A MORE SECURE WEB —

Why big ISPs aren't happy about Google's plans for encrypted DNS

DNS over HTTPS will make it harder for ISPs to monitor or modify DNS queries.

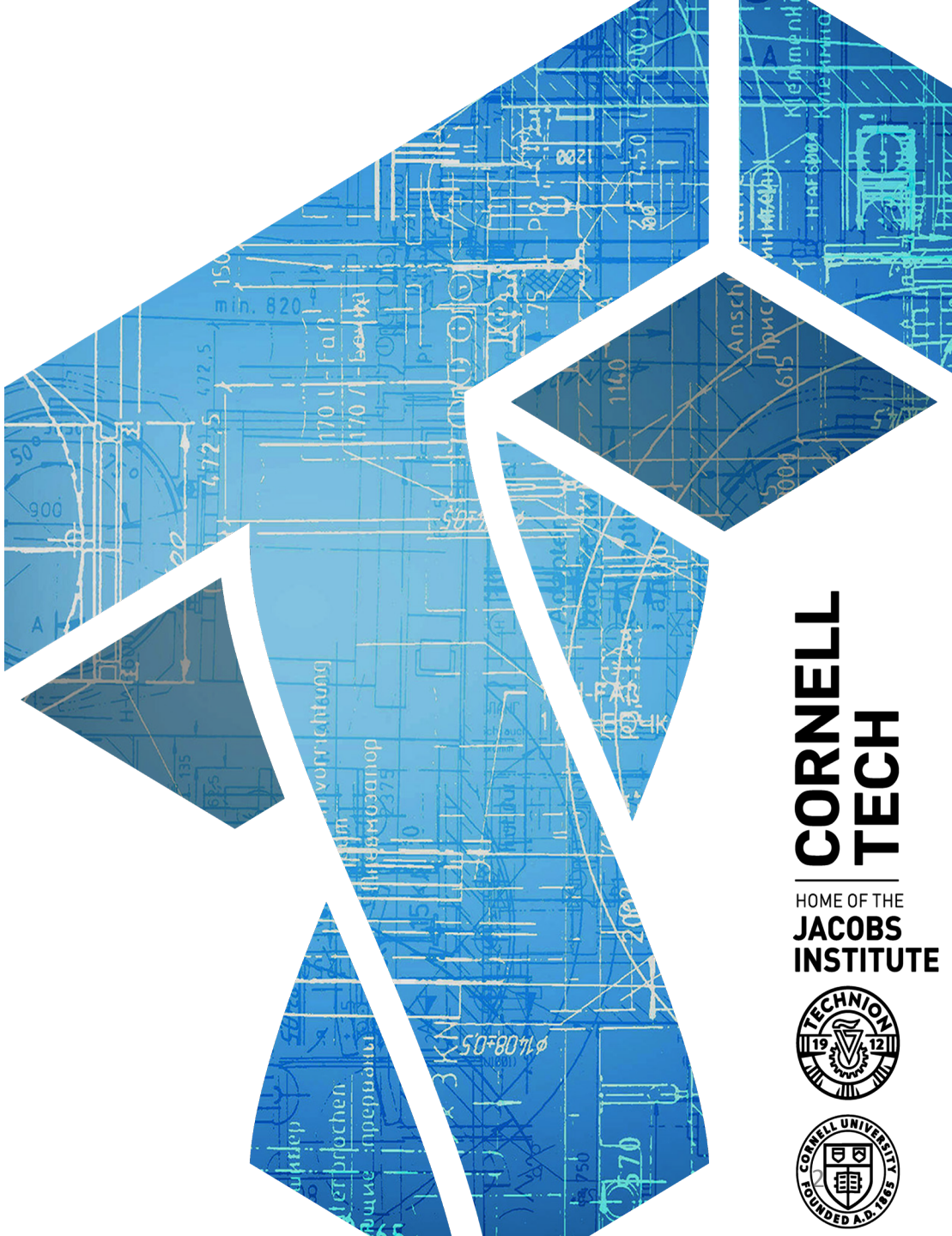
TIMOTHY B. LEE - 9/30/2019, 6:57 PM

https://arstechnica.com/tech-policy/2019/09/isps-worry-a-new-chrome-feature-will-stop-them-from-spying-on-you/

CS 5435: Network security

Instructor: Tom Ristenpart

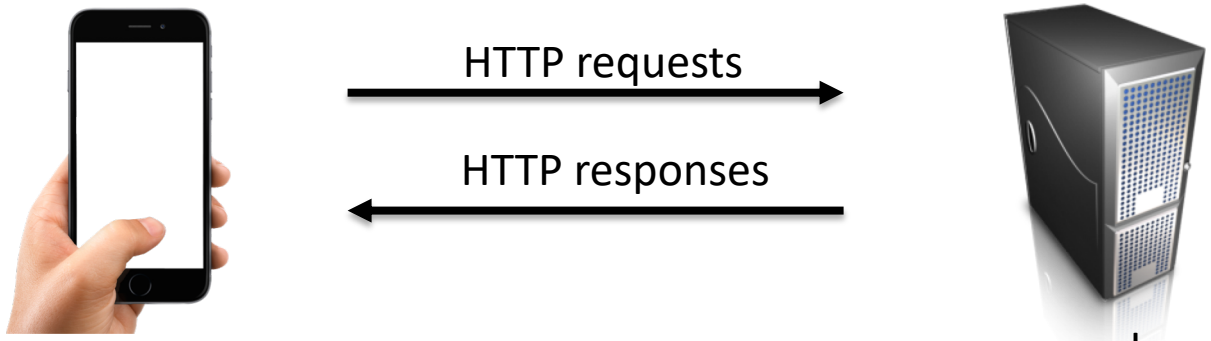
https://github.com/tomrist/cs5435-fall2019



CORNELL TECH

HOME OF THE JACOBS INSTITUTE

The web runs on HTTP



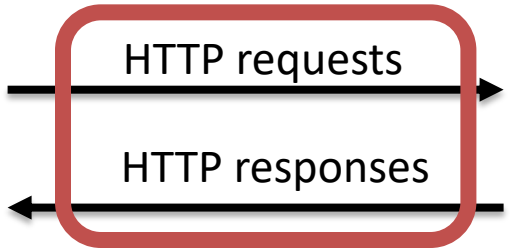
Method **File** **HTTP version** **Headers**

```
GET /index.html HTTP/1.1
Accept: image/gif, image/x-bitmap, image/jpeg, */*
Accept-Language: en
Connection: Keep-Alive
User-Agent: Mozilla/1.22 (compatible; MSIE 2.0; Windows 95)
Host: www.example.com
Referer: http://www.google.com?q=dingbats

```

Blank line

Data – none for GET

The web runs on HTTP



example.com

HTTP version

Status code

Reason phrase

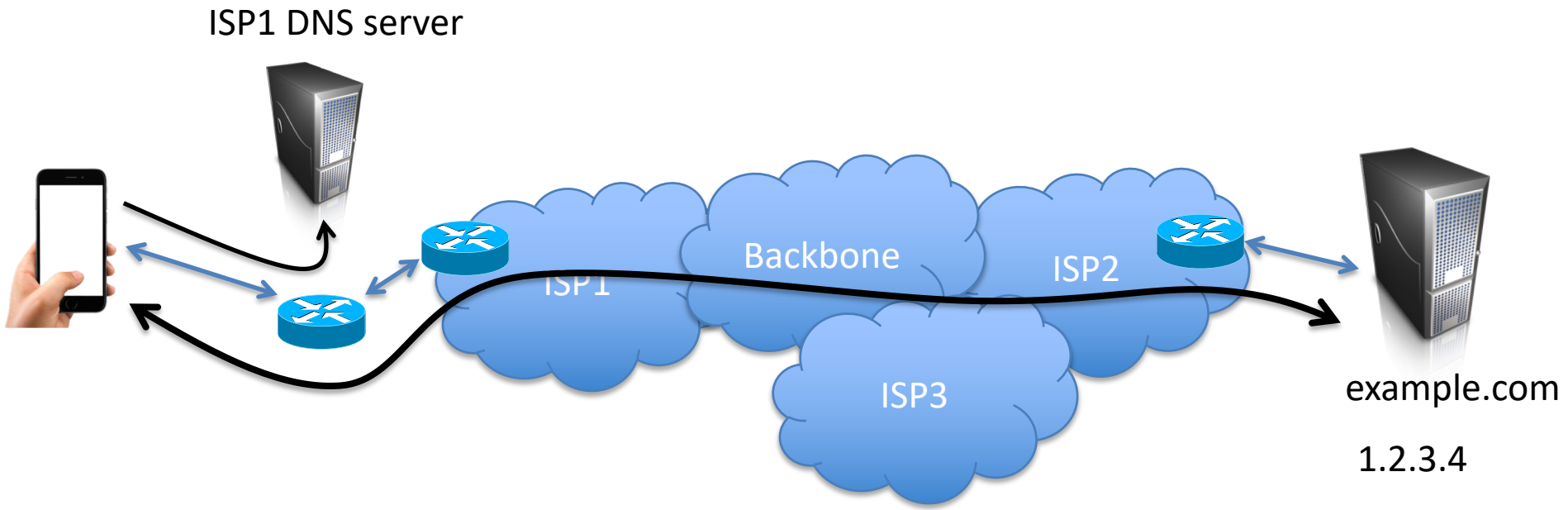
Headers

```
HTTP/1.0 200 OK
Date: Sun, 21 Apr 1996 02:20:42 GMT
Server: Microsoft-Internet-Information-Server/5.0
Connection: keep-alive
Content-Type: text/html
Last-Modified: Thu, 18 Apr 1996 17:39:05 GMT
Set-Cookie: …
Content-Length: 2543

<HTML> Some data... blah, blah, blah </HTML>
```

Data

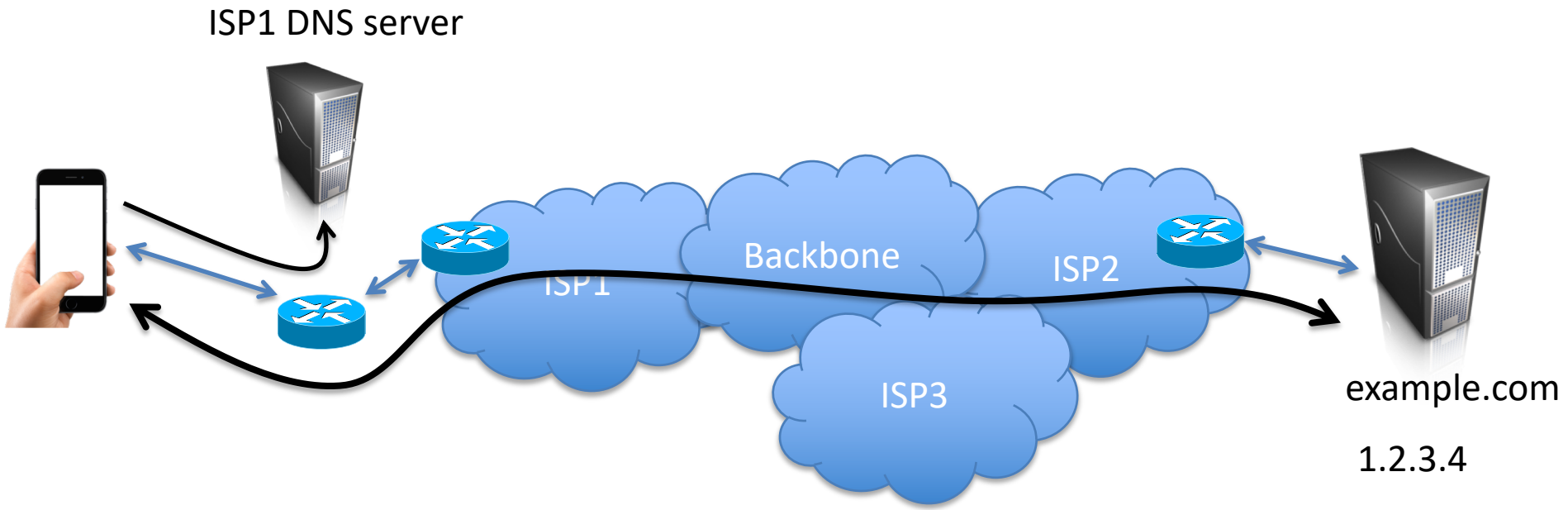
Cookies

Steps to send an HTTP request (pre HTTP/3)

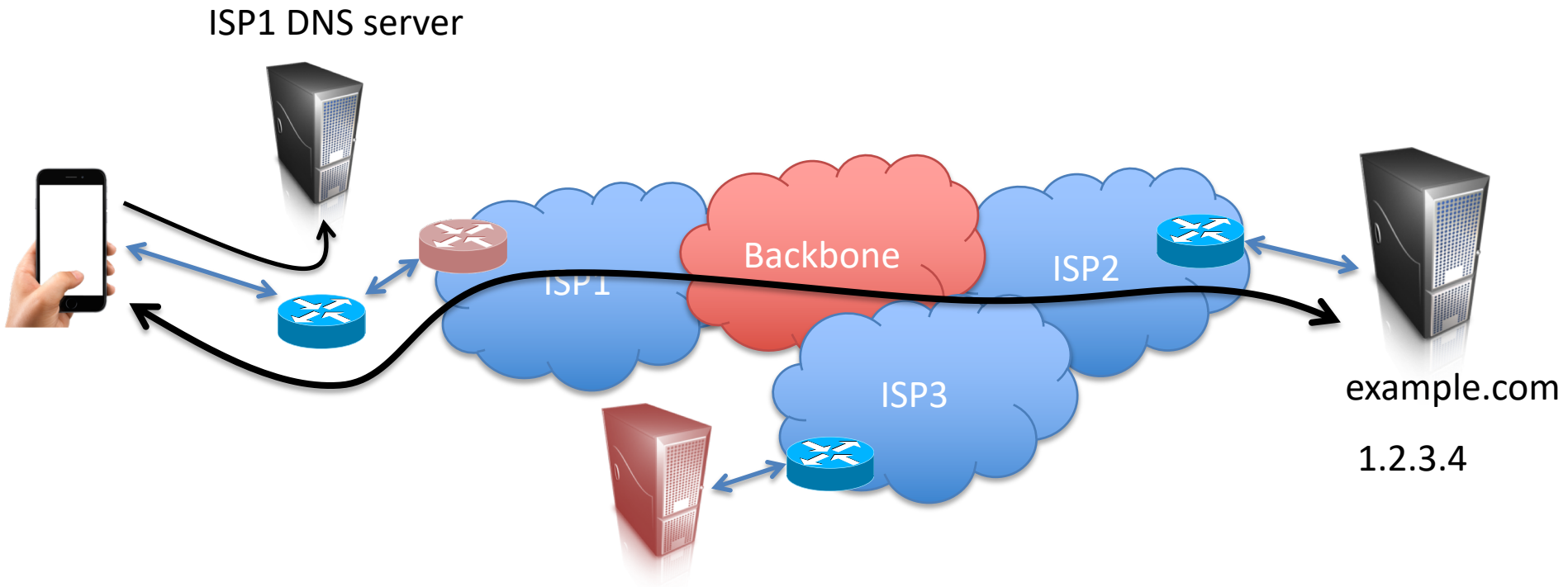


1. DNS lookup on example.com to get IP address (1.2.3.4)
2. TCP connection setup via 4-way handshake of IP packets to and from 1.2.3.4
3. Send HTTP request over TCP connection

Network threat models



Network threat models



(1) Malicious hosts } Off-path attackers

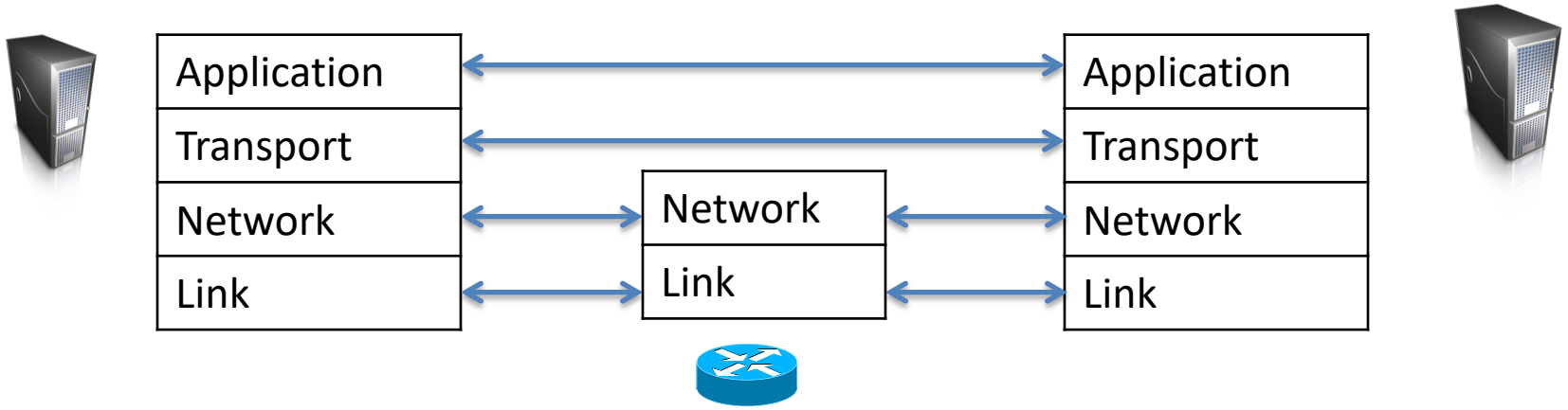
On-path attackers {
(2) Subverted routers or links
(3) Malicious ISPs or backbone

Some attacks we'll cover

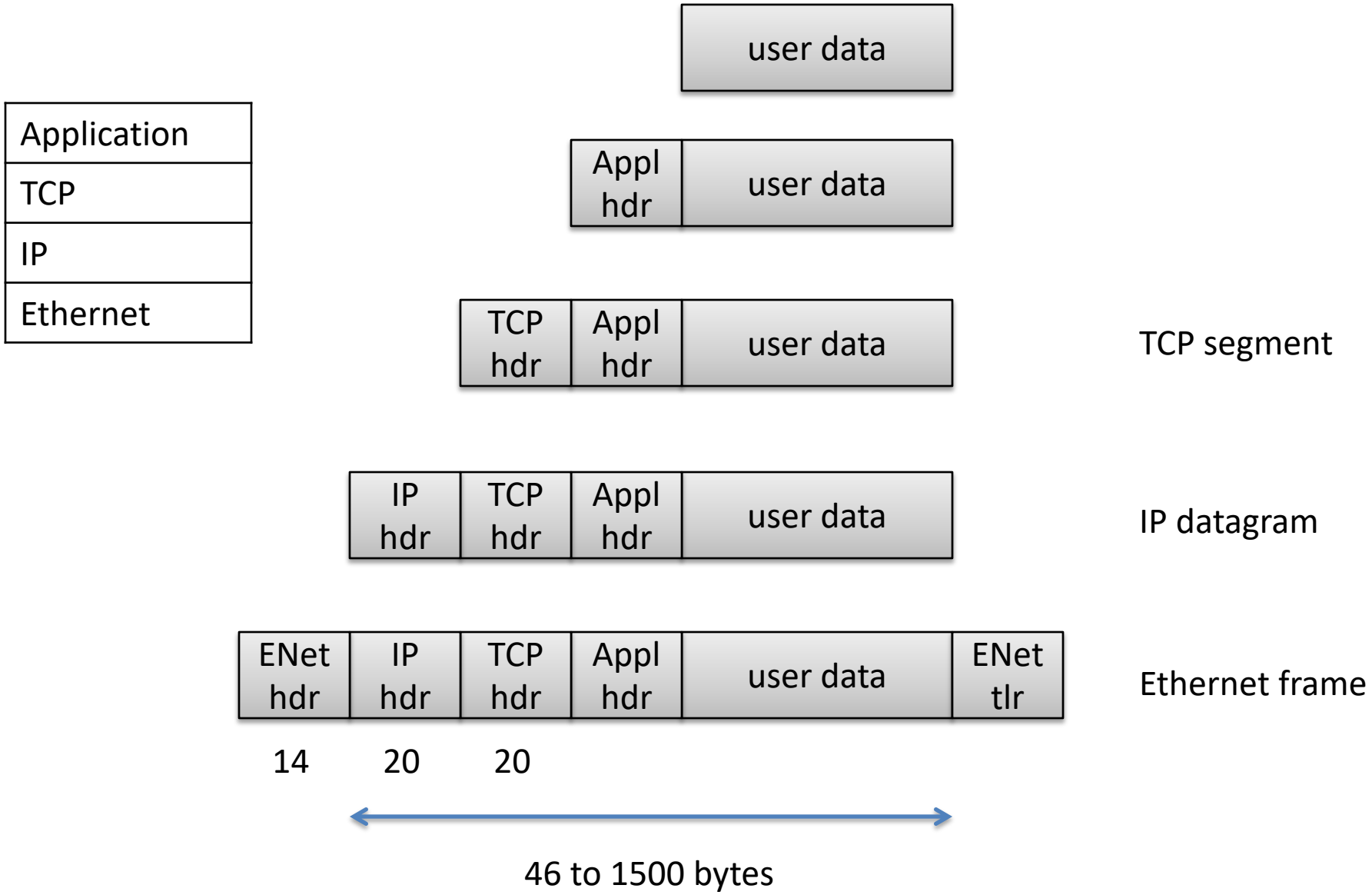
- BGP IP hijacking
- DNS cache poisoning
- IP spoofing
  - Simple untraceable DoS attacks
- Off-path TCP injection
  - Allows injecting traffic into other connections

Internet protocol stack

Application	HTTP, DNS, FTP, SMTP, SSH, etc.
Transport	TCP, UDP
Network	IP, ICMP, …
Link	802x (802.11, Ethernet)



Internet protocol stack

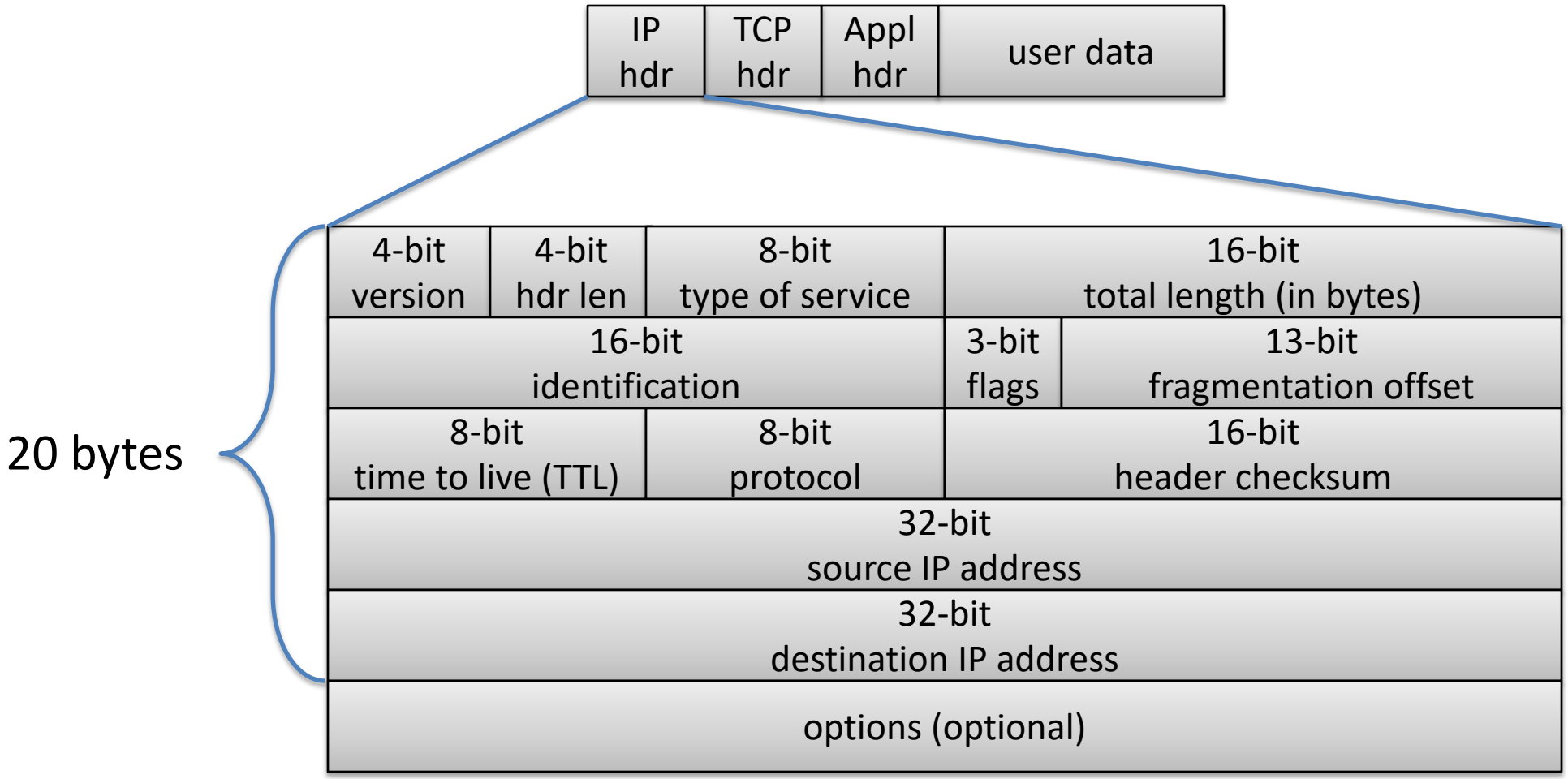


IP protocol (IPv4)

- Connectionless and no state along path
- Unreliable no guarantees, best effort delivery

- ICMP (Internet Control Message Protocol)
  - error messages, etc.
  - often used by tools such as ping, traceroute

IPv4 header


IP hdr
TCP hdr
Appl hdr
user data
20 bytes
4-bit version
4-bit hdr len
8-bit type of service
16-bit total length (in bytes)
16-bit identification
3-bit flags
13-bit fragmentation offset
8-bit time to live (TTL)
8-bit protocol
16-bit header checksum
32-bit source IP address
32-bit destination IP address
options (optional)

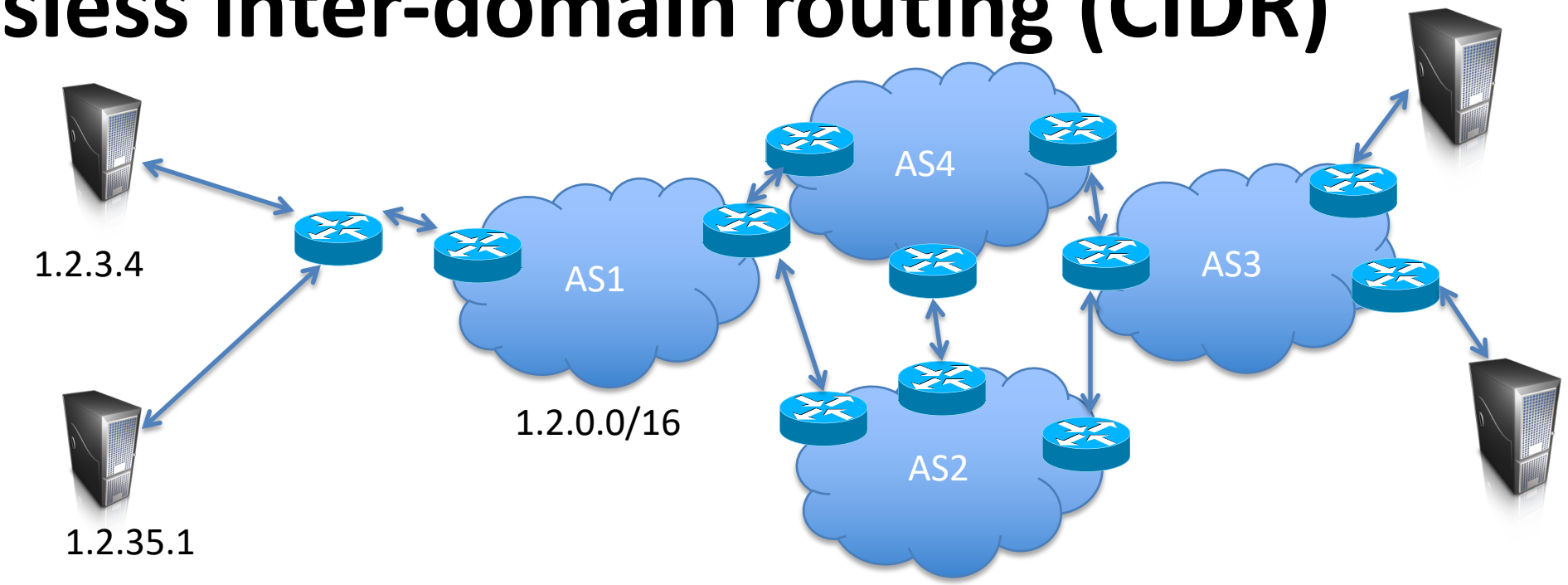
Classless inter-domain routing (CIDR)

128.168.0.0/16

a.b.c.d / x

x indicates number of bits used for a routing prefix
IP addresses with same /x prefix share some portion of route

Classless inter-domain routing (CIDR)



Prefixes used to setup hierarchical routing

Autonomous systems (AS) assigned a.b.c.d/x manages addresses prefixed by a.b.c.d/x

Border gateway protocol (BGP) used to ***announce routes*** between AS's

- Routers prefer more specific prefixes, shorter paths (+ AS-specific policies)
- AS gets update, recomputes routes, announces new paths to neighbors, etc.

~700,000+ routes on the internet currently (according to CloudFlare)

BGP had no security model

- BGP unauthenticated
  - Anyone can advertise any routes
  - False routes may be propagated to other AS's
- This allows ***IP hijacking***
  - AS announces it originates a prefix it shouldn't
  - AS announces it has shorter path to a prefix
  - AS announces more specific prefix

In-class 5-min exercise:

What attacks/problems can result form BGP insecurity?

How would you prevent IP hijacking?

BGP security efforts

- Advertisement filtering
  - Rules that AS's use to filter out bad requests
  - E.g.: only accept an advertisement for IP address owned by advertising AS
- Cryptographic efforts:
  - Resource Public Key Infrastructure (RPKI)
    - Digitally sign advertisements to bind it to valid AS
    - https://blog.cloudflare.com/rpki/
  - BGPsec (cryptographic validation of AS paths)
  - Both still only partially deployed

BGP Incident:

Summary:	Routing Leak briefly takes down Google
Start:	2015-03-12 08:58:00
End:	Unknown
Details:	This morning, users of Google around the world were unable to access many of the company's services due to a routing leak in India. Beginning at 08:58 UTC Indian broadband provider Hathway (AS17488) incorrectly announced over 300 Google prefixes to its Indian transit provider Bharti Airtel (AS9498). Bharti in turn announced these routes to the rest of the world, and a number of ISPs accepted these routes including US carriers Cogent (AS174), Level 3 (AS3549) as well as overseas incumbent carriers Orange (France Telecom, AS5511), Singapore Telecom (Singtel, AS7473) and Pakistan Telecom (PTCL, AS17557). Like many

http://www.securerouting.net/incident/20/

https://dyn.com/blog/routing-leak-briefly-takes-google/

More incidents

- 1997: AS 7007 incident
  - Announced specific routes for most of IPv4 address space, took down much of Internet
  - "Okay, so panic ensued, and we unlugged *everything* at 12:15PM almost to the second." [sic]
  - http://www.merit.edu/mail.archives/nanog/1997-04/msg00444.html
- 2008 Pakistan attempts to block Youtube
  - youtube is 208.65.152.0/22 , youtube.com = 208.65.153.238
  - Pakistan ISP advertises 208.65.153.0/24 (more specific, prefix hijacking)
  - Internet thinks youtube.com is in Pakistan … outage resolved in 2 hours…

- 2018: BGP leak/hijack of AWS Route53 DNS servers
  - Used to serve up IP addresses for (only) myetherwallet.com
  - The served IP addresses went to Russian AS

Domain Name System (DNS)

We don’t want to have to remember IP addresses

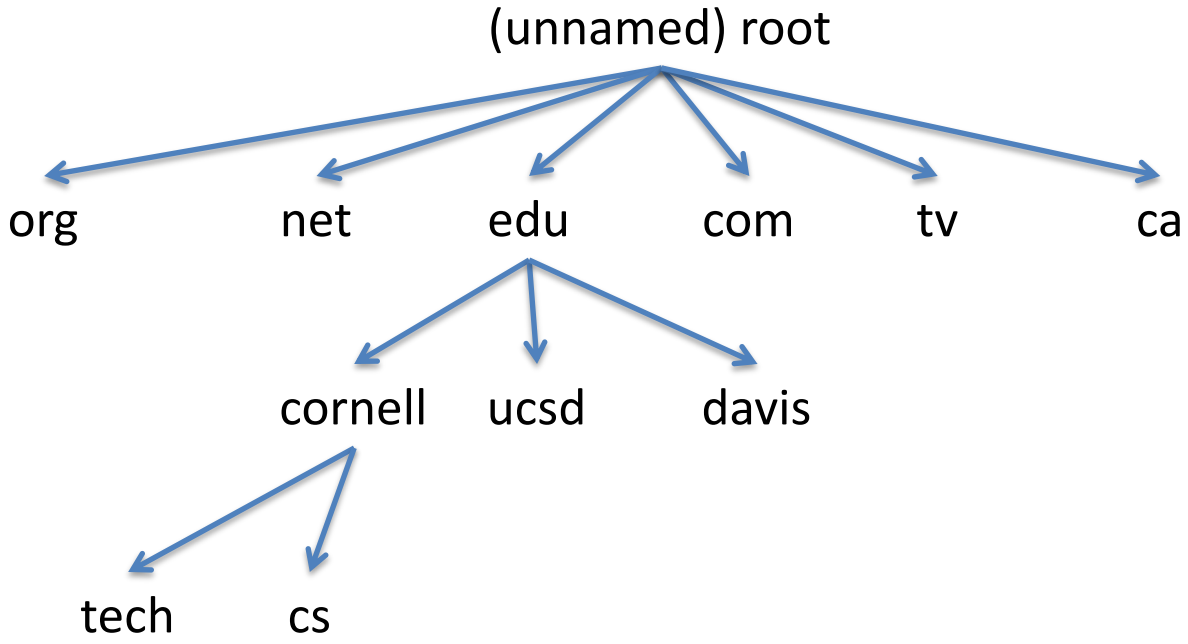
DNS solves this:
What is IP address for myetherwallet.com?

IP address in answer section

Information on ***name servers*** that are authoritative for domain

```
Tue Oct 01 21:53:37:website$ dig myetherwallet.com

; <<>> DiG 9.10.6 <<>> myetherwallet.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 59696
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 2, ADDITIONAL: 5

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;myetherwallet.com.             IN      A

;; ANSWER SECTION:
myetherwallet.com.      300     IN      A       104.18.201.107
myetherwallet.com.      300     IN      A       104.18.202.107

;; AUTHORITY SECTION:
myetherwallet.com.      141990  IN      NS      ali.ns.cloudflare.com.
myetherwallet.com.      141990  IN      NS      ivan.ns.cloudflare.com.

;; ADDITIONAL SECTION:
ali.ns.cloudflare.com.  42241   IN      A       173.245.58.59
ivan.ns.cloudflare.com. 52319   IN      A       173.245.59.120
ali.ns.cloudflare.com.  42241   IN      AAAA    2400:cb00:2049:1::adf5:3a3b
ivan.ns.cloudflare.com. 102167  IN      AAAA    2400:cb00:2049:1::adf5:3b78
```

Heirarchical domain name space



Top Level domains (TLD)

Second Level domains

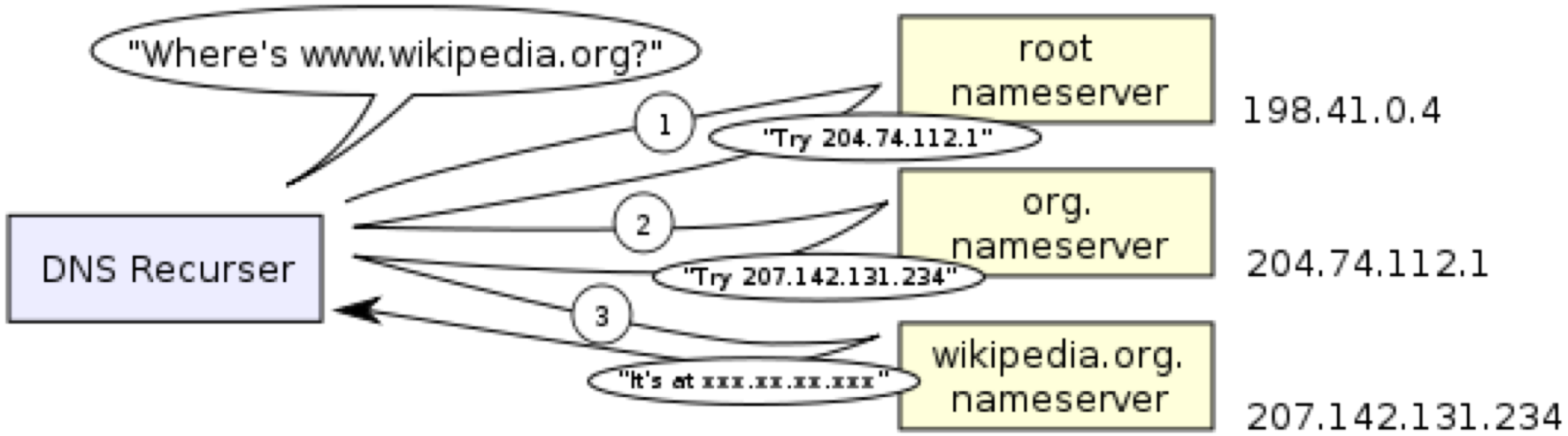
max 63 characters

ICANN (Internet Corporation for Assigned Names and Numbers)

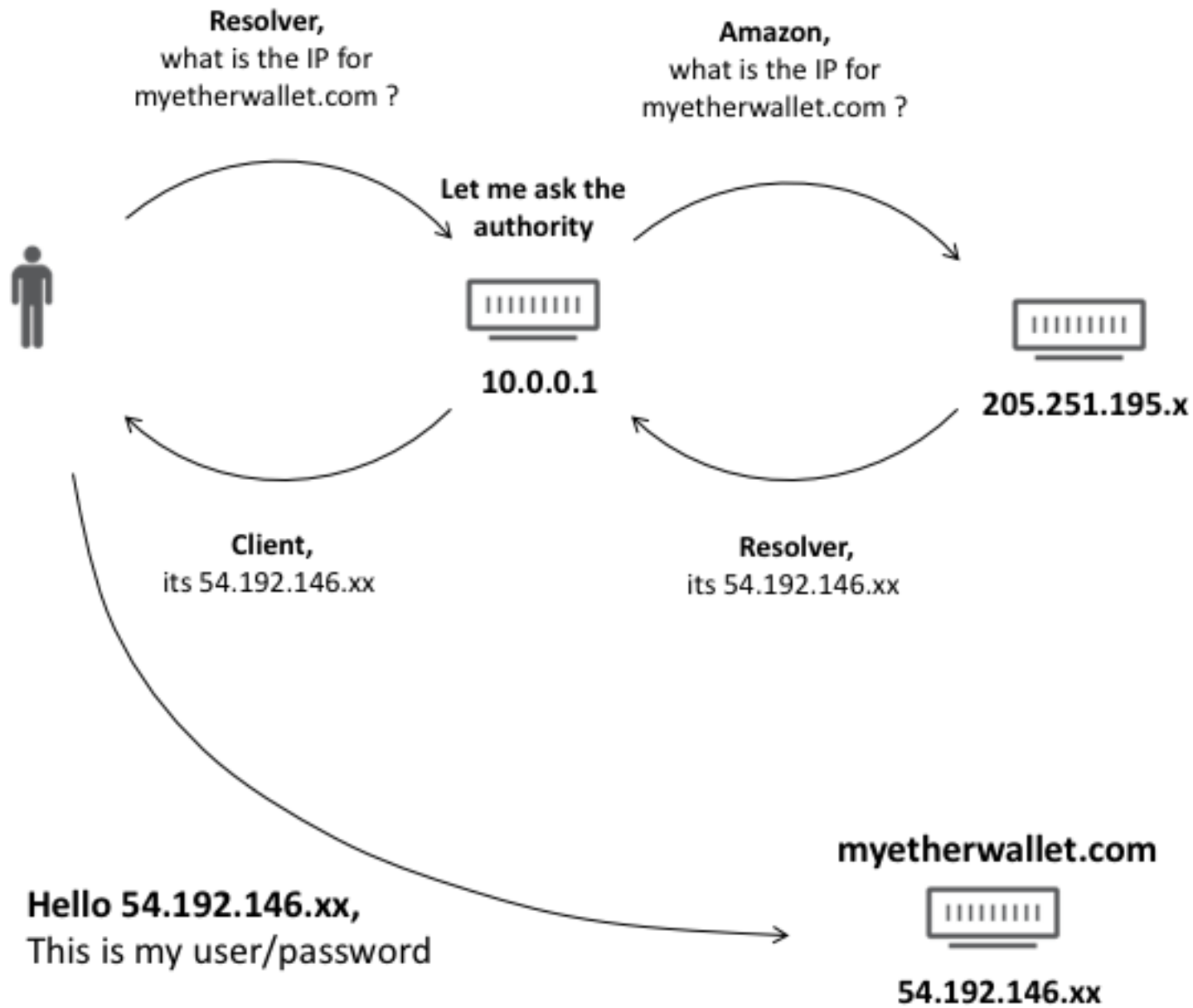
root nameservers and authoritative nameservers

Zone: subtree

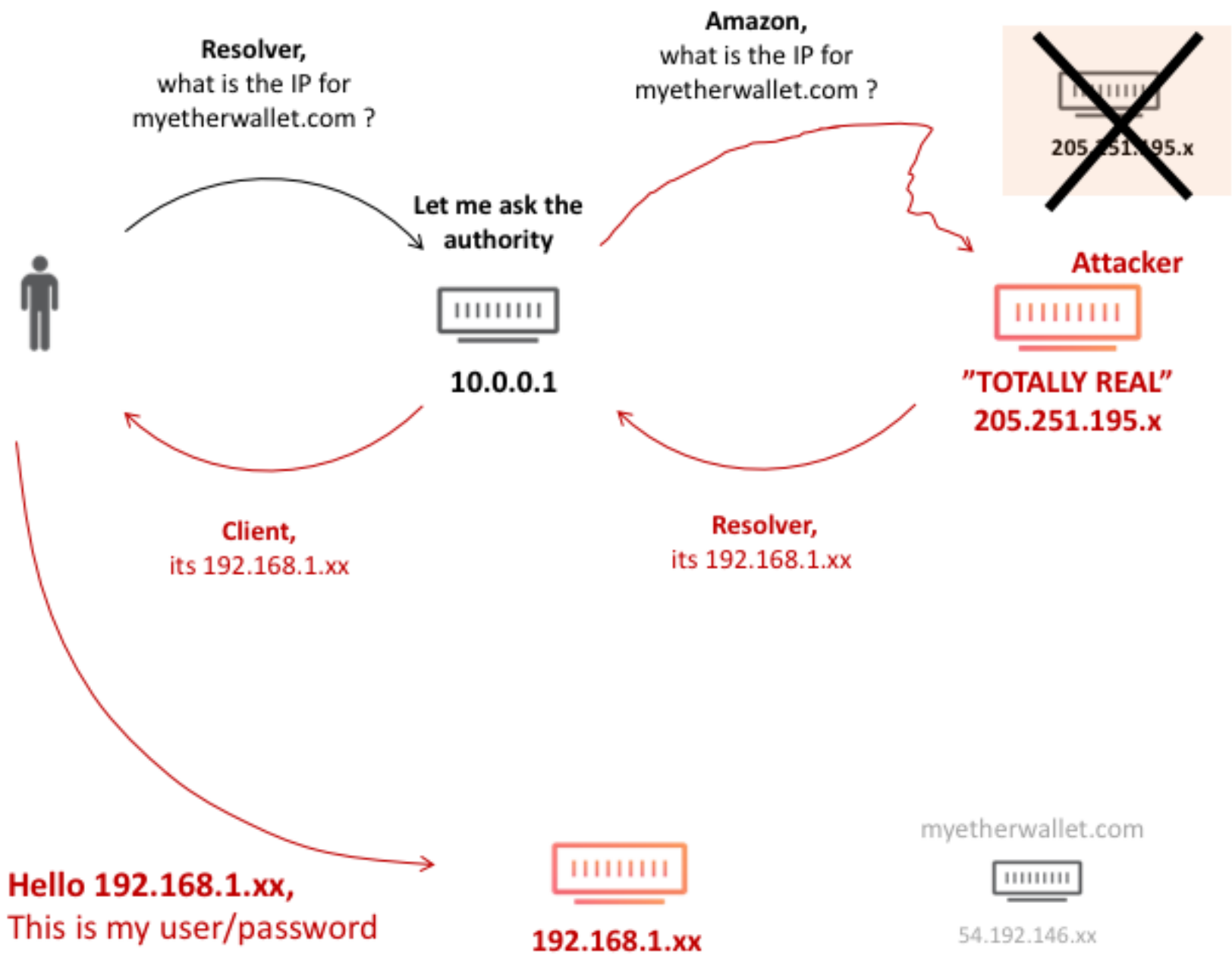
Resolving names



From http://en.wikipedia.org/wiki/File:An_example_of_theoretical_DNS_recursion.svg



https://blog.cloudflare.com/bgp-leaks-and-crypto-currencies/



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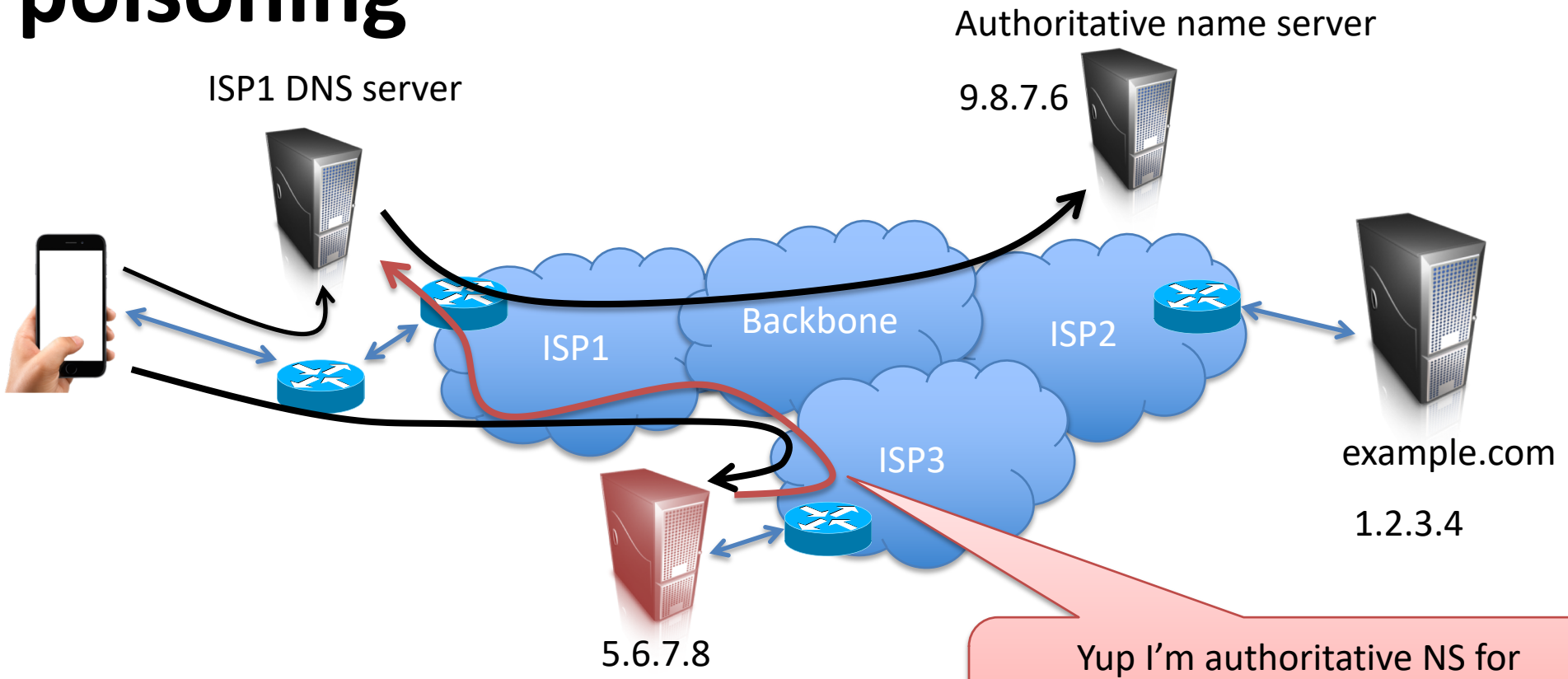
Other attacks against DNS

- DNS is plaintext protocol without authentication
  - What can on-path adversaries do?
- DNS cache poisoning by off-path adversaries
  - Flaw in DNS protocol that allows inserting records

- DNS typo-squatting
- Compromise DNS admin accounts, edit records

DNS poisoning



<u>Goal:</u>

Sneak in reply as if it came from authoritative NS

DNS protocol

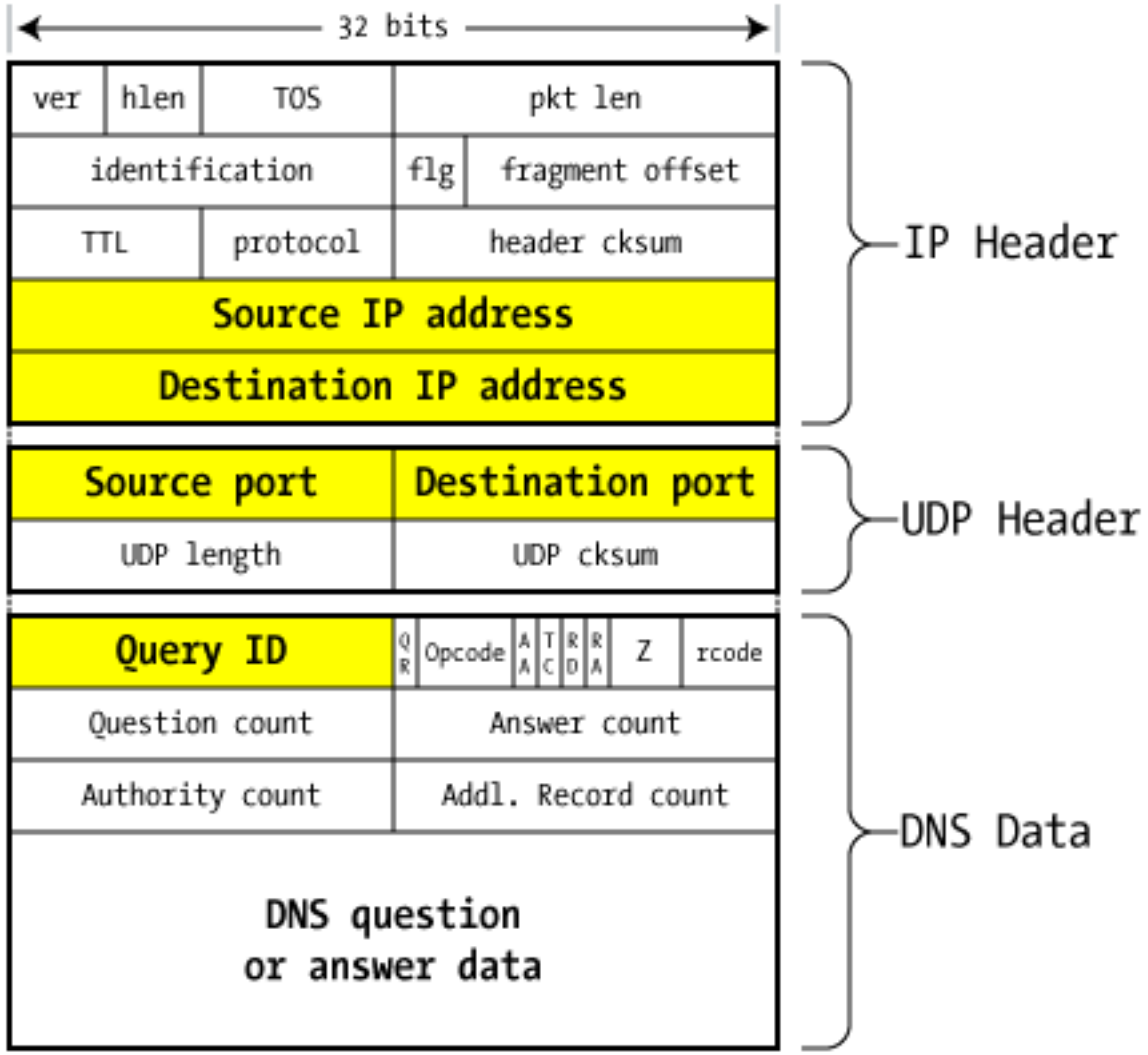
DNS uses User Datagram Protocol (UDP)

- Connectionless transport protocol
- Port is used to distinguish different network end points on same system
- Port 53 is standard dst. port for DNS

Normally:
Request = one UDP datagram
Response = one UDP datagram

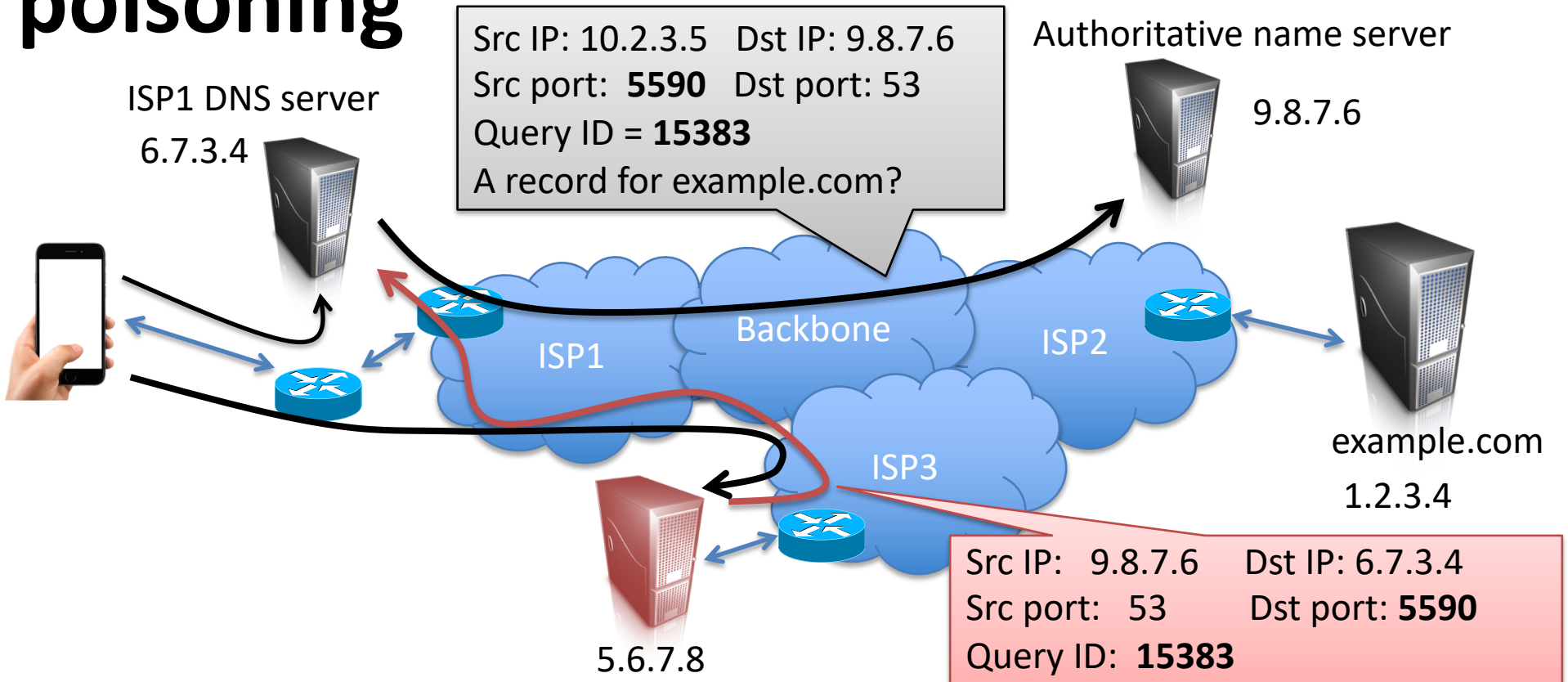
DNS:
Query ID is 16-bit number

Response must include same query ID
Response must be to src port of request



http://unixwiz.net/techtips/iguide-kaminsky-dns-vuln.html

DNS poisoning



Goal:

Sneak in reply as if it came from authoritative NS

Requires:

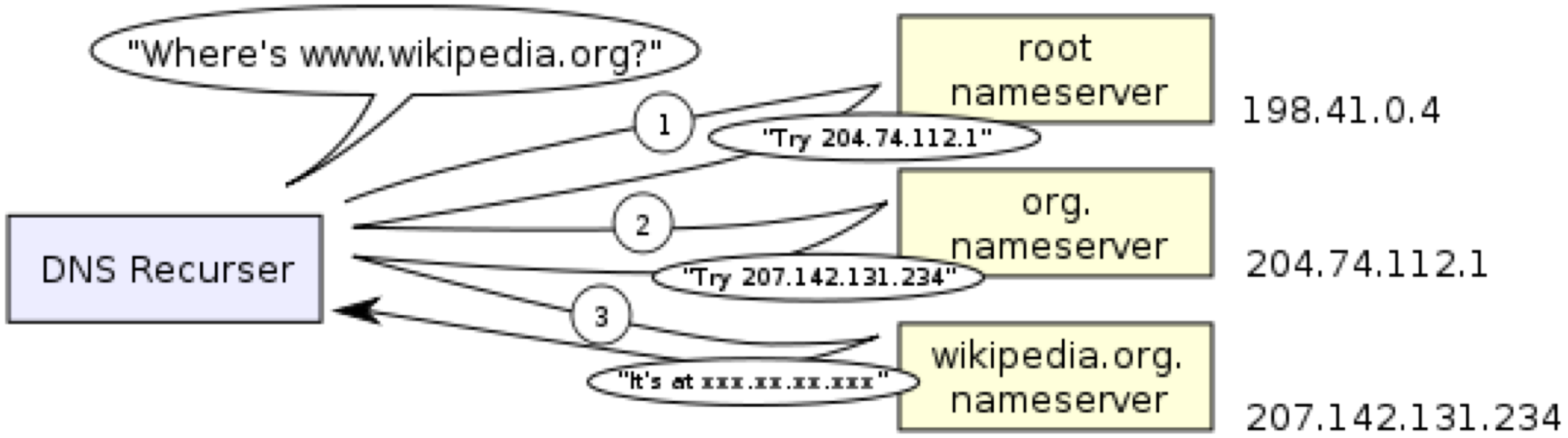
- Spoofing the src IP address of name server
- Guessing query ID, knowing source port of request
- Getting timing right

If deterministic (e.g., counters) can be predicted

Just random query IDs can be defeated (2^{16} space too small)

More advanced DNS cache poisoning

- Target NS response to trick ISP1 resolver into thinking malicious server is authoritative NS
- Can do many attempts by forcing DNS requests to ISP1 that trigger fresh requests for step 3 below



DNS cache poisoning defenses

- Query ID size is fixed at 16 bits
- Repeat each query with fresh Query ID
  - Doubles the space
- Randomize UDP ports
- DNSsec
  - Cryptographically sign DNS responses, verify via chain of trust from roots on down
- DNS-over-HTTPS
  - Send DNS requests over encrypted, authenticated channel to NS's

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  - Allows injecting traffic into other connections