

CPSC 317 – Winter 1 2025

Introduction to Computer Networking

Application Layer Protocols – DNS

Module 3.3

Norm & Ibtissem

READING

- Reading: 2.4

Learning Goals

Domain Name Service (DNS)

- Define the purpose and major design goals of DNS
- For each design goal, describe the strategy/technology/design approach used to address the problem
- Define the purpose of the various servers in the hierarchy of name servers
- Trace how DNS resolves a name to an IP address
- Describe the different resource records returned by a DNS server
- Interpret the information returned by dig or displayed by Wireshark.
- Apply the information returned by dig to determine the next server to contact or to determine the final answer

Naming and Network Structure

- How do we know which destination IP address to use?
- Problems:
 - Humans have a hard time remembering numbers
 - Addresses can change
- Solution: Map user-friendly names to IP addresses
 - Names are easier to remember
 - Names can mask address changes
- Domain Name System (DNS)

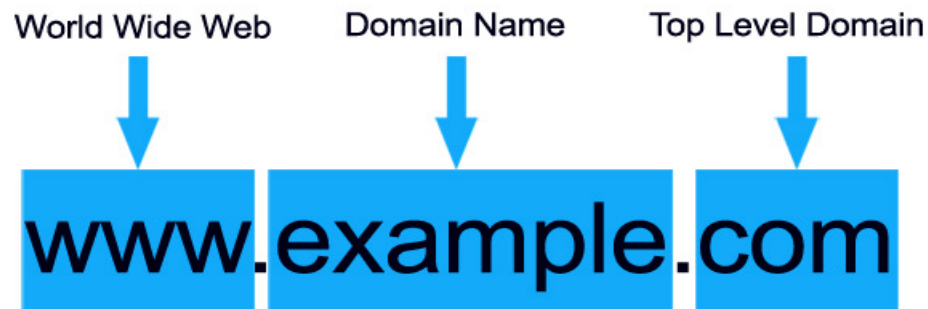
www.students.cs.ubc.ca:80



198.162.1.10:80

Domain Name

- A **domain name** is an identification string that defines a realm of administrative autonomy, authority or control within the Internet.
- Domain names are formed by the rules and procedures of the Domain Name System (DNS).



What is DNS?

- A **distributed database** implemented by a hierarchy of many name servers
- An **application-layer protocol** used by hosts to communicate with name servers to **resolve** names (translate names to addresses)

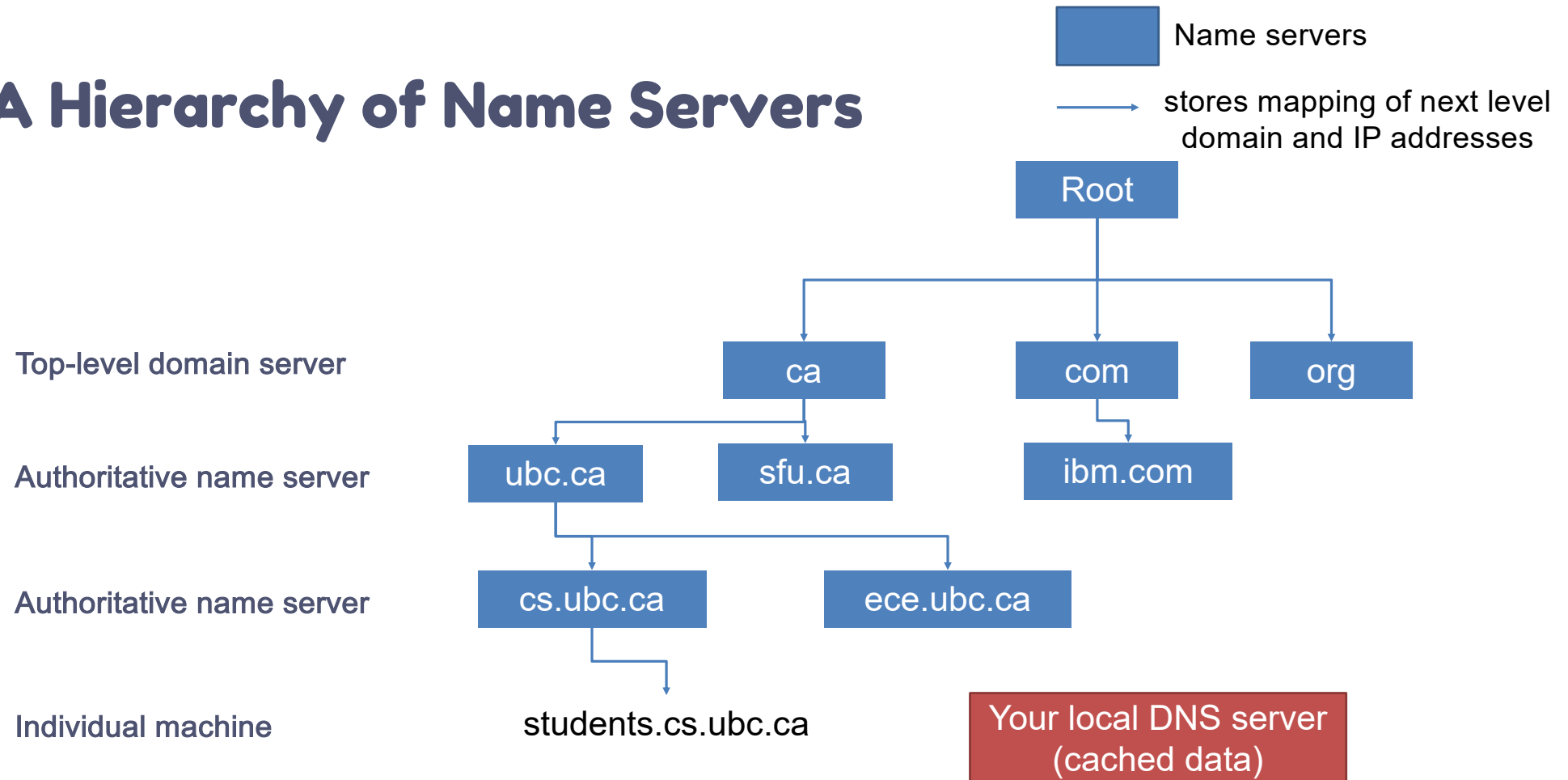
DNS Goals (Design Challenges)

- Scale (names, users, updates, etc.)
 - 364.6 million domain name registrations (September 2021)
- Ease of management (uniqueness of names, etc.)
 - Who decides if cs.ubc.ca can name a host “students”?
- Availability and consistency and security
 - Is there only one answer for the question: “What is the IP address of www.cs.ubc.ca?”?
How do we ensure this?
- Performance
 - OpenDNS, Cloudflare, Google each serve > 1 trillion requests per day (>11 million per second)

Solution:

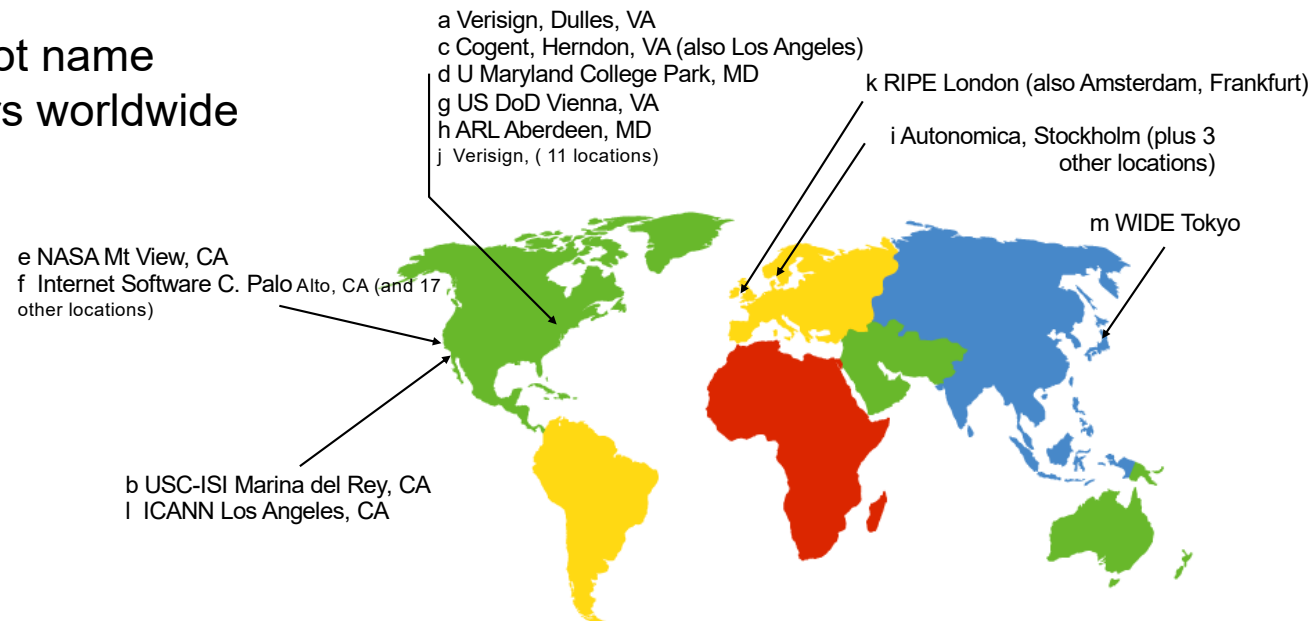
- Hierarchical design
- Caching
- Replication

A Hierarchy of Name Servers



DNS: Root Name Servers

13 root name
servers worldwide



TLD and Authoritative Servers

- **Top-level domain (TLD) servers:** responsible for domains ending in
 - .com, .org, .net, .edu, etc. (e.g., Network Solutions maintains servers for .com TLD, Educause for .edu TLD), and
 - all top-level country domains .uk, .fr, .ca, .jp, etc.
- **Authoritative DNS servers:** provide authoritative hostname to IP mappings for an organization's subdomains and servers (e.g., Web and mail)
 - Can be maintained by organization or service provider

Who Knows What?

- Every server knows the address of the root name servers
- Root servers know the address of all TLD servers
- Every node knows the addresses of its children
- An *authoritative* DNS server stores name-to-address mappings (resource records) for all names in the domain that it has authority for
- Therefore, each server:
 - Stores only a subset of the total DNS database (scalable!)

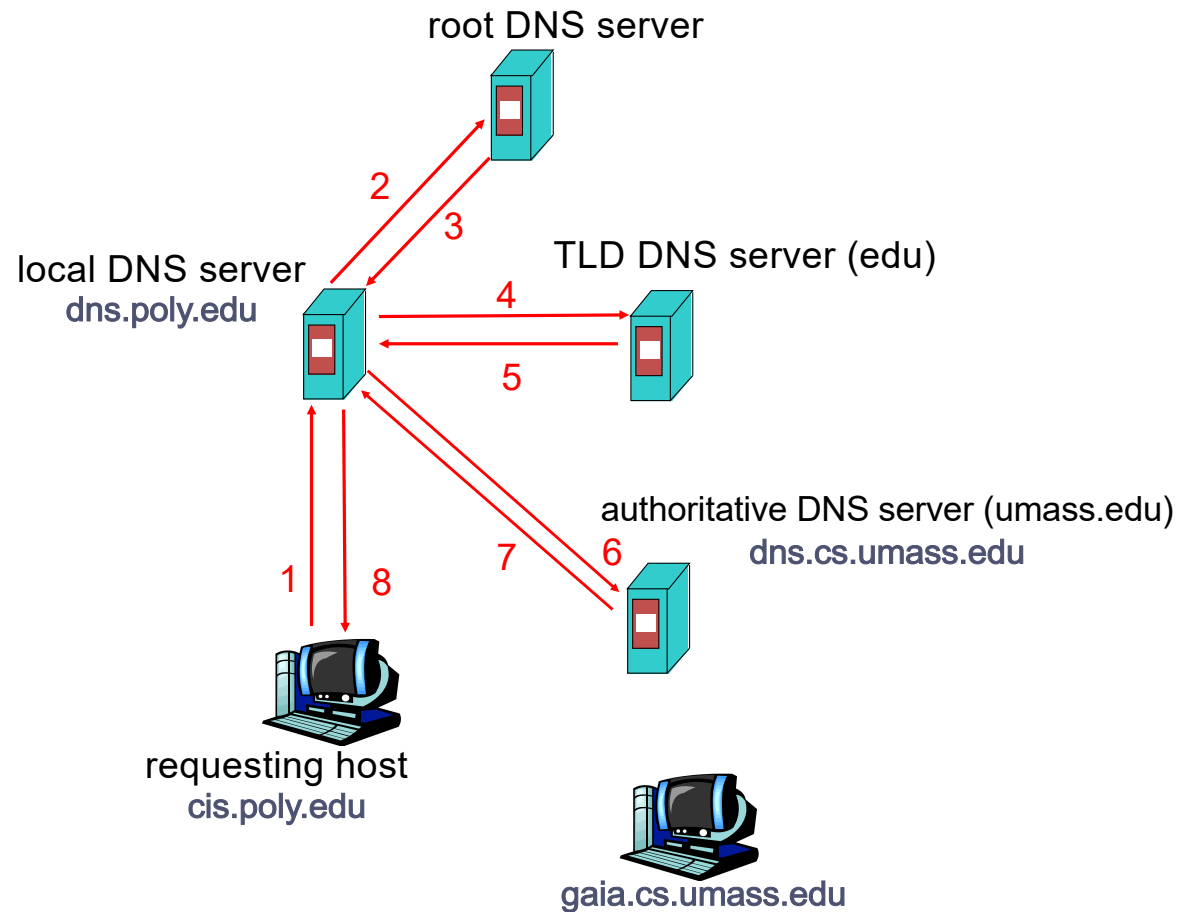
Local Name Server

- Does not belong to the hierarchy
- Each ISP (residential ISP, company, university) has one
 - Also called “default name server”
- When a host makes a DNS query, the query is sent to the local DNS server
 - Acts as a proxy, forwards query into hierarchy of DNS servers
 - Local DNS server resolves queries **iteratively**
- You will build a local name server in PA2

DNS LOOKUPS

Host at cis.poly.edu wants the IP address for the domain name gaia.cs.umass.edu.

- Host contacts local DNS server.
- Local DNS server contacts the root server and subsequent DNS servers iteratively.
- Each contacted server replies with name of next server to contact.
- Authoritative server returns the IP address of the requested domain.
- Local DNS server returns IP address to the host.



DNS Caching

- If every DNS request started at a root server, the root servers would be a bottleneck
- Solution: caching
 - Local DNS servers cache responses to queries
 - Responses include a “time to live” (TTL) field
 - Server deletes cached entry after TTL expires
- Caching is effective because
 - The top-level name servers very rarely change
 - Popular sites are visited often → the local DNS server often has the information cached

Inserting records into DNS

- Example: I just created the startup “Network Utopia”
- Register name networkutopia.com at a **registrar** (e.g., Network Solutions)
 - I provide registrar with names and IP addresses of my authoritative name servers (primary and secondary)
 - Registrar inserts two RRs into the com TLD server for each authoritative name server:
`(networkutopia.com, dns1.networkutopia.com, NS)`
`(dns1.networkutopia.com, 212.212.212.1, A)`
`(networkutopia.com, dns2.networkutopia.com, NS)`
`(dns2.networkutopia.com, 212.212.212.2, A)`
- In my authoritative servers, add a Type A record for www.networkutopia.com
 - `(networkutopia.com, 212.212.212.100, A)`
- How do people get the IP address of my Web site?

DNS Goals

- Scaling (names, users, updates, etc.) – Yes
 - Can add TLDs just by changing root database or new domains just by changing a TLD server
- Ease of management (uniqueness of names, etc.) – Yes
 - Each autonomous administration manages own names and servers, and can further delegate
 - Easily ensures uniqueness of names
 - And consistency of databases
- Availability and consistency and security – Yes
 - Domains replicate independently
- Fast lookups – Yes
 - Caching is a key, locality is very high

DETAILS

DNS RECORDS

DNS servers store **resource records (RRs)**

RR is (name, type, value, TTL)

Type	Name	Value	Example
A (<u>A</u> ddress)	hostname	IPv4 address	(www.cs.ubc.ca, A, 142.103.6.5, TTL
AAAA (<u>A</u> ddress x 4)	hostname	IPv6 address	(www.google.com, AAAA, 2607:f8b0:400a:80b::2004, TTL)
NS (<u>N</u> ame <u>S</u> erver)	domain	name of DNS server for domain	(cs.ubc.ca, NS, fs1.ugrad.cs.ubc.ca, TTL)
CNAME (<u>C</u> anonical <u>N</u> AME)	alias	canonical name	(foo.com, CNAME, relay1.bar.foo.com, TTL)

DNS Protocol

- Client-Server interaction on UDP Port 53
 - Message size limited by max UDP segment size (512 bytes)
 - For larger DNS messages, could use EDNS
 - Spec supports TCP too, but not always implemented
 - Reliability via repeating requests if the client times out
- Query and Reply messages
 - Both with the same message format
- Resolution is almost always “iterative”

DNS protocol messages

query and *reply* messages, both with same *message format*

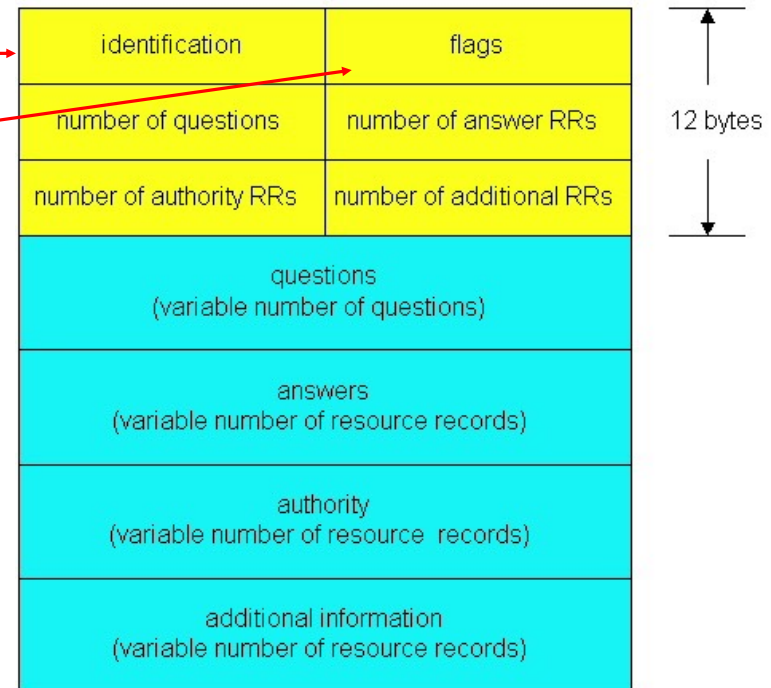
identification: 16 bit # set in query,
reply uses same #

flags: query or reply, reply is authoritative

Resource records (RRs):


<Name, Type, Class, TTL, RDLENGTH, RDATA>

- Name: a fully qualified domain name
- Type: a valid RR type (e.g., A, AAAA, ...)
- Class: mostly IN for internet application



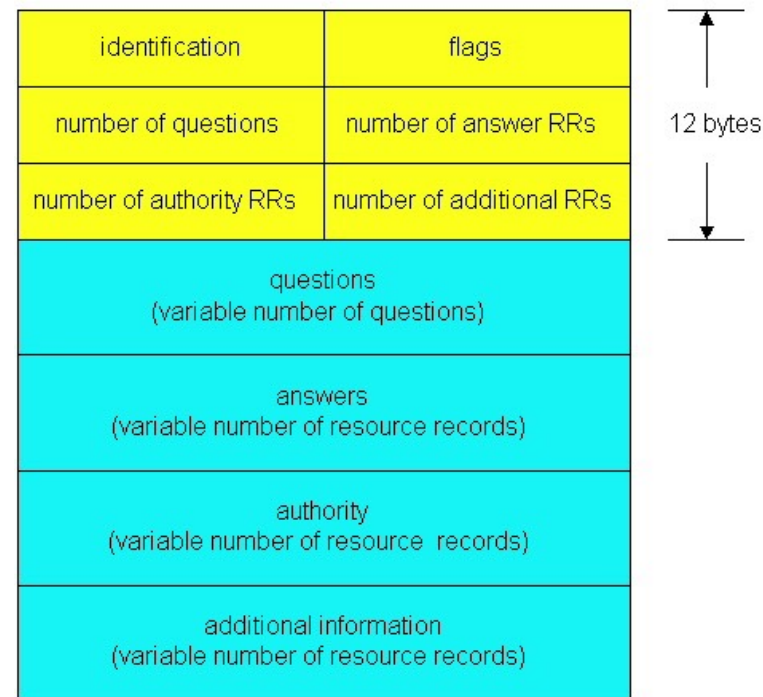
Resource Records (RR) in a query

- **Questions** are always
 <Name, Type, Class> tuples
- The question is the only section
 included in a query

identification	flags	 12 bytes
number of questions	number of answer RRs	
number of authority RRs	number of additional RRs	
questions (variable number of questions)		
answers (variable number of resource records)		
authority (variable number of resource records)		
additional information (variable number of resource records)		

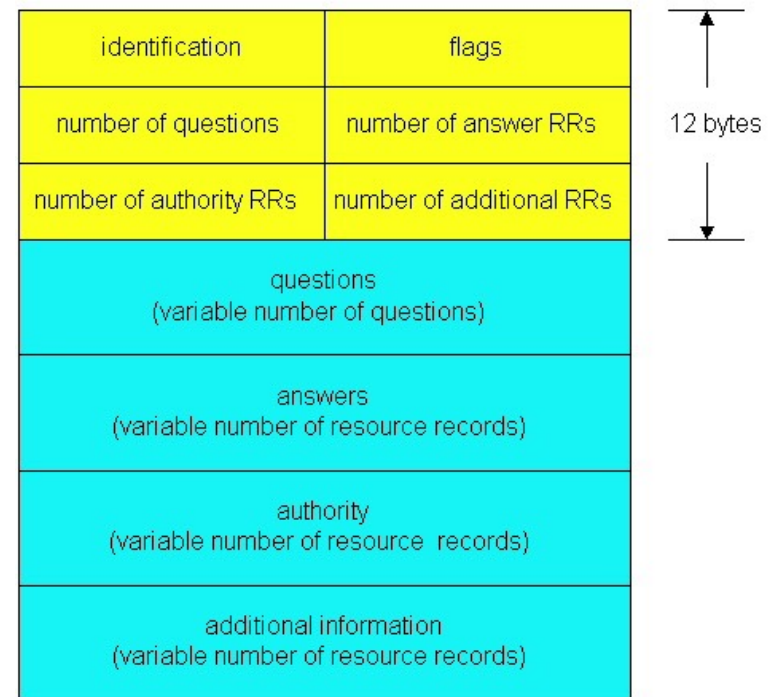
Resource Records (RR) in a reply

- **Answers** are RRs that match the Name, Type, Class from the question
- If a DNS server has CNAME pointers for the requested query with same class, returns CNAME records in the answer
- There may be multiple answers, since there may be multiple RRs with the same labels



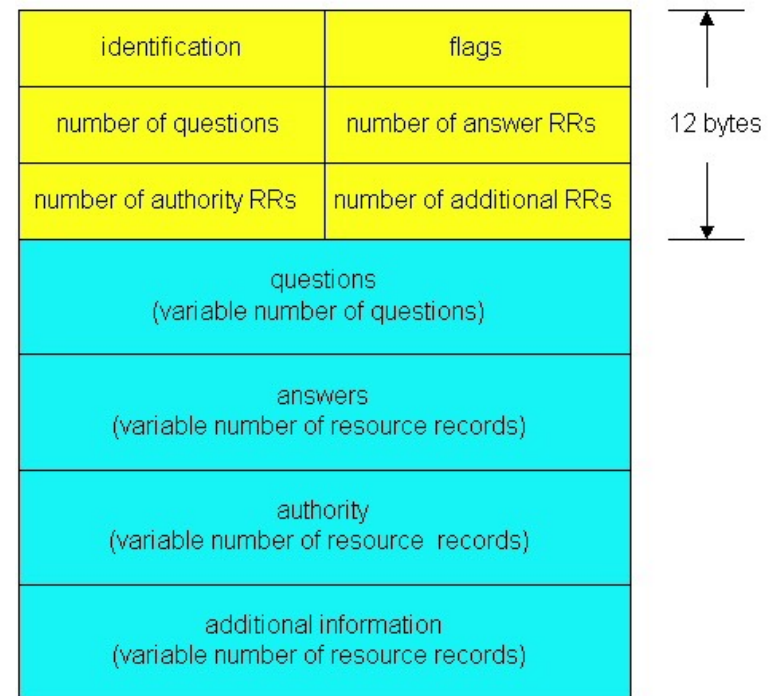
Resource Records (RR) in a reply

- **Authority** RRs are type NS records pointing to name servers closer to the target name in the naming hierarchy
- Used to redirect the client to a “better” server
- This field is optional



Resource Records (RR) in a reply

- **Additional** RRs are records that the name server believes may be useful to the client
- Most commonly used to supply A or AAAA (address) records for the name servers listed in the Authority section



Query at a Root name server

```
$ dig +noedns @a.root-servers.net www.cs.ubc.ca

; <<>> DiG 9.10.6 <<>> +noedns @a.root-servers.net www.cs.ubc.ca
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 13410
;; flags: qr rd; QUERY: 1, ANSWER: 0, AUTHORITY: 4, ADDITIONAL: 8
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;www.cs.ubc.ca.                IN      A

;; AUTHORITY SECTION:
ca.                            172800  IN      NS      any.ca-servers.ca.
ca.                            172800  IN      NS      x.ca-servers.ca.
ca.                            172800  IN      NS      c.ca-servers.ca.
ca.                            172800  IN      NS      j.ca-servers.ca.

;; ADDITIONAL SECTION:
any.ca-servers.ca.            172800  IN      A        199.4.144.2
any.ca-servers.ca.            172800  IN      AAAA     2001:500:a7::2
x.ca-servers.ca.              172800  IN      A        199.253.250.68
x.ca-servers.ca.              172800  IN      AAAA     2620:10a:80ba::68
c.ca-servers.ca.              172800  IN      A        185.159.196.2
c.ca-servers.ca.              172800  IN      AAAA     2620:10a:8053::2
j.ca-servers.ca.              172800  IN      A        198.182.167.1
j.ca-servers.ca.              172800  IN      AAAA     2001:500:83::1

;; Query time: 7 msec
;; SERVER: 198.41.0.4#53(198.41.0.4)
;; WHEN: Fri Feb 11 09:50:52 PST 2022
;; MSG SIZE rcvd: 284
```

Next Step : Query at TLD Name Server

```
$ dig +noedns @any.ca-servers.ca www.cs.ubc.ca
```

```
; <<>> DiG 9.10.6 <<>> +noedns @any.ca-servers.ca www.cs.ubc.ca
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 10677
;; flags: qr rd; QUERY: 1, ANSWER: 0, AUTHORITY: 3, ADDITIONAL: 3
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;www.cs.ubc.ca.                IN      A

;; AUTHORITY SECTION:
ubc.ca.                        86400   IN      NS      hub.ubc.ca.
ubc.ca.                        86400   IN      NS      nightbird.eis.utoronto.ca.
ubc.ca.                        86400   IN      NS      dns3.ubc.ca.

;; ADDITIONAL SECTION:
nightbird.eis.utoronto.ca. 86400   IN      A        128.100.72.90
dns3.ubc.ca.                86400   IN      A        142.103.1.1
hub.ubc.ca.                  86400   IN      A        137.82.1.1

;; Query time: 37 msec
;; SERVER: 199.4.144.2#53(199.4.144.2)
;; WHEN: Fri Feb 11 09:51:43 PST 2022
;; MSG SIZE rcvd: 161
```

Next Step: Query at Authoritative Name Server

```
$ dig +noedns @nightbird.eis.utoronto.ca www.cs.ubc.ca
```

```
; <<>> DiG 9.10.6 <<>> +noedns @nightbird.eis.utoronto.ca www.cs.ubc.ca
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 60085
;; flags: qr rd; QUERY: 1, ANSWER: 0, AUTHORITY: 3, ADDITIONAL: 3
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;www.cs.ubc.ca.                IN      A

;; AUTHORITY SECTION:
cs.ubc.ca.                     86400   IN      NS      fs1.ugrad.cs.ubc.ca.
cs.ubc.ca.                     86400   IN      NS      temp120.cs.ubc.ca.
cs.ubc.ca.                     86400   IN      NS      ns1.cs.ubc.ca.

;; ADDITIONAL SECTION:
ns1.cs.ubc.ca.                 86400   IN      A       142.103.6.6
fs1.ugrad.cs.ubc.ca.          86400   IN      A       198.162.35.1
temp120.cs.ubc.ca.            86400   IN      A       137.82.61.120

;; Query time: 61 msec
;; SERVER: 128.100.72.90#53(128.100.72.90)
;; WHEN: Fri Feb 11 09:53:07 PST 2022
;; MSG SIZE rcvd: 143
```

Final Step: Finding the IP Address

```
$ dig +noedns @temp120.cs.ubc.ca www.cs.ubc.ca

; <<>> DiG 9.10.6 <<>> +noedns @temp120.cs.ubc.ca www.cs.ubc.ca
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 22393
;; flags: qr aa rd; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;www.cs.ubc.ca.                IN      A

;; ANSWER SECTION:
www.cs.ubc.ca.                 3600    IN      A      142.103.6.5

;; Query time: 8 msec
;; SERVER: 137.82.61.120#53(137.82.61.120)
;; WHEN: Fri Feb 11 09:53:48 PST 2022
;; MSG SIZE  rcvd: 47
```

In-class activity

- ICA33

Next Topic: Application Layer Protocols – E-mail