Lecture 7: Application Layer
Domain Name System

COMP 332, Spring 2018

Victoria Manfredi

WESLEYAN UNIVERSITY

Acknowledgements: materials adapted from Computer Networking: A Top Down Approach 7th edition: ©1996-2016, J.F Kurose and K.W. Ross, All Rights Reserved as well as from slides by Abraham Matta at Boston University and some material from Computer Networks by Tannenbaum and Wetherall.

Today

1. Announcements
   - homework 3 due Wednesday by 11:59p
   - parsing HTTP requests and responses
     - put any decoding in a try block
     - send raw bytes even if can't decode
       - browser/server will be able to decode in homework 4
   - client needs to generate HTTP request
     - "Connection: close\r\n" in header will close socket after each response
   - ip.addr == 151.101.117.164 and tcp.port == 55555

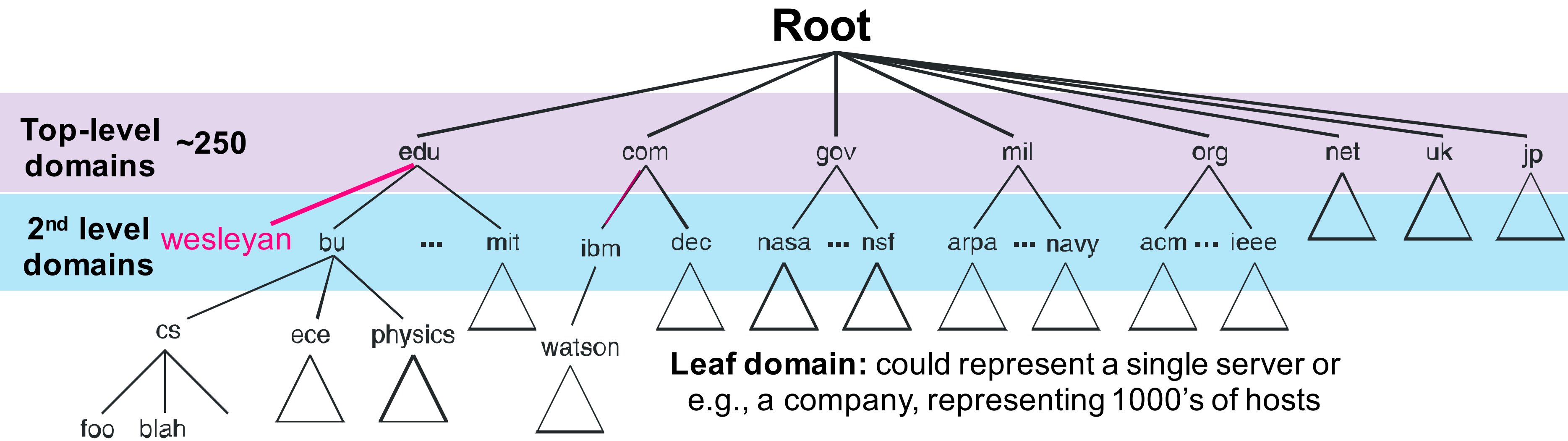
2. Domain names

3. Domain Name System
   - name resolution
   - protocol
   - dig and wireshark
   - attacks

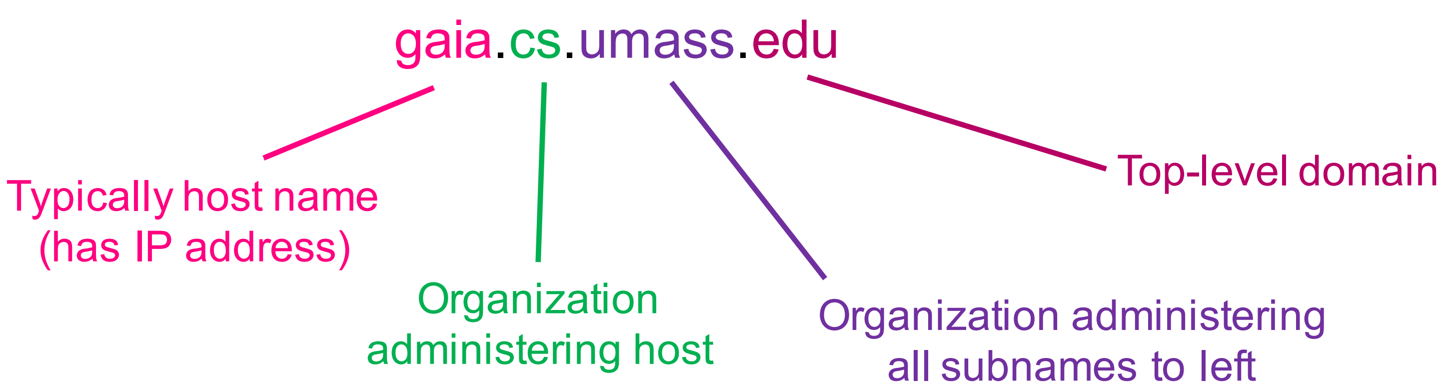
Domain Names

OVERVIEW

Internet domain name space



Hierarchical administering of names



Hostname may not map to unique IP address

```
> dig vumanfredi.web.wesleyan.edu

; <<>> DiG 9.8.3-P1 <<>> vumanfredi.web.wesleyan.edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 58367
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;vumanfredi.web.wesleyan.edu.   IN      A

;; ANSWER SECTION:
vumanfredi.web.wesleyan.edu. 3589 IN    CNAME   wesfiles.wesleyan.edu.
wesfiles.wesleyan.edu.  533     IN      A       129.133.6.79
```

```
> dig dlicata.web.wesleyan.edu

; <<>> DiG 9.8.3-P1 <<>> dlicata.web.wesleyan.edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 45830
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;dlicata.web.wesleyan.edu.      IN      A

;; ANSWER SECTION:
dlicata.web.wesleyan.edu. 3600  IN      CNAME   wesfiles.wesleyan.edu.
wesfiles.wesleyan.edu.  524     IN      A       129.133.6.79
```

Hostname vs. domain

Hostname

- comprises host + domain
- may be a domain if it has been properly organized into domain name system

Domain

- may be a hostname if it has been assigned to an Internet host and is associated with the host's IP address

Internet domain name space

Rightmost (highest) domain is organization, structure, country

Domain	Usage	Example
com	business	watson.ibm.com
edu	educational	gaia.cs.umass.edu
gov	US non-military government	nasa.gov
mil	US military	arpa.mil
org	non-profit organization	acm.org
jp	Japan	osaka-u.ac.jp

Problem

People have multiple identifiers

- SSN, name, passport #

Internet hosts, routers have multiple identifiers

- IP address (32 bit)
  - used for addressing packets
  - processed by routers
- "name", e.g., www.google.com
  - used by humans
  - canonical "true" name vs. aliases

Q: how to map between IP address and name, and vice versa?

Domain Name System

OVERVIEW

Domain Name System (DNS) for Internet

Two components

1. App layer protocol
   - translates between identifiers
     - hostnames ⇔IP addresses
   - used by other app-layer protocols
     - HTTP, SMTP, …

Core Internet function implemented as application-layer protocol complexity at network's "edge"

2. Distributed hierarchical database
   - organized into hierarchy that follows name hierarchy
   - distributed across many name servers
   - no name server has all domain resource records (mappings)

Q: why not centralize DNS?

- single point of failure, handles less traffic volume, need to go to distant centralized database, harder to maintain

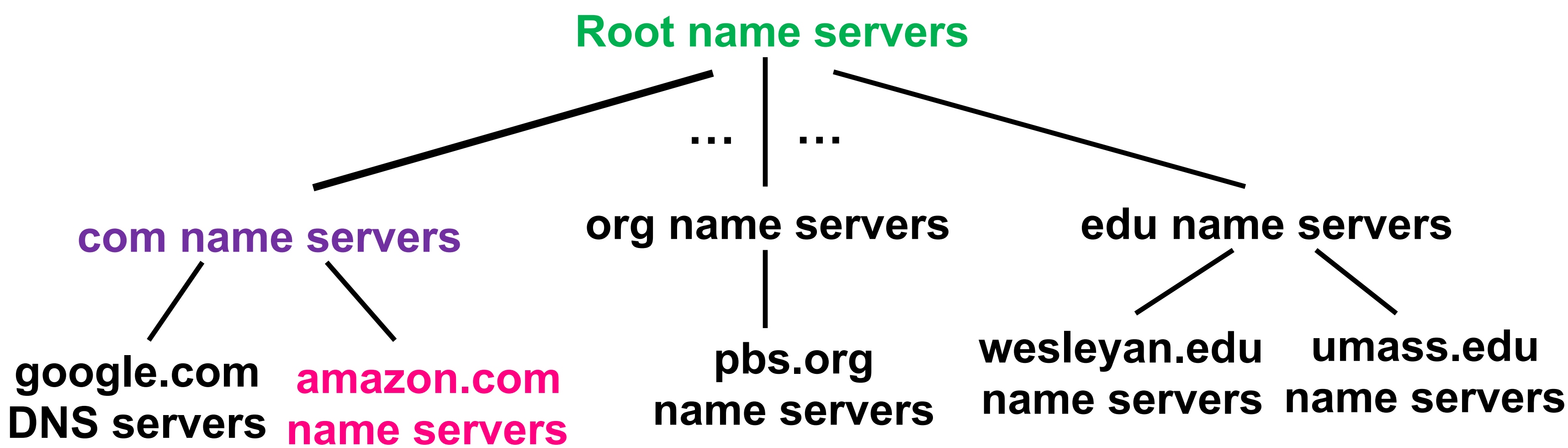
Other DNS services

Not just hostname ⇔ IP address translation

Also

- host aliasing
  - canonical vs. alias names
  - to have simpler hostnames
- mail server aliasing
  - to have simpler email address
- load distribution
  - replicated Web servers
    - multiple IP addresses may be associated with same canonical name
  - DNS response contains list of IP addresses
    - rotated since client typically chooses top address

A distributed, hierarchical database



Client wants IP for www.amazon.com

- client queries root server to find com name server
- client queries com name server to get amazon.com name server
- client queries amazon.com name server to get IP address for www.amazon.com

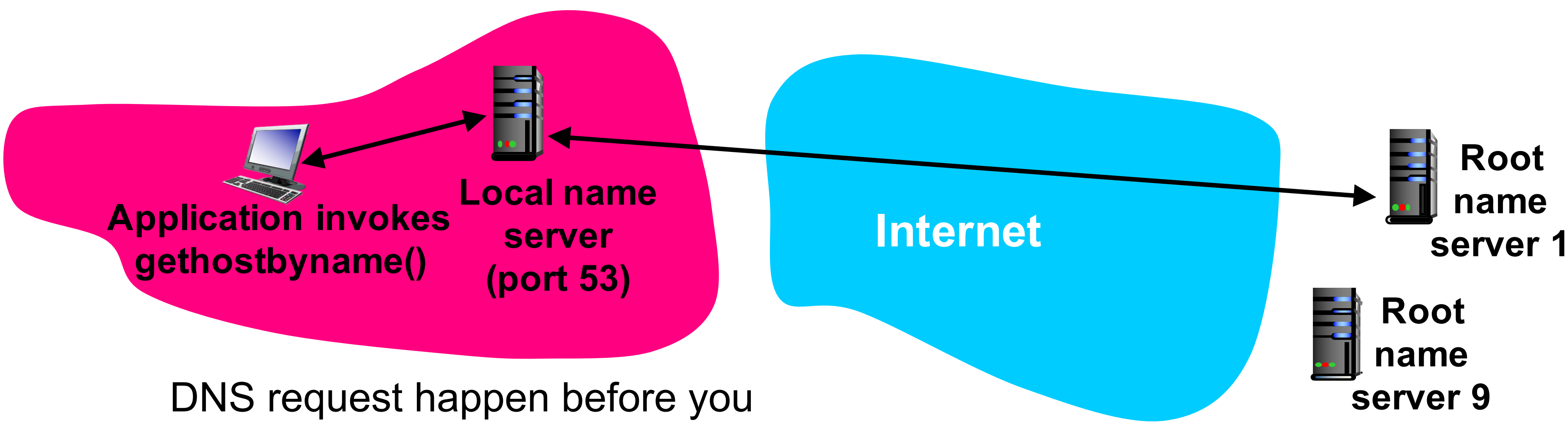
Local name server

Each ISP (residential, company, university) has one

- does not strictly belong to hierarchy
- on linux, located in resolv.conf

When host makes DNS query, sent 1st to its local name server

- has local cache of recent name-to-address translation pairs
  - but may be out of date!
- acts as proxy, forwards query into hierarchy if it cannot resolve



DNS request happen before you even open TCP connection to host

Python 3

socket.gethostbyname(*hostname*)

- Translate a host name to IPv4 address format. The IPv4 address is returned as a string, such as'100.50.200.5'. If the host name is an IPv4 address itself it is returned unchanged. See gethostbyname_ex() for a more complete interface. gethostbyname() does not support IPv6 name resolution, and getaddrinfo() should be used instead for IPv4/v6 dual stack support.

socket.gethostname()

- Return a string containing the hostname of the machine where the Python interpreter is currently executing.

AF_INET address family

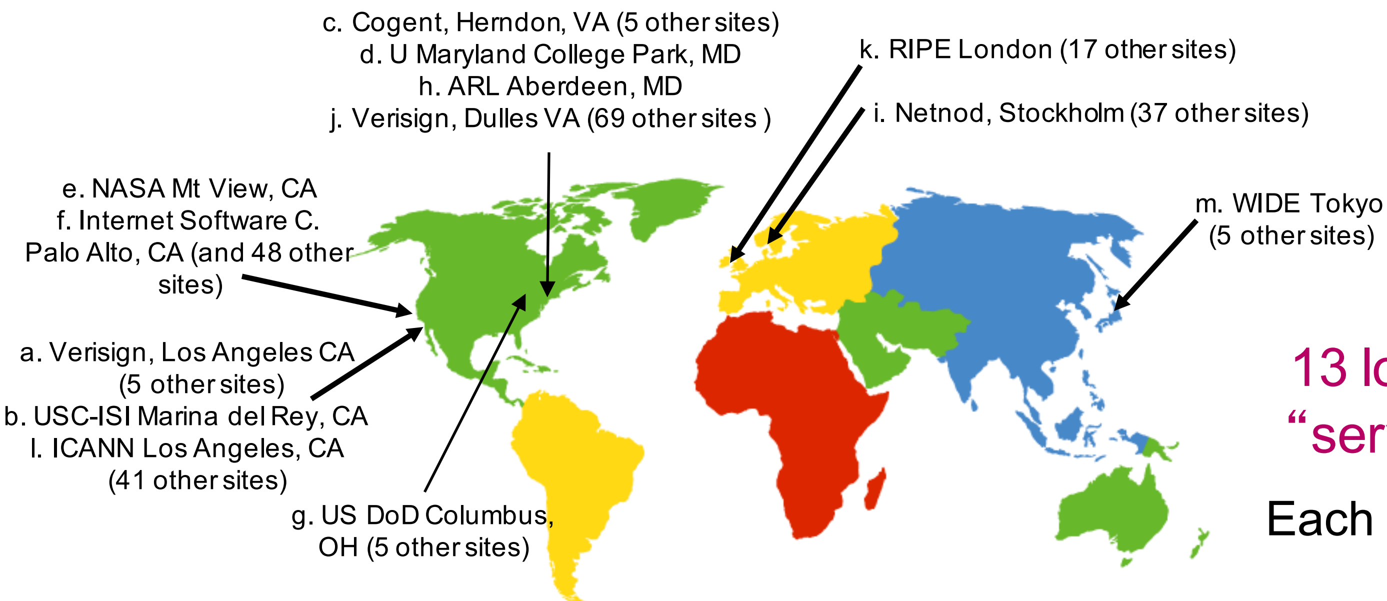
- *host* is a string representing either a hostname in Internet domain notation like 'daring.cwi.nl' or an IPv4 address like '100.50.200.5',

Root name servers

Know name servers and their ip addresses for top-level domains

Contact authoritative name server if name mapping not known

- get mapping and return mapping to local name server



13 logical root name "servers" worldwide

Each "server" replicated many times

http://www.root-servers.org/

Top-level domain and authoritative servers

Top-level domain (TLD) servers

- know authoritative name servers and their ip addresses for (sub)-domains in their zone
- responsible for com, org, net, edu, aero, jobs, museums, and all top-level country domains, e.g.: uk, fr, ca, jp
- Network Solutions maintains servers for .com TLD
- Educause for .edu TLD

Authoritative servers

- know ip addresses for all hosts in organization's domain
- organization's own name server(s)
- provides authoritative hostname to IP mappings for organization's named hosts
- maintained by organization or service provider

Domain Name System

NAME RESOLUTION

Resolving non-local names

No single name server has complete information

If local name server can't resolve address

- contacts root name server

13 root name servers world-wide

- each has addresses of name servers for all TLD name servers
  - e.g., wesleyan.edu, ibm.com

What happens?

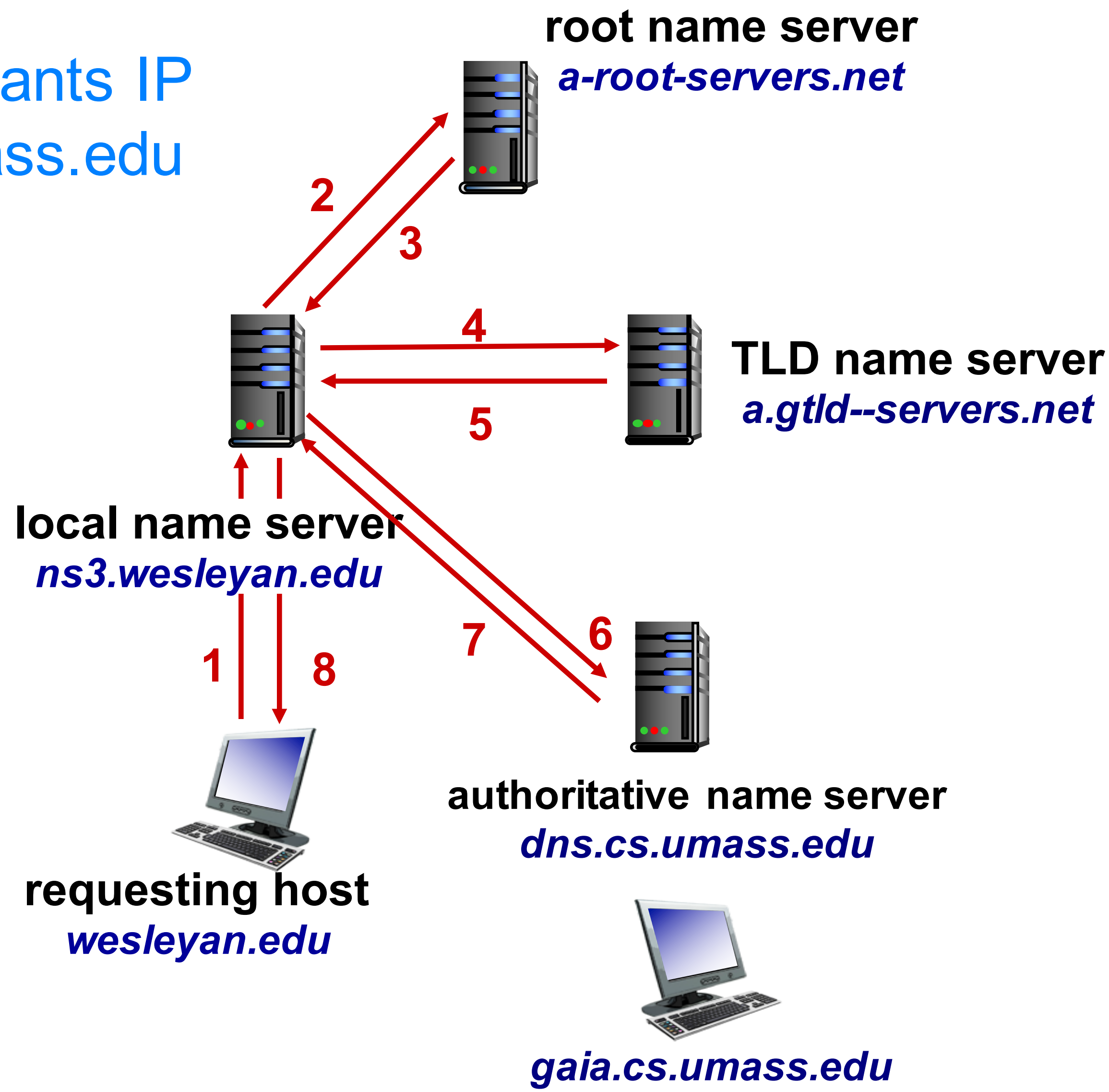
- contacted root server
  - returns IP address of name server which should be contacted next
- contacted TLD name server
  - may itself return a pointer to another name server
- iterative process of following name server pointers

Iterative name resolution

Host at wesleyan.edu wants IP address for gaia.cs.umass.edu

Iterated query

- requesting server is responsible for name resolution
- contacted server replies with name of server to contact
- “I don’t know this name, but ask this server”



Q: why is this useful?

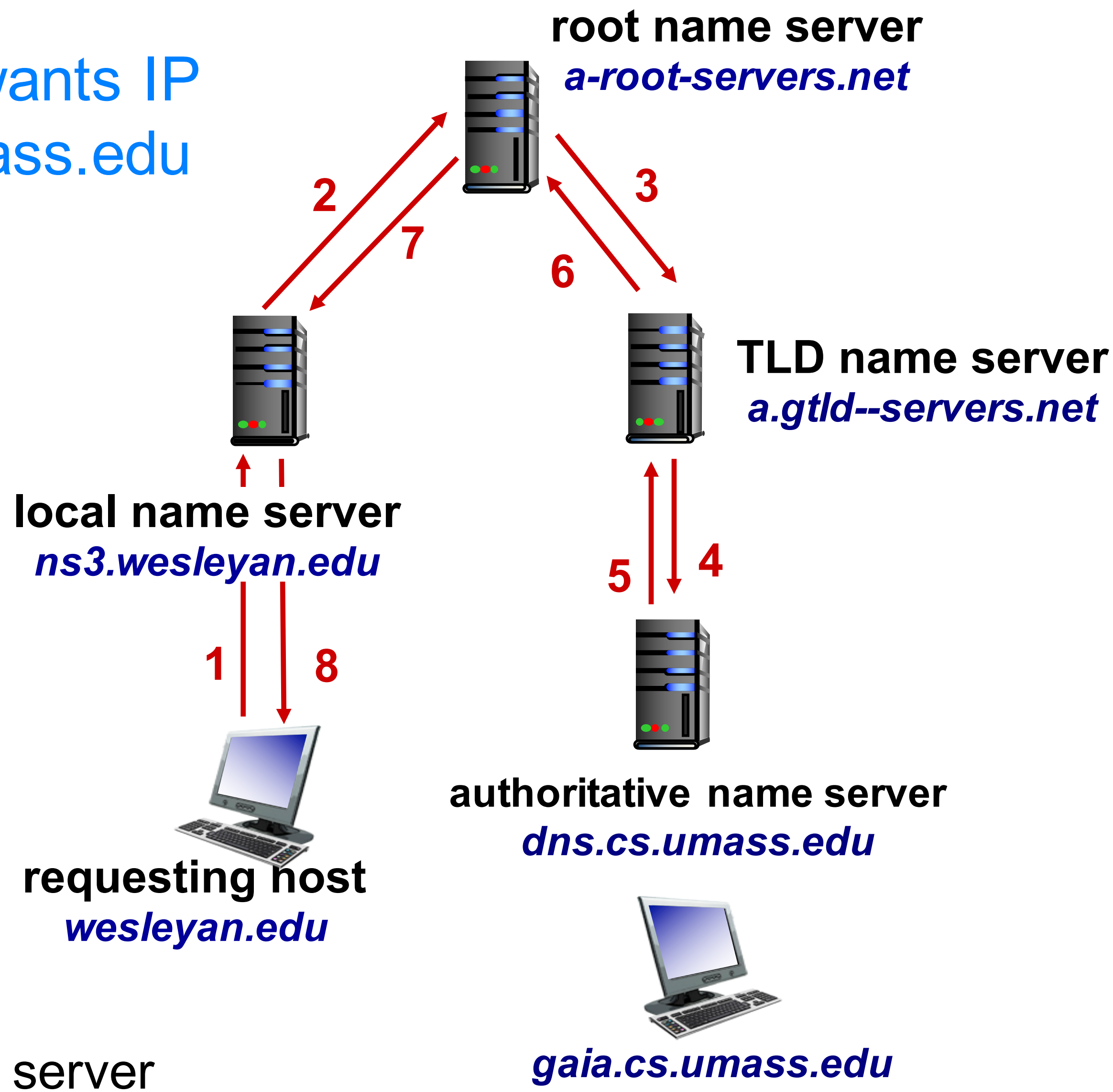
Reduces load on other servers

Recursive name resolution

Host at wesleyan.edu wants IP address for gaia.cs.umass.edu

Recursive query

- puts burden of name resolution on contacted name server
- heavy load at upper levels of hierarchy



Q: why is this useful?

Reduces load on requesting server

Domain Name System
PROTOCOL

DNS resource records

DNS: distributed database storing resource records (RR)

RR format: `(name, value, type, ttl)`

What you pass to index in on — What is returned

type=A

- `name` is hostname
- `value` is IP address

type=NS

- `name` is domain (e.g., foo.com)
- `value` is hostname of authoritative name server for this domain

type=CNAME

- `name` is alias name for some "canonical" (the real) name
- `value` is canonical name
- `www.ibm.com` is really `servereast.backup2.ibm.com` or `ibm.com` is really `www.ibm.com`

type=MX

- `value` is name of mailserver associated with `name`

DNS protocol

Specifies message formats for exchanges with DNS servers

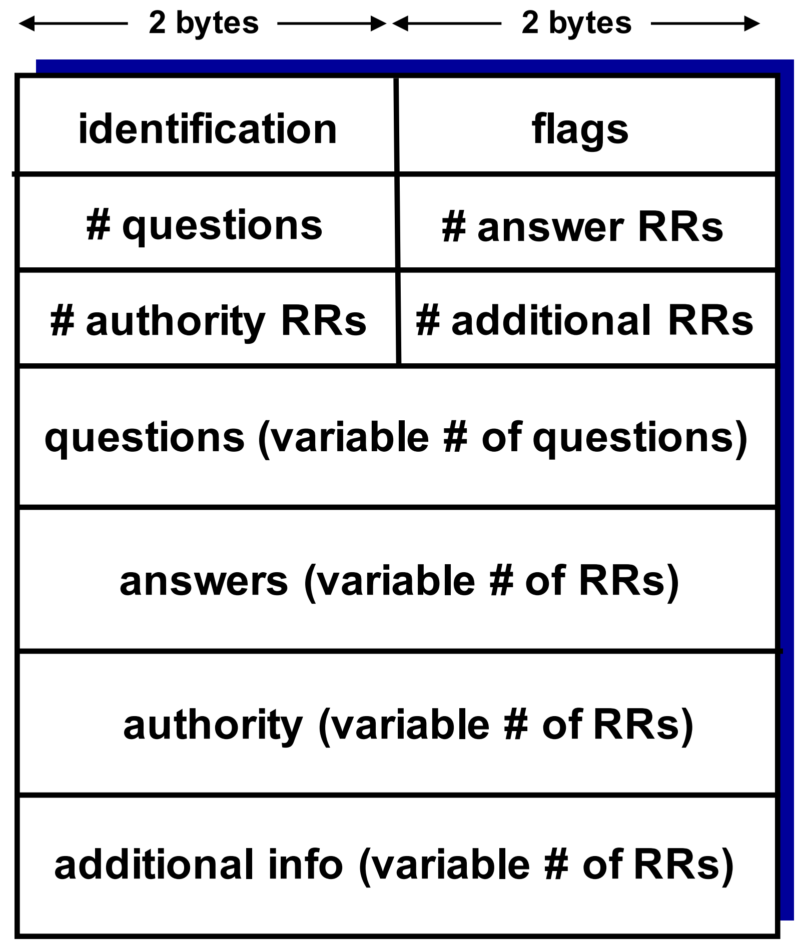
Query and reply messages

- have same format, different header field values
- use UDP (port 53)

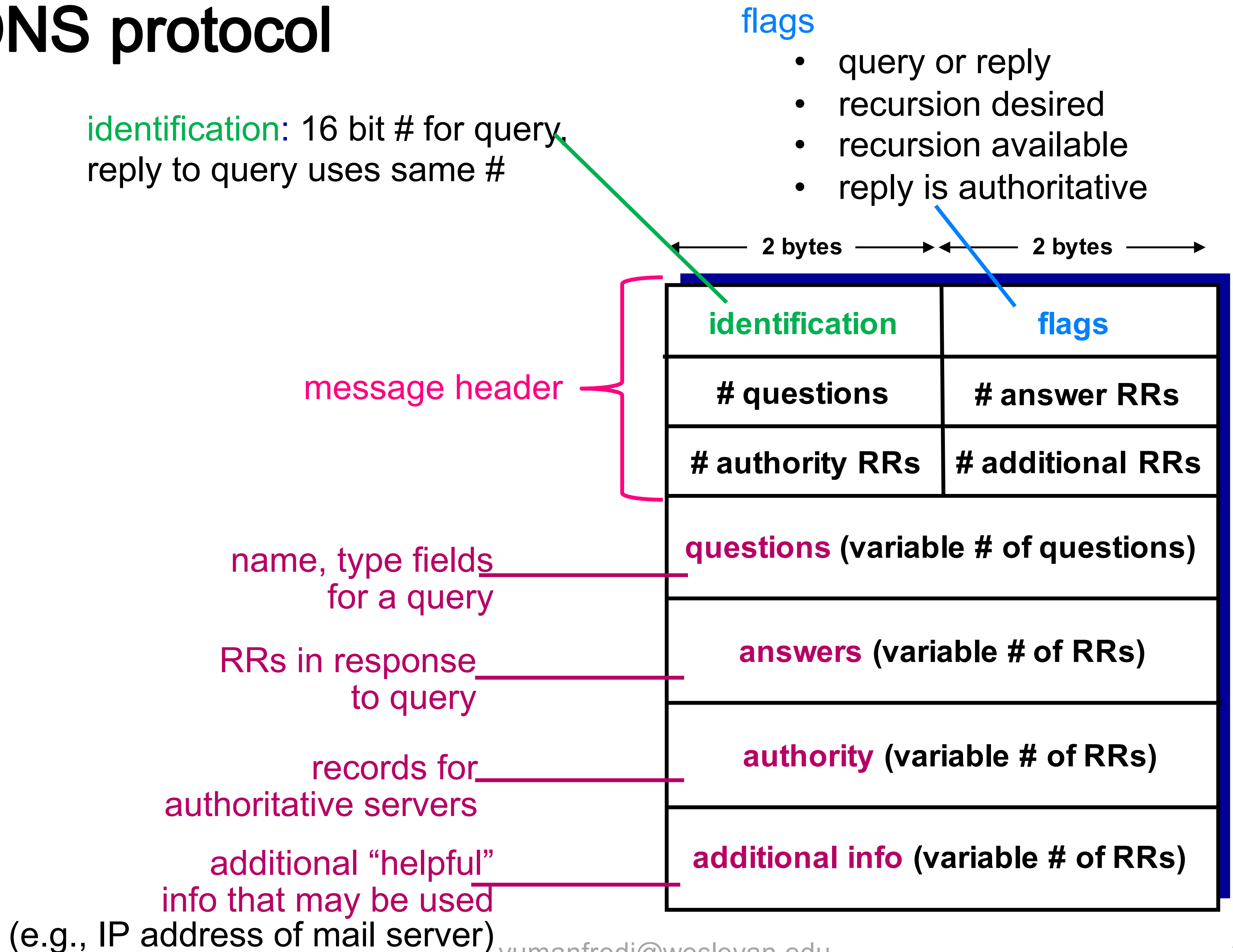
A query to DNS can multiple RRs

Q: Why UDP?

Reduce delay, overhead



DNS protocol



Caching and updating records

Once (any) name server learns mapping, it caches mapping

- cache entries timeout (disappear) after some time (TTL)
- marked as “non-authoritative” mapping with address of authoritative server
- TLD servers typically cached in local name servers
  - thus root name servers not often visited

Cached entries may be out-of-date (best effort name-to-address translation!)

- if name host changes IP address, may not be known Internet-wide until all TTLs expire

Update/notify mechanisms proposed IETF standard

- RFC 2136

Inserting records into DNS

Example

- new startup "Network Utopia"

Register name networkuptopia.com at DNS registrar

- e.g., Network Solutions, delegated by ICANN
- need to provide registrar with names and IP addresses of your authoritative name server (primary and secondary)
- registrar inserts two RRs into .com TLD (top-level) server

```
(networkutopia.com, dns1.networkutopia.com, NS)
(dns1.networkutopia.com, 212.212.212.1, A)
```

Create

- authoritative server Type A record for www.networkuptopia.com
- type MX record for networkutopia.com

Domain Name System

DIG AND WIRESHARK

dig wesleyan.edu

```
> dig wesleyan.edu

; <<>> DiG 9.8.3-P1 <<>> wesleyan.edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 65061
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;wesleyan.edu.                  IN      A

;; ANSWER SECTION:
wesleyan.edu.           21493   IN      A       129.133.7.68

;; Query time: 2 msec
;; SERVER: 129.133.52.12#53(129.133.52.12)
;; WHEN: Sun Feb 18 08:25:59 2018
;; MSG SIZE  rcvd: 46
```

dig inria.fr

```
> dig inria.fr

; <<>> DiG 9.8.3-P1 <<>> inria.fr
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 11551
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;inria.fr.                      IN      A

;; ANSWER SECTION:
inria.fr.               7169    IN      A       128.93.162.84

;; Query time: 8 msec
;; SERVER: 129.133.52.12#53(129.133.52.12)
;; WHEN: Sun Feb 18 08:22:23 2018
;; MSG SIZE  rcvd: 42
```

Wireshark for dig inria.fr query

```
▶ Frame 27: 68 bytes on wire (544 bits), 68 bytes captured (544 bits) on interface 0
▶ Ethernet II, Src: 78:4f:43:73:43:26 (78:4f:43:73:43:26), Dst: 129.133.176.1 (3c:8a:b0:1e:18:01)
▶ Internet Protocol Version 4, Src: 129.133.187.174, Dst: 129.133.52.12
▶ User Datagram Protocol, Src Port: 51519 (51519), Dst Port: 53 (53)
▼ Domain Name System (query)
     [Response In: 28]
     Transaction ID: 0x2d1f
   ▶ Flags: 0x0100 Standard query
     Questions: 1
     Answer RRs: 0
     Authority RRs: 0
     Additional RRs: 0
   ▼ Queries
     ▼ inria.fr: type A, class IN
          Name: inria.fr
          [Name Length: 8]
          [Label Count: 2]
          Type: A (Host Address) (1)
          Class: IN (0x0001)
```

Wireshark for dig inria.fr response

```
▶ Frame 28: 84 bytes on wire (672 bits), 84 bytes captured (672 bits) on interface 0
▶ Ethernet II, Src: 129.133.176.1 (3c:8a:b0:1e:18:01), Dst: 78:4f:43:73:43:26 (78:4f:43:73:43:26)
▶ Internet Protocol Version 4, Src: 129.133.52.12, Dst: 129.133.187.174
▶ User Datagram Protocol, Src Port: 53 (53), Dst Port: 51519 (51519)
▼ Domain Name System (response)
    [Request In: 27]
    [Time: 0.007877000 seconds]
    Transaction ID: 0x2d1f
  ▶ Flags: 0x8180 Standard query response, No error
    Questions: 1
    Answer RRs: 1
    Authority RRs: 0
    Additional RRs: 0
  ▼ Queries
    ▼ inria.fr: type A, class IN
        Name: inria.fr
        [Name Length: 8]
        [Label Count: 2]
        Type: A (Host Address) (1)
        Class: IN (0x0001)
  ▼ Answers
    ▼ inria.fr: type A, class IN, addr 128.93.162.84
        Name: inria.fr
        Type: A (Host Address) (1)
        Class: IN (0x0001)
        Time to live: 7169
        Data length: 4
        Address: 128.93.162.84
```

What really happens when you type URL?

1. DNS query
   - sent to get ip address for hostname over UDP

2. TCP socket opened to ip address

3. HTTP msgs sent over TCP socket

4. TCP socket shutdown

Load inria.fr webpage

129.133.188.34	129.133.52.11	DNS	68	Standard query 0xe8ca A inria.fr
129.133.52.11	129.133.188.34	DNS	84	Standard query response 0xe8ca A 128.93.162.84
129.133.188.34	129.133.52.11	DNS	68	Standard query 0x67ba AAAA inria.fr
JuniperN_1e:18:01	Broadcast	ARP	64	Gratuitous ARP for 129.133.176.1 (Request) [ETHERN
129.133.52.11	129.133.188.34	DNS	119	Standard query response 0x67ba
129.133.188.34	128.93.162.84	TCP	74	33302 > http [SYN] Seq=0 Win=29200 Len=0 MSS=1460
128.93.162.84	129.133.188.34	TCP	74	http > 33302 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=
129.133.188.34	128.93.162.84	TCP	66	33302 > http [ACK] Seq=1 Ack=1 Win=29312 Len=0 TSv
129.133.188.34	128.93.162.84	HTTP	382	GET / HTTP/1.1
128.93.162.84	129.133.188.34	TCP	66	http > 33302 [ACK] Seq=1 Ack=317 Win=15616 Len=0 T
128.93.162.84	129.133.188.34	HTTP	558	HTTP/1.1 301 Moved Permanently (text/html)
129.133.188.34	128.93.162.84	TCP	66	33302 > http [ACK] Seq=317 Ack=493 Win=30336 Len=0
129.133.188.34	128.93.162.84	TCP	66	33302 > http [FIN, ACK] Seq=317 Ack=493 Win=30336
128.93.162.84	129.133.188.34	TCP	66	http > 33302 [FIN, ACK] Seq=493 Ack=317 Win=15616
129.133.188.34	128.93.162.84	TCP	66	33302 > http [ACK] Seq=318 Ack=494 Win=30336 Len=0
129.133.188.34	129.133.52.11	DNS	72	Standard query 0x52a5 A www.inria.fr
129.133.188.34	129.133.52.11	DNS	72	Standard query 0x1f32 AAAA www.inria.fr
128.93.162.84	129.133.188.34	TCP	66	http > 33302 [ACK] Seq=494 Ack=318 Win=15616 Len=0
129.133.52.11	129.133.188.34	DNS	142	Standard query response 0x1f32 CNAME ezp3.inria.f
129.133.52.11	129.133.188.34	DNS	107	Standard query response 0x52a5 CNAME ezp3.inria.f
129.133.188.34	128.93.162.84	TCP	74	36018 > https [SYN] Seq=0 Win=29200 Len=0 MSS=1460
128.93.162.84	129.133.188.34	TCP	74	https > 36018 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len
129.133.188.34	128.93.162.84	TCP	66	36018 > https [ACK] Seq=1 Ack=1 Win=29312 Len=0 TS
129.133.188.34	128.93.162.84	TLSv1.2	255	Client Hello
128.93.162.84	129.133.188.34	TCP	66	https > 36018 [ACK] Seq=1 Ack=190 Win=15616 Len=0

Domain Name System

ATTACKS

Attacking DNS

Distributed Denial-of-Service (DDoS) attacks

- bombard root servers with traffic
  - not successful to date
  - traffic filtering
  - local DNS servers cache IPs of TLD servers, allowing root server bypass
- bombard TLD servers
  - potentially more dangerous

Redirect attacks

- man-in-middle
  - intercept queries
- DNS poisoning
  - send bogus replies to DNS server, which caches

Exploit DNS for DDoS

- send queries with spoofed source address: target IP
- requires amplification

Turkey hijacks DNS to enable censorship

BGPMON Now part of OpenDNS

HOME BLOG ABOUT US PRODUCTS AND SERVICES CLIENT PORTAL

Turkey Hijacking IP addresses for popular Global DNS providers

Posted by Andree Toonk - March 29, 2014 - Hijack, News and Updates - 26 Comments

At BGPmon we see numerous BGP hijacks every single day, some are interesting because of the size and scale of the hijack or as we've seen today because of the targeted hijacked prefixes. It all started last weekend when the Turkish president ordered the censorship of twitter.com. This started with a block of twitter by returning false twitter IP addresses by Turk Telekom DNS servers. Soon users in Turkey discovered that changing DNS providers to Google DNS or OpenDNS was a good method of bypassing the censorship. But as of around 9am UTC today (Saturday March 29) this changed when Turk Telekom started to hijack the IP address for popular free and open DNS providers such as Google's 8.8.8.8, OpenDNS' 208.67.222.222 and Level3's 4.2.2.2. **BGP hijack** Using the Turk Telekom looking glass we can see that AS9121 (Turk Telekom) has specific /32 routes for these IP addresses. Since this is the most specific route possible for an IPv4 address, this route will always be selected and the result is that traffic for this IP address is sent to this new bogus route.

```
show router bgp routes 8.8.8.8
```