

Domain Name System



<http://xkcd.com/302/>

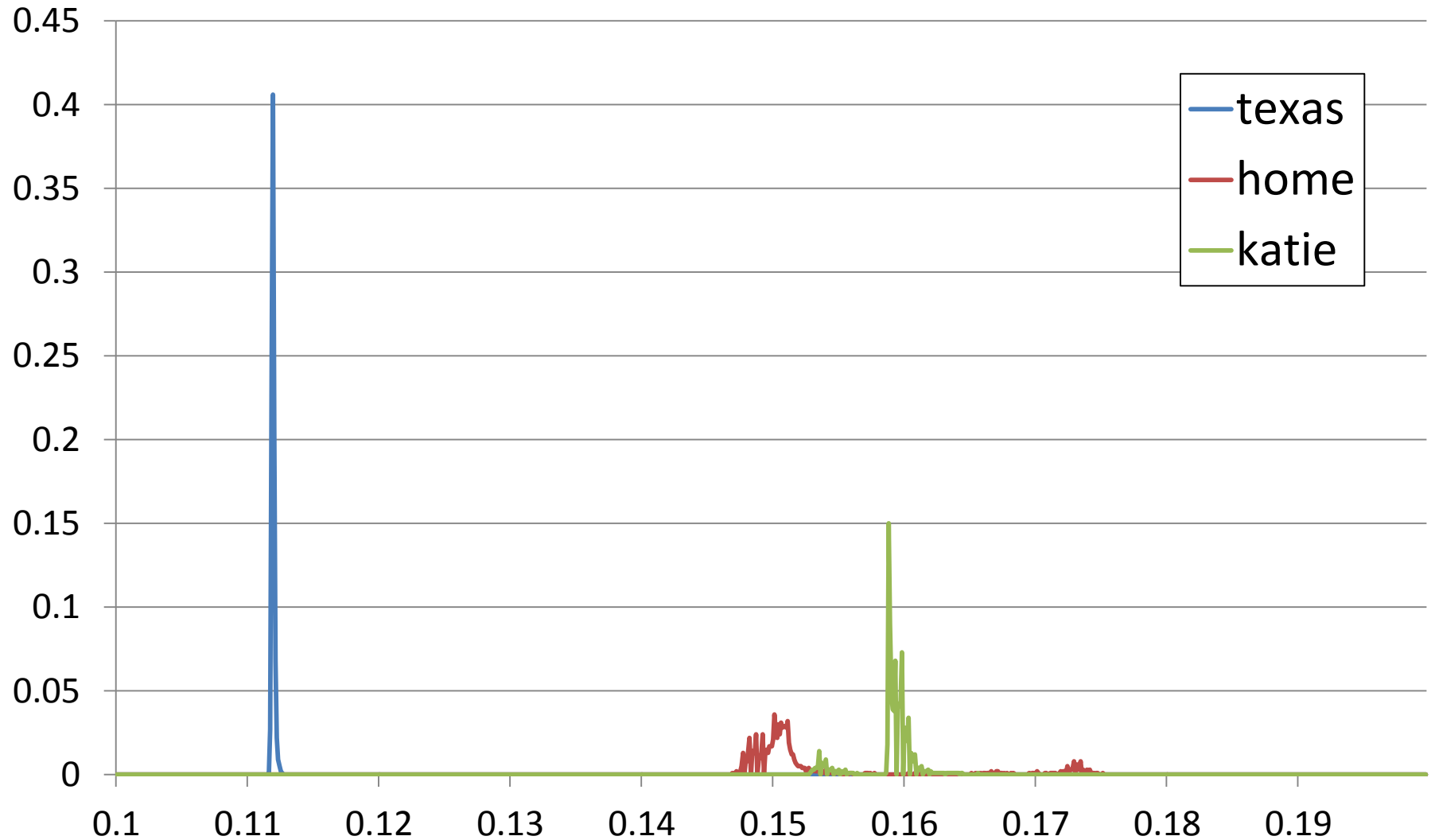
Overview

- Final project + presentation
- Some TCP and UDP experiments
- Domain Name System (DNS)
 - Hierarchical name space
 - Maps friendly names to IP address
 - Large distributed database of records

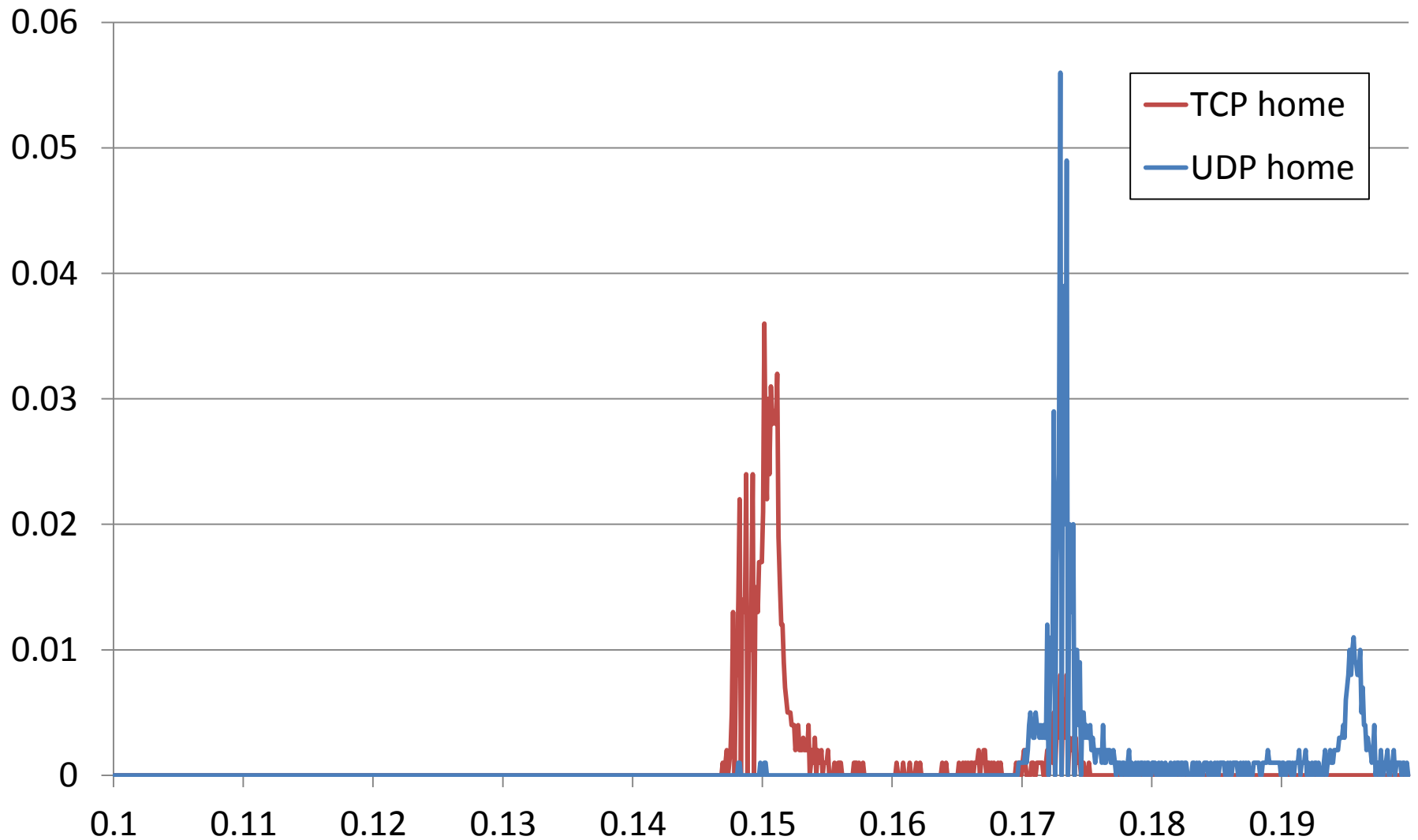
TCP/UDP experiments

- Send 1K of data, receive 1K back
 - Every ten seconds until something it failed
 - High resolution timing, start of send to end of receive
 - Endpoints:
 - home (cable modem) \leftrightarrow london
 - katie \leftrightarrow london
 - data center in Texas \leftrightarrow london
 - TCP and UDP
 - UDP no attempt to recover from packet loss
 - home, 6719 exchanges
 - katie, 151
 - texas, 842

TCP send/rcv time



TCP vs UDP



Names and IP addresses

- Why use names instead of IP address?
 - Names are easier for humans to remember
 - www.bbc.co.uk versus 64.91.253.46
 - IP address could change if changing ISPs
 - Single name could map to multiple IP address
 - Load balance over several servers
 - Send user to nearest server to reduce latency
 - Allow multiple names to go to same place

Hierarchical network names

- **Host name:** `www.cs.princeton.edu`
 - **Domain:** registrar for each top-level domain (e.g., .edu)
 - **Host name:** local administrator assigns to each host
- **IP addresses:** `128.112.7.156`
 - **Prefixes:** ICANN, regional Internet registries, and ISPs
 - **Hosts:** static configuration, or dynamic using DHCP
- **MAC addresses:** `00-15-C5-49-04-A9`
 - **Blocks:** assigned to vendors by the IEEE
 - **Adapters:** assigned by the vendor from its block

Domain Name System

- Domain Name System (DNS)
 - Maps host name to IP address
 - DNS resolver, sends query
 - DNS server, provides response
- How does the server know the answer?

Option 1: Local file

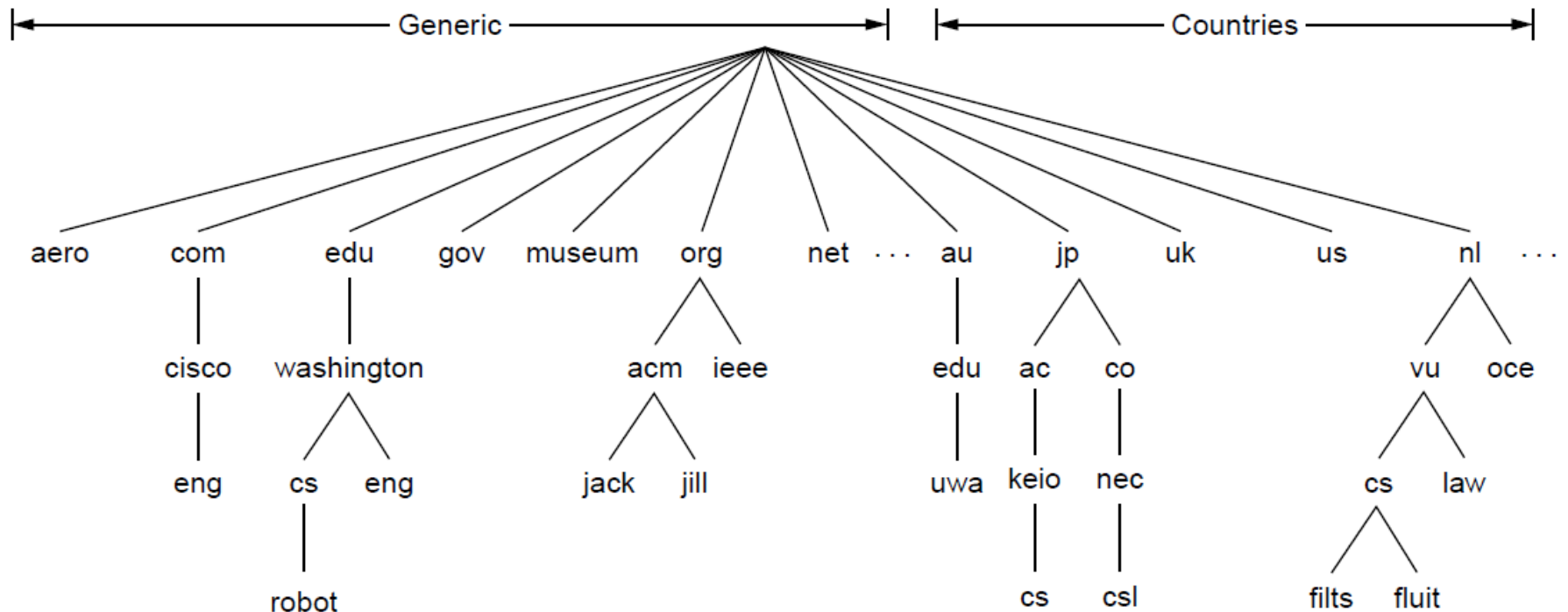
- Store name to address mapping in local file
 - ARPANET prior to 1983, hosts.txt
 - Flat namespace
 - SRI updated hosts.txt, others downloaded it
 - Worked in a world of a small number of large computers
 - Doesn't scale as more and more computers were placed on the network

Option 2: Central server

- Central server
 - All name to address mapping stored in one place
 - All queries go to central server
- Problems:
 - Single point of failure
 - Server may experience high volume of traffic
 - Server may be distant from a host wanting a lookup
 - Single point of update
 - Does not scale

Domain Name System (DNS)

- Distributed, hierarchical collection of servers
 - Name space is hierarchical



Generic Top Level Domains (TLDs)

Domain	Intended use	Start date	Restricted?
com	Commercial	1985	No
edu	Educational institutions	1985	Yes
gov	Government	1985	Yes
int	International organizations	1988	Yes
mil	Military	1985	Yes
net	Network providers	1985	No
org	Non-profit organizations	1985	No
aero	Air transport	2001	Yes
biz	Businesses	2001	No
coop	Cooperatives	2001	Yes
info	Informational	2002	No
museum	Museums	2002	Yes
name	People	2002	No
pro	Professionals	2002	Yes
cat	Catalan	2005	Yes
jobs	Employment	2005	Yes
mobi	Mobile devices	2005	Yes
tel	Contact details	2005	Yes
travel	Travel industry	2005	Yes
xxx	Sex industry	2010	No

Top level domains

- Top-level domains (TLD)
 - Around 22 generic TLDs, e.g. com, net, org, edu
 - Most popular with US organizations
 - Around 250 country specific TLDs
 - Two letter ISO code, e.g. au, ch, se
 - Some violations, e.g. uk instead of gb
 - TLDs run by registrars appointed by Internet Corporation for Assigned Names and Numbers (ICANN)
 - Money in names
 - Cybersquatting
 - Country of Tavalu sold lease to .tv for 50 million

Top level domains

- Set to expand, you can buy your own TLD!
 - June 2011
 - ICANN approves creation of TLDs for brands and organizations
 - \$185,000 initial application, \$25,000 annual fee
 - Is an easy-to-remember domain name relevant anymore?
 - Google the name instead
 - What name should you type to get to General Motors?

Second-level domains

- Second-level domains
 - Getting name-of-company.com is easy
 - Buy from a registrar for the desired TLD, small annual fee



superwidget.com is already taken. ([Get info](#)) [Use Domain Buy to get this name](#)

View alternative results below or search again:



[Important information about Private Registration.](#) [Why register multiple domains?](#)

[Select All](#)

[More Domain Options](#)

<input type="checkbox"/>	superwidget.co	✓	\$17.99 SALE!	Save \$12.00
<input type="checkbox"/>	superwidget.info	✓	\$1.99*	BEST VALUE!
<input type="checkbox"/>	superwidget.net	✓	\$9.99* SAVE!	Save \$5.00
<input type="checkbox"/>	superwidget.org	✓	\$6.99* SALE!	Save \$8.00
<input type="checkbox"/>	superwidget.us	✓	\$3.99 SALE!	SPECIAL!
<input type="checkbox"/>	superwidget.ca	✓	\$12.99/yr	
<input type="checkbox"/>	superwidget.biz	✓	\$5.99* SALE!	Save \$9.00
<input type="checkbox"/>	superwidget.mobi	✓	\$6.99*	Save \$11.00
<input type="checkbox"/>	superwidget.me	✓	\$8.99 SALE!	Save \$11.00
<input type="checkbox"/>	superwidget.tv	✓	\$39.99/yr	

Add

View: [Available](#) | [Backorder](#)

We also recommend...

Additional

Premium

International

[Select All](#)

Show:

All

☐ bestsuperwidget.com
☐ superwidgetnow.com
☐ freesuperwidget.com
☐ superwidgettoday.com
☐ superwidgetshop.com
☐ superwidgetblog.com
☐ mysuperwidget.com
☐ superwidgetsite.com
☐ thesuperwidnet.com

Add

[Continue to Registration >](#)

Subdomains

- Further hierarchy under a second-level domain
 - e.g. mail.company.com, www.company.com, inf.phy.cam.ac.uk
 - Each domain controls the subdomains under it
- Domain resource records
 - Each domain has a set of data about its server(s)
 - At a minimum, the IP address for a name

Domain resource record

Type	Meaning	Value
SOA	Start of authority	Parameters for this zone
A	IPv4 address of a host	32-Bit integer
AAAA	IPv6 address of a host	128-Bit integer
MX	Mail exchange	Priority, domain willing to accept email
NS	Name server	Name of a server for this domain
CNAME	Canonical name	Domain name
PTR	Pointer	Alias for an IP address
SPF	Sender policy framework	Text encoding of mail sending policy
SRV	Service	Host that provides it
TXT	Text	Descriptive ASCII text

- A - most important, maps hostnames to IPv4 addresses
- MX - username@company.com go to this server name
- NS - server that stores the record
- Fields have a TTL - time-to-live, for caching

Setting DNS resource record

Set Nameservers

If you are hosting your Web site with us (you have a hosting account with us associated with this domain) or you want to Park or Forward your domain, we will automatically set your nameservers for you.

- ☐ I want to **park** my domains.
- ☐ I want to **forward** my domains.
- ☐ I have a **hosting account** with these domains.
- ☒ I have **specific nameservers** for my domains.

Nameserver 1: *

NS1.LINODE.COM

Nameserver 2: *

NS2.LINODE.COM

Nameserver 3:

NS3.LINODE.COM

Nameserver 4:

NS4.LINODE.COM

[Add more](#) | [Manage DS Records](#)

* Required

Did You Know?

Domains using our nameservers benefit from our worldwide DNS presence through Anycast DNS.

[Learn More](#)

SOA Record

Primary DNS	Email	Default TTL	Refresh Rate	Retry Rate	Expire Time	Options
ns1.linode.com	a@b.com	Default	Default	Default	Default	Settings

NS Records

Name Server	Subdomain	TTL	Options
ns1.linode.com	keithv.com	Default	Edit Remove
ns2.linode.com	keithv.com	Default	Edit Remove
ns3.linode.com	keithv.com	Default	Edit Remove
ns4.linode.com	keithv.com	Default	Edit Remove
ns5.linode.com	keithv.com	Default	Edit Remove

[Add a new NS record](#)**MX Records**

Mail Server	Preference	Subdomain	TTL	Options
mx1.emailsrvr.com	10		Default	Edit Remove
mx2.emailsrvr.com	20		Default	Edit Remove

[Add a new MX record](#)**A/AAAA Records**

Hostname	IP Address	TTL	Options
	69.164.194.211	Default	Edit Remove
mail	69.164.194.211	Default	Edit Remove
www	69.164.194.211	Default	Edit Remove

[Add a new A record](#)**CNAME Records**

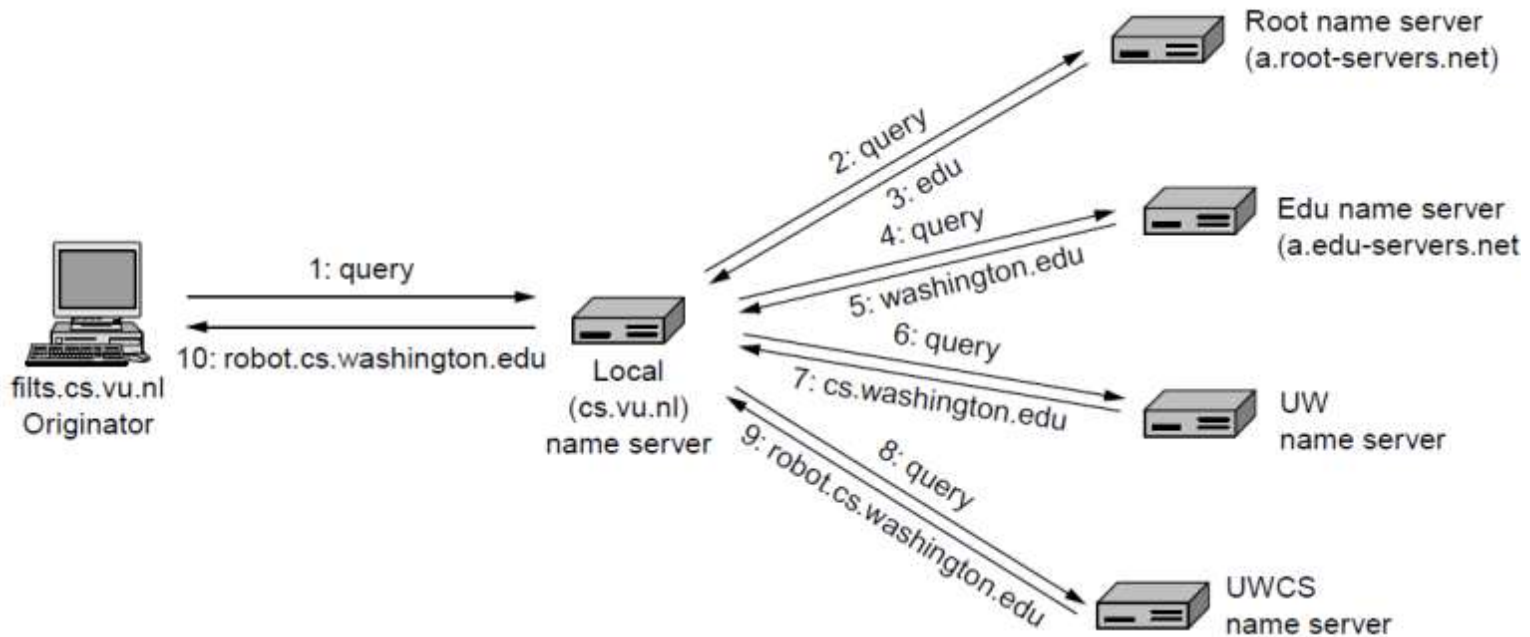
Hostname	Aliases to	TTL	Options
----------	------------	-----	---------

[Add a new CNAME record](#)**TXT Records**

Name	Value	TTL	Options
------	-------	-----	---------

[Add a new TXT record](#)

Name resolution



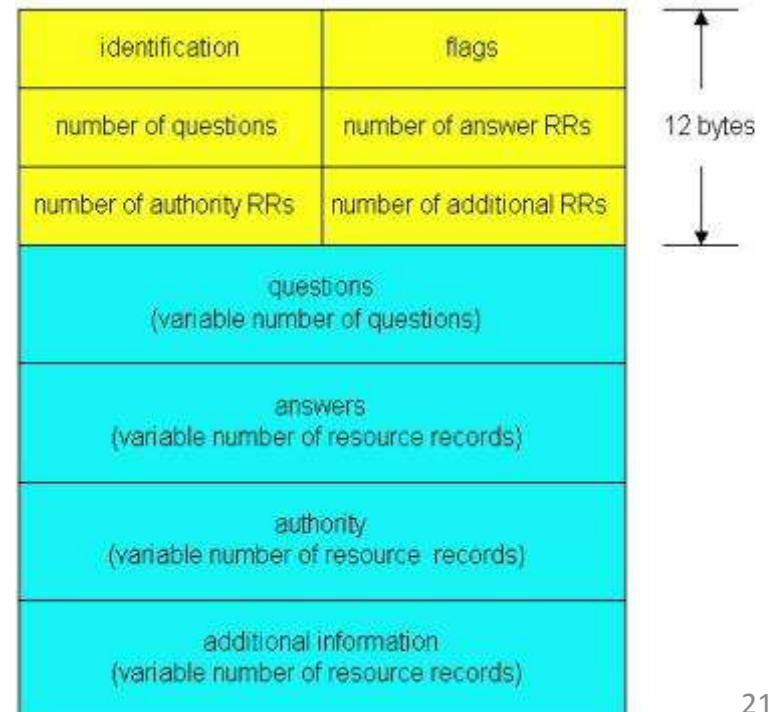
- Step 1: Host contacts its local DNS server
 - Host configured with local server
 - Manually configured (e.g. `/etc/resolve.conf`) or via DHCP
 - A "recursive query", originator waits for complete answer from local DNS server

DNS query

- Name lookup via DNS query
 - Transported over UDP
 - Retry same server with exponential backoff
 - Can switch to trying other DNS servers

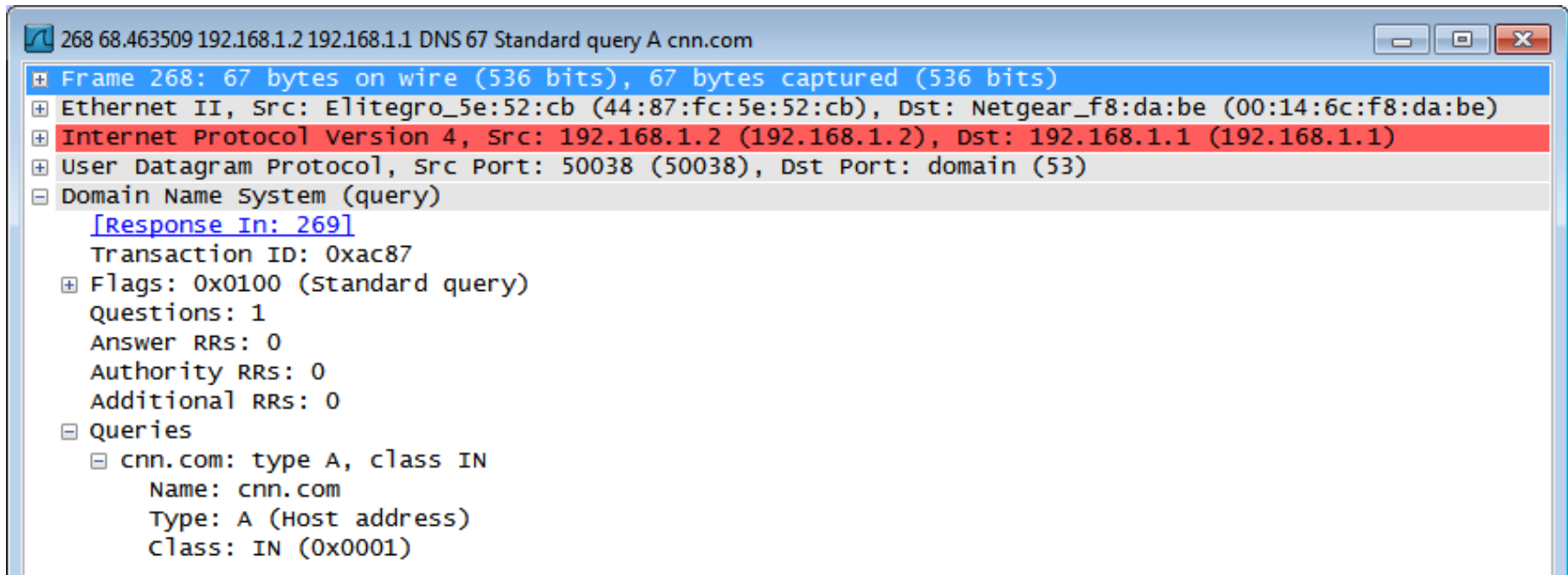
- Identification:
 - 16 bit # for query, reply uses same #

- Flags:
 - Query or reply
 - Recursion desired
 - Recursion available
 - Reply is authoritative

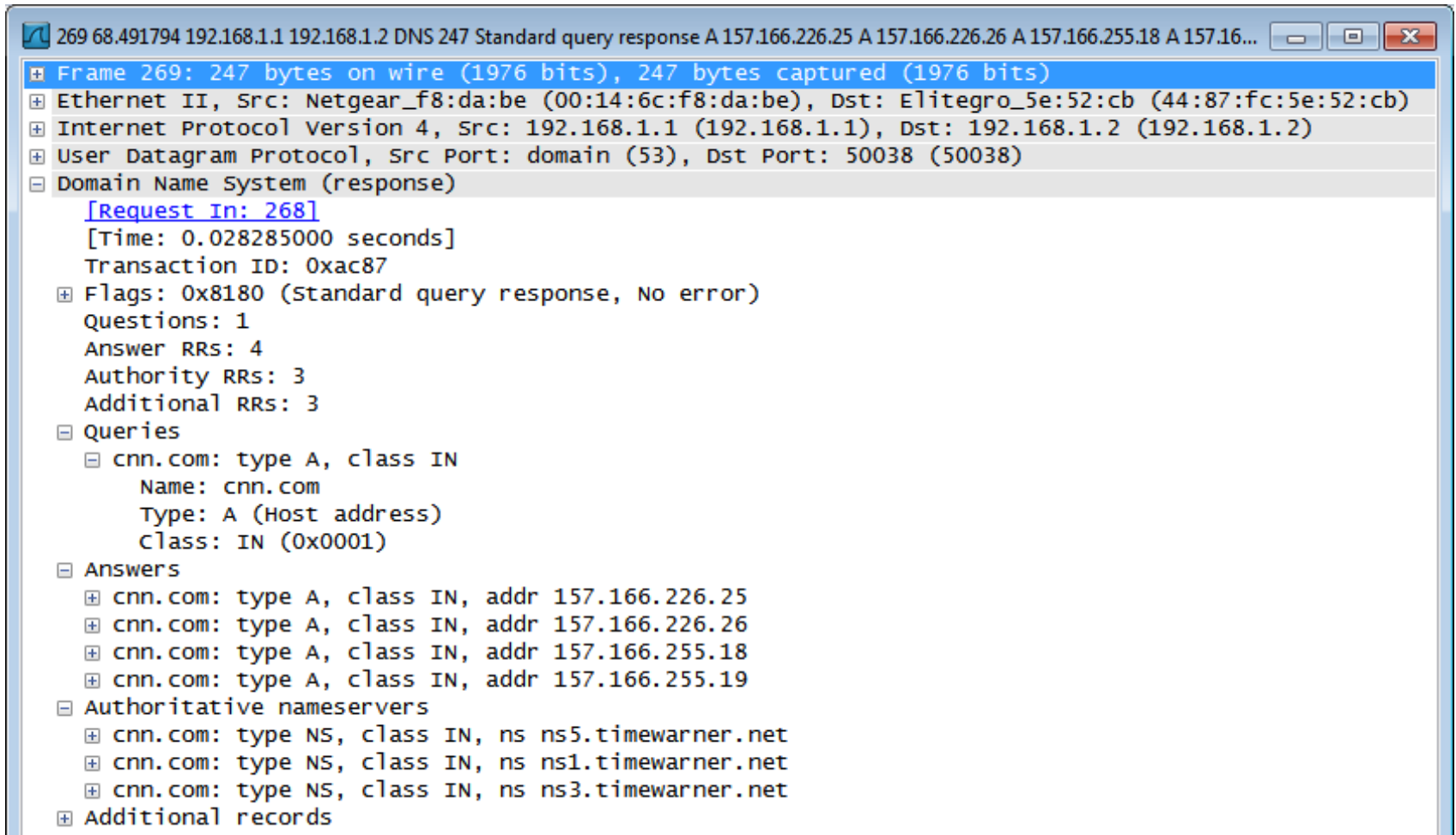


Example DNS query

```
status = getaddrinfo("cnn.com", "80", &hints, &res);
```



Example DNS response



DNS query to nowhere?

- Request lookup of a bogus domain name

```
status = getaddrinfo("fewavbawe34332.com", "80", &hints, &res);
```

The image shows a network packet capture on the left and a web browser on the right. The packet capture shows a DNS query for the domain 'fewavbawe34332.com'. The query is a standard query response with a transaction ID of 0xfc33. The query is for a type A record (Host address) for the domain 'fewavbawe34332.com'. The response is a standard query response with a transaction ID of 0xfc33. The response is for a type A record (Host address) for the domain 'fewavbawe34332.com'. The response is a standard query response with a transaction ID of 0xfc33. The response is for a type A record (Host address) for the domain 'fewavbawe34332.com'.

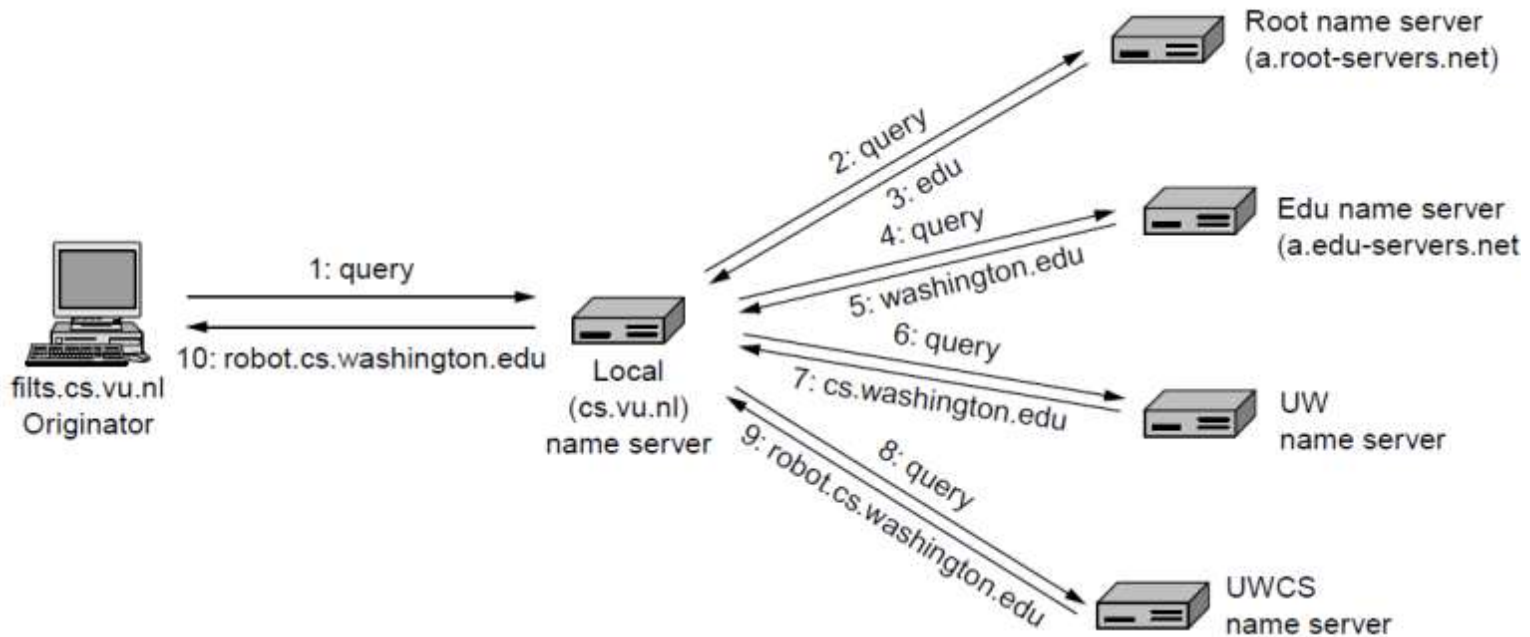
The web browser shows the search results for 'fewavbawe34332.com' on the search.bresnan.net website. The search results are categorized into 'Web Results' and 'Related Searches'. The 'Web Results' section includes links to 'Stock Alert: *VELA*', 'Dove® For Women', 'GCLL Hot Stock of 2011!', 'Mortgage Rates Hit 2.50%', and 'Mutual Funds- Scottrade'. The 'Related Searches' section includes links to 'The Few', 'Maths Worksheets', 'Math Homework Help', 'Multiplication Math', 'Math Help', 'Printable Math Worksheets', 'Saxon Math', 'Help Algebra', 'My Algebra', and 'Math Problem'. The 'Sponsored Results' section includes links to 'Stock Alert: *VELA*', 'Dove® For Women', 'GCLL Hot Stock of 2011!', and 'Mutual Funds- Scottrade'.

Domain Name Servers

- Distributed, hierarchical collection of servers
 - Root servers, named: letter.root-servers.net, A-M
 - a.root-servers.net, actually a geographically distributed set of servers reached via anycast routing

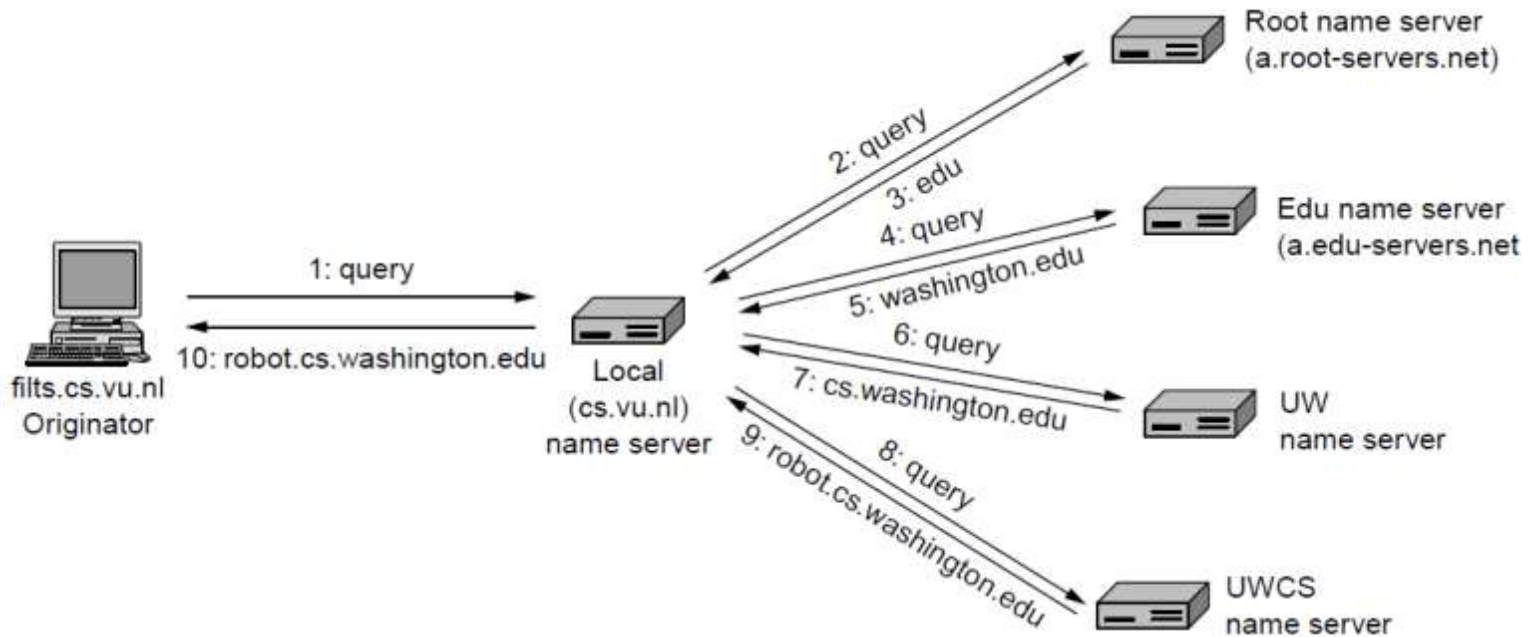


Name resolution



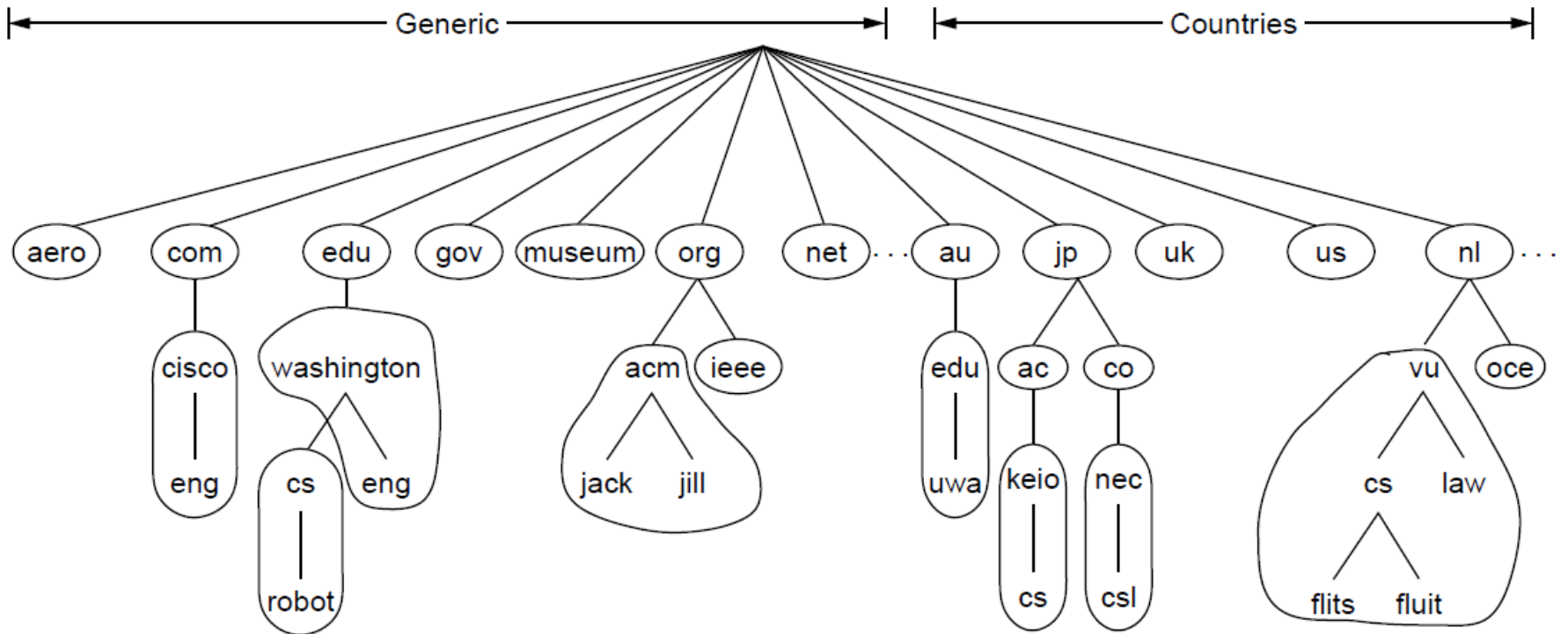
- Step 2/3: Root NS responds with NS handling .edu
 - An "iterative query"
 - Local NS has ongoing conversation with multiple servers to find answer for originator

Name resolution

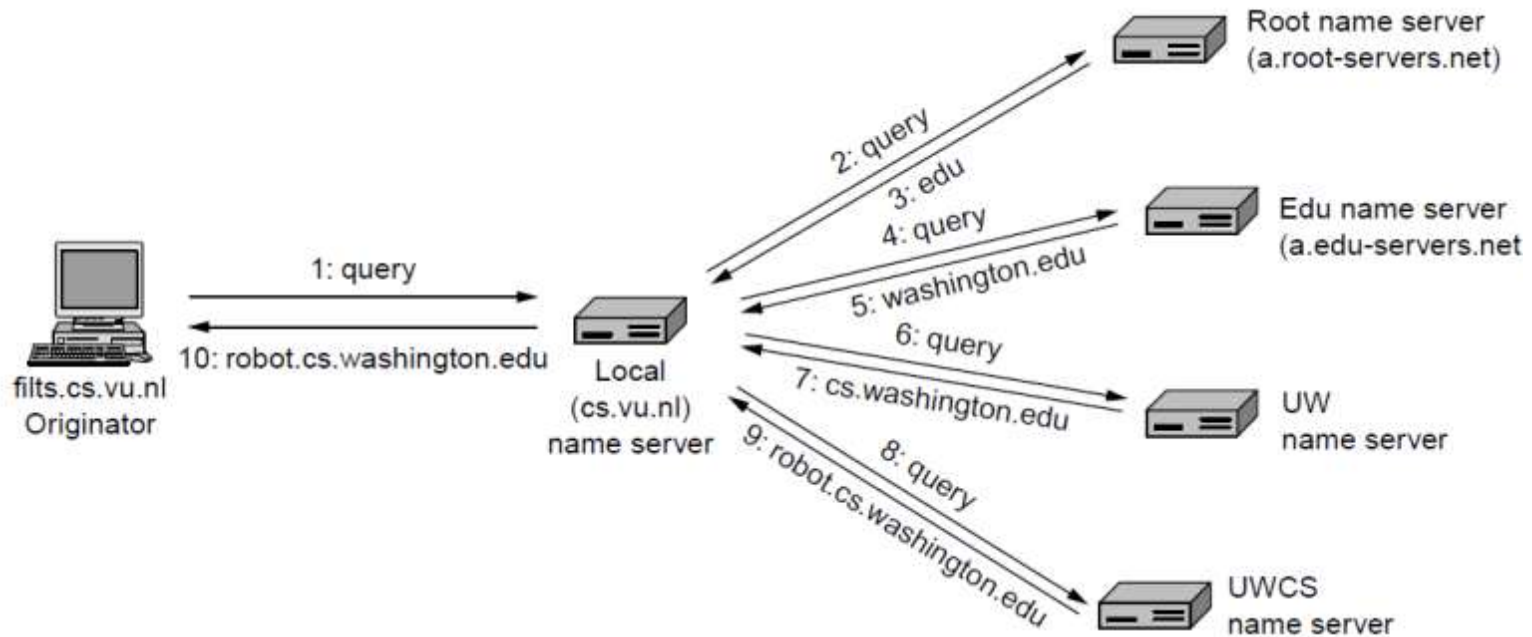


- Step 4/5: edu NS responds with NS for UW
 - Name space divided into non-overlapping zones
 - Zone has a primary name server, 1+ secondary
 - Zone boundaries controlled by domain owner

Name space zones



Name resolution



- Step 6/7: UW NS responds with NS for UWCS
 - UW CS department runs their own DNS server
- Step 8/9: UWCS NS responds with address of robot
 - UWCS NS is the authoritative server
 - The actual DNS record is stored here

Caching

- Recursive queries sufficient to find mapping
 - But expensive, loads root servers
 - Time consuming, incur many RTTs
 - Cache records for certain amount of time (TTL)
- Different levels of caching
 - In the resolver's operating system
 - Local DNS server
 - Can remember steps in the recursive query
 - Go directly to authoritative server for a new hostname at a previous found domain name

Negative caching

- Negative caching
 - Normally DNS cache stores only successful name resolutions
 - But common misspellings can be expensive to lookup
 - Talk to root server and then TLD server before discovering it is a bogus domain name
 - DNS servers can store negative entries and quickly return that name can't be resolved

Cache poisoning

- DNS cache poisoning

- Fool DNS server into entering a non-authoritative entry
- Users get sent to wrong IP address
- Controller of spoofed domain name can:
 - Spread malicious software
 - Steal information
 - e.g. <http://www.wellsfargo.com> now goes a web server running a site very similar to real site... User sees the correct URL in their browser.
- <http://www.youtube.com/watch?v=1d1tUefYn4U>



Example Windows DNS cache

```
Administrator: cmd
c:\source\c\Socket\Release>ipconfig /displaydns

Windows IP Configuration

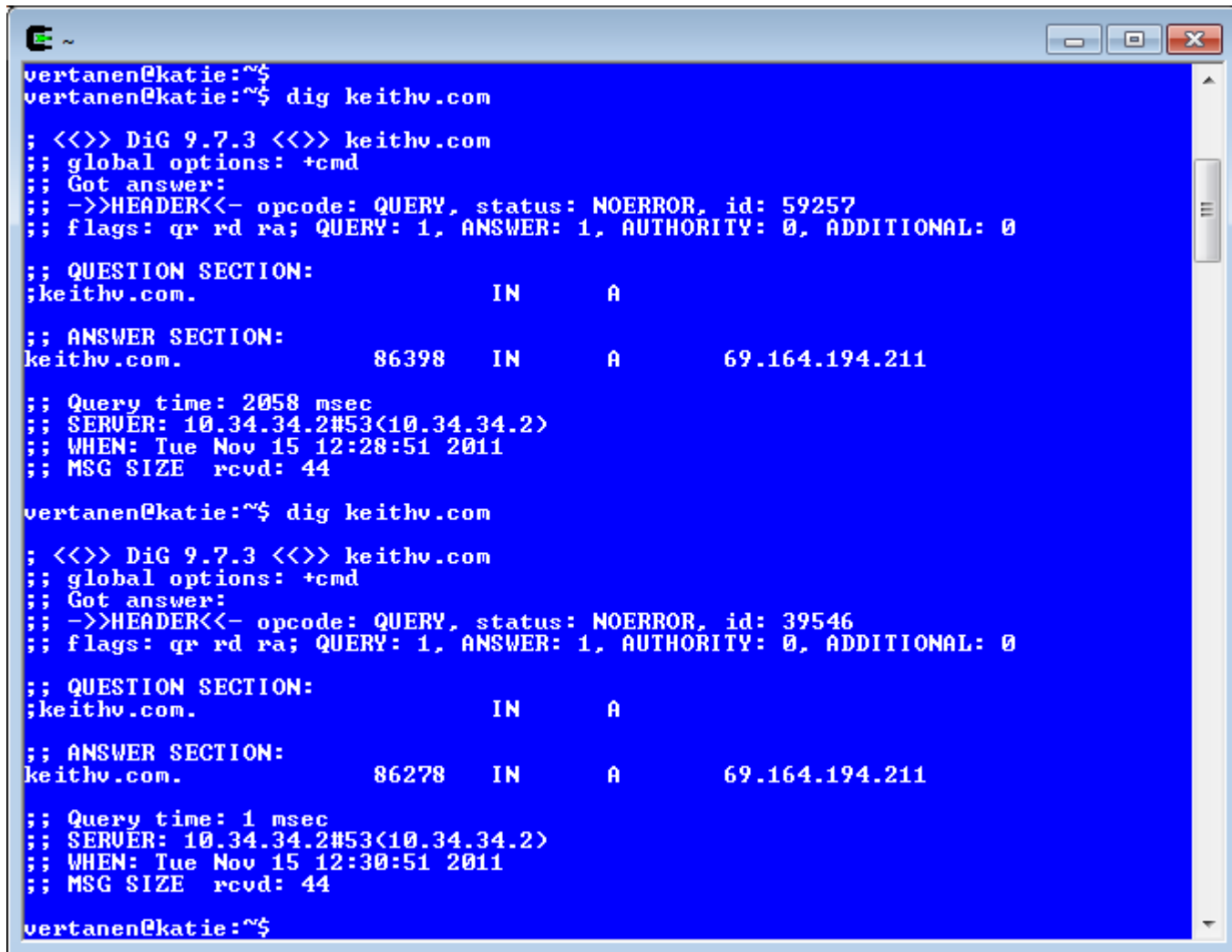
    adx.g.doubleclick.net
    -----
    Record Name . . . . . : adx.g.doubleclick.net
    Record Type . . . . . : 5
    Time To Live . . . . . : 31
    Data Length . . . . . : 8
    Section . . . . . : Answer
    CNAME Record . . . . . : pagead.l.doubleclick.net

    widgets.amung.us
    -----
    Record Name . . . . . : widgets.amung.us
    Record Type . . . . . : 1
    Time To Live . . . . . : 76
    Data Length . . . . . : 4
    Section . . . . . : Answer
    A (Host) Record . . . : 173.192.225.170

    www.keithv.com
    -----
    Record Name . . . . . : www.keithv.com
    Record Type . . . . . : 1
    Time To Live . . . . . : 44062
    Data Length . . . . . : 4
    Section . . . . . : Answer
    A (Host) Record . . . : 69.164.194.211

    Record Name . . . . . : ns2.linode.com
    Record Type . . . . . : 1
    Time To Live . . . . . : 44062
    Data Length . . . . . : 4
    Section . . . . . : Additional
    A (Host) Record . . . : 65.19.178.10
```

Exploring DNS with dig



```
vertanen@katie:~$  
vertanen@katie:~$ dig keithv.com  
  
; <<>> DiG 9.7.3 <<>> keithv.com  
;; global options: +cmd  
;; Got answer:  
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 59257  
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0  
  
;; QUESTION SECTION:  
;keithv.com.                IN      A  
  
;; ANSWER SECTION:  
keithv.com.                 86398   IN      A      69.164.194.211  
  
;; Query time: 2058 msec  
;; SERVER: 10.34.34.2#53(10.34.34.2)  
;; WHEN: Tue Nov 15 12:28:51 2011  
;; MSG SIZE rcvd: 44  
  
vertanen@katie:~$ dig keithv.com  
  
; <<>> DiG 9.7.3 <<>> keithv.com  
;; global options: +cmd  
;; Got answer:  
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 39546  
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0  
  
;; QUESTION SECTION:  
;keithv.com.                IN      A  
  
;; ANSWER SECTION:  
keithv.com.                 86278   IN      A      69.164.194.211  
  
;; Query time: 1 msec  
;; SERVER: 10.34.34.2#53(10.34.34.2)  
;; WHEN: Tue Nov 15 12:30:51 2011  
;; MSG SIZE rcvd: 44  
  
vertanen@katie:~$
```

What the heck?

```
vertanen@katie:~$ dig youtube.com
;; youtube.com.      204      IN      A      173.194.33.47
;; youtube.com.      204      IN      A      173.194.33.32
;; Query time: 2 msec
;; SERVER: 10.34.34.2#53(10.34.34.2)
;; WHEN: Tue Nov 15 13:35:22 2011
;; MSG SIZE rcvd: 285

vertanen@katie:~$ dig bustathief.com
;; <<>> DiG 9.7.3 <<>> bustathief.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<- opcode: QUERY, status: NOERROR, id: 47570
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0
;; QUESTION SECTION:
;; bustathief.com.                IN      A
;; ANSWER SECTION:
bustathief.com.      14400    IN      A      173.236.130.141
;; Query time: 68 msec
;; SERVER: 10.34.34.2#53(10.34.34.2)
;; WHEN: Tue Nov 15 13:35:35 2011
;; MSG SIZE rcvd: 48

vertanen@katie:~$ dig thief.com
;; <<>> DiG 9.7.3 <<>> thief.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<- opcode: QUERY, status: NOERROR, id: 31446
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0
;; QUESTION SECTION:
;; thief.com.                     IN      A
;; ANSWER SECTION:
thief.com.           86398    IN      A      216.218.248.171
;; Query time: 2344 msec
;; SERVER: 10.34.34.2#53(10.34.34.2)
;; WHEN: Tue Nov 15 13:35:45 2011
;; MSG SIZE rcvd: 43

vertanen@katie:~$

kvertanen@li264-110:~$ dig bustathief.com
;; <<>> DiG 9.7.3 <<>> bustathief.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<- opcode: QUERY, status: NOERROR, id: 49288
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0
;; QUESTION SECTION:
;; bustathief.com.                IN      A
;; ANSWER SECTION:
bustathief.com.      14400    IN      A      173.236.130.141
;; Query time: 181 msec
;; SERVER: 109.74.193.20#53(109.74.193.20)
;; WHEN: Tue Nov 15 15:07:17 2011
;; MSG SIZE rcvd: 48

kvertanen@li264-110:~$ dig thief.com
;; <<>> DiG 9.7.3 <<>> thief.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<- opcode: QUERY, status: NOERROR, id: 32839
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 2, ADDITIONAL: 0
;; QUESTION SECTION:
;; thief.com.                     IN      A
;; ANSWER SECTION:
thief.com.           86400    IN      A      216.218.248.171
;; AUTHORITY SECTION:
thief.com.           86400    IN      NS      zone.area.com.
thief.com.           86400    IN      NS      zone.rwx.com.
;; Query time: 260 msec
;; SERVER: 109.74.193.20#53(109.74.193.20)
;; WHEN: Tue Nov 15 15:07:21 2011
;; MSG SIZE rcvd: 90

kvertanen@li264-110:~$
```

```
kvertanen@li264-110:~$  
kvertanen@li264-110:~$ dig keithv.com  
  
; <<>> DiG 9.7.3 <<>> keithv.com  
;; global options: +cmd  
;; Got answer:  
;; ->>HEADER<- opcode: QUERY, status: NOERROR, id: 43485  
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 5, ADDITIONAL: 0  
  
;; QUESTION SECTION:  
;keithv.com.                IN      A  
  
;; ANSWER SECTION:  
keithv.com.                 86400   IN      A      69.164.194.211  
  
;; AUTHORITY SECTION:  
keithv.com.                 86400   IN      NS      ns1.linode.com.  
keithv.com.                 86400   IN      NS      ns4.linode.com.  
keithv.com.                 86400   IN      NS      ns5.linode.com.  
keithv.com.                 86400   IN      NS      ns3.linode.com.  
keithv.com.                 86400   IN      NS      ns2.linode.com.  
  
;; Query time: 127 msec  
;; SERVER: 109.74.193.20#53(109.74.193.20)  
;; WHEN: Tue Nov 15 14:05:33 2011  
;; MSG SIZE rcvd: 141  
  
kvertanen@li264-110:~$ dig keithv.com  
  
; <<>> DiG 9.7.3 <<>> keithv.com  
;; global options: +cmd  
;; Got answer:  
;; ->>HEADER<- opcode: QUERY, status: NOERROR, id: 47487  
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 5, ADDITIONAL: 0  
  
;; QUESTION SECTION:  
;keithv.com.                IN      A  
  
;; ANSWER SECTION:  
keithv.com.                 86391   IN      A      69.164.194.211  
  
;; AUTHORITY SECTION:  
keithv.com.                 86391   IN      NS      ns1.linode.com.  
keithv.com.                 86391   IN      NS      ns4.linode.com.  
keithv.com.                 86391   IN      NS      ns5.linode.com.  
keithv.com.                 86391   IN      NS      ns3.linode.com.  
keithv.com.                 86391   IN      NS      ns2.linode.com.  
  
;; Query time: 0 msec  
;; SERVER: 109.74.193.20#53(109.74.193.20)  
;; WHEN: Tue Nov 15 14:05:42 2011  
;; MSG SIZE rcvd: 141  
  
kvertanen@li264-110:~$
```

```
kvertanen@li264-110:~$ dig +norec keithv.com @a.root-servers.net

; <<>> DiG 9.7.3 <<>> +norec keithv.com @a.root-servers.net
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 43988
;; flags: qr; QUERY: 1, ANSWER: 0, AUTHORITY: 13, ADDITIONAL: 14

;; QUESTION SECTION:
;keithv.com.                IN      A

;; AUTHORITY SECTION:
com.          172800  IN      NS      a.gtld-servers.net.
com.          172800  IN      NS      b.gtld-servers.net.
com.          172800  IN      NS      c.gtld-servers.net.
com.          172800  IN      NS      d.gtld-servers.net.
com.          172800  IN      NS      e.gtld-servers.net.
com.          172800  IN      NS      f.gtld-servers.net.
com.          172800  IN      NS      g.gtld-servers.net.
com.          172800  IN      NS      h.gtld-servers.net.
com.          172800  IN      NS      i.gtld-servers.net.
com.          172800  IN      NS      j.gtld-servers.net.
com.          172800  IN      NS      k.gtld-servers.net.
com.          172800  IN      NS      l.gtld-servers.net.
com.          172800  IN      NS      m.gtld-servers.net.

;; ADDITIONAL SECTION:
a.gtld-servers.net. 172800  IN      AAAA    2001:503:a83e::2:30
a.gtld-servers.net. 172800  IN      A       192.5.6.30
b.gtld-servers.net. 172800  IN      AAAA    2001:503:231d::2:30
b.gtld-servers.net. 172800  IN      A       192.33.14.30
c.gtld-servers.net. 172800  IN      A       192.26.92.30
d.gtld-servers.net. 172800  IN      A       192.31.80.30
e.gtld-servers.net. 172800  IN      A       192.12.94.30
f.gtld-servers.net. 172800  IN      A       192.35.51.30
g.gtld-servers.net. 172800  IN      A       192.42.93.30
h.gtld-servers.net. 172800  IN      A       192.54.112.30
i.gtld-servers.net. 172800  IN      A       192.43.172.30
j.gtld-servers.net. 172800  IN      A       192.48.79.30
k.gtld-servers.net. 172800  IN      A       192.52.178.30
l.gtld-servers.net. 172800  IN      A       192.41.162.30

;; Query time: 18 msec
;; SERVER: 198.41.0.4#53(198.41.0.4)
;; WHEN: Tue Nov 15 14:13:12 2011
;; MSG SIZE rcvd: 500

kvertanen@li264-110:~$
```

```
kvertanen@li264-110:~$ dig +norec keithv.com @k.gtld-servers.net

;; <<>> DiG 9.7.3 <<>> +norec keithv.com @k.gtld-servers.net
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 58455
;; flags: qr; QUERY: 1, ANSWER: 0, AUTHORITY: 4, ADDITIONAL: 7

;; QUESTION SECTION:
;keithv.com.                IN      A

;; AUTHORITY SECTION:
keithv.com.                 172800  IN      NS      ns1.linode.com.
keithv.com.                 172800  IN      NS      ns2.linode.com.
keithv.com.                 172800  IN      NS      ns3.linode.com.
keithv.com.                 172800  IN      NS      ns4.linode.com.

;; ADDITIONAL SECTION:
ns1.linode.com.             172800  IN      AAAA    2600:3c00::a
ns1.linode.com.             172800  IN      A       69.93.127.10
ns2.linode.com.             172800  IN      AAAA    2600:3c01::a
ns2.linode.com.             172800  IN      A       65.19.178.10
ns3.linode.com.             172800  IN      A       75.127.96.10
ns4.linode.com.             172800  IN      A       207.192.70.10
ns4.linode.com.             172800  IN      AAAA    2600:3c03::a

;; Query time: 16 msec
;; SERVER: 192.52.178.30#53(192.52.178.30)
;; WHEN: Tue Nov 15 14:12:32 2011
;; MSG SIZE rcvd: 255

kvertanen@li264-110:~$
kvertanen@li264-110:~$
kvertanen@li264-110:~$
kvertanen@li264-110:~$
kvertanen@li264-110:~$
kvertanen@li264-110:~$
kvertanen@li264-110:~$
```

```
kvertanen@li264-110:~$ dig +norec keithv.com @ns3.linode.com

;; <<>> DiG 9.7.3 <<>> +norec keithv.com @ns3.linode.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 38338
;; flags: qr aa; QUERY: 1, ANSWER: 1, AUTHORITY: 5, ADDITIONAL: 8

;; QUESTION SECTION:
;keithv.com.                IN      A

;; ANSWER SECTION:
keithv.com.                 86400   IN      A           69.164.194.211

;; AUTHORITY SECTION:
keithv.com.                 86400   IN      NS           ns1.linode.com.
keithv.com.                 86400   IN      NS           ns5.linode.com.
keithv.com.                 86400   IN      NS           ns4.linode.com.
keithv.com.                 86400   IN      NS           ns2.linode.com.
keithv.com.                 86400   IN      NS           ns3.linode.com.

;; ADDITIONAL SECTION:
ns1.linode.com.             86400   IN      A           69.93.127.10
ns1.linode.com.             86400   IN      AAAA        2600:3c00::a
ns2.linode.com.             86400   IN      A           65.19.178.10
ns2.linode.com.             86400   IN      AAAA        2600:3c01::a
ns3.linode.com.             86400   IN      A           75.127.96.10
ns4.linode.com.             86400   IN      A           207.192.70.10
ns4.linode.com.             86400   IN      AAAA        2600:3c03::a
ns5.linode.com.             86400   IN      A           109.74.194.10

;; Query time: 94 msec
;; SERVER: 75.127.96.10#53(75.127.96.10)
;; WHEN: Tue Nov 15 14:11:19 2011
;; MSG SIZE rcvd: 305

kvertanen@li264-110:~$
kvertanen@li264-110:~$
```

Summary

- Domain Name System (DNS)
 - Global distributed database
 - Maps human friendly names to IP addresses
 - Critical for the functioning of the Internet
 - DNS resolution multistep process involving:
 - Root servers, top-level domain servers, authoritative servers
 - Caching to improve performance