CSCI-351
DATA COMMUNICATION AND NETWORKS

Lecture 12: DNS

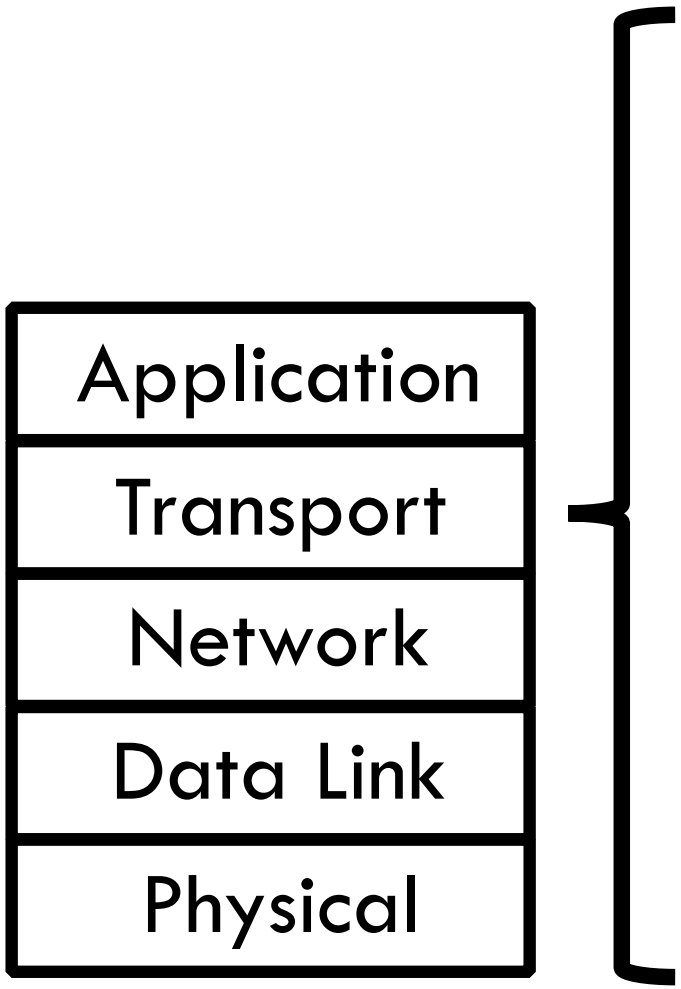
The slide is built with the help of Prof. Alan Mislove, Christo Wilson, and David Choffnes's class

Quiz solution

2

Transport Layer?

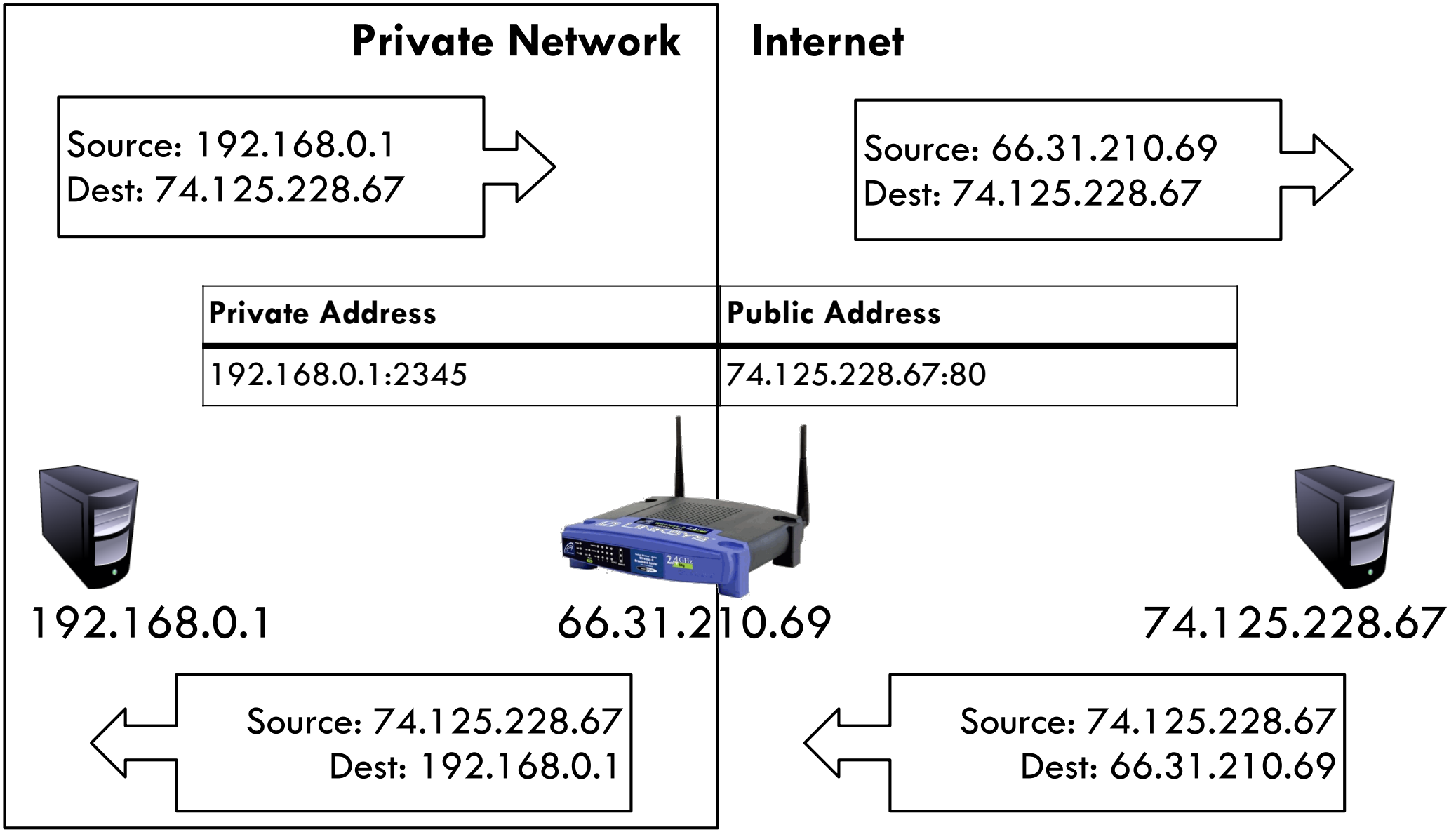
- Project 2 will be announced



The IPv4 Shortage

- Problem: consumer ISPs typically only give one IP address per-household
  - Additional IPs cost extra
  - More IPs may not be available
- NAT and DHCP

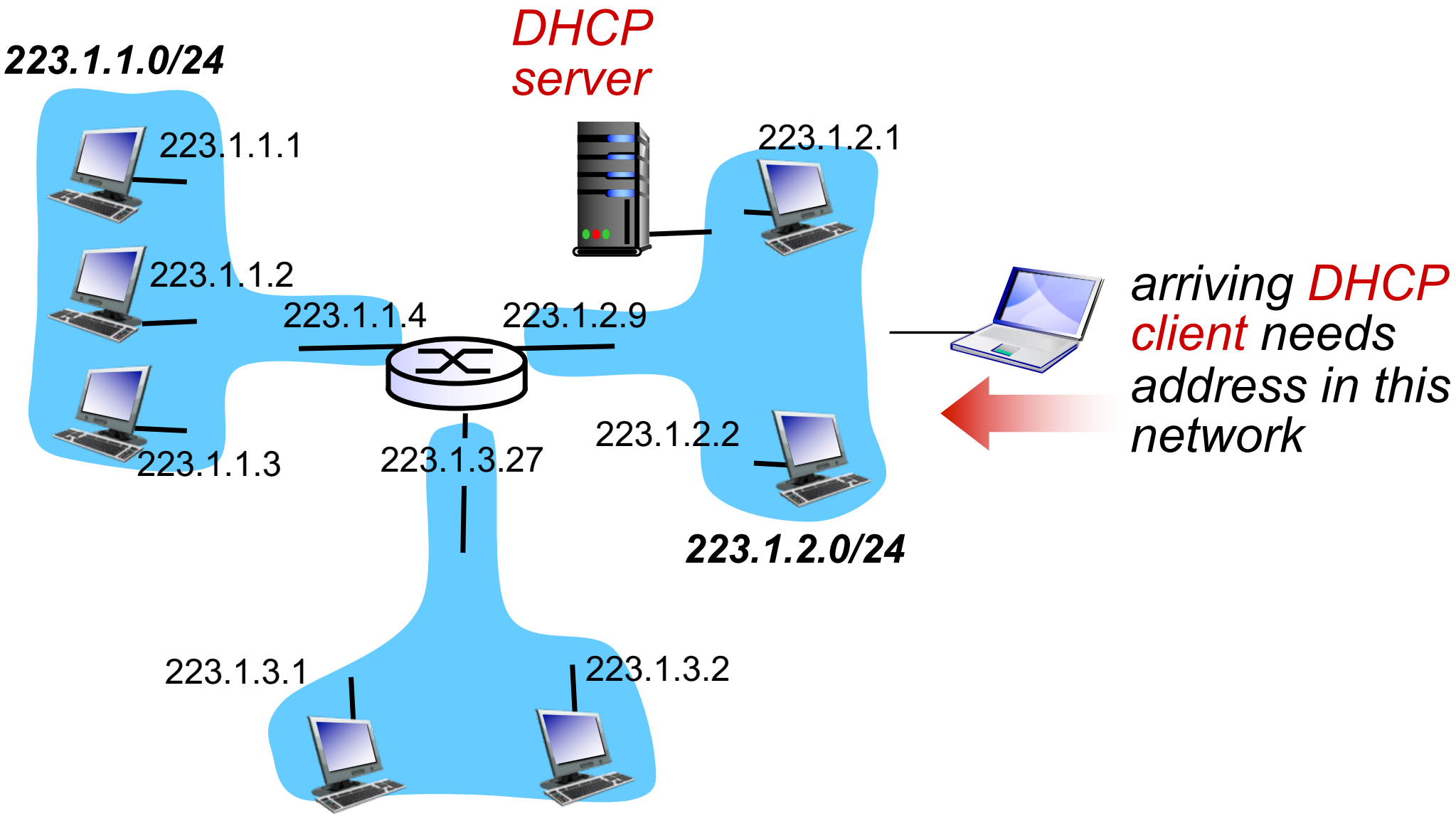
Basic NAT Operation



DHCP: Dynamic Host Configuration Protocol

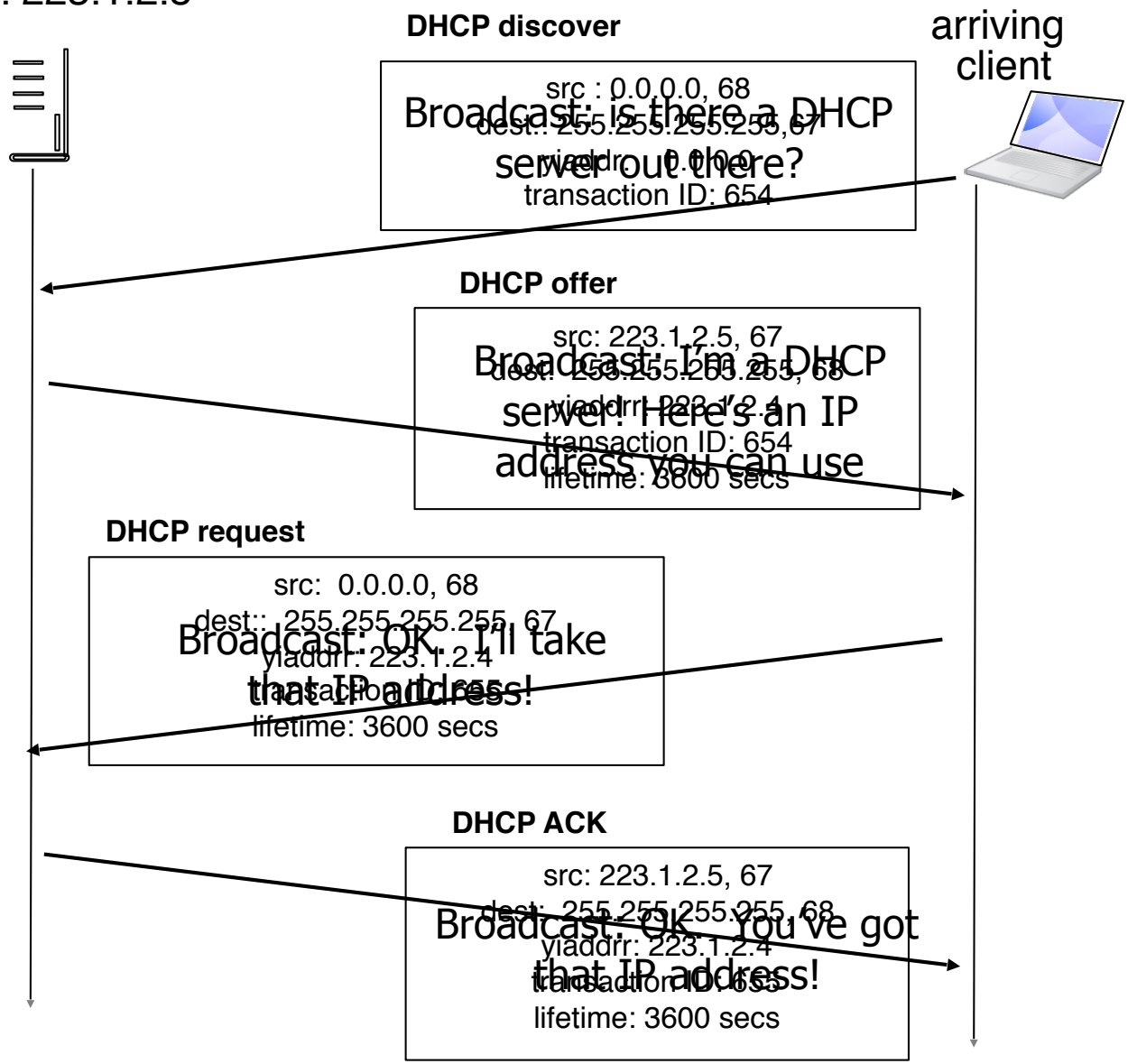
- Let's say that a ISP has X customers, How many IPs does it need to have?
  - X?
- Goal: allow host to *dynamically* obtain its IP address from network server when it joins network
  - can renew its lease on address in use
  - allows reuse of addresses (only hold address while connected/"on")
  - support for mobile users who want to join network (more shortly)

DHCP Client-Server



DHCP Client-Server

DHCP server: 223.1.2.5



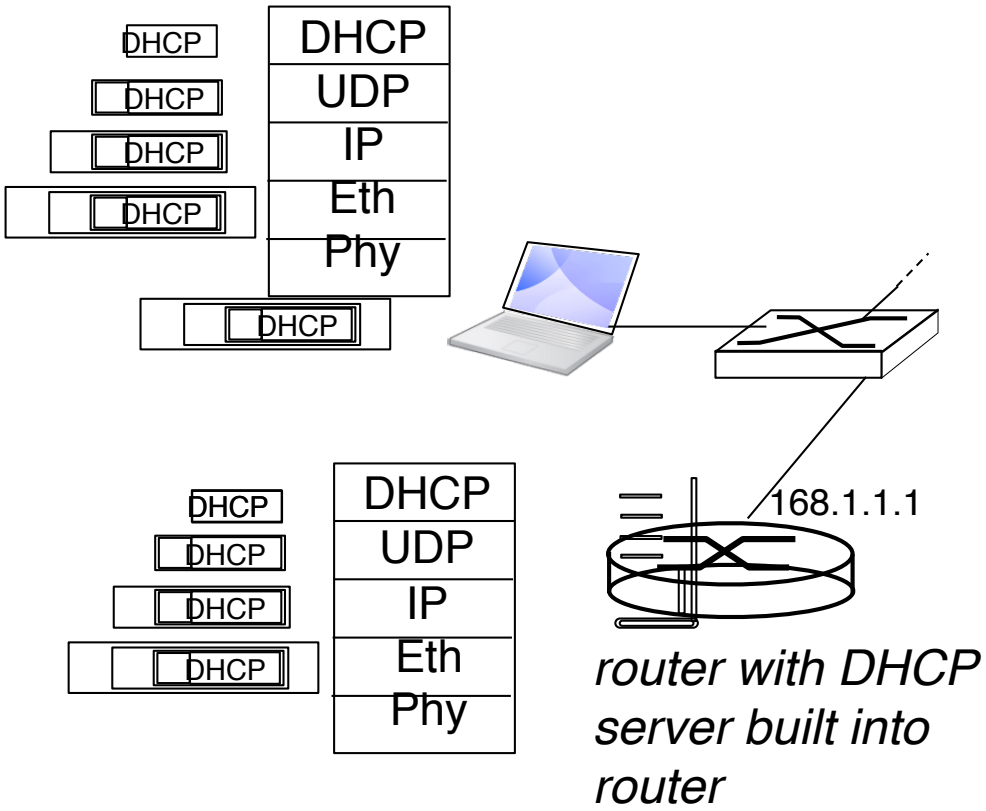
DHCP: More than IP address

- DHCP can return more than just allocated IP address on subnet
  - address of first-hop router for client
  - name and IP address of DNS sever
  - network mask (indicating network versus host portion of address)

DHCP Header (Do not memorize)

Dynamic Host Configuration Protocol				
Bit Offset	0–15		16–31	
0	OpCode	Hardware Type	Hardware Length	Hops
32	Transaction ID			
64	Seconds Elapsed		Flags	
96	Client IP Address			
128	Your IP Address			
160	Server IP Address			
196	Gateway IP Address			
228+	Client Hardware Address (16 bytes)			
	Server Host Name (64 bytes)			
	Boot File (128 bytes)			
	Options			

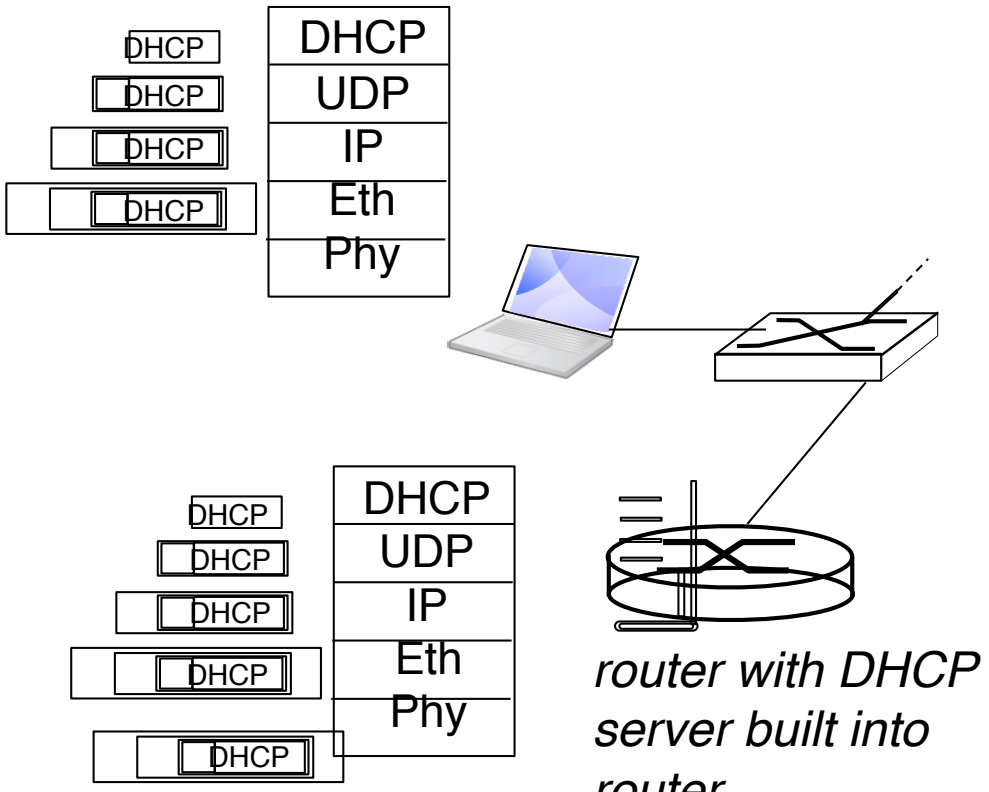
DHCP: example



router with DHCP server built into router

- connecting laptop needs its IP address, addr of first-hop router, addr of DNS server: use DHCP
- DHCP request encapsulated in UDP, encapsulated in IP, encapsulated in 802.1 Ethernet
- Ethernet frame broadcast (dest: FFFFFFFFFFFF) on LAN, received at router running DHCP server
- Ethernet demuxed to IP demuxed, UDP demuxed to DHCP

DHCP: example



router with DHCP server built into router

- DCP server formulates DHCP ACK containing client's IP address, IP address of first-hop router for client, name & IP address of DNS server
- encapsulation of DHCP server, frame forwarded to client, demuxing up to DHCP at client
- client now knows its IP address, name and IP address of DSN server, IP address of its first-hop router

CSCI-351
DATA COMMUNICATION AND NETWORKS

Lecture 12: DNS

The slide is built with the help of Prof. Alan Mislove, Christo Wilson, and David Choffnes's class

Layer 8 (The Carbon-based nodes)

- If you want to…
  - Call someone, you need to ask for their phone number
    - You can't just dial "P R O F C H U N G"
  - Mail someone, you need to get their address first
- What about the Internet?
  - If you need to reach Google, you need their IP
  - Does anyone know Google's IP?
- Problem:
  - People can't remember IP addresses
  - Need human readable names that map to IPs

Internet Names and Addresses

- Addresses, e.g. 129.10.117.100
  - Computer usable labels for machines
  - Conform to structure of the network
- Names, e.g. www.rit.edu
  - Human usable labels for machines
  - Conform to organizational structure
- How do you map from one to the other?
  - Domain Name System (DNS)

History

- Before DNS, all mappings were in *hosts.txt*
  - */etc/hosts* on Linux
  - C:*Windows**System32**drivers**etc**hosts* on Windows
- Centralized, manual system
  - Changes were submitted to SRI via email
  - Machines periodically FTP new copies of *hosts.txt*
  - Administrators could pick names at their discretion
  - Any name was allowed
    - tijay_server_at_rit_pwns_joo_lol_kthxbye

Towards DNS

- Eventually, the *hosts.txt* system fell apart
  - Not scalable, SRI couldn't handle the load
  - Hard to enforce uniqueness of names
    - e.g RIT
      - Rochester Institute of Technology?
      - Revolution in Training (US Navy)
  - Many machines had inaccurate copies of *hosts.txt*
- Thus, DNS was born

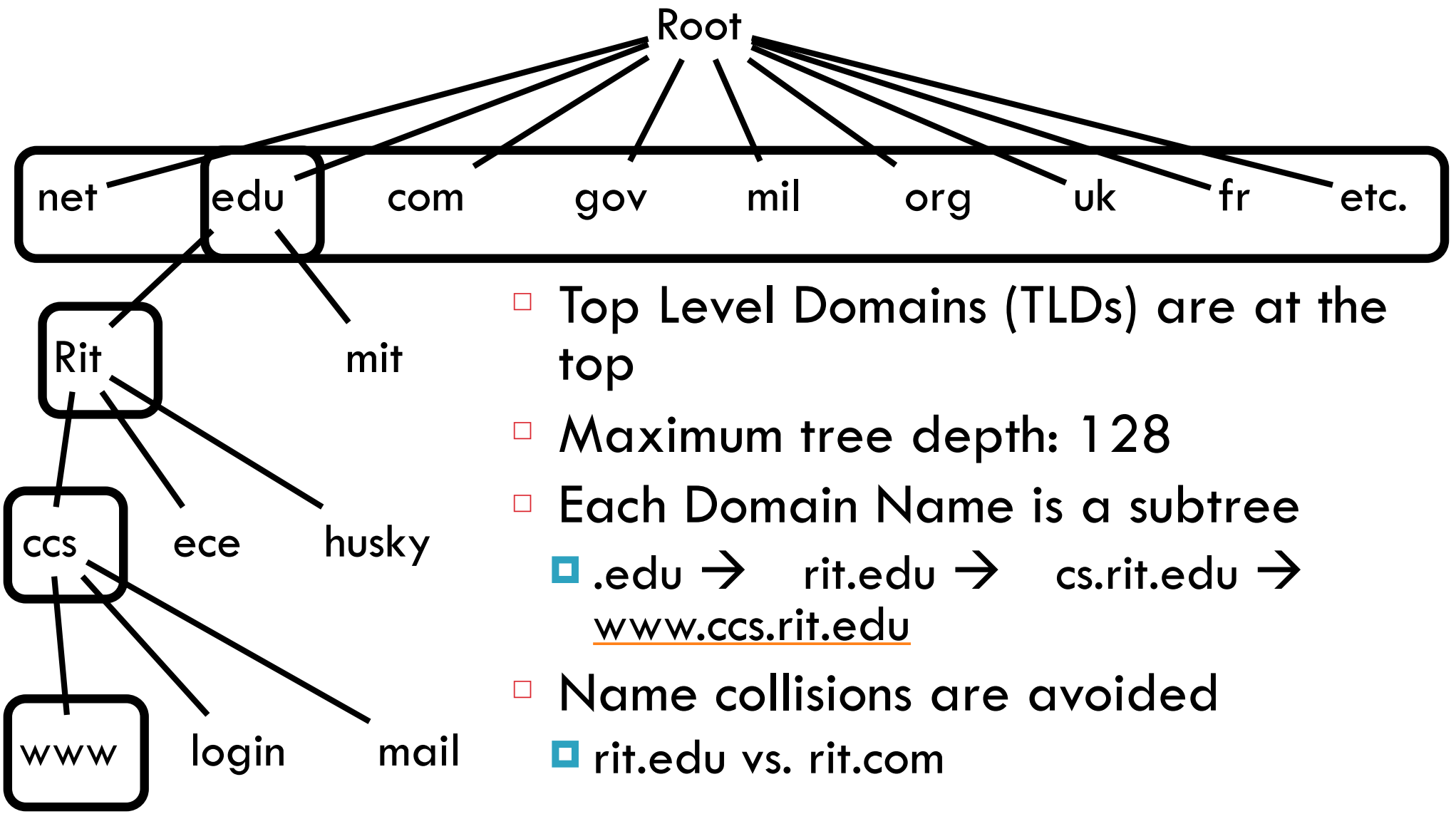
Outline

- DNS Basics
- DNS Security

DNS at a High-Level

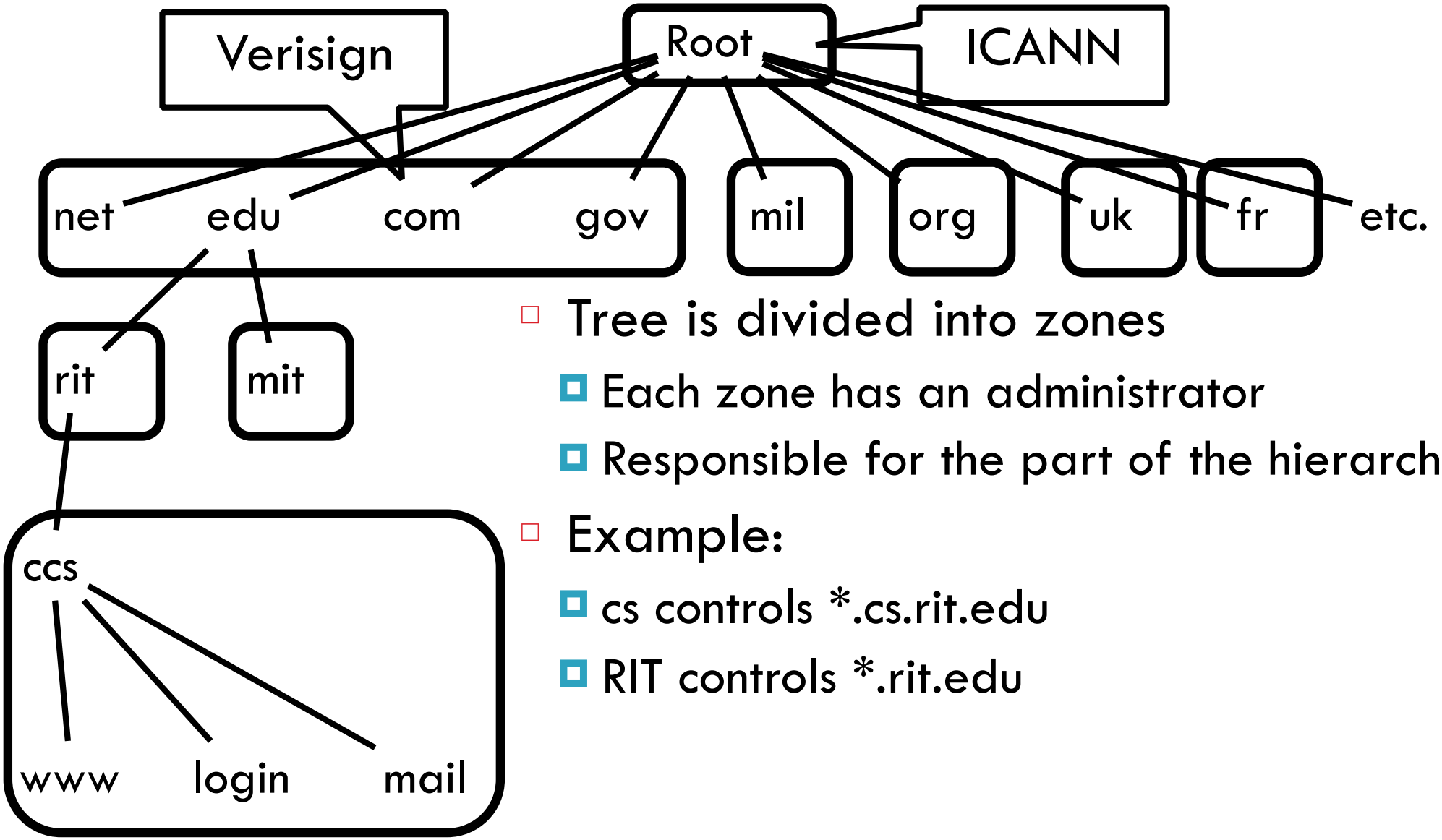
- Domain Name System
- Distributed database
  - No centralization
- Simple client/server architecture
  - UDP port 53, some implementations also use TCP
  - Why?
- Hierarchical namespace
  - As opposed to original, flat namespace
  - e.g. .com → google.com → mail.google.com

Naming Hierarchy



- Top Level Domains (TLDs) are at the top
- Maximum tree depth: 128
- Each Domain Name is a subtree
  - .edu → rit.edu → cs.rit.edu → www.ccs.rit.edu
- Name collisions are avoided
  - rit.edu vs. rit.com

Hierarchical Administration



- Tree is divided into zones
  - Each zone has an administrator
  - Responsible for the part of the hierarchy
- Example:
  - cs controls *.cs.rit.edu
  - RIT controls *.rit.edu

Server Hierarchy

- Functions of each DNS server:
  - Authority over a portion of the hierarchy
    - No need to store all DNS names
  - Store all the records for hosts/domains in its zone
    - May be replicated for robustness
  - Know the addresses of the root servers
    - Resolve queries for unknown names
- Root servers know about all TLDs
  - The buck stops at the root servers

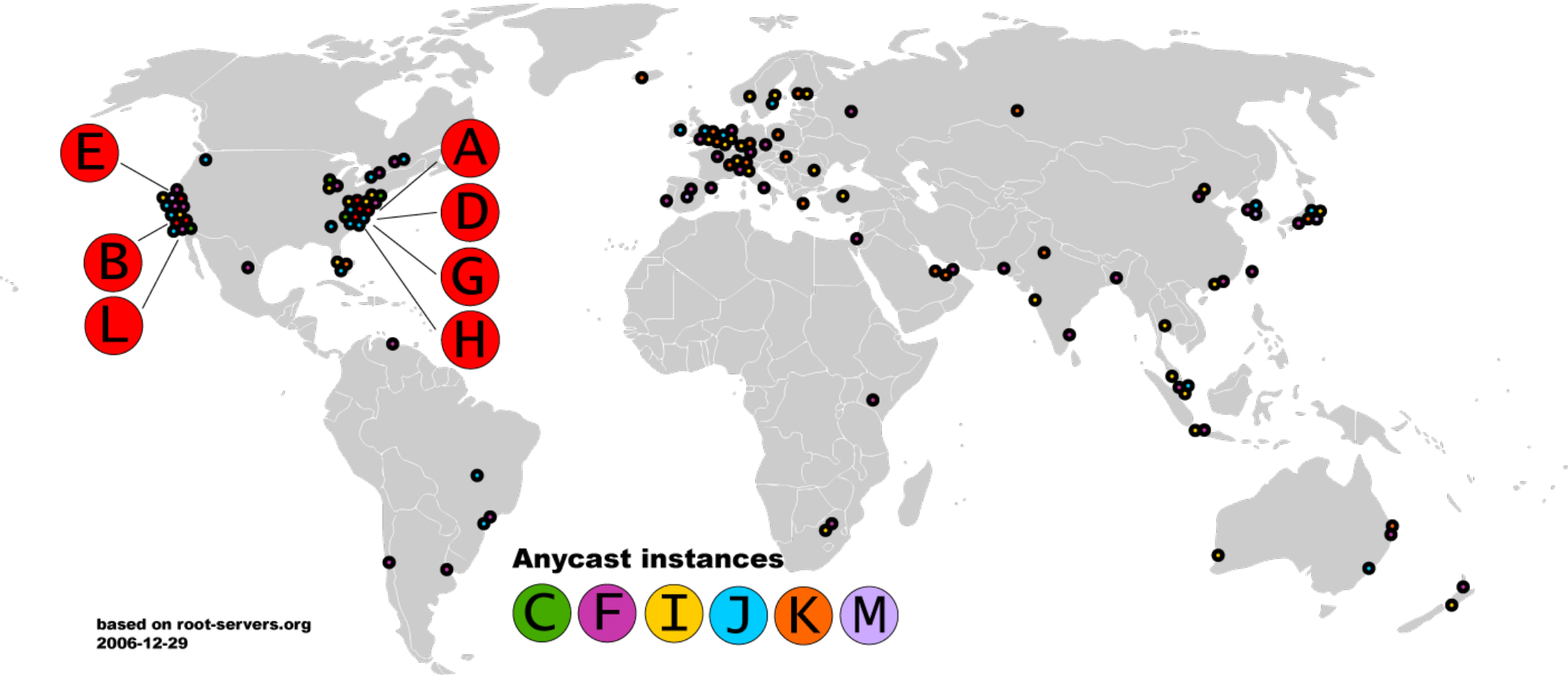
Root Name Servers

- Responsible for the Root Zone File
  - Lists the TLDs and who controls them
  - ~272KB in size

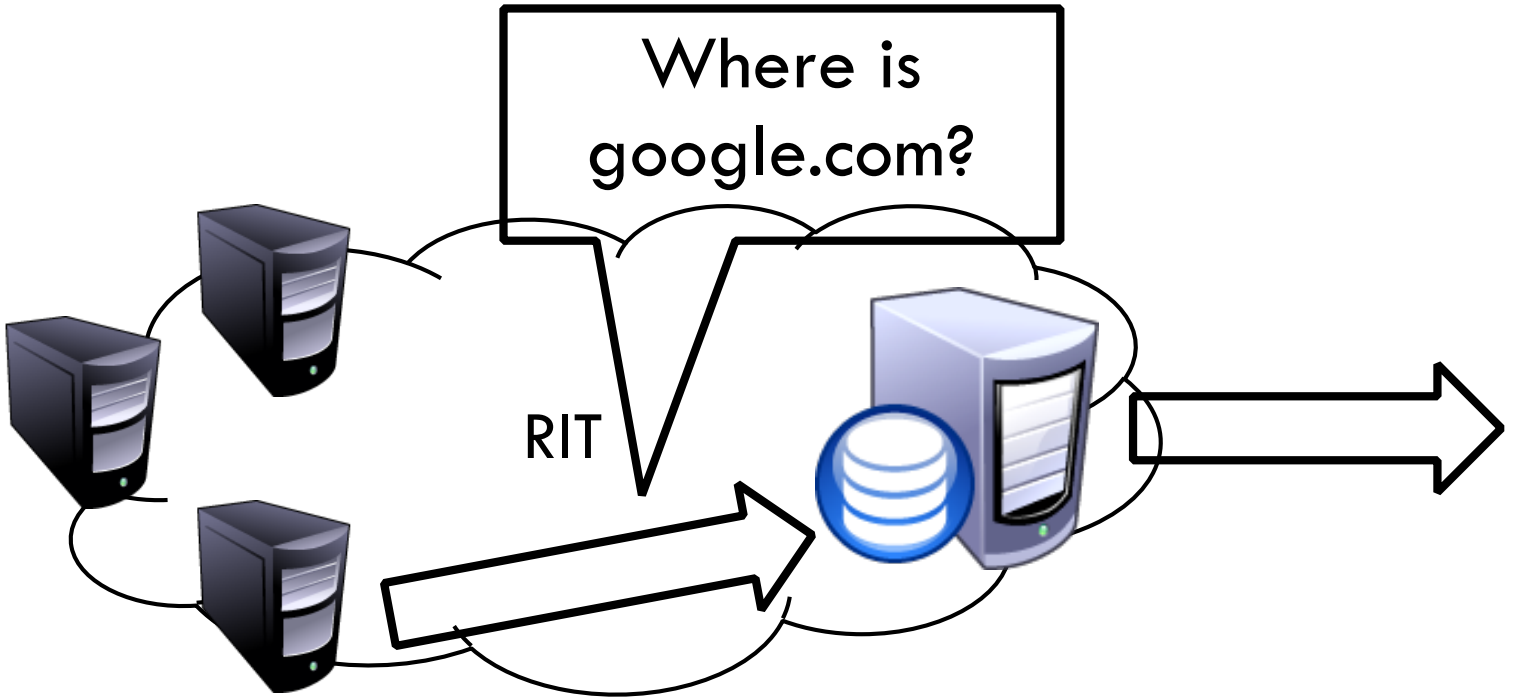
com.	172800	IN	NS	a.gtld-servers.net.
com.	172800	IN	NS	b.gtld-servers.net.
com.	172800	IN	NS	c.gtld-servers.net.

- Administered by ICANN
  - 13 root servers, labeled A→M
  - 6 are anycasted, i.e. they are globally replicated
- Contacted when names cannot be resolved
  - In practice, most systems cache this information

Map of the Roots

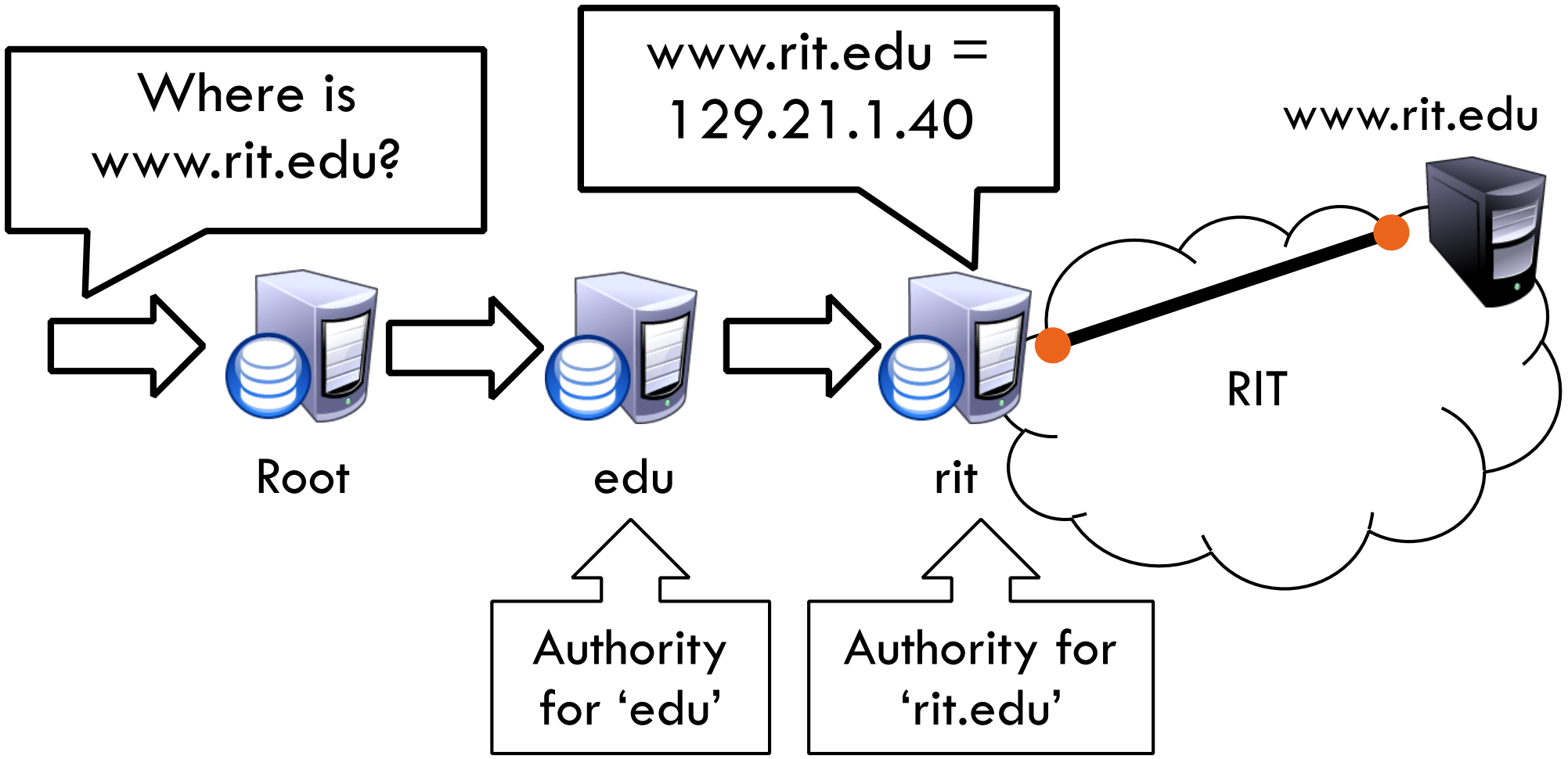


Local Name Servers



- Each ISP/company has a local, default name server
- Often configured via DHCP
- Hosts begin DNS queries by contacting the local name server
- Frequently cache query results

Authoritative Name Servers



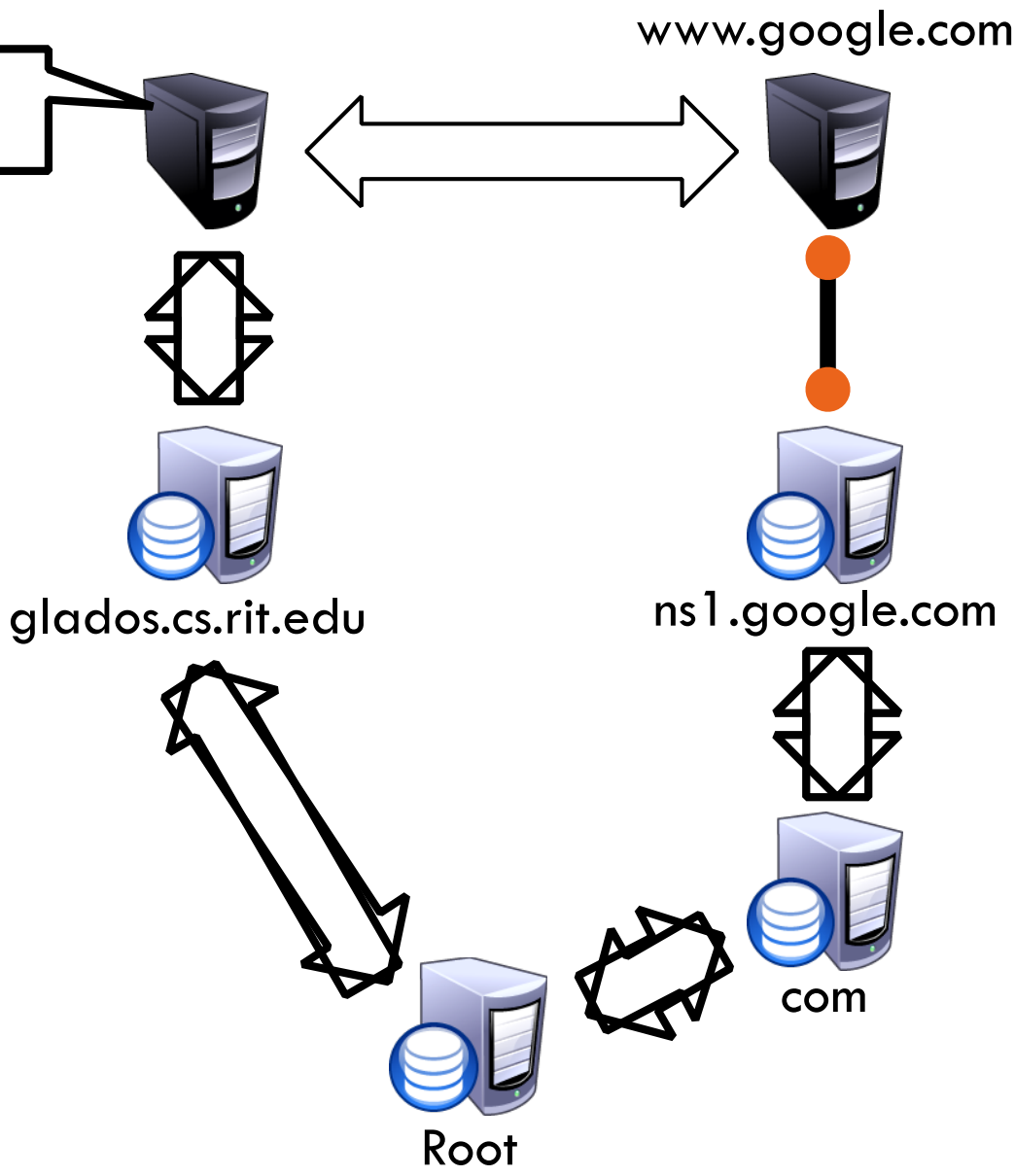
- Stores the name→IP mapping for a given host

Basic Domain Name Resolution

- Every host knows a local DNS server
  - Sends all queries to the local DNS server
- If the local DNS can answer the query, then you're done
  1. Local server is also the authoritative server for that name
  2. Local server has cached the record for that name
- Otherwise, go down the hierarchy and search for the authoritative name server
  - Every local DNS server knows the root servers
  - Use cache to skip steps if possible
    - e.g. skip the root and go directly to .edu if the root file is cached

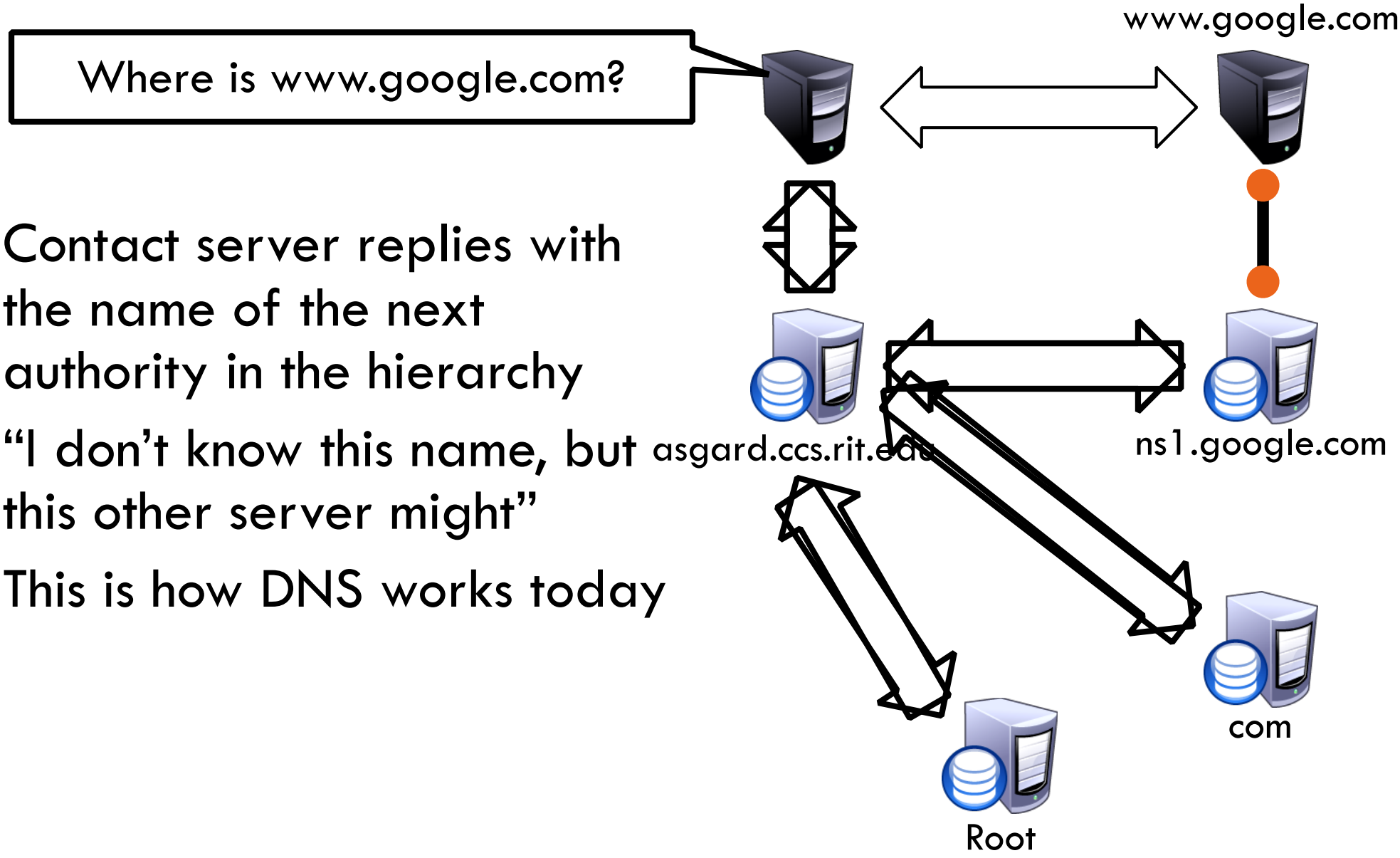
Recursive DNS Query

- Puts the burden of resolution on the contacted name server
- How does glados know who to forward responses too?
  - Random IDs embedded in DNS queries
- What have we said about keeping state in the network?



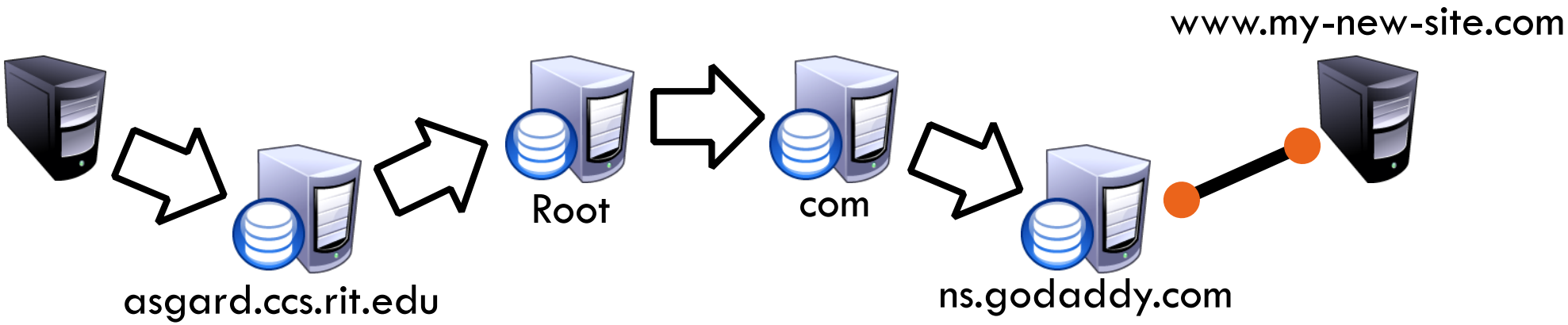
Iterated DNS query

- Contact server replies with the name of the next authority in the hierarchy
- "I don't know this name, but this other server might"
- This is how DNS works today



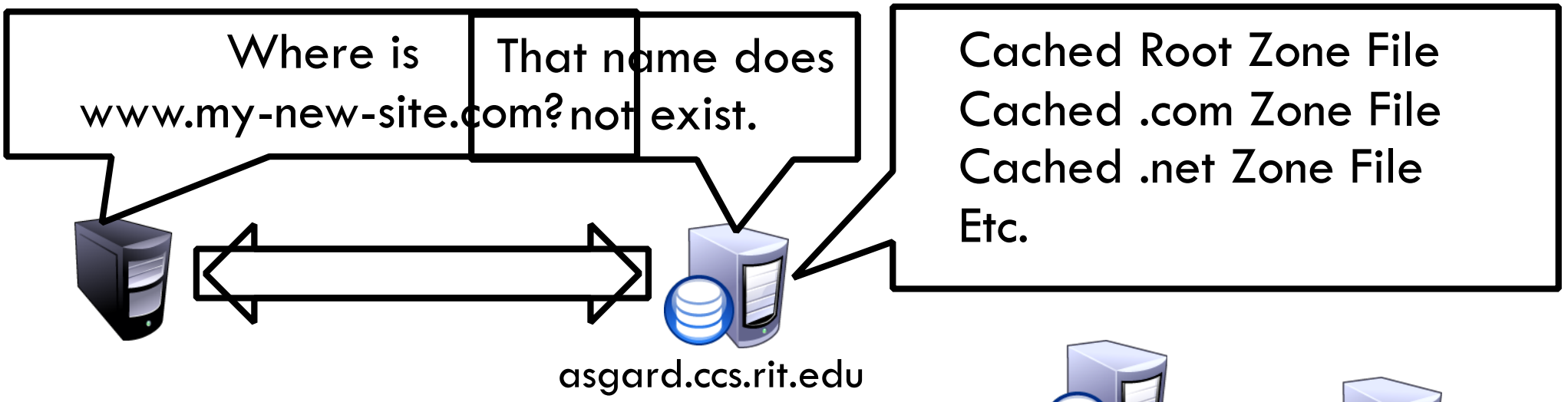
DNS Propagation

- How many of you have purchased a domain name?
  - Did you notice that it took ~72 hours for your name to become accessible?
  - This delay is called DNS Propagation



Caching vs. Freshness

- DNS Propagation delay is caused by caching



- Zone files may be cached for 1-72 hours

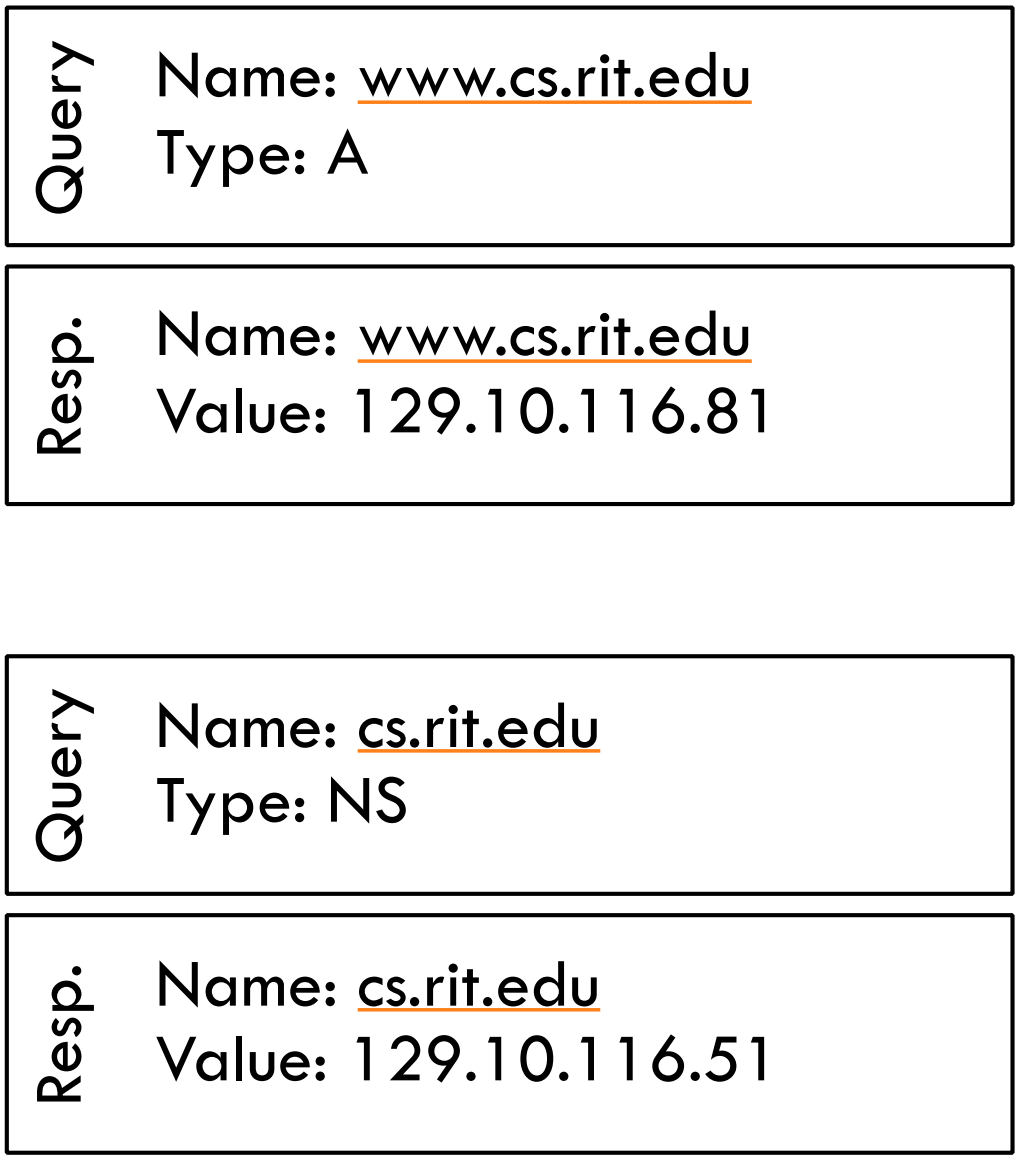
DNS Resource Records

- DNS queries have two fields: name and type
- Resource record is the response to a query
  - Four fields: (name, value, type, TTL)
  - There may be multiple records returned for one query
- What are do the name and value mean?
  - Depends on the type of query and response

DNS Types

- Type = A / AAAA
  - Name = domain name
  - Value = IP address
  - A is IPv4, AAAA is IPv6

- Type = NS
  - Name = partial domain
  - Value = name of DNS server for this domain
  - "Go send your query to this other server"



DNS Types, Continued

- Type = CNAME
  - Name = hostname
  - Value = canonical hostname
  - Useful for aliasing
  - CDNs use this

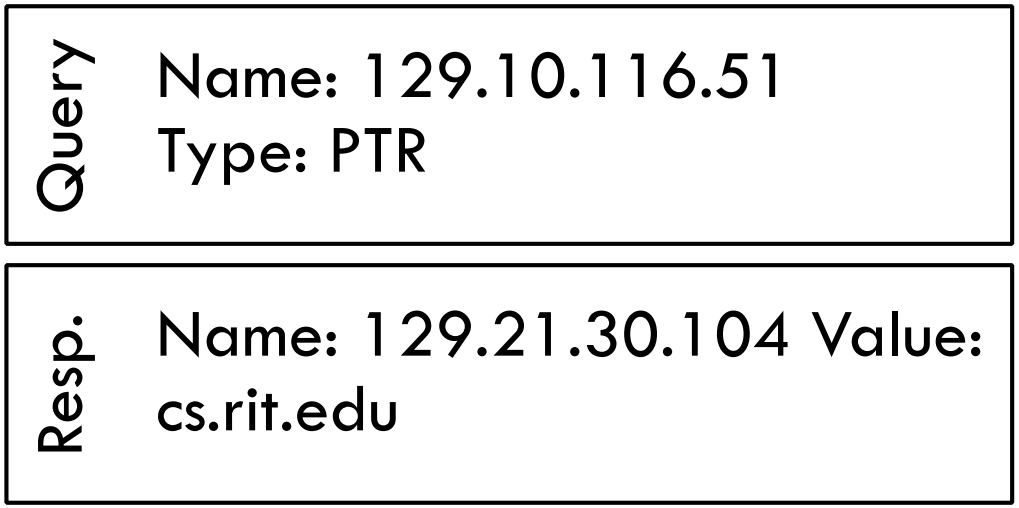
Query	Name: foo.mysite.com Type: CNAME
Resp.	Name: foo.mysite.com Value: bar.mysite.com

- Type = MX
  - Name = domain in email address
  - Value = canonical name of mail server

Query	Name: cs.rit.edu Type: MX
Resp.	Name: cs.rit.edu Value: pony-express.cs.rit.edu.

Reverse Lookups

- What about the IP→name mapping?
- Separate server hierarchy stores reverse mappings
  - Rooted at in-addr.arpa and ip6.arpa
- Additional DNS record type: PTR
  - Name = IP address
  - Value = domain name
- Not guaranteed to exist for all IPs



Demo

- Dig: (Domain Information Grouper)
  - Very useful tool to send a DNS request and parse the DNS response

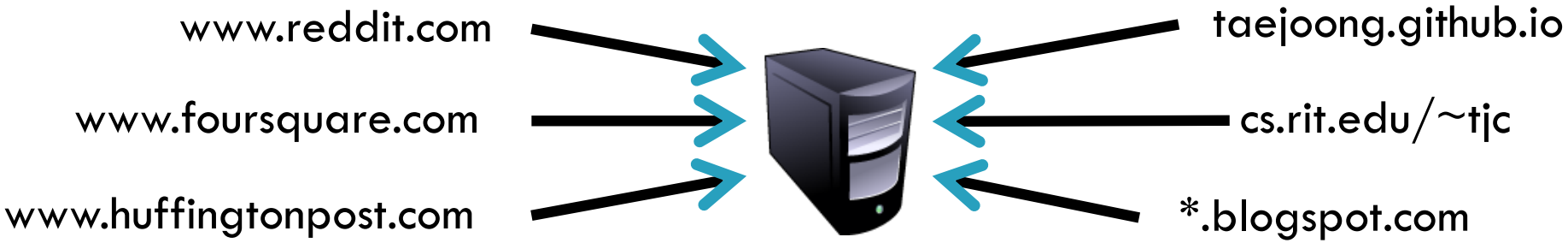
DNS as Indirection Service

- DNS gives us very powerful capabilities
  - Not only easier for humans to reference machines!

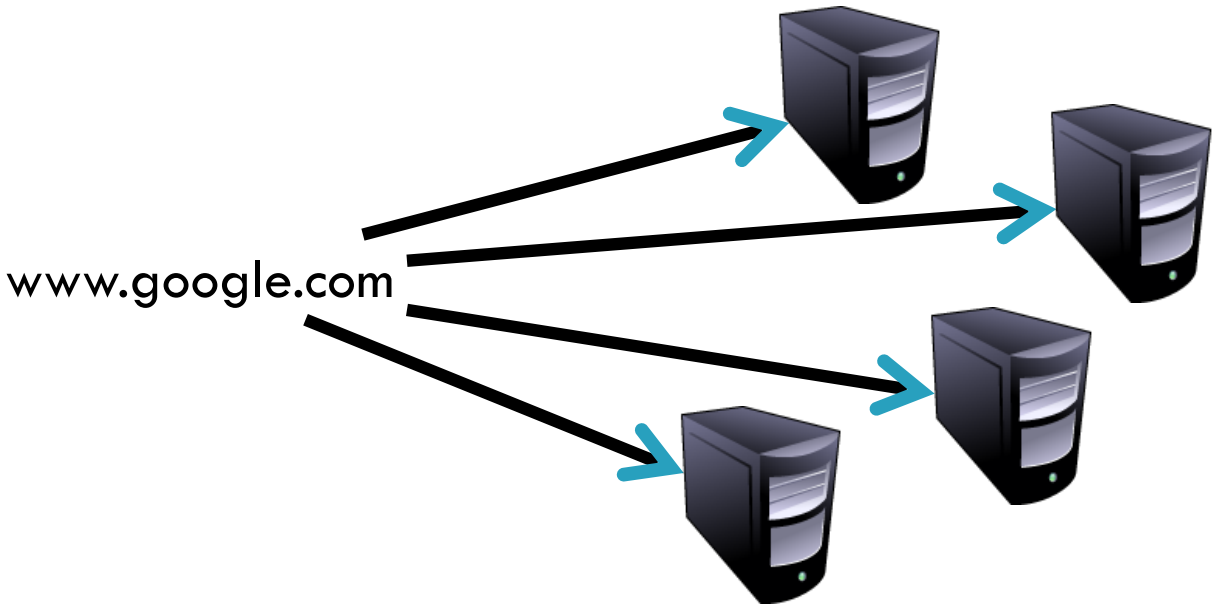
- Changing the IPs of machines becomes trivial
  - e.g. you want to move your web server to a new host
  - Just change the DNS record!

Aliasing and Load Balancing

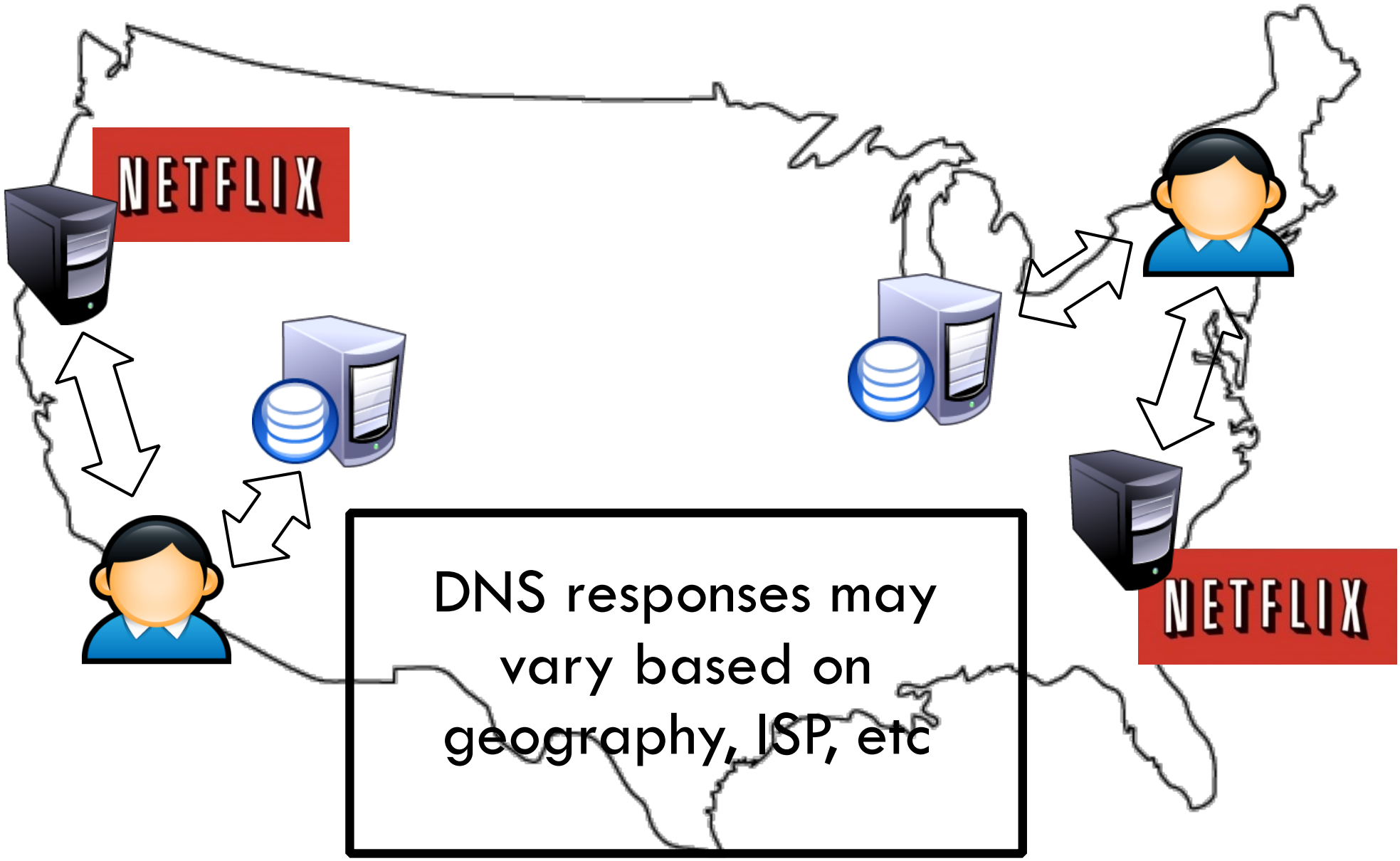
- One machine can have many aliases



- One domain can map to multiple machines



Content Delivery Networks



Outline

- DNS Basics
- DNS Security

The Importance of DNS

- Without DNS…
  - How could you get to any websites?
- You are your mailserver
  - When you sign up for websites, you use your email address
  - What if someone hijacks the DNS for your mail server?
- DNS is the root of trust for the web
  - When a user types www.bankofamerica.com, they expect to be taken to their bank's website
  - What if the DNS record is compromised?

Denial Of Service

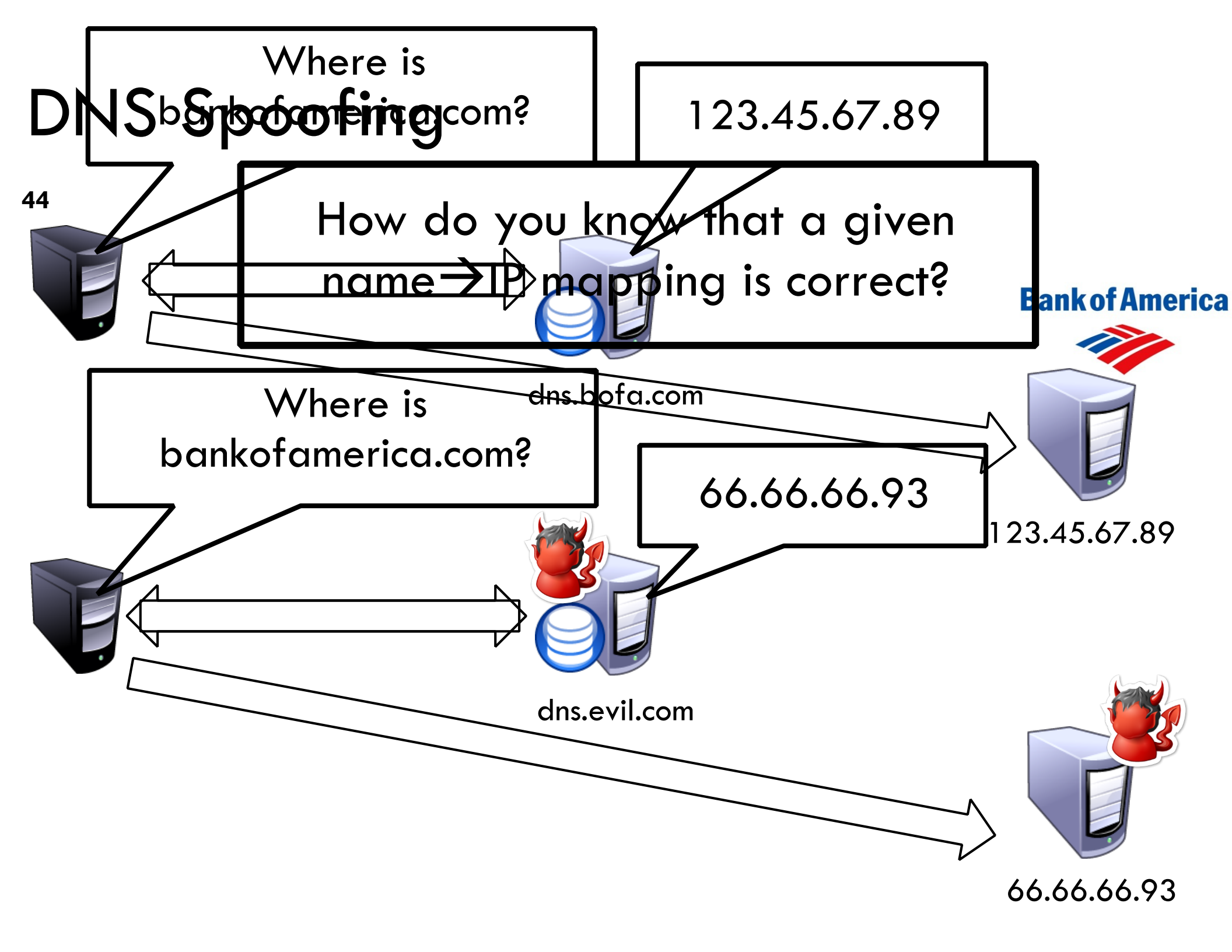
- Flood DNS servers with requests until they fail
- October 2002: massive DDoS against the root name servers
  - What was the effect?
  - … users didn't even notice
  - Root zone file is cached almost everywhere
- More targeted attacks can be effective
  - Local DNS server → cannot access DNS
  - Authoritative server → cannot access domain

DNS Hijacking

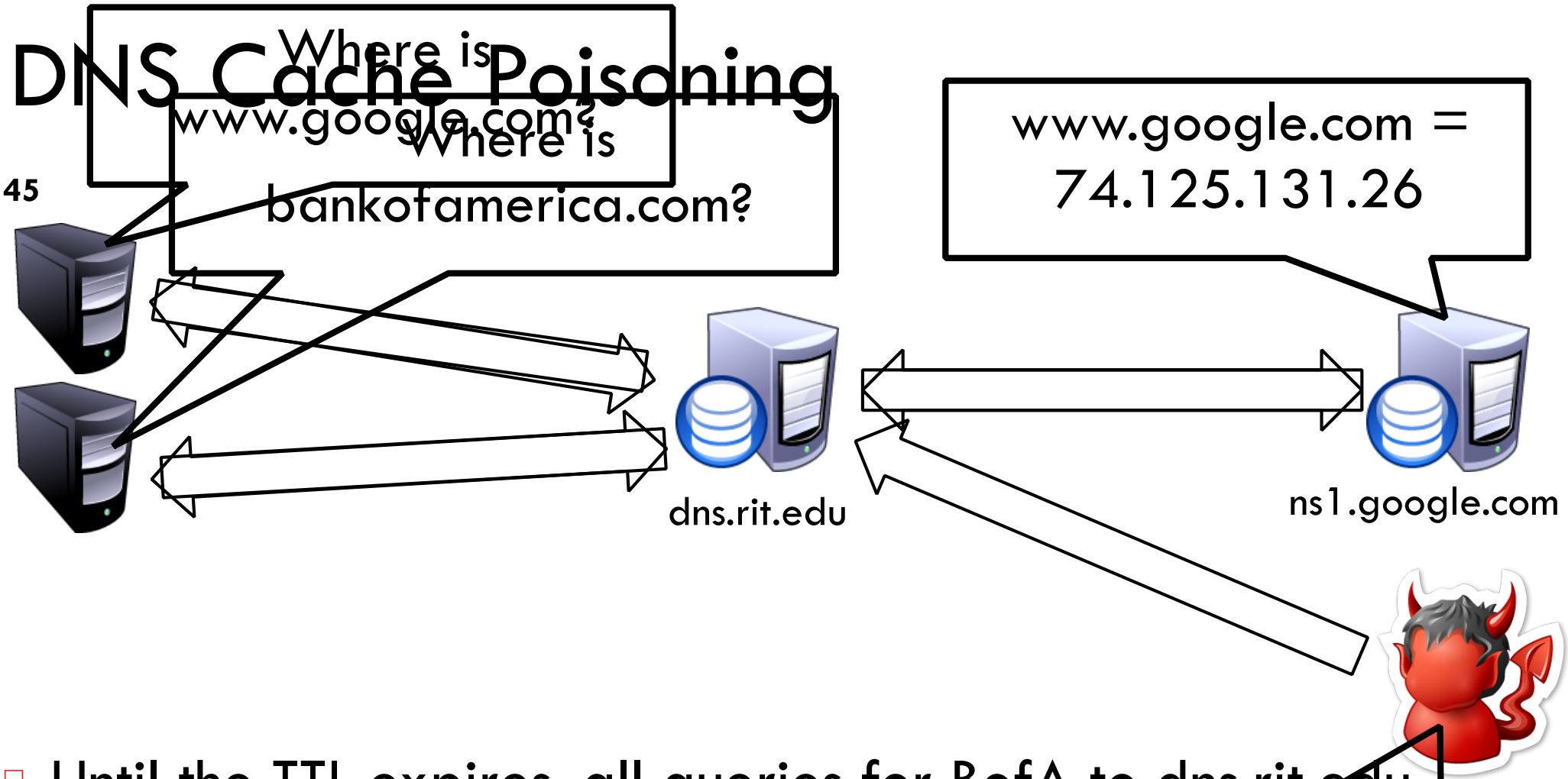
- Infect their OS or browser with a virus/trojan
  - e.g. Many trojans change entries in /etc/hosts
  - *.bankofamerica.com → evilbank.com
- Man-in-the-middle

- Response Spoofing
  - Eavesdrop on requests
  - Outrace the servers response

DNS Spoofing



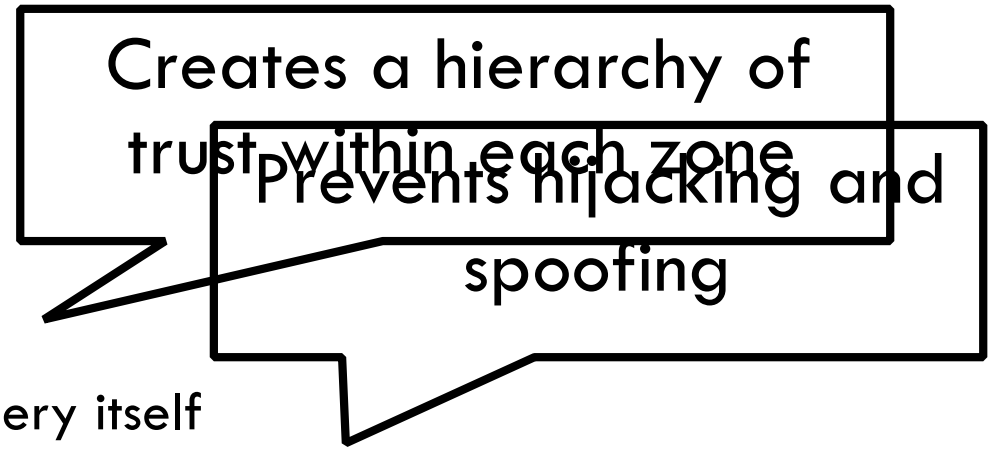
DNS Cache Poisoning



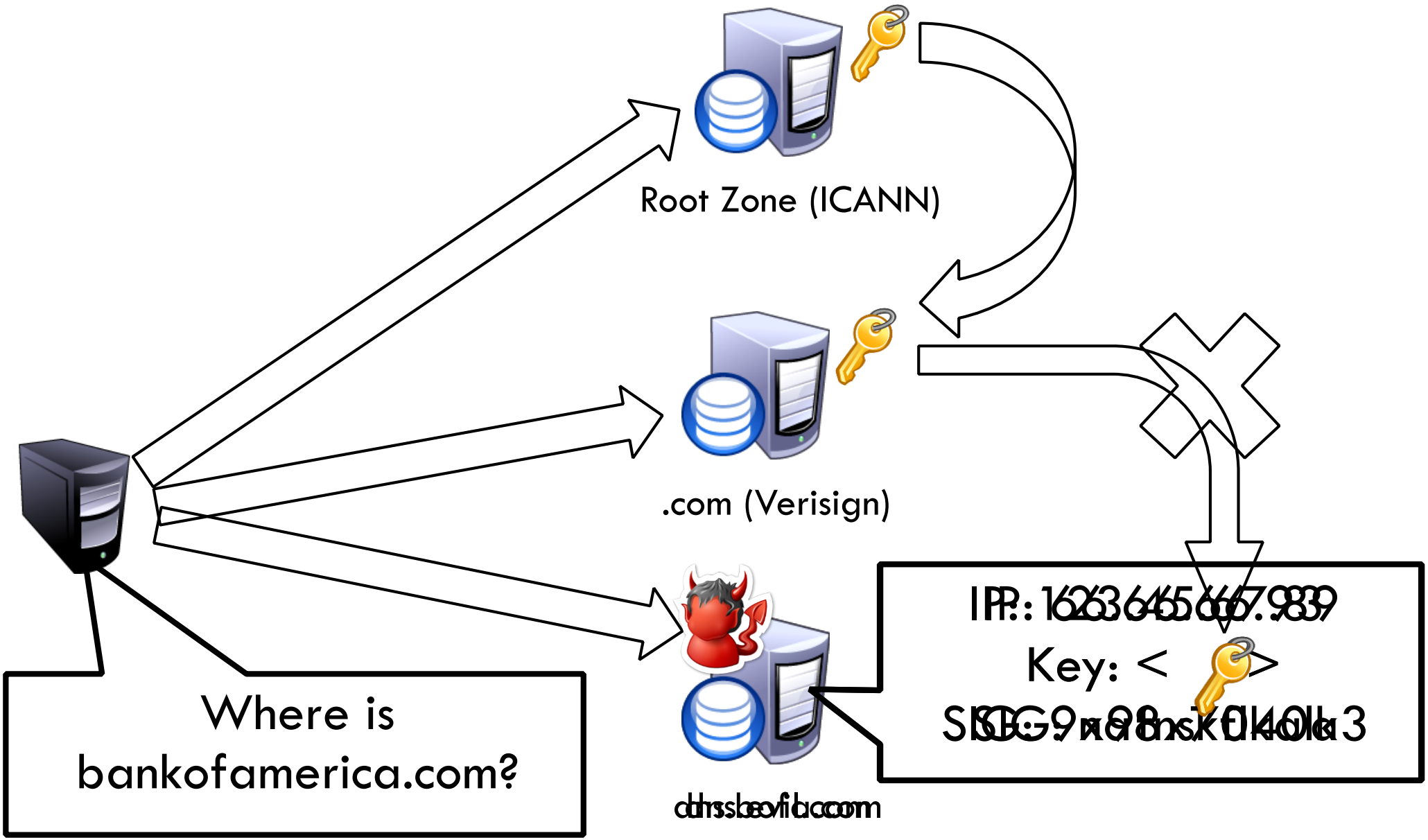
- Until the TTL expires, all queries for BofA to dns.rit.edu will return poisoned result
- Much worse than spoofing/man-in-the-middle
  - Whole ISPs can be impacted!

Solution: DNSSEC

- Cryptographically sign critical resource records
  - Resolver can verify the cryptographic signature
- Two new resource types
  - Type = DNSKEY
    - Name = Zone domain name
    - Value = Public key for the zone
  - Type = RRSIG
    - Name = (type, name) tuple, i.e. the query itself
    - Value = Cryptographic signature of the query results
- Deployment
  - On the roots since July 2010
  - Verisign enabled it on .com and .net in January 2011
  - Comcast is the first major ISP to support it (January 2012)

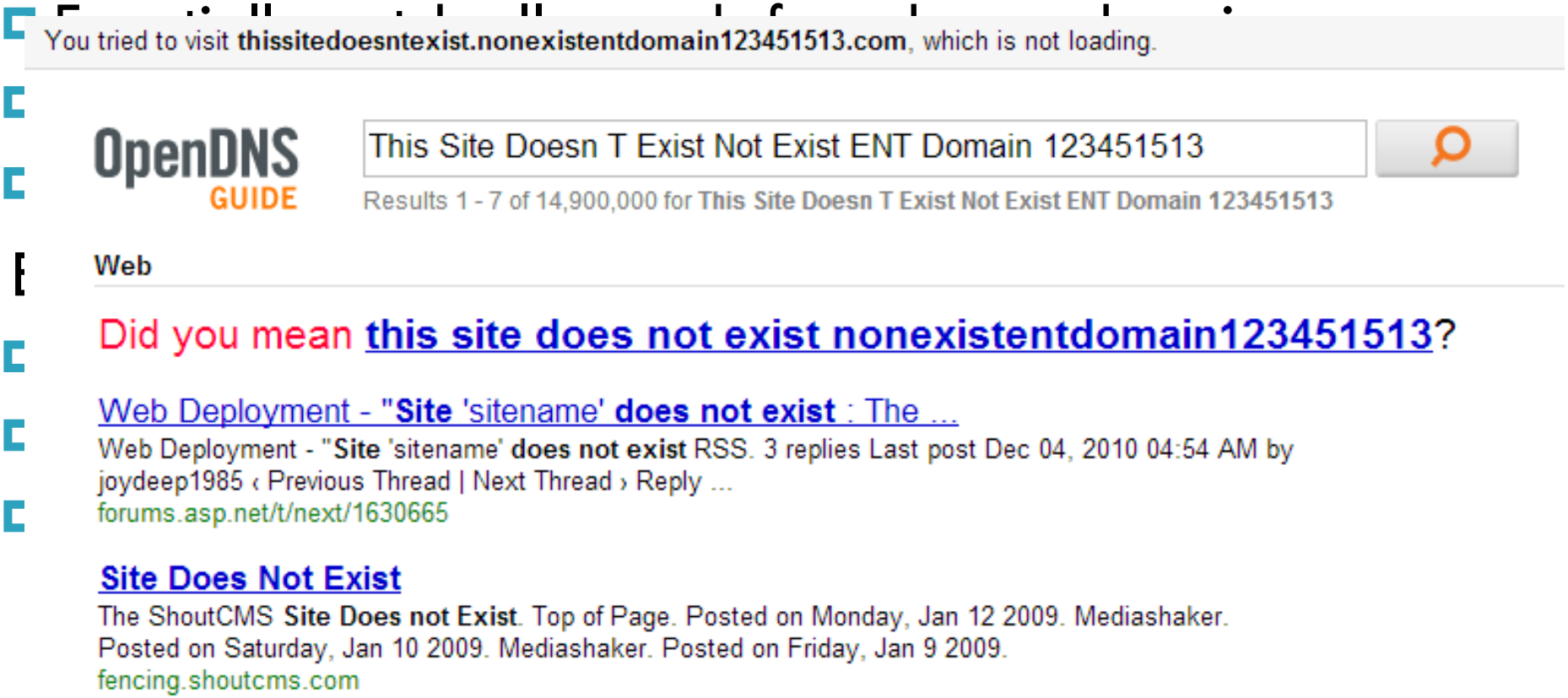


DNSSEC Hierarchy of Trust



Site Finder

- September 2003: Verisign created DNS wildcards for *.com and *.net
- [illegible]



Much More to DNS

- Caching: when, where, how much, etc.
- Other uses for DNS (i.e. DNS hacks)
  - Content Delivery Networks (CDNs)
  - Different types of DNS load balancing
  - Dynamic DNS (e.g. for mobile hosts)
- DNS and botnets
- Politics and growth of the DNS system
  - Governance
  - New TLDs (.xxx, .biz), eliminating TLDs altogether
  - Copyright, arbitration, squatting, typo-squatting