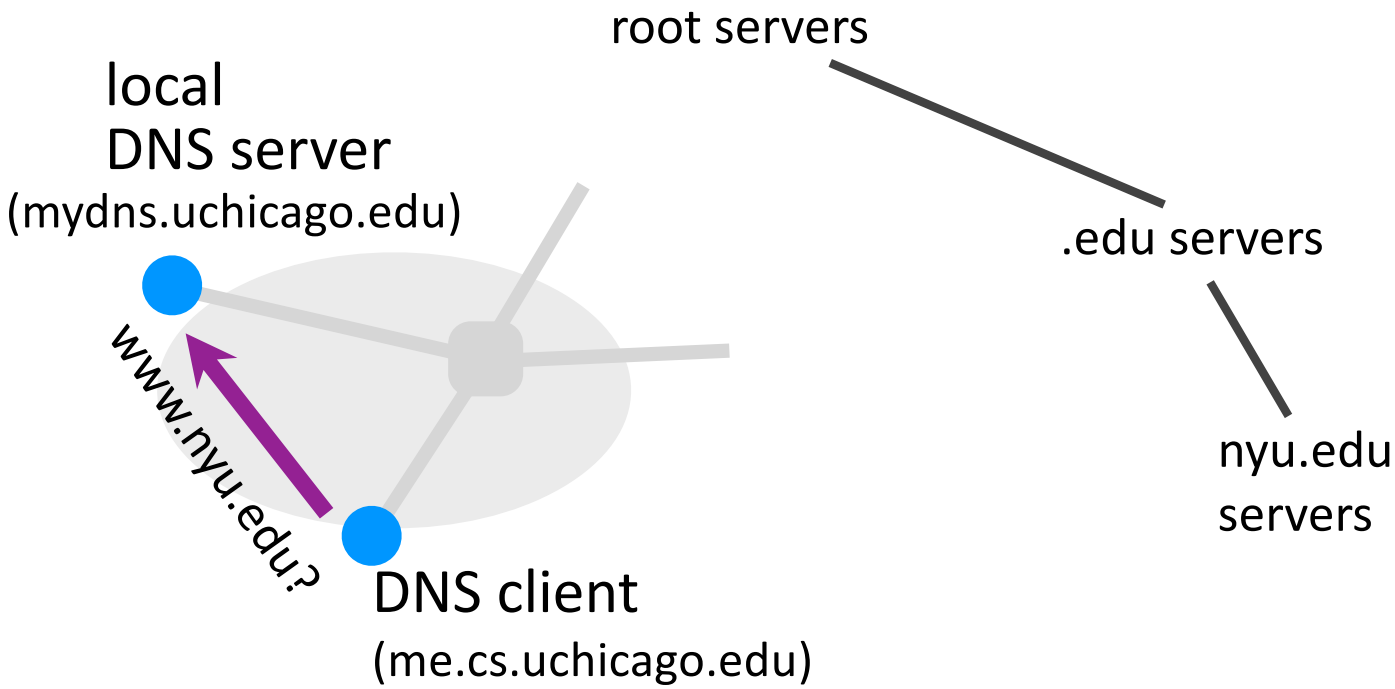
Oct 24, 2018

CS 232/332

Inserting Resource Records into DNS

- Example: you just created company “FooBar”
- You get a block of IP addresses from your ISP
  - say 212.44.9.128/25
- Register foobar.com at registrar (e.g., Go Daddy)
  - Provide registrar with names and IP addresses of your authoritative name server(s)
  - Registrar inserts RR pairs into the .com TLD server:
    - (foobar.com, dns1.foobar.com, NS)
    - (dns1.foobar.com, 212.44.9.129, A)
- Store resource records in your server dns1.foobar.com
  - e.g., type A record for www.foobar.com
  - e.g., type MX record for foobar.com


root servers
local
DNS server
(mydns.uchicago.edu)
.edu servers
nyu.edu
servers
DNS client
(me.cs.uchicago.edu)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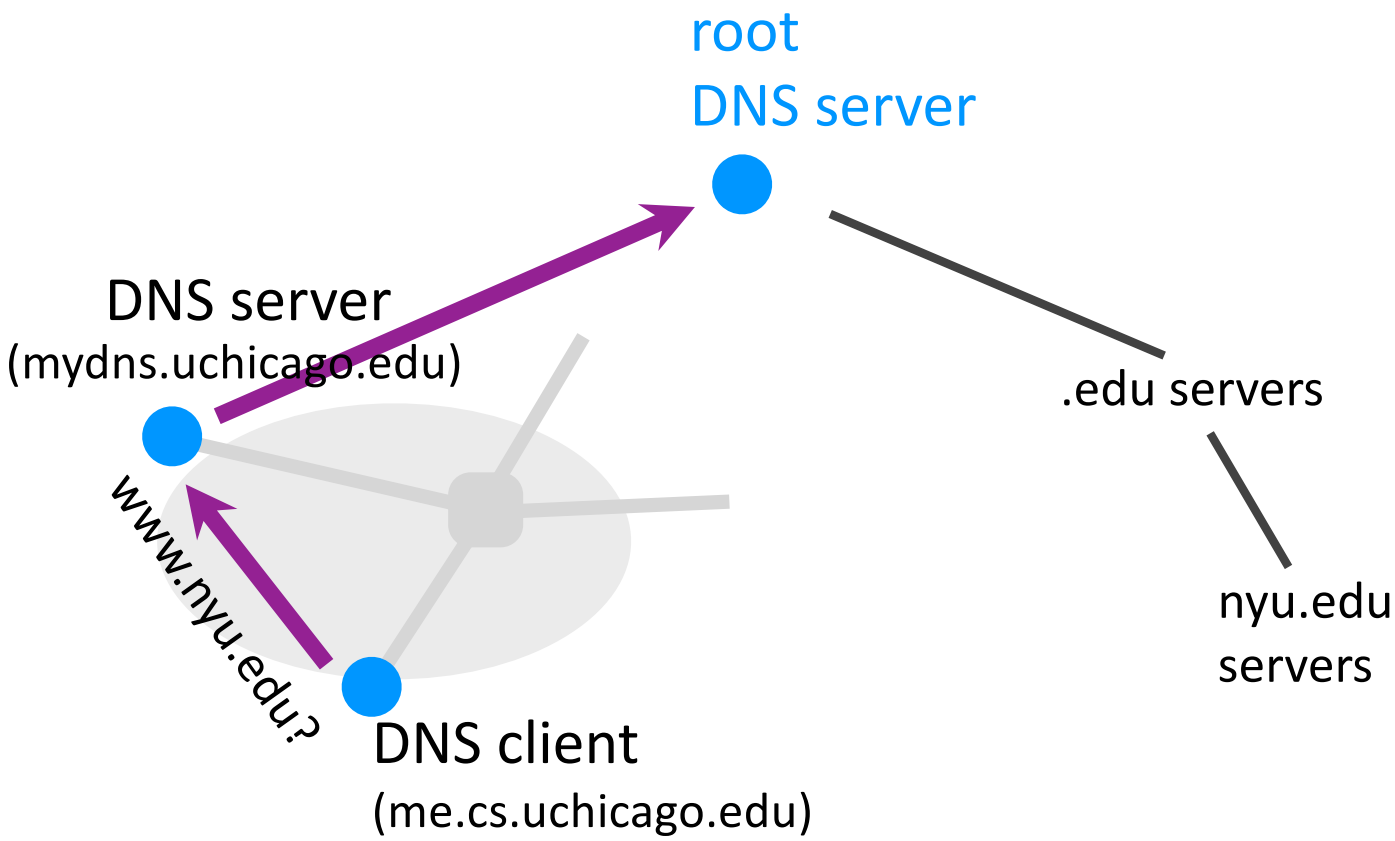
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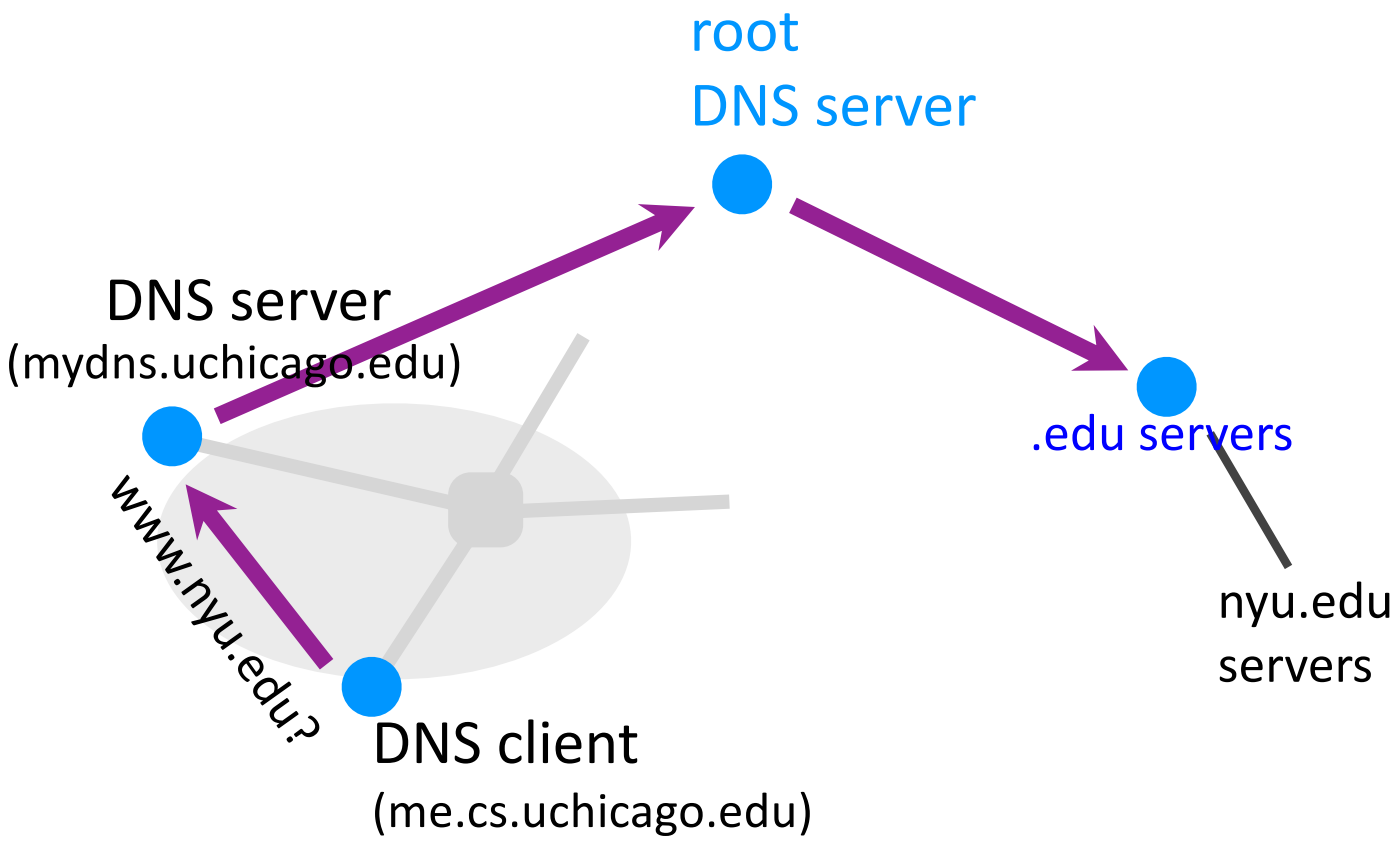
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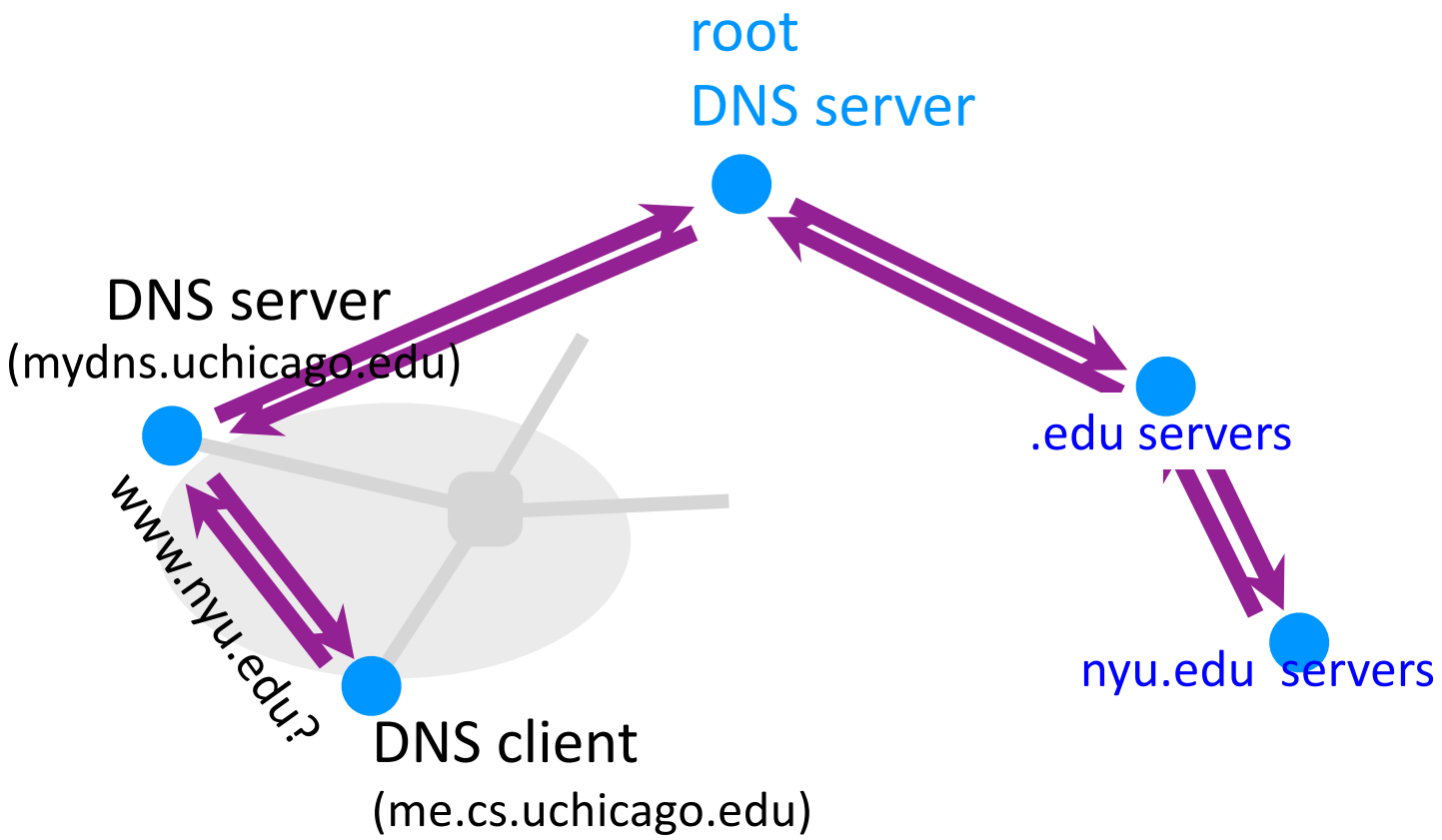
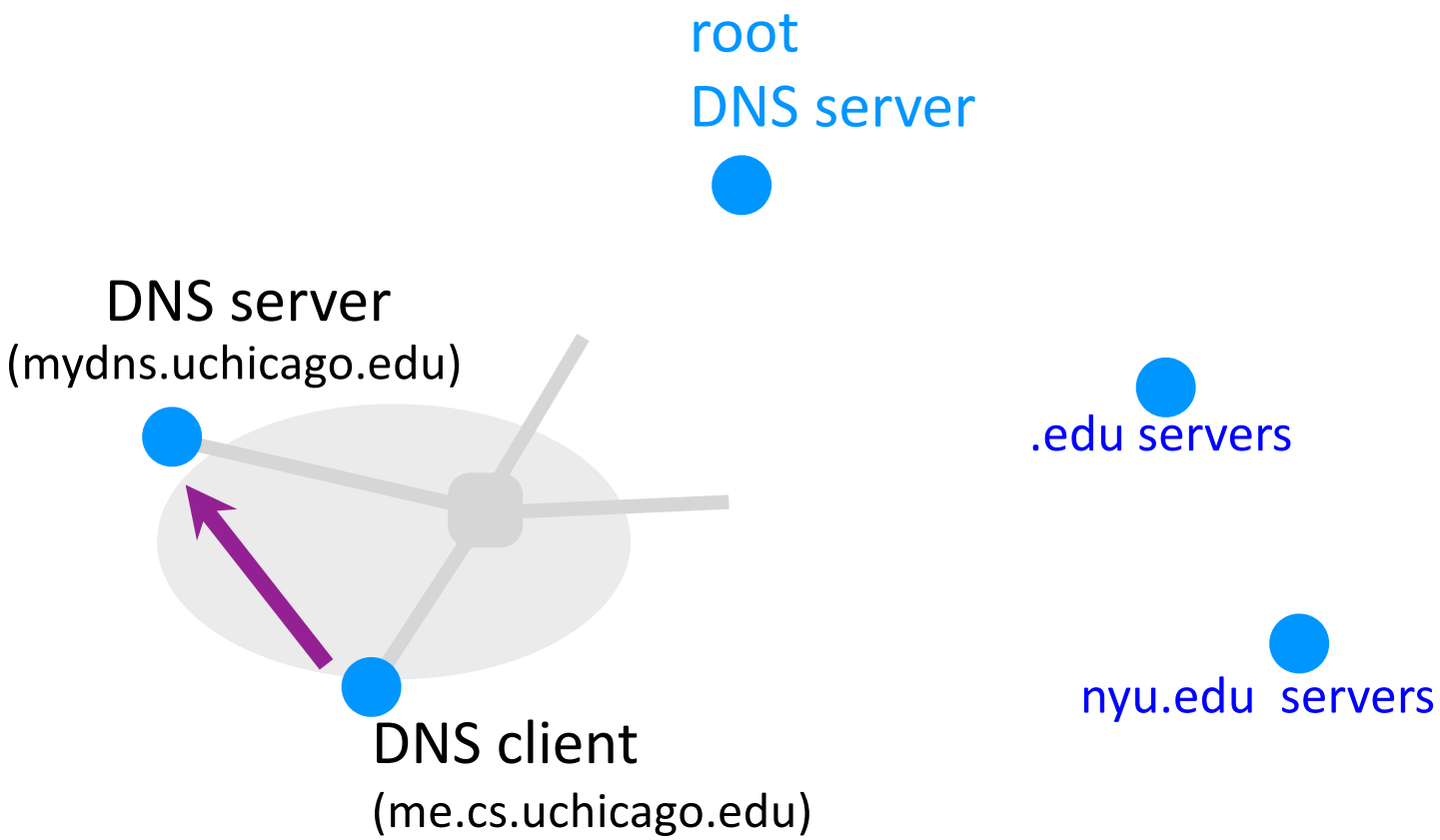
recursive DNS query

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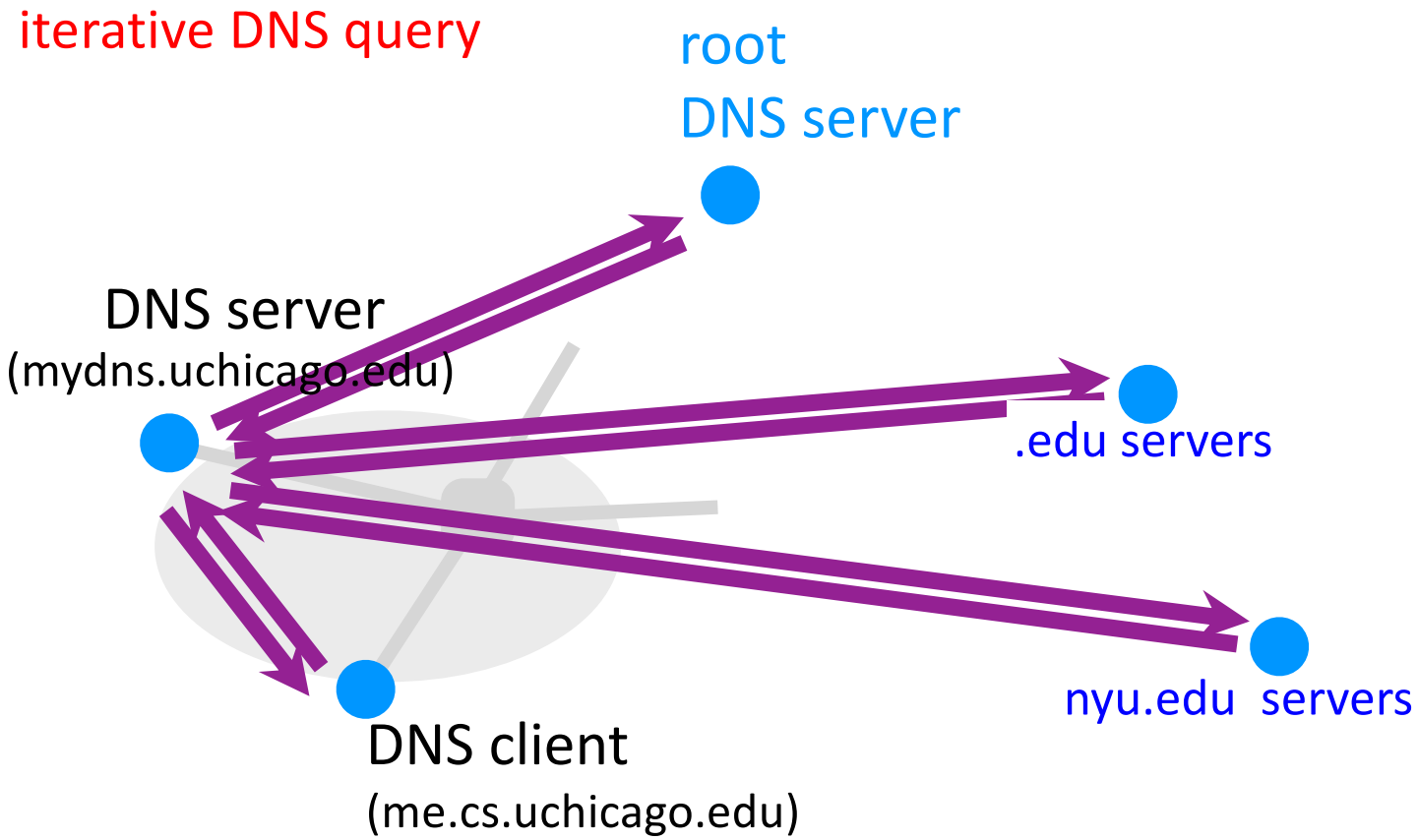
iterative DNS query
root
DNS server
DNS server
(mydns.uchicago.edu)
.edu servers
nyu.edu servers
DNS client
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The Tour Continues…

- IP Addressing and Allocation
- DNS
- IP Routing
- Transport layer (TCP, congestion control)

Addressing, Forwarding, Routing

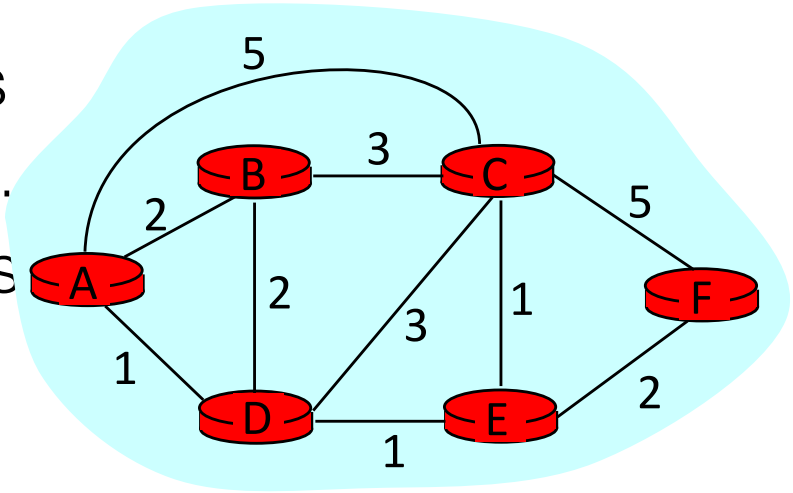
- Addressing: we covered already
- Forwarding: Local router process determines output link (a.k.a “next hop”) for each packet
  - *read address from packet’s network layer header*
  - *search forwarding table*
- Routing: Network-wide process that determines the content of forwarding tables

  → *determines the end-to-end path for each destination*

Routing

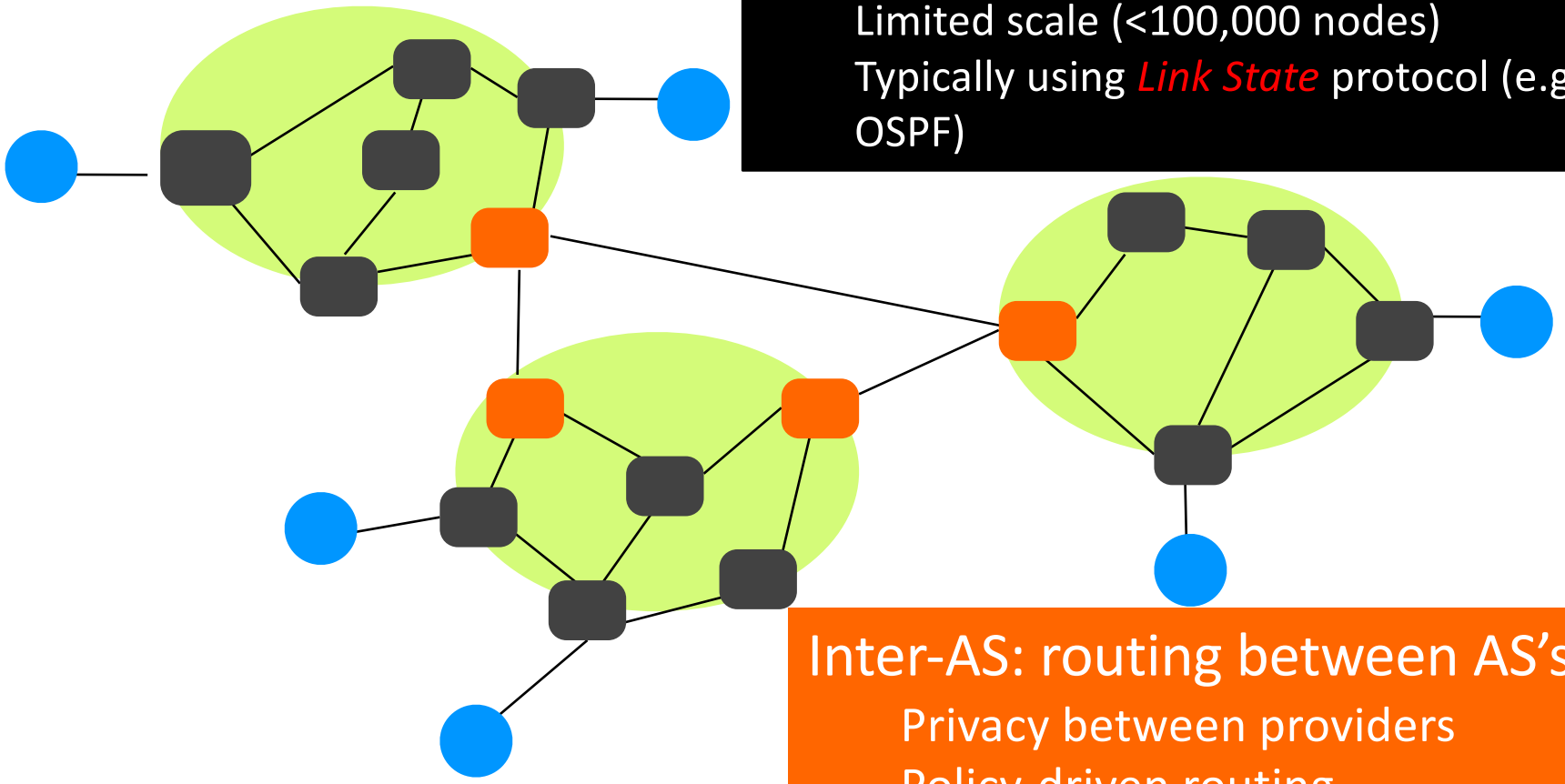
- Goal: determine "good" path through network from source to destination

- Network modeled as a graph
  - Routers → nodes, Link →edges
    - Edge cost: delay, congestion level,.
  - A node knows only its neighbors and the cost to reach them



- How does each node learns how to reach every other node along the shortest path?

Intra-AS & Inter-AS Routing



Intra-AS: routing within a single AS

- Trusted domain (within one company)
- Limited scale (<100,000 nodes)
- Typically using *Link State* protocol (e.g. OSPF)

Inter-AS: routing between AS's

- Privacy between providers
- Policy-driven routing
- BGP, a *Path Vector* protocol
  - Variant of *Distance Vector* routing

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  - Policy-driven routing
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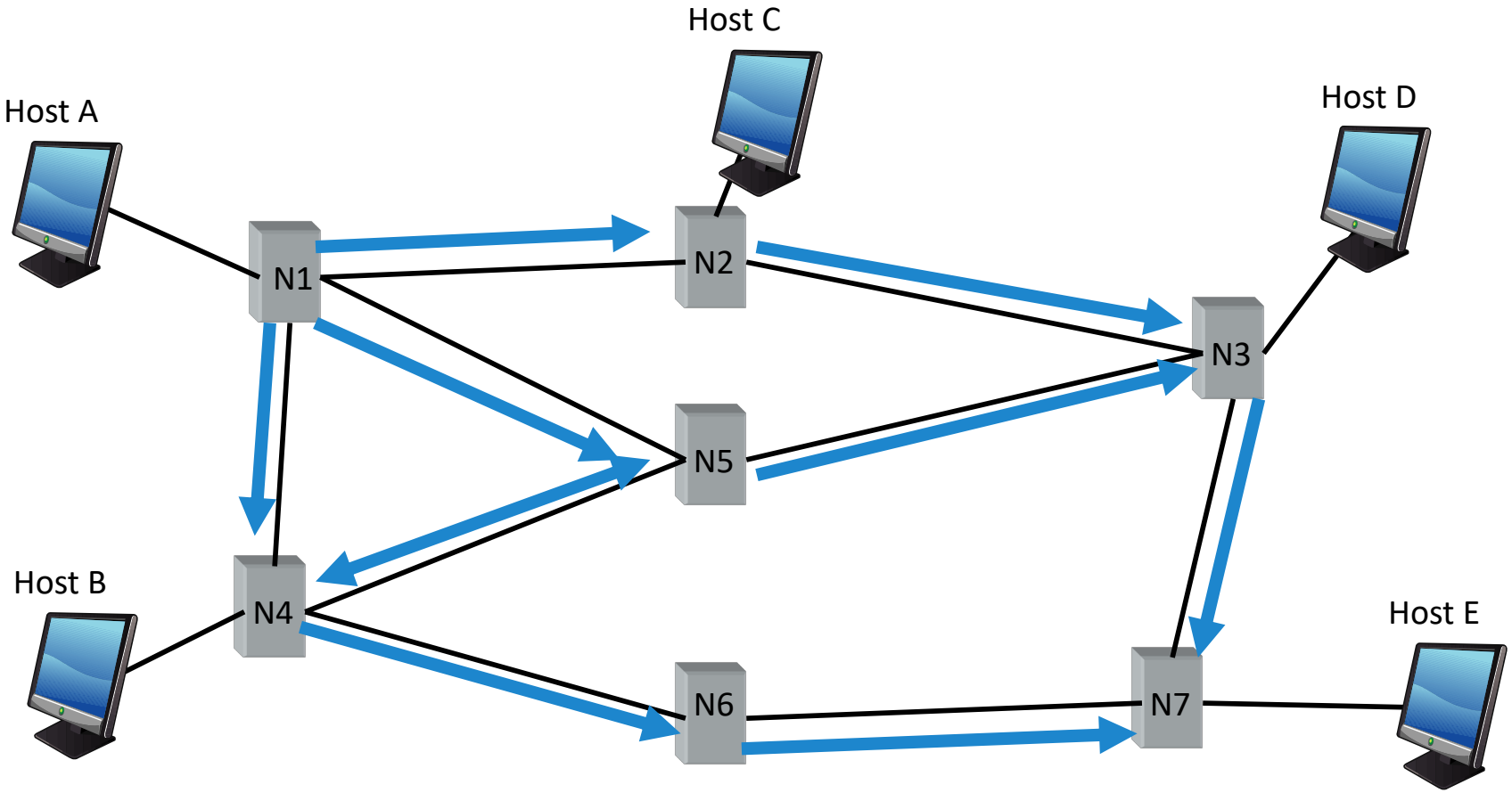
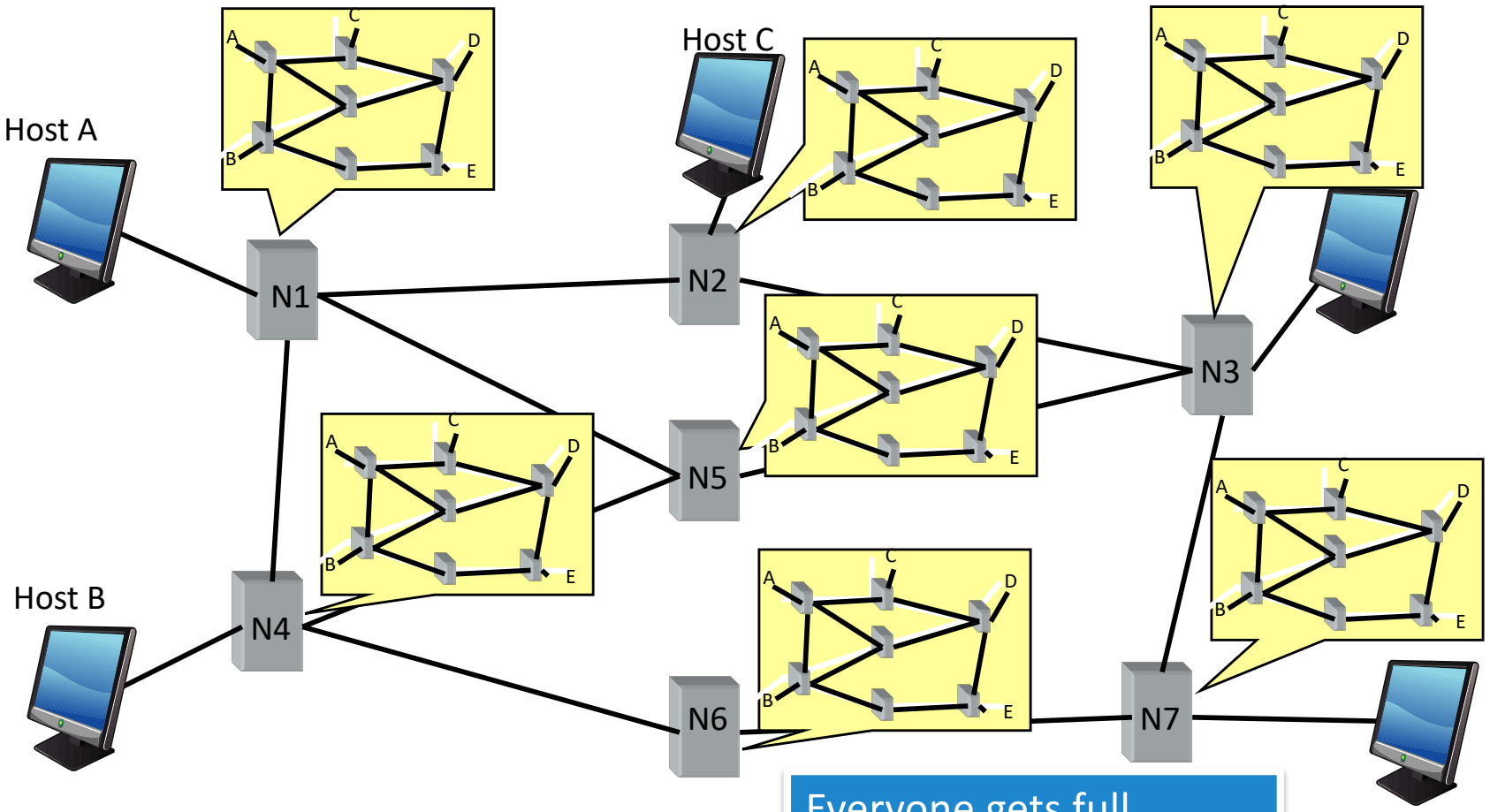
    - Variant of *Distance Vector* routing

Link State: Control Traffic

- Each node floods its local information to every other node in network
- Each node ends up knowing entire network topology
  → use Dijkstra to compute shortest path to every other node

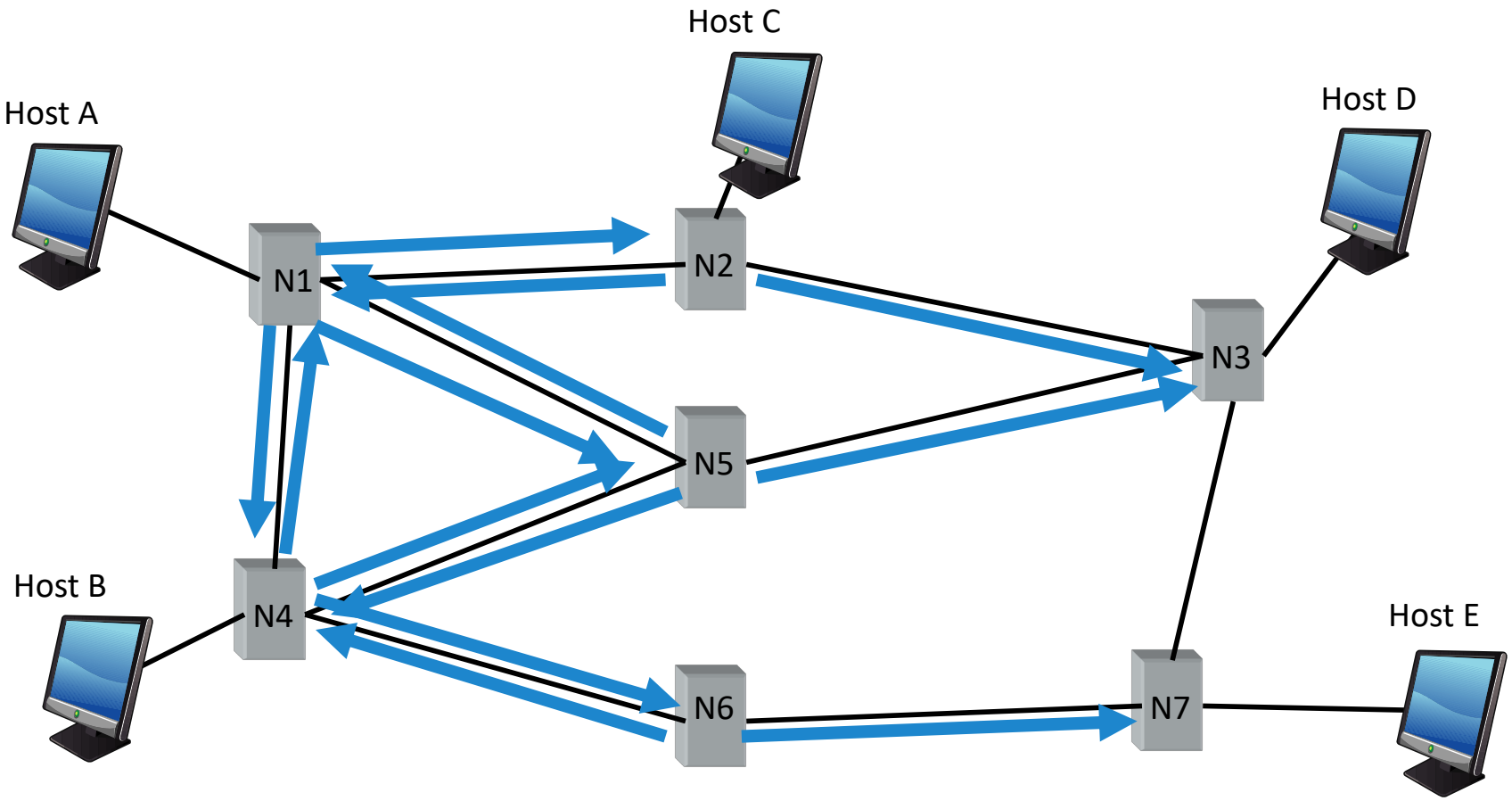


Link State: Node State

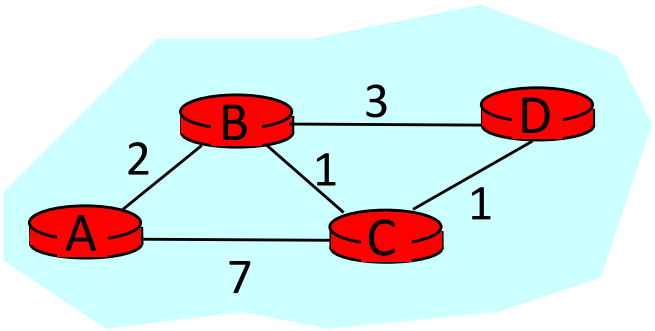


Distance Vector: Control Traffic

- When the routing table of a node changes, it sends table to neighbors
  - A node updates its table with information received from neighbors



Example: Distance Vector Algorithm



Node A

Dest.	Cost	NextHop
B	2	B
C	7	C
D	∞	-

Node B

Dest.	Cost	NextHop
A	2	A
C	1	C
D	3	D

1 ***Initialization:***
2 **for all** neighbors *V* **do**
3 **if** *V* adjacent to *A*
4 D(*A, V*) = c(*A,V*);
5 **else**
6 D(*A, V*) = ∞;
…

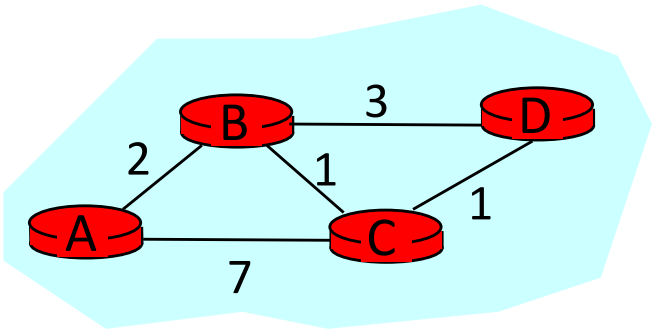
Node C

Dest.	Cost	NextHop
A	7	A
B	1	B
D	1	D

Node D

Dest.	Cost	NextHop
A	∞	-
B	3	B
C	1	C

Example: 1st Iteration (C → A)



Node A

Dest.	Cost	NextHop
B	2	B
C	7	C
D	∞	-

Node B

Dest.	Cost	NextHop
A	2	A
C	1	C
D	3	D

(D(C,A), D(C,B), D(C,D))

Node C

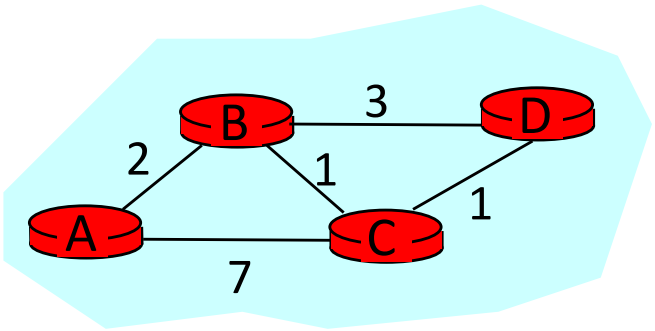
Dest.	Cost	NextHop
A	7	A
B	1	B
D	1	D

Node D

Dest.	Cost	NextHop
A	∞	-
B	3	B
C	1	C

```
...
7 loop:
...
12  else if (update D(V, Y) received from V)
13    for all destinations Y do
14      if (destination Y through V)
15        D(A,Y) = D(A,V) + D(V, Y);
16      else
17        D(A, Y) = min(D(A, Y),
                        D(A, V) + D(V, Y));
18  if (there is a new minimum for dest. Y)
19    send D(A, Y) to all neighbors
20  forever
```

Example: 1st Iteration (C → A)



Node A

Dest.	Cost	NextHop
B	2	B
C	7	C
D	**8**	**C**

Node B

Dest.	Cost	NextHop
A	2	A
C	1	C
D	3	D

D(A,D)= min(D(A, D),D(A,C)+D(C,D)
= min(∞ , 7 + 1) = 8

(D(C,A), D(C,B), D(C,D))

Node C

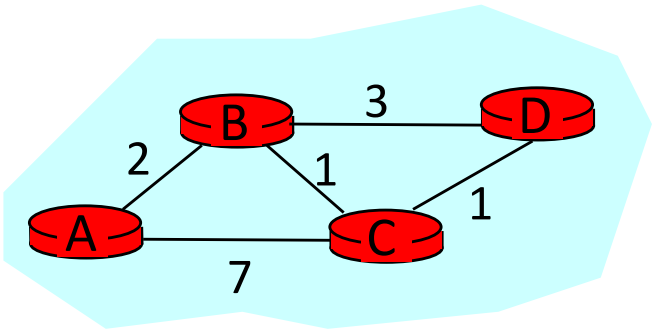
Dest.	Cost	NextHop
A	7	A
B	1	B
D	1	D

Node D

Dest.	Cost	NextHop
A	∞	-
B	3	B
C	1	C

…
7 ***loop:***
…
12 **else if** (update D(*V, Y*) received from *V*)
13 **for all** destinations Y **do**
14 **if** (destination *Y* through *V*)
15 D(*A,Y*) = D(*A,V*) + D(*V, Y*);
16 **else**
17 D(A, Y) = min(D(*A, Y*),
D(*A, V*) + D(*V, Y*));
18 **if** (there is a new minimum for dest. *Y*)
19 **send** D(*A, Y*) to all neighbors
20 **forever**

Example: 1st Iteration (C → A)



Node A

Dest.	Cost	NextHop
B	2	B
C	7	C
D	8	C

Node B

Dest.	Cost	NextHop
A	2	A
C	1	C
D	3	D

…
7 ***loop:***
…

```
12  else if (update D(V, Y) received from V)
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16      else
17        D(A, Y) = min(D(A, Y),
                        D(A, V) + D(V, Y));
18  if (there is a new minimum for dest. Y)
19    send D(A, Y) to all neighbors
20  forever
```

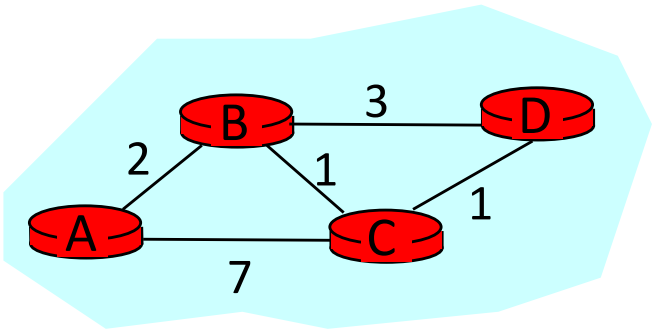
Node C

Dest.	Cost	NextHop
A	7	A
B	1	B
D	1	D

Node D

Dest.	Cost	NextHop
A	∞	-
B	3	B
C	1	C

Example: 1st Iteration (B→A, C→A)



Node A

Dest.	Cost	NextHop
B	2	B
C	3	B
D	5	B

Node B

Dest.	Cost	NextHop
A	2	A
C	1	C
D	3	D

D(A,D) = min(D(A,D), D(A,B) + D(B,D))
= min(8, 2 + 3) = 5

D(A,C) = min(D(A,C), D(A,B) + D(B,C))
= min(7, 2 + 1) = 3

…
7 ***loop:***
…
12 **else if** (update D(*V, Y*) received from *V*)
13 **for all** destinations Y **do**
14 **if** (destination *Y* through *V*)
15 D(*A,Y*) = D(*A,V*) + D(*V, Y*);
16 **else**
17 D(A, Y) = min(D(*A, Y*),
D(*A, V*) + D(*V, Y*));
18 **if** (there is a new minimum for dest. *Y*)
19 **send** D(*A, Y*) to all neighbors
20 **forever**

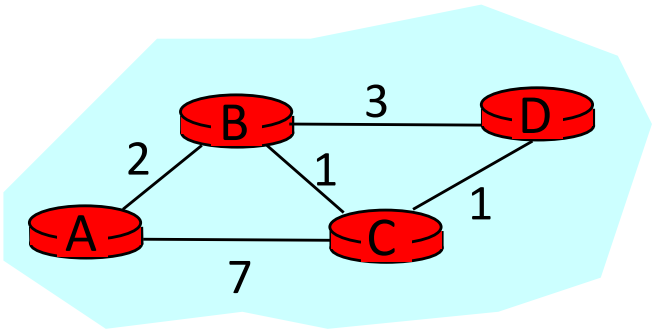
Node C

Dest.	Cost	NextHop
A	7	A
B	1	B
D	1	D

Node D

Dest.	Cost	NextHop
A	∞	-
B	3	B
C	1	C

Example: End of 1st Iteration



Node A

Dest.	Cost	NextHop
B	2	B
C	3	B
D	5	B

Node B

Dest.	Cost	NextHop
A	2	A
C	1	C
D	2	C

Node C

Dest.	Cost	NextHop
A	3	B
B	1	B
D	1	D

Node D

Dest.	Cost	NextHop
A	4	B
B	3	B
C	1	C

...
7 ***loop:***
...
12 **else if** (update D(*V, Y*) received from *V*)
13 **for all** destinations Y **do**
14 **if** (destination *Y* through *V*)
15 D(*A,Y*) = D(*A,V*) + D(*V, Y*);
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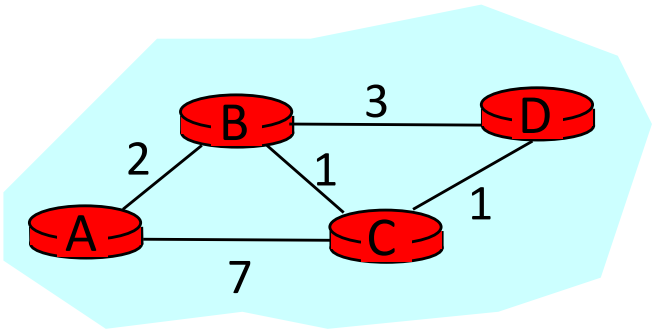
D(*A, V*) + D(*V, Y*));
18 **if** (there is a new minimum for dest. *Y*)
19 **send** D(*A, Y*) to all neighbors
20 **forever**

Example: End of 3nd Iteration



...
7 ***loop:***
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13 **for all** destinations Y **do**
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D(*A, V*) + D(*V, Y*));
18 **if** (there is a new minimum for dest. *Y*)
19 **send** D(*A, Y*) to all neighbors
20 **forever**

Node A

Dest.	Cost	NextHop
B	2	B
C	3	B
D	4	B

Node B

Dest.	Cost	NextHop
A	2	A
C	1	C
D	2	C

Node C

Dest.	Cost	NextHop
A	3	B
B	1	B
D	1	D

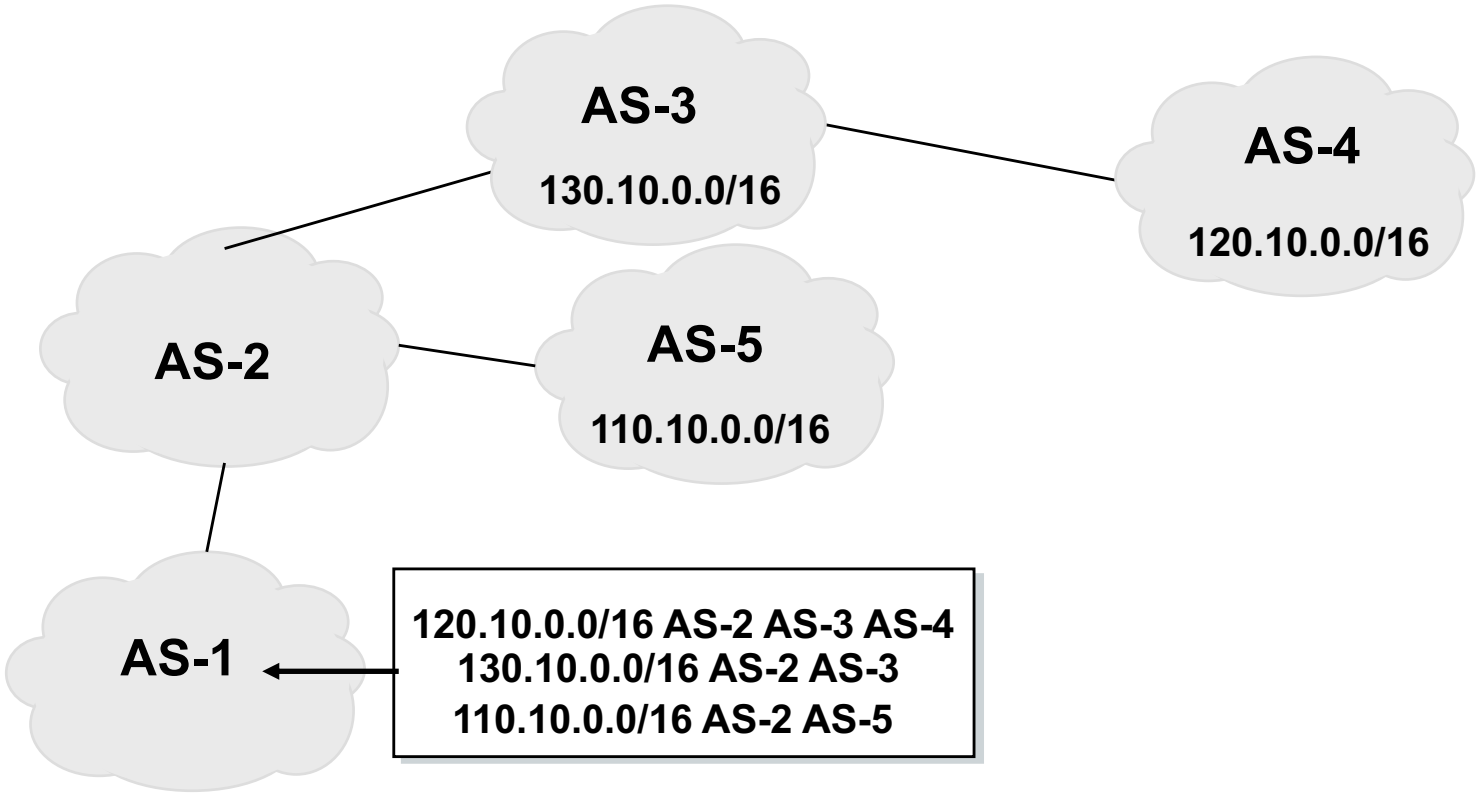
Node D

Dest.	Cost	NextHop
A	4	C
B	2	C
C	1	C

Nothing changes → algorithm terminates

BGP: a Path-Vector Protocol

- An AS-path: sequence of AS's a route traverses
- Used for loop detection and to apply policy
- Default choice: route with fewest # of AS's



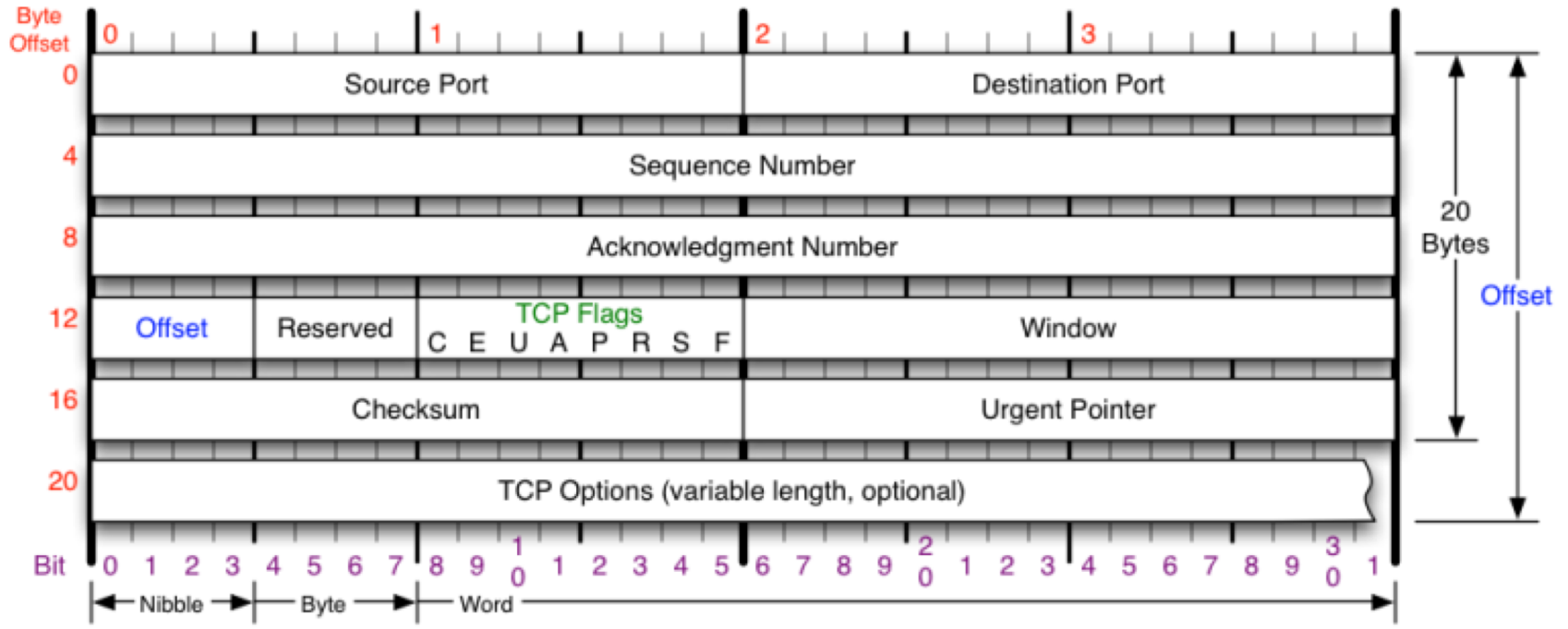
The Tour Continues…

- IP Addressing and Allocation
- DNS
- IP Routing
- Transport layer (TCP, congestion control)

TCP (Transmission Control Protocol)

- Multiplexes between services
- Multi-packet connections
- Handles loss, duplication, & out-of-order delivery
  — all received data ACKnowledged
- Flow control
  — sender doesn’t overwhelm recipient
- Congestion control
  — sender doesn’t overwhelm network

TCP header



TCP Flags

C E U A P R S F

Congestion Window
C 0x80 Reduced (CWR)
E 0x40 ECN Echo (ECE)
U 0x20 Urgent
A 0x10 Ack
P 0x08 Push
R 0x04 Reset
S 0x02 Syn
F 0x01 Fin

Congestion Notification

ECN (Explicit Congestion Notification). See RFC 3168 for full details, valid states below.

Packet State	DSB	ECN bits
Syn	0 0	1 1
Syn-Ack	0 0	0 1
Ack	0 1	0 0
No Congestion	0 1	0 0
No Congestion	1 0	0 0
Congestion	1 1	0 0
Receiver Response	1 1	0 1
Sender Response	1 1	1 1

TCP Options

0 End of Options List
1 No Operation (NOP, Pad)
2 Maximum segment size
3 Window Scale
4 Selective ACK ok
8 Timestamp

Checksum

Checksum of entire TCP segment and pseudo header (parts of IP header)

Offset

Number of 32-bit words in TCP header, minimum value of 5. Multiply by 4 to get byte count.

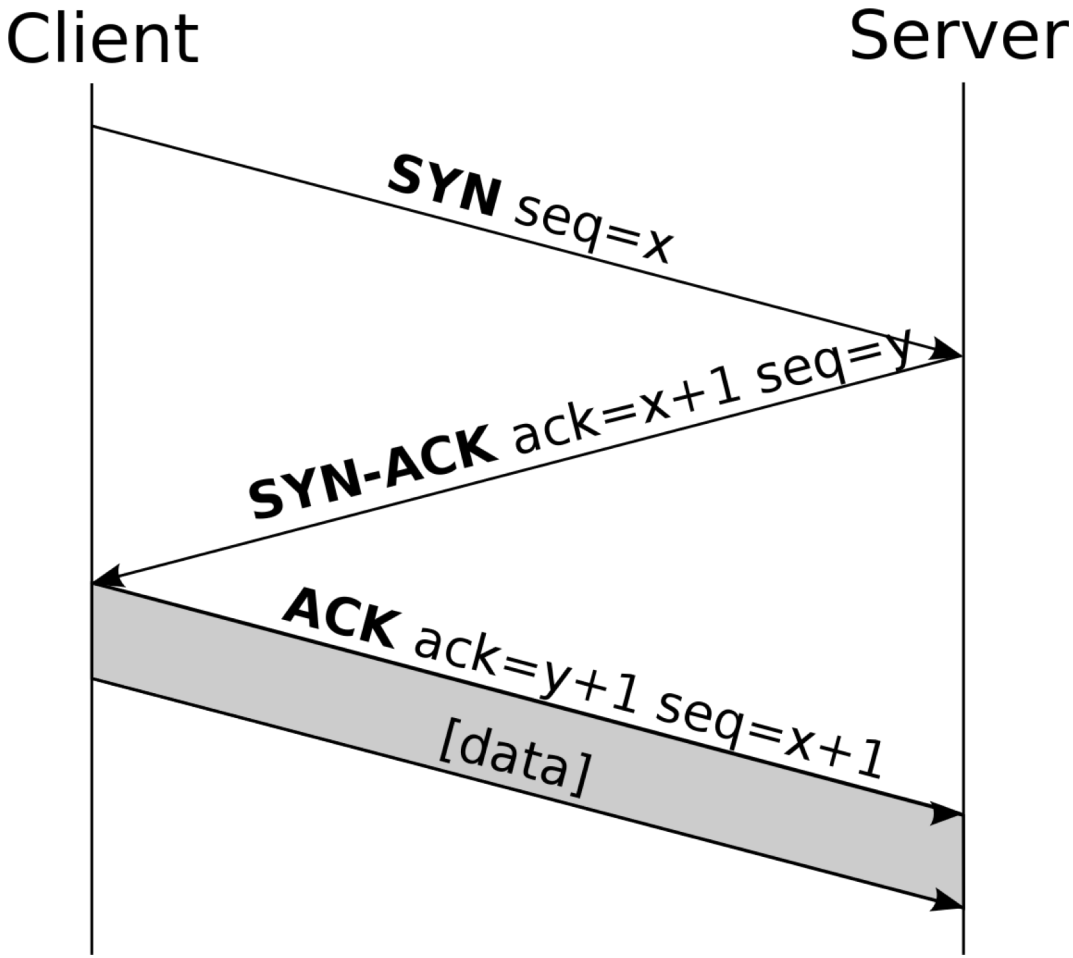
RFC 793

Please refer to RFC 793 for the complete Transmission Control Protocol (TCP) Specification.

TCP connections

- Explicit connection setup & teardown
- Explicit control flags (e.g., SYN, ACK, FIN, RST)
- Sequence numbers — reliability & ordering

Setup: 3-way handshake



Source: Wikimedia commons

Let’s Talk About Attacks…

Network threat model

- Network scanning
- Attacks on confidentiality
  (e.g., eavesdropping)
- Attacks on integrity
  (e.g., spoofing, packet injection)
- Attacks on availability
  (e.g., denial of service (DoS))
  - Resource exhaustion (e.g., CPU, memory, B/W)
  - Easy to perform, very difficult to defend

Network Scanning: Ping

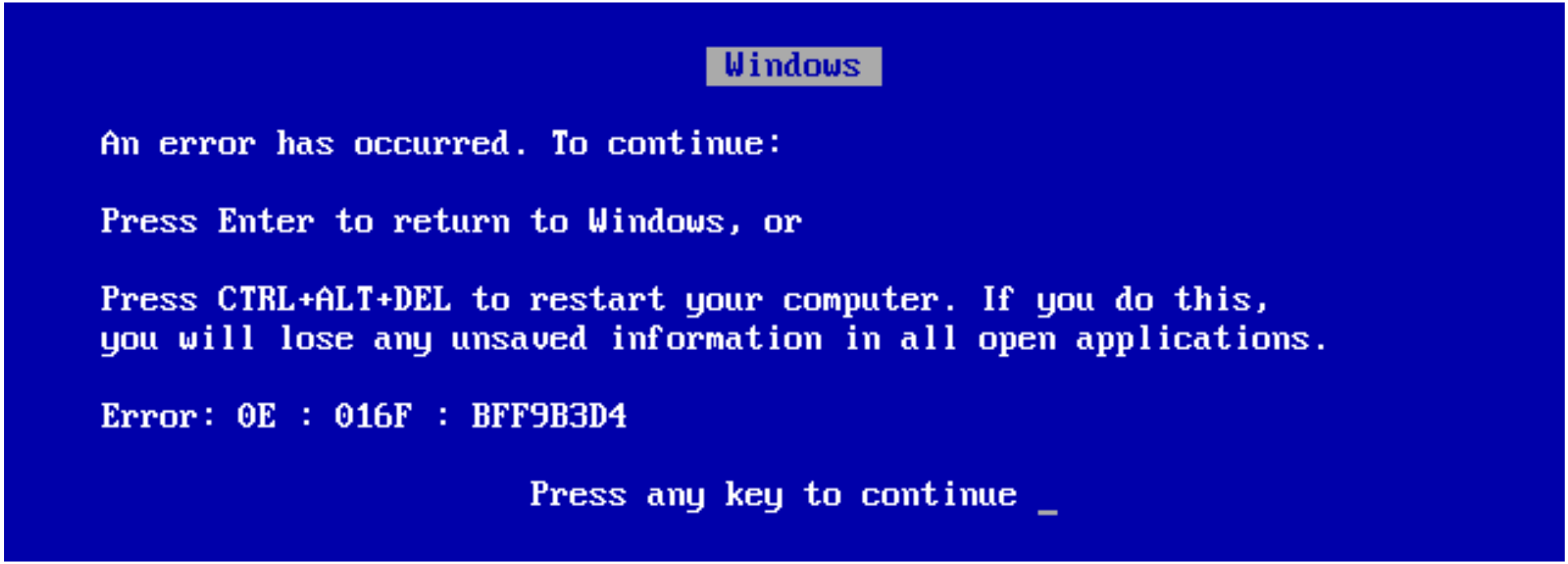
- Essential, low-level network utility
- Sends a “ping” ICMP message to a host on the internet

```
$ ping 66.66.0.255
PING 66.66.0.255 (66.66.0.255) 56(84) bytes of data.
64 bytes from 66.66.0.255: icmp_seq=1 ttl=58 time=41.2 ms
```

- Destination host is supposed to respond with a “pong”
  - Indicating that it can receive packets
- By default, ping messages are 56 bytes long (+ some header bytes)
  - Maximum size 65535 bytes
- What if you send a ping that is >65535 bytes long?

Ping of Death

- $ ping –s 65535 66.66.0.255
  - Attack identified in 1997
  - IPv6 version identified/fixed in 2013



Network Scanning: Traceroute

- traceroute — hops between me and host
  - Sends repeated ICMP reqs w/ increasing TTL

```
thor Wed Oct 24(12:51am)[~]:-> traceroute www.slack.com
traceroute to www.slack.com (52.85.115.213), 64 hops max, 52 byte packets
 1  v11router (128.135.11.1)  1.265 ms  0.788 ms  0.778 ms
 2  a06-021-100-to-d19-07-200.p2p.uchicago.net (10.5.1.186)  1.292 ms  0.749 ms  0.833 ms
 3  d19-07-200-to-h01-391-300.p2p.uchicago.net (10.5.1.46)  2.124 ms  2.435 ms  2.072 ms
 4  192.170.192.34 (192.170.192.34)  0.755 ms
    192.170.192.32 (192.170.192.32)  0.810 ms  0.701 ms
 5  192.170.192.36 (192.170.192.36)  0.887 ms  0.918 ms  0.877 ms
 6  r-equinix-isp-ae2-2213.wiscnet.net (216.56.50.45)  1.625 ms  1.803 ms  1.866 ms
 7  * * *
 8  * * *
 9  * * *
10  * * *
11  178.236.3.103 (178.236.3.103)  4.516 ms  4.326 ms  4.320 ms
12  * * *
13  * * *
14  * * *
15  server-52-85-115-213.ind6.r.cloudfront.net (52.85.115.213)  4.554 ms  4.398 ms  4.757 ms
thor Wed Oct 24(12:52am)[~]:->
```

Port Scanning

- What services are running on a server? Nmap

```
linux3 Wed Oct 24(12:54am)[~]:-> nmap www.cs.uchicago.edu

Starting Nmap 7.01 ( https://nmap.org ) at 2018-10-24 00:55 CDT
Nmap scan report for www.cs.uchicago.edu (34.203.108.171)
Host is up (0.019s latency).
Other addresses for www.cs.uchicago.edu (not scanned): 54.164.17.80 54.85.61.218
rDNS record for 34.203.108.171: ec2-34-203-108-171.compute-1.amazonaws.com
Not shown: 998 filtered ports
PORT    STATE SERVICE
80/tcp  open  http
443/tcp open  https

Nmap done: 1 IP address (1 host up) scanned in 4.99 seconds
linux3 Wed Oct 24(12:55am)[~]:->
```

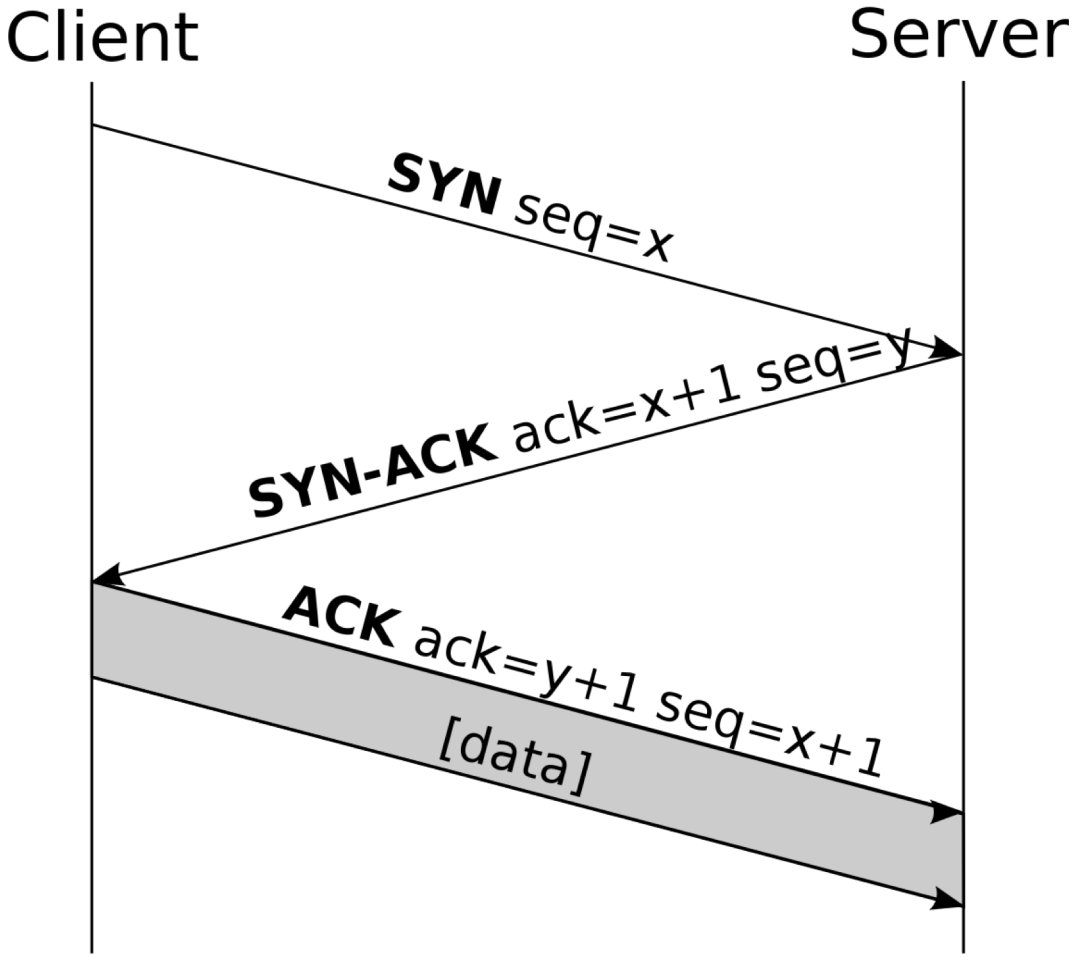
- 5 seconds to scan a single machine!!

Port Scanning on Steroids

- How do you speed up scans for all IPv4?
  - Don't wait for responses; pipeline
  - Parallelize: divide & conquer IPv4 ranges
  - Randomize permutations w/o collisions
- Result: the zmap tool
  - Scan all of IPv4 in 45mins (w/ GigE cxn)
  - IPv4 in 5 mins w/ 10GigE

SYN scan

Only send SYN



Responses:

- SYN-ACK — port open
- RST — port closed
- Nothing — filtered (e.g., firewall)

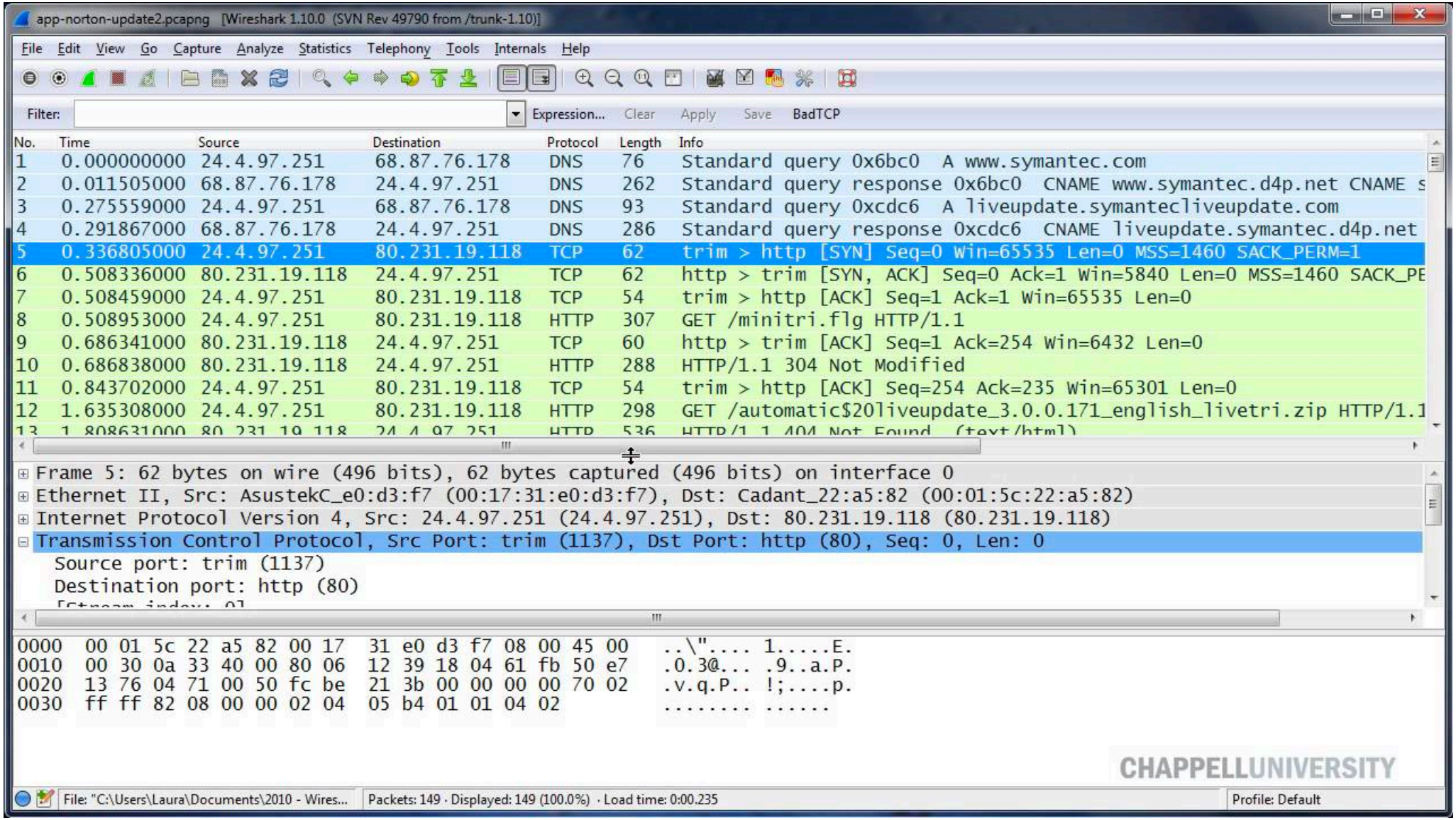
Eavesdropping

Tools: Wireshark, tcpdump, Bro, …

Steps:

1. Parse data link layer frames
2. Identify network flows
3. Reconstruct IP packet fragments
4. Reconstruct TCP connections
5. Parse app protocol messages

Wireshark, Detailed Protocol Analyzer



(TS//SI//NF) FAA702 Operations

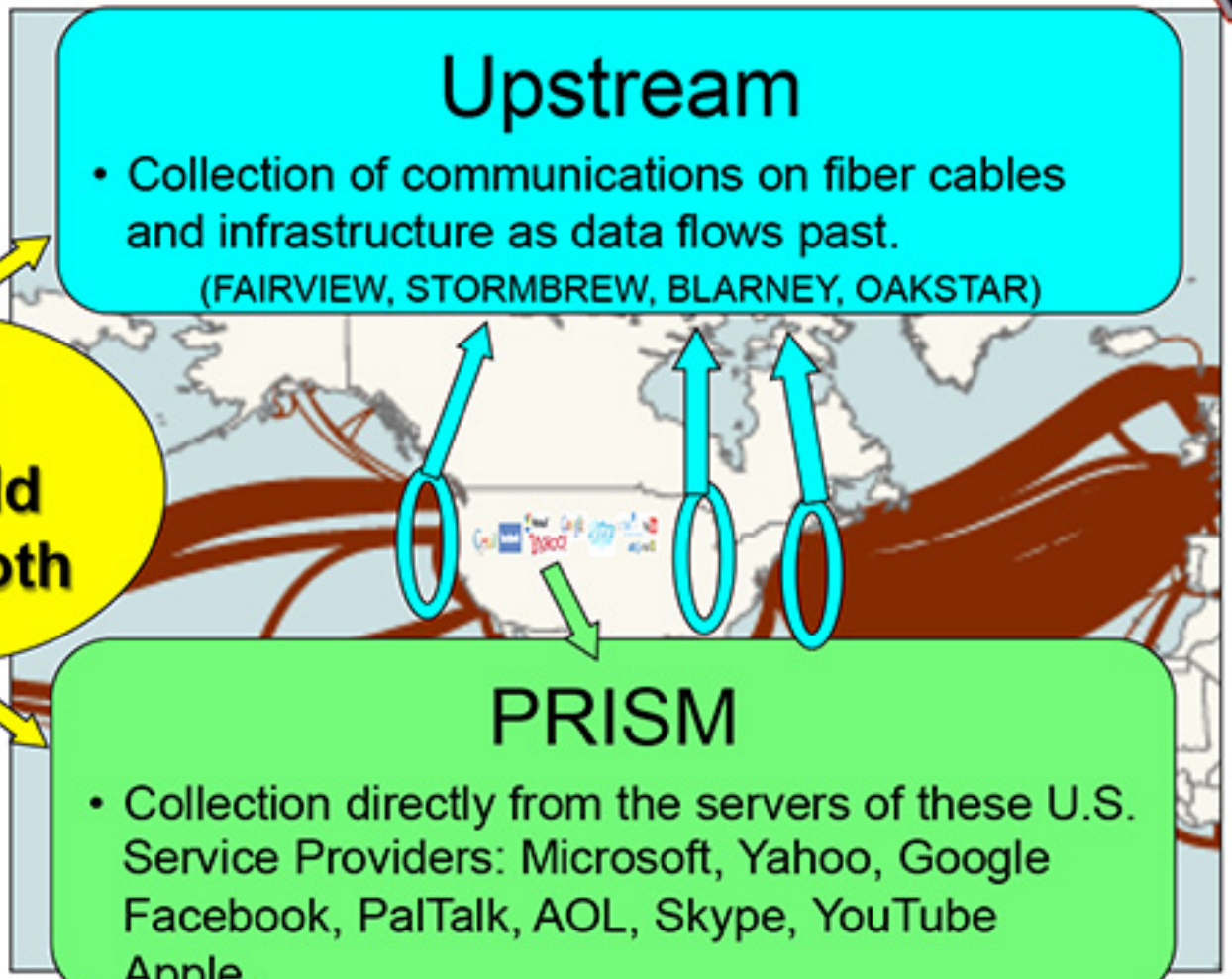
Two Types of Collection

Upstream

- Collection of communications on fiber cables and infrastructure as data flows past.

(FAIRVIEW, STORMBREW, BLARNEY, OAKSTAR)

You Should Use Both



PRISM

- Collection directly from the servers of these U.S. Service Providers: Microsoft, Yahoo, Google Facebook, PalTalk, AOL, Skype, YouTube Apple.

From Snowden archives, dated April 2013

(TS//SI//NF) PRISM Collection Details

Current Providers

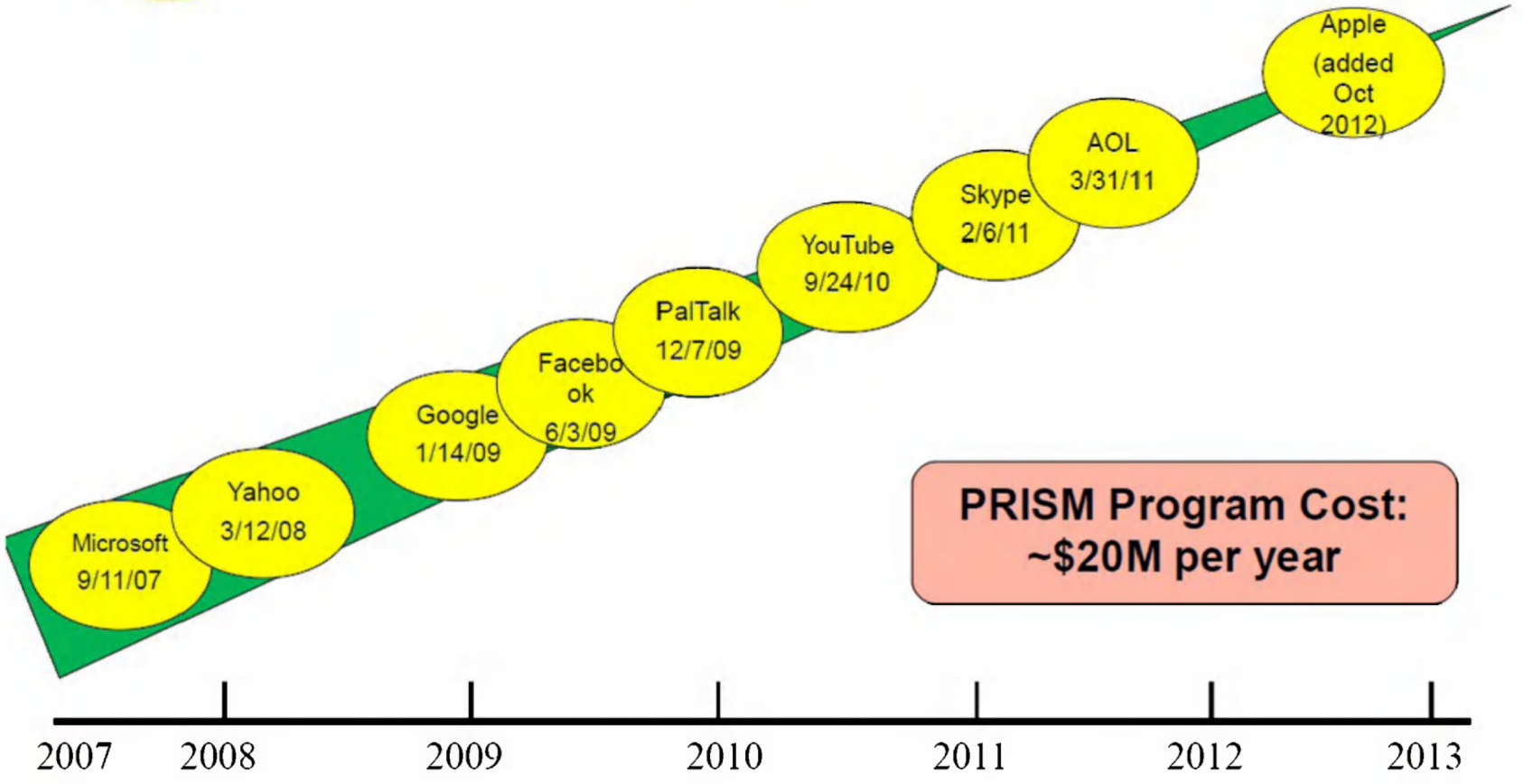
- Microsoft (Hotmail, etc.)
- Google
- Yahoo!
- Facebook
- PalTalk
- YouTube
- Skype
- AOL
- Apple

What Will You Receive in Collection (Surveillance and Stored Comms)? It varies by provider. In general:

- E-mail
- Chat – video, voice
- Videos
- Photos
- Stored data
- VoIP
- File transfers
- Video Conferencing
- Notifications of target activity – logins, etc.
- Online Social Networking details
- **Special Requests**

Complete list and details on PRISM web page:
Go PRISMFAA

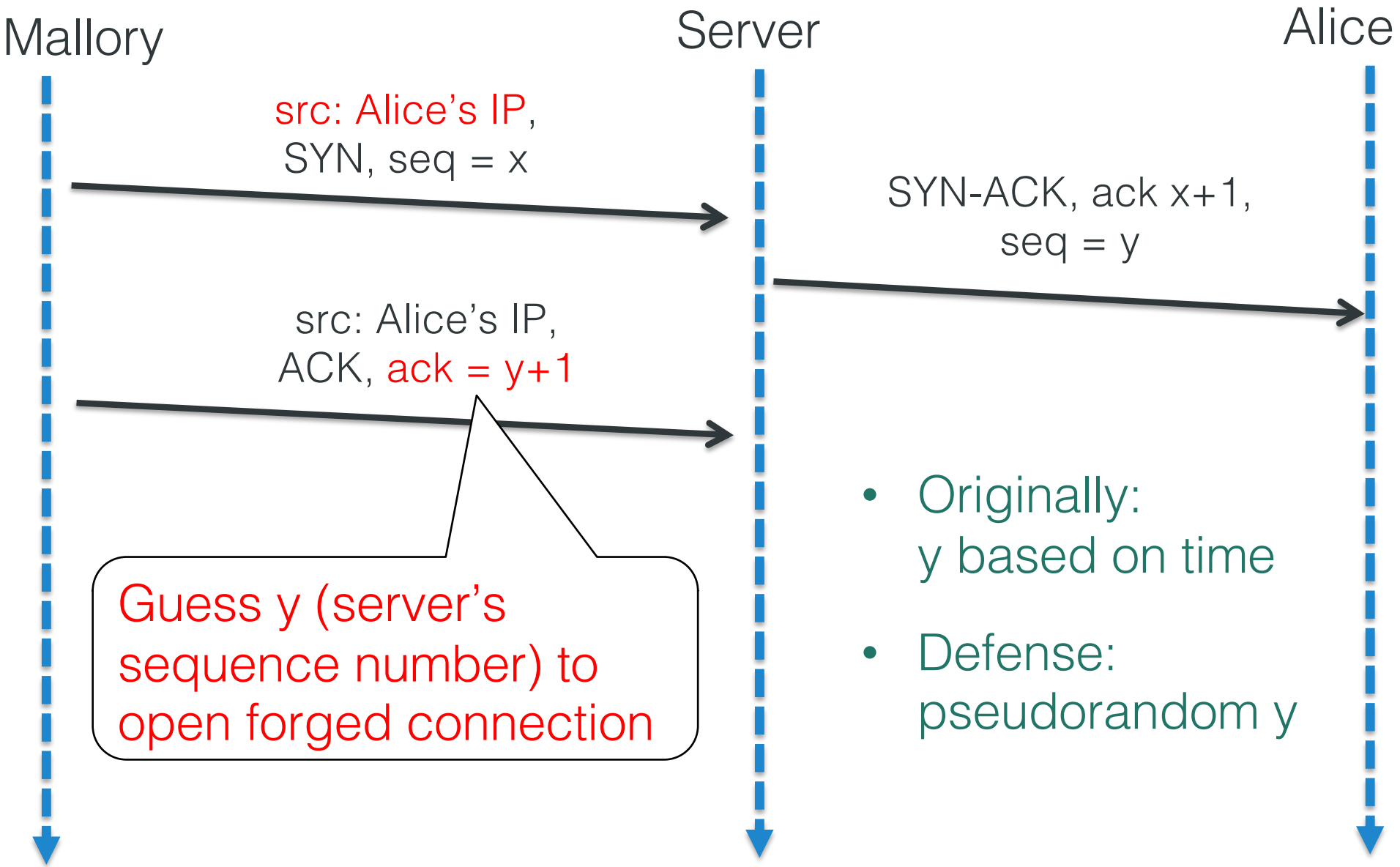
(TS//SI//NF) Dates When PRISM Collection Began For Each Provider



PRISM Program Cost: ~$20M per year

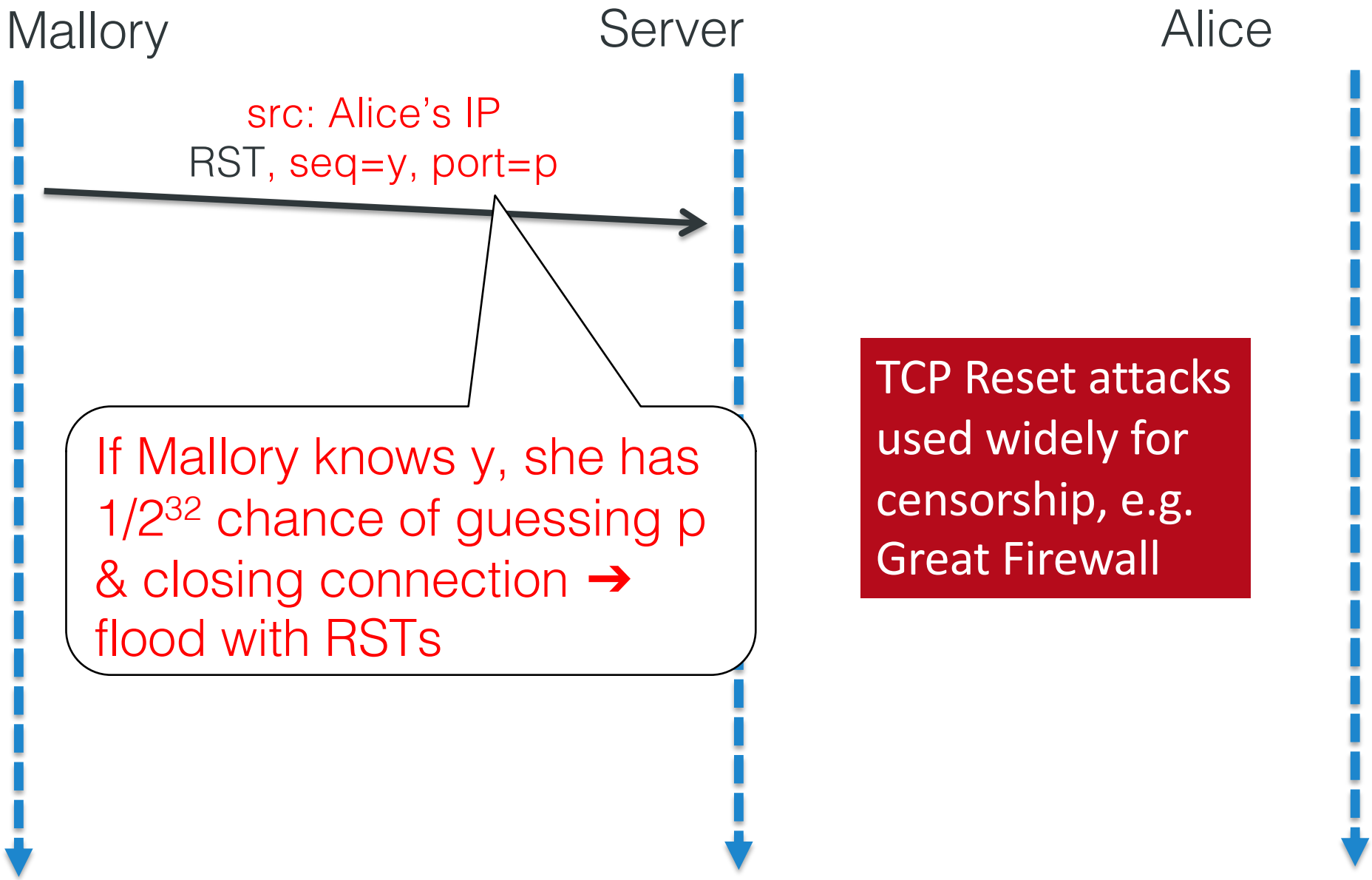
Active Attacks

Active Attacks: Blind Spoofing



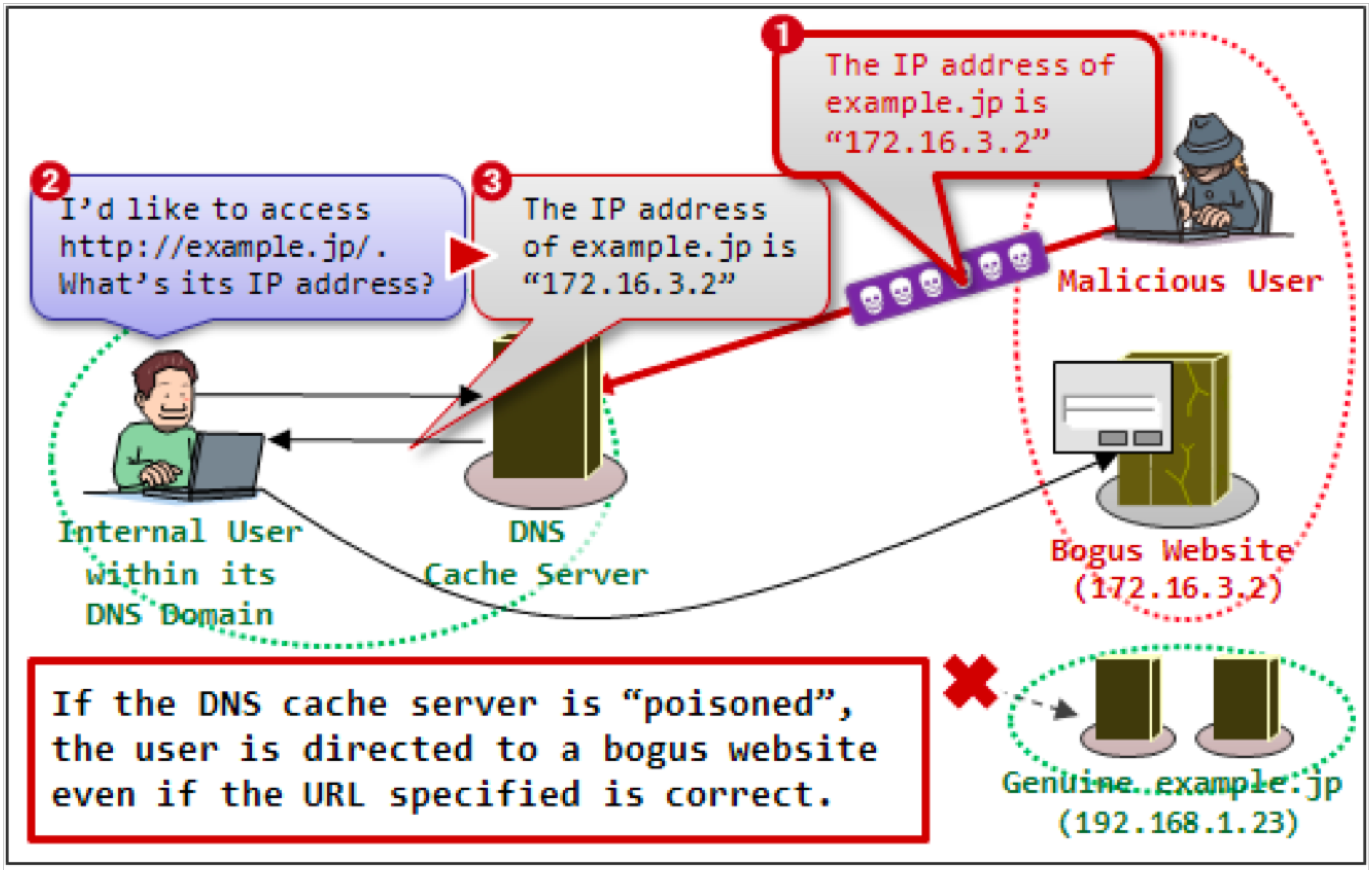
- Originally: y based on time
- Defense: pseudorandom y

RST Hijacking



TCP Reset attacks used widely for censorship, e.g. Great Firewall

DNS Cache Poisoning



DNS Cache Poisoning (cont.)

Defense: randomize 16-bit QID