CS4700/CS5700 Fundamentals of Computer Networks

Lecture 17: Domain Name System

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Human Involvement

- Just like your friend needs to tell you his phone number for you to call him
- Somehow, an application needs to know the IP address of the communication peer
- There is no magic, some out-of-band mechanism is needed
  - Word of mouth
  - Read it in the advertisement in the paper
  - Etc.
- But IP addresses are bad for humans to remember and tell each other
- So need names that makes some sense to humans

Internet Names & Addresses

- Names: *e.g. www.rice.edu*
  - human-usable labels for machines
  - conforms to “organizational” structure
- Addresses: *e.g. 128.42.247.150*
  - router-usable labels for machines
  - conforms to “network” structure
- How do you map from one to another?
  - Domain Name System (DNS)

DNS: History

- Initially all host-addess mappings were in a file called hosts.txt (in /etc/hosts)
  - Changes were submitted to SRI by email
  - New versions of hosts.txt ftp'd periodically from SRI
  - An administrator could pick names at their discretion
  - Any name is allowed: eugenesdesktopatrice

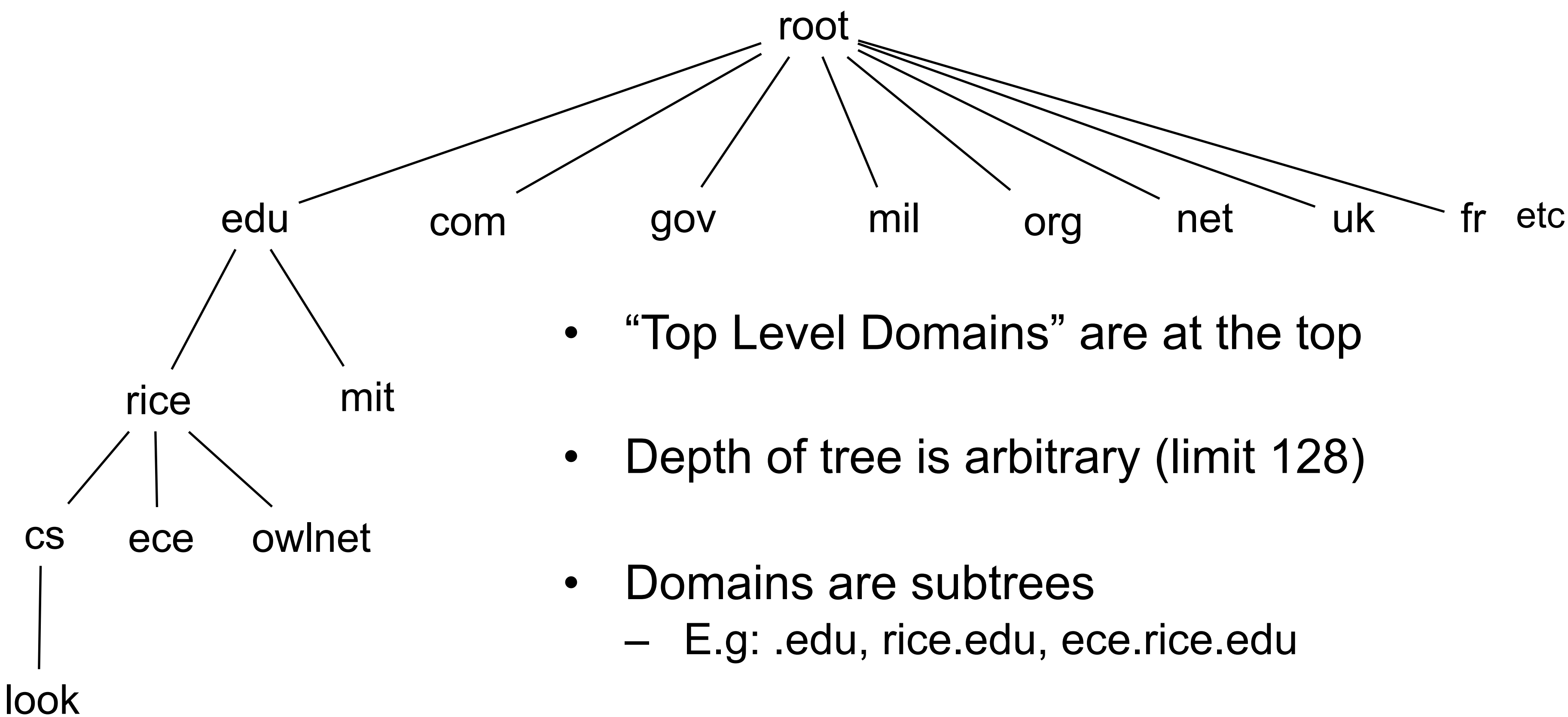
- As the Internet grew this system broke down because:
  - SRI couldn't handled the load
  - Hard to enforce uniqueness of names
  - Many hosts had inaccurate copies of hosts.txt

- Domain Name System (DNS) was born

Basic DNS Features

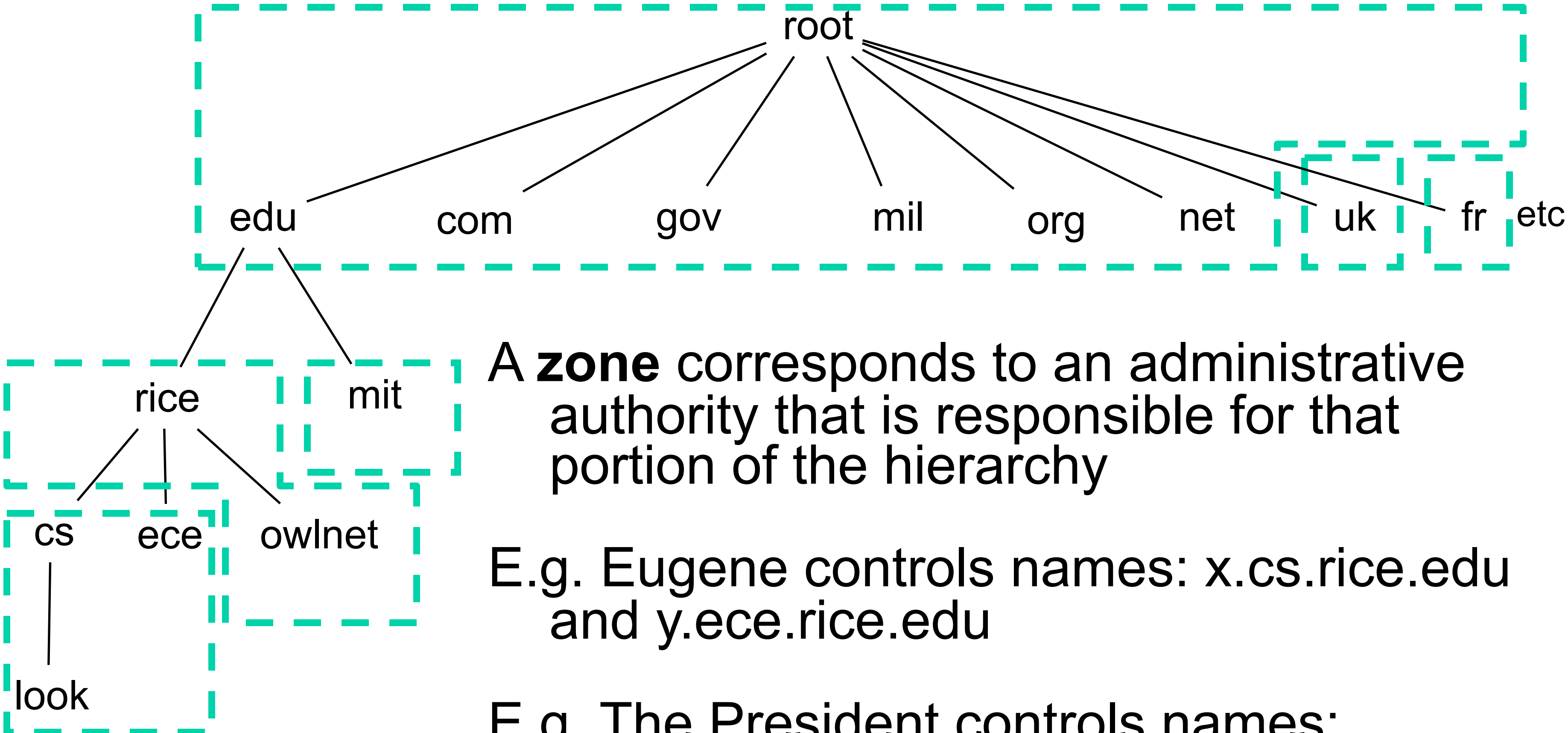
- Hierarchical namespace
  - as opposed to original flat namespace
- Distributed storage architecture
  - as opposed to centralized storage (plus replication)
- Client--server interaction on UDP Port 53
  - but can use TCP if desired

Naming Hierarchy



- "Top Level Domains" are at the top
- Depth of tree is arbitrary (limit 128)
- Domains are subtrees
  - E.g: .edu, rice.edu, ece.rice.edu
- Name collisions avoided
  - E.g. rice.edu and rice.com can coexist, but uniqueness is job of domain

Host names are administered hierarchically



A **zone** corresponds to an administrative authority that is responsible for that portion of the hierarchy

E.g. Eugene controls names: x.cs.rice.edu and y.ece.rice.edu

E.g. The President controls names: x.rice.edu and y.owlnet.rice.edu

Server Hierarchy

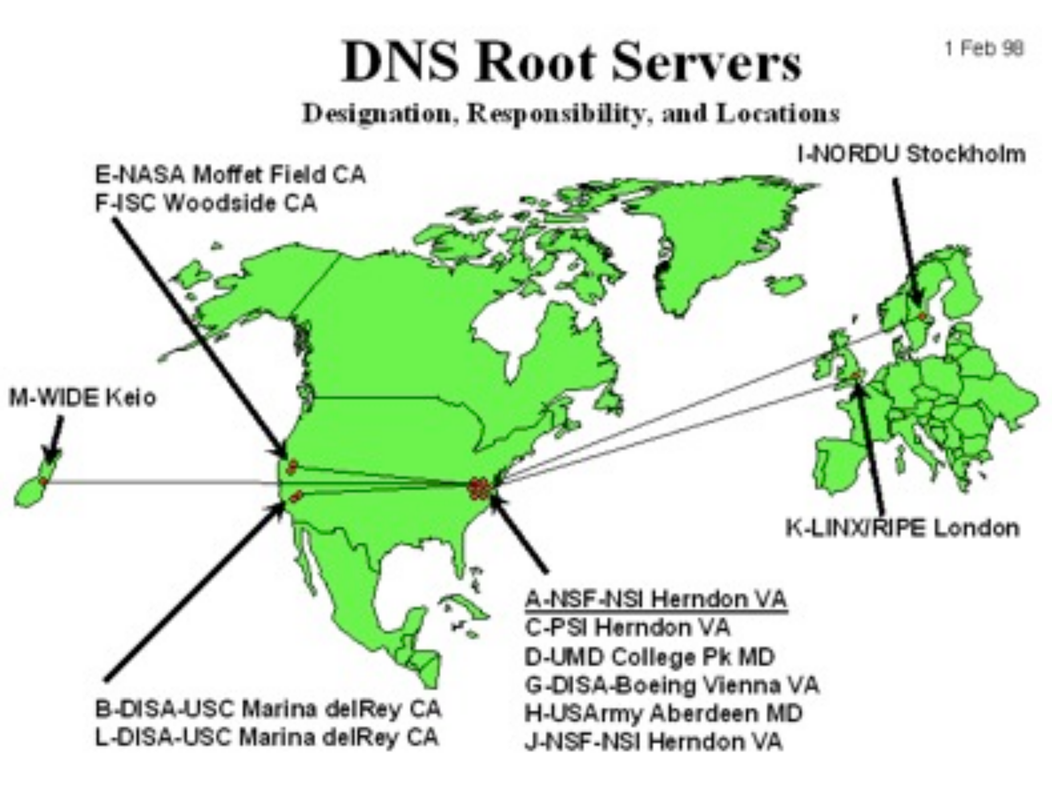
- Each server has authority over a portion of the hierarchy
  - A server maintains only a subset of all names
- Each server contains all the records for the hosts or domains in its zone
  - might be replicated for robustness
- Every server knows the root
- Root server knows about all top-level domains

DNS Name Servers

- Local name servers:
  - Each ISP (company) has local default name server
  - Host DNS query first goes to local name server
  - Local DNS server IP address usually learned from DHCP
  - Frequently cache query results
- Authoritative name servers:
  - For a host: stores that host's (name, IP address)
  - Can perform name/address translation for that host's name

DNS: Root Name Servers

- Contacted by local name server that can not resolve name
- Root name server:
  - Contacts authoritative name server if name mapping not known
  - Gets mapping
  - Returns mapping to local name server
- ~ Dozen root name servers worldwide



Basic Domain Name Resolution

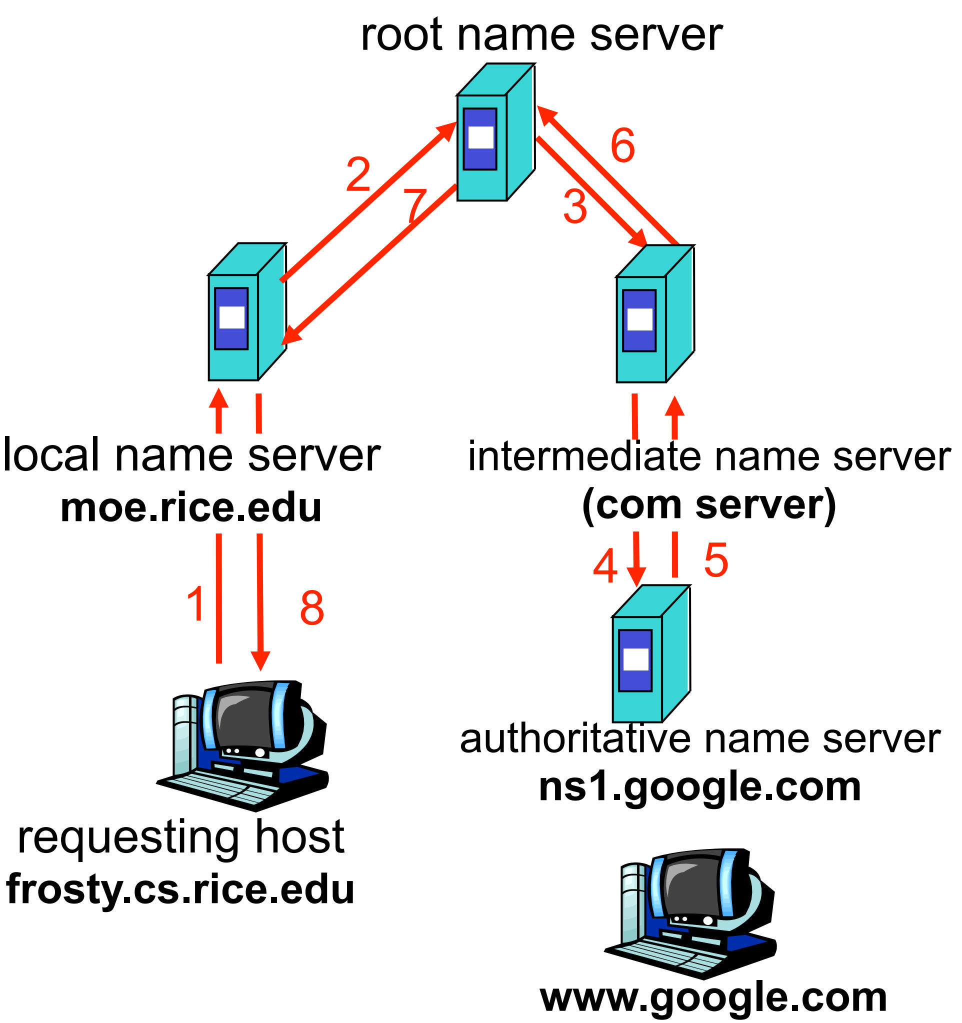
- Every host knows a local DNS server
  - Through DHCP, for example
  - Sends all queries to a local DNS server
- Every local DNS server knows the ROOT servers
  - When no locally cached information exists about the query, talk to a root server, and go down the name hierarchy from the root
  - If we lookup www.rice.edu, and we have a cached entry for the .edu name server, then we can go directly to the .edu name server and bypass the root server

Example of Recursive DNS Query

Root name server:
- May not know authoritative name server
- May know intermediate name server: who to contact to find authoritative name server?

Recursive query:
- Puts burden of name resolution on contacted name server
- Heavy load?

How does moe knows reply #7 is for frosty?



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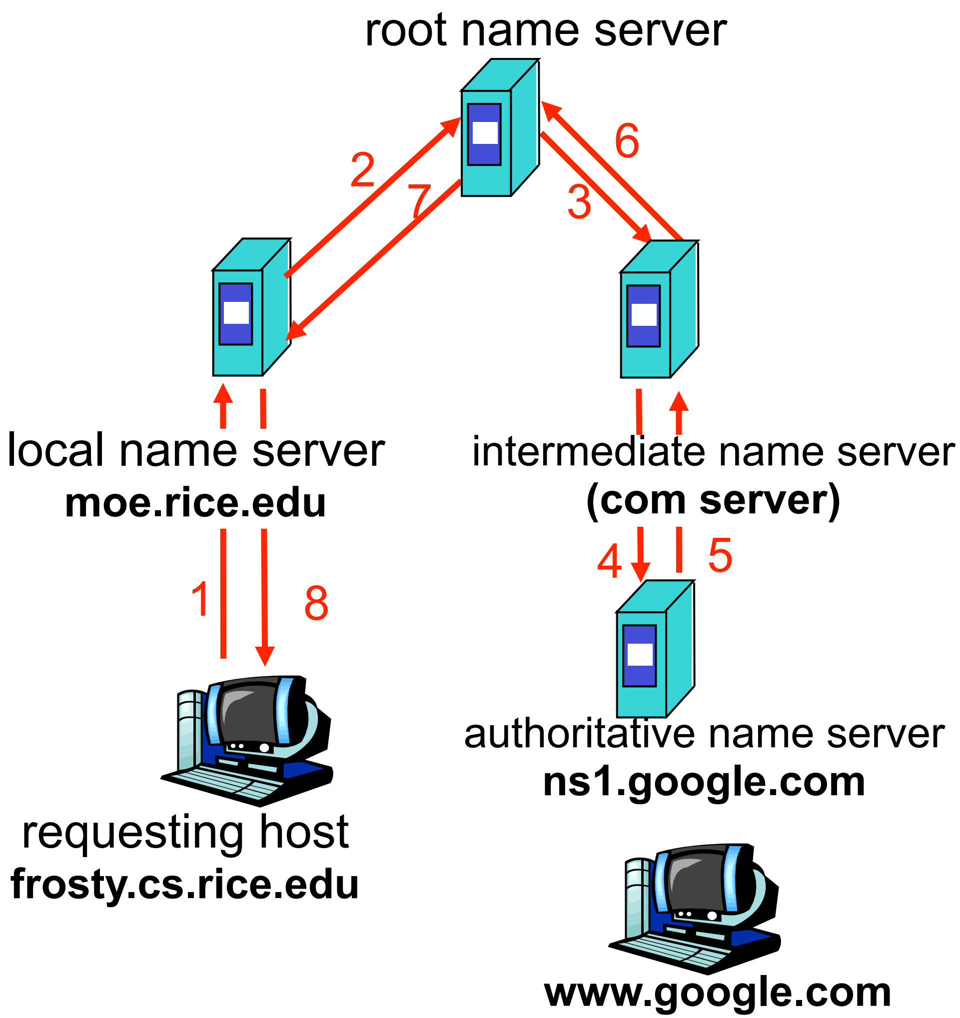
Randomly choose an ID and use in all related messages to match replies to original queries

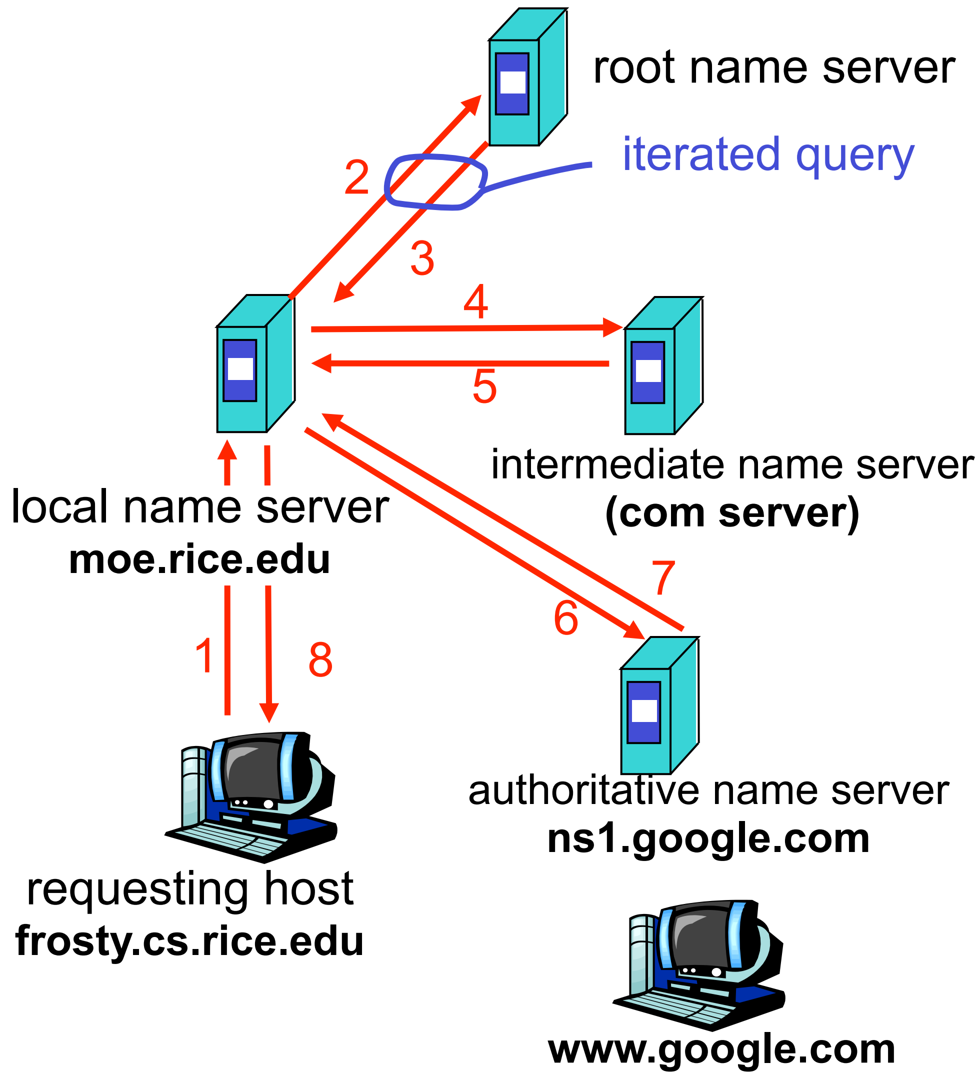


Example of Iterated DNS Query

Iterated query:

- Contacted server replies with name of server to contact
- "I don't know this name, but ask this server"

This is how today's DNS system behaves



DNS Resource Records

- DNS Query:
  - Two fields: (name, type)

- Resource record is the response to a query
  - Four fields: (name, value, type, TTL)
  - There can be multiple valid responses to a query

- Type = A:
  - name = hostname
  - value = IP address

DNS Resource Records (cont'd)

- Type = NS:
  - name = domain
  - value = name of dns server for domain
- Type = CNAME:
  - name = hostname
  - value = canonical name
- Type = MX:
  - name = domain in email address
  - value = canonical name of mail server and priority

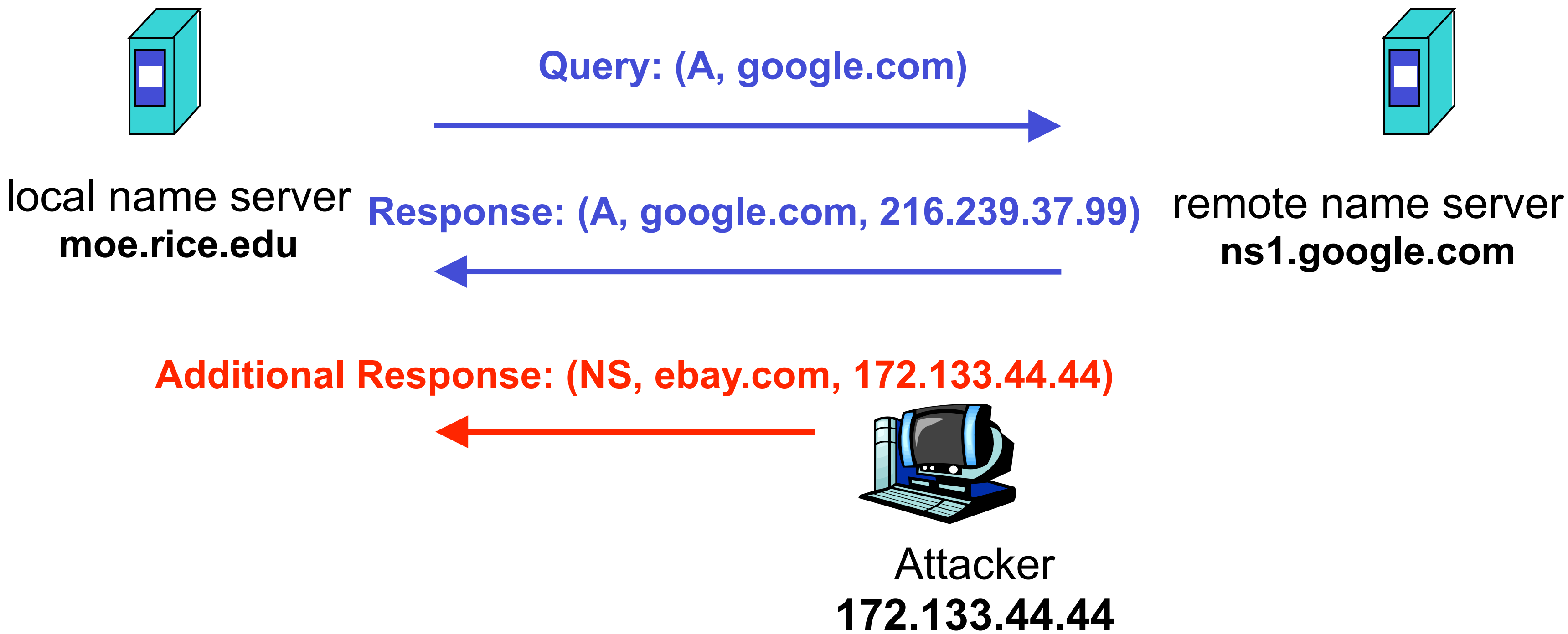
DNS as Indirection Service

- Can refer to machines by name, not address
  - Not only easier for humans
  - Also allows machines to change IP addresses without having to change way you refer to machine
- Can refer to machines by alias
  - www.rice.edu can be generic web server
  - But DNS can point this to particular machine that can change over time
- Can refer to a set of machines by alias
  - Return IP address of least-loaded server

DNS Security

- Man-in-the-middle
- Spoofing responses
  - eavesdrop on requests and race the real DNS server to respond
- Name Chaining
  - AKA cache poisoning
  - Attacker waits for a query, injects possibly unrelated response resource record (frequently NS or CNAME record)
  - Bogus record is cached for later use

Cache Poisoning Attack



- Until the TTL expires, queries to moe.rice.edu for ebay.com's nameserver will return the poison entry from the cache

Solution: DNSSEC

- Cryptographically sign critical resource records
  - Resolver can verify the cryptographic signature

- Two New resource record type:

- Type = KEY:
  - name = Zone domain name
  - value = Public key for the zone

- Type = SIG:
  - name = (type, name) tuple (i.e. a query)
  - value = Cryptographic signature of query result

Security 2: Denial of Service

- Caching can mitigate the effect of a large-scale denial of service attack
- October 2002: root name servers subjected to massive DoS attack
  - By and large, users didn't notice
  - Locally cached records used
- More directed denial of service can be effective
  - DoS local name server → cannot access DNS
  - DoS authoritative names server → cannot access domain

Special Topics

- DNS caching
  - Improve performance by saving results of previous lookups
  - E.g. results of address records and name server records (e.g. if .edu name server is cached, then can bypass root server the second time looking for a .edu host)
- DNS “hacks”
  - Return records based on requesting IP address
  - Round-robin DNS
- Dynamic DNS
  - Allows remote updating of IP address for mobile hosts
- DNS politics (ICANN) and branding battles

More Special Topics

- Suppose you want your own top-level domain…
- AlterNIC, OpenNIC et al.
  - “Alternative” DNS hierarchies, with their own top-level domains
    - (.glue, .geek, .fur, .indy, …)
  - Can return results from the “regular” DNS hierarchy where there is no collision
    - (.biz)