Naming in Networking

Jennifer Rexford

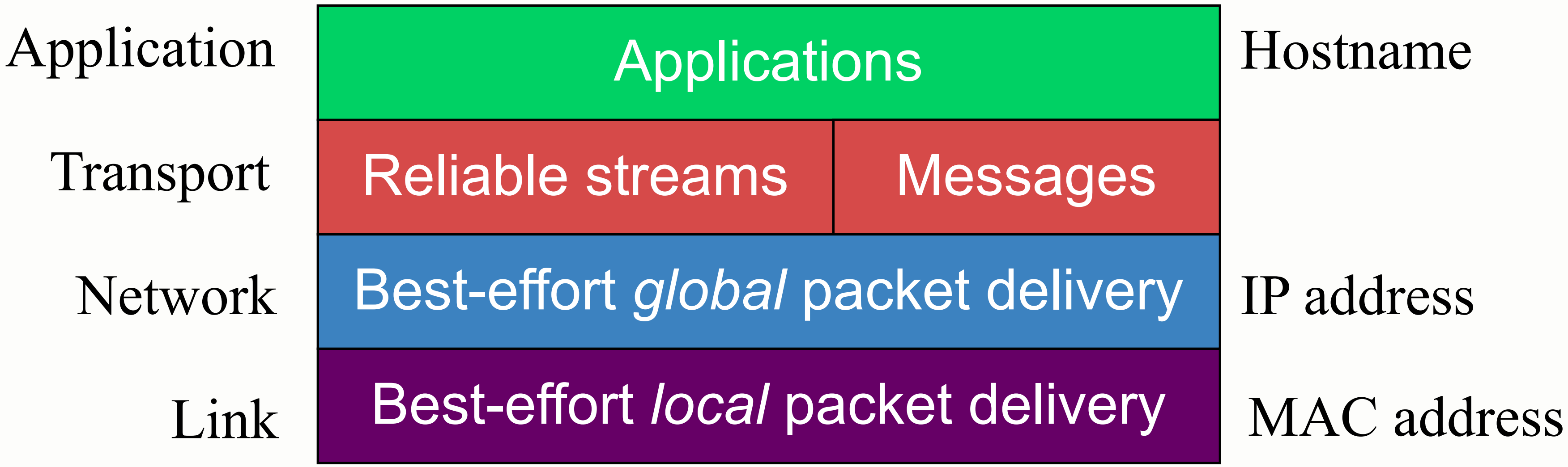
COS 316 Guest Lecture

Names

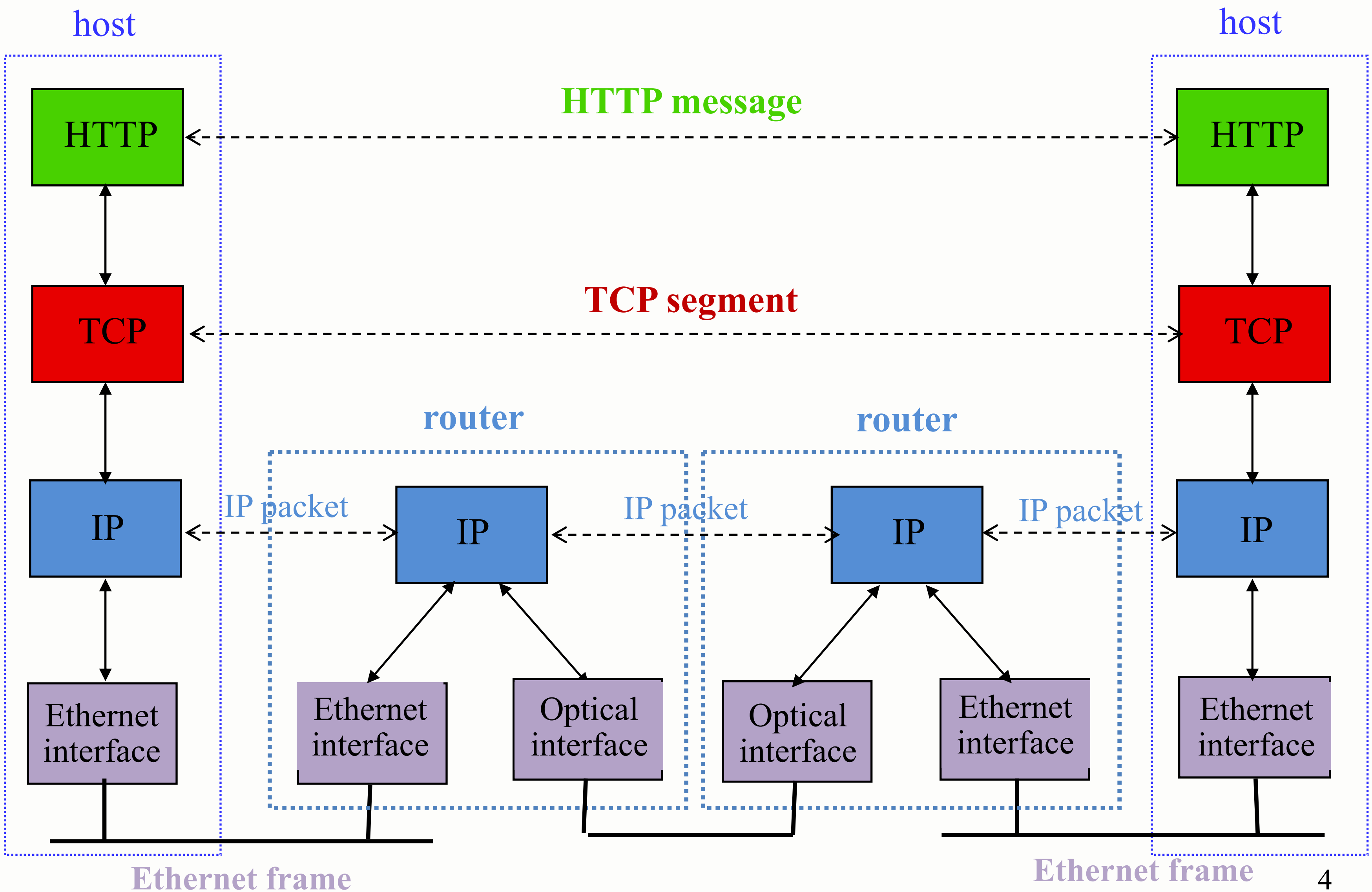
Type of Name	Example
Uniform Resource Locator	http://www.cs.princeton.edu/~jrex/foo.html
E-mail	jrex@cs.princeton.edu
Hostname	www.cs.princeton.edu
Internet Protocol	128.112.7.156
Media Access Control	00:15:C5:49:04:A9

Today's lecture focuses on the last three!

Internet Protocol Layers



Internet Protocol Stack



What’s in a Name?

- Human readable?
  - If end users interact with the names
- Fixed length?
  - If names must be processed at high speed
- Large name space?
  - If many nodes need unique names
- Hierarchical names?
  - If the system is very large and/or federated
- Self-certifying?
  - If preventing “spoofing” is important

Different Layers, Different Names

- **Host name** (e.g., www.cs.princeton.edu)
  - Mnemonic, variable-length, appreciated *by humans*
  - Hierarchical, based on organizations
- **IP address** (e.g., 128.112.7.156)
  - Numerical 32-bit address appreciated *by routers*
  - Hierarchical, based on organizations and topology
- **MAC address** (e.g., 00:15:C5:49:04:A9)
  - Numerical 48-bit address appreciated *by adapters*
  - Non-hierarchical, unrelated to network topology

Hierarchical Allocation Processes

- **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 equipment vendors by the IEEE
  - Adapters: assigned by the vendor from its block

Host Names vs. IP Addresses

- Names are easier (for us!) to remember
  - www.cnn.com vs. 64.236.16.20
- IP addresses can change underneath
  - E.g., renumbering when changing providers
- Name could map to multiple IP addresses
  - www.cnn.com to multiple replicas of the Web site
- Map to different addresses in different places
  - E.g., to reduce latency, or return different content
- Multiple names for the same address
  - E.g., aliases like ee.mit.edu and cs.mit.edu

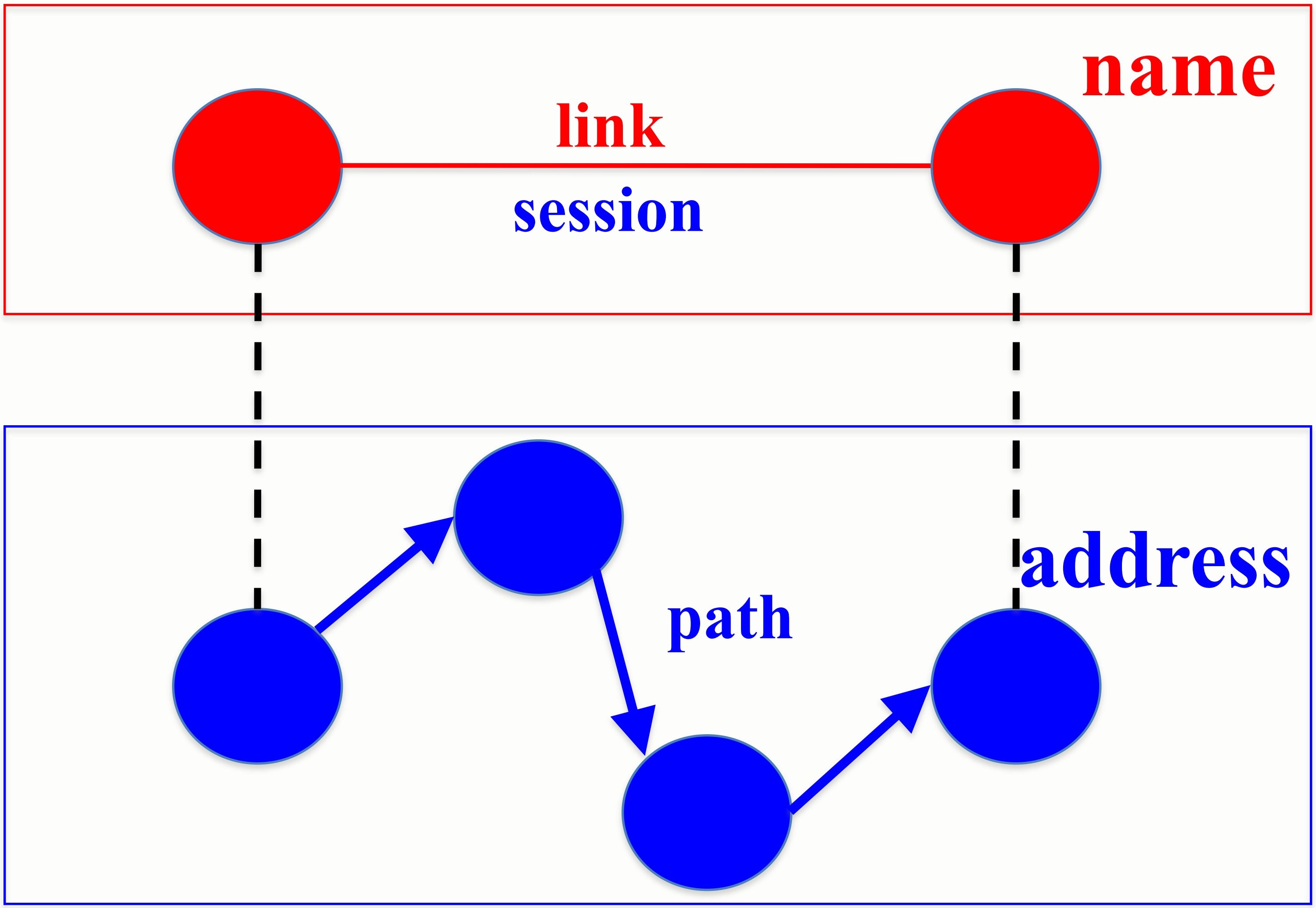
IP vs. MAC Addresses

- LANs designed for arbitrary network protocols
  - Not just for IP (e.g., IPX, Appletalk, X.25, …)
  - Different LANs may have different address schemes
- A host may move to a new location
  - So, cannot simply assign a static IP address
  - Instead, must reconfigure the adapter
- Must identify the adapter during bootstrap
  - Need to talk to the adapter to assign it an IP address

Hostname, IP, and MAC

	Hostname	IP Address	MAC Address
Example	www.cs.princeton.edu	128.112.7.156	00:15:C5:49:04:A9
Size	Hierarchical, human readable, variable length	Hierarchical, machine readable, 32 bits (in IPv4)	Flat, machine readable, 48 bits
Read by	Humans, hosts	Internet routers	LAN switches
Allocation, top-level	Domain name assigned by registrar (e.g., for .edu)	Variable-length prefixes, assigned by ICANN, RIR, or ISP	Fixed-sized blocks, assigned by IEEE to vendors (e.g., Dell)
Allocation, low-level	Host name assigned by local administrator	Interface, by DHCP or local administrator	Interface, by equipment vendor

Directory: Translate Name to Address



Directory

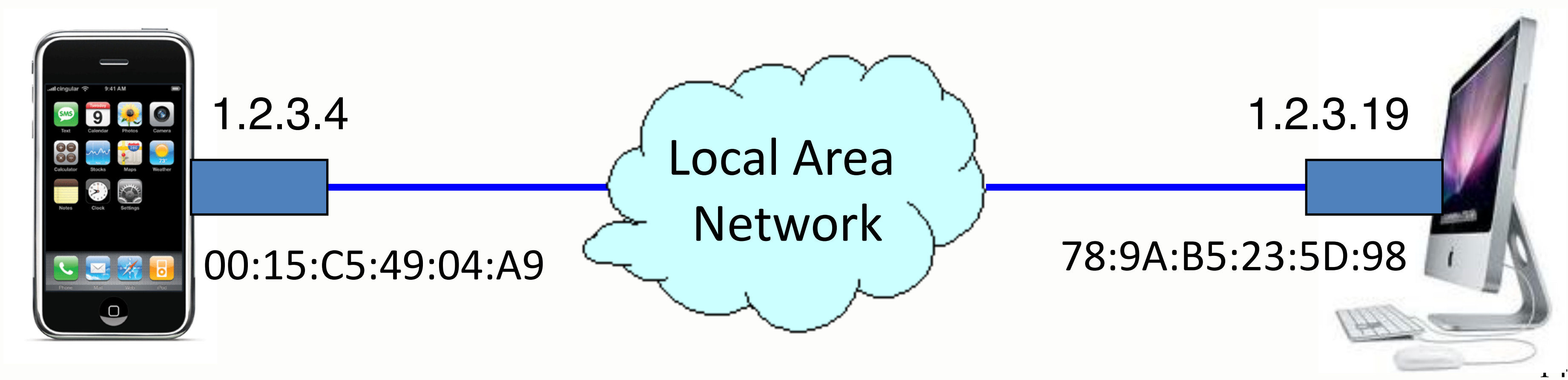
- A key-value store
  - Key: name, value: address(es)
  - Answer queries: given name, return address(es)
- Caching the response
  - Reuse the response, for a period of time
  - Better performance and lower overhead
- Allow entries to change
  - Updating the address(es) associated with a name
  - Invalidating or expiring cached responses

Directory Design: Three Extremes

- Flood the query (e.g., ARP)
  - The named node responds with its own address
  - But, high overhead in large networks

Address Resolution Protocol (ARP)

- Every host in a LAN maintains an ARP table
  - (IP address, MAC address) pair
- Consult the table when sending a packet
  - Map destination IP address to dest MAC address
  - Transmit the IP packet within an Ethernet frame



Address Resolution Protocol (ARP)

- But, what if the key is not in the table?
  - Sender broadcast: "Who has IP address 1.2.3.19?"
  - Receiver answer: "MAC address 78:9A:B5:23:5D:98"
  - Sender caches the result in its local ARP cache

Address Resolution Protocol (ARP)

- Managing the ARP cache
  - Storing all key-value pairs introduces overhead
  - Entries become stale (e.g., IP assigned to new host)
  - Remove an entry if not used for some period of time

Directory Design: Three Extremes

- Flood the query (e.g., ARP)
  - The named node responds with its address
  - But, high overhead in large networks
- Push data to all nodes (e.g., /etc/hosts)
  - All nodes store a full copy of the directory
  - But, high overhead for many names and updates
- Central directory server
  - All data and queries handled by one node
  - But, poor performance, scalability, and reliability

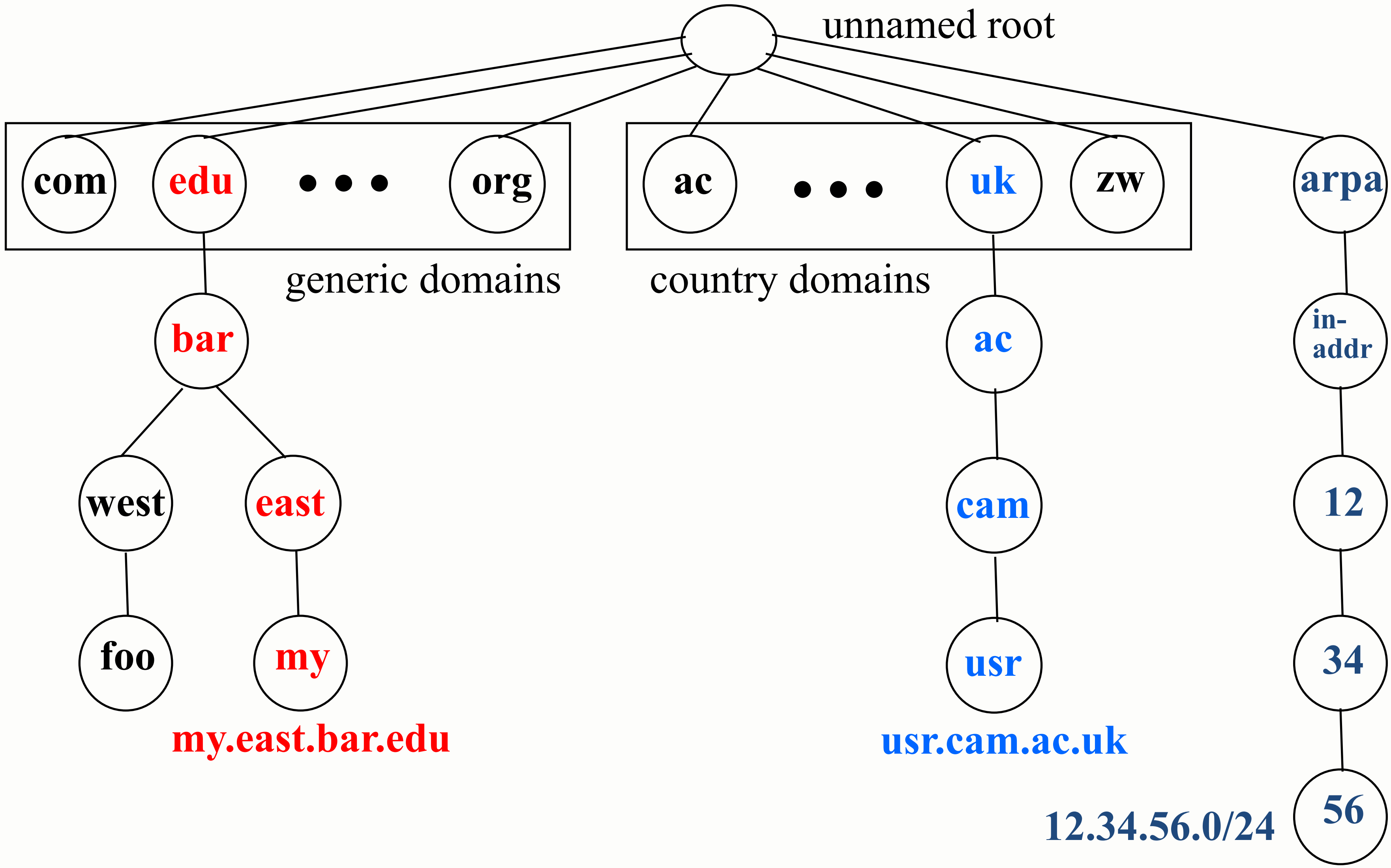
Distributed Directory Design

- Hierarchical directory (e.g., DNS)
  - Follow the hierarchy of the name space
  - Distribute the directory, distribute the queries
  - Enable decentralized updates to the directory
- Distributed Hash Table (e.g., P2P applications)
  - Directory as a hash table with flat names
  - Each directory node handles range of hash outputs
  - Use hash to direct query to the directory node

Domain Name System (DNS)

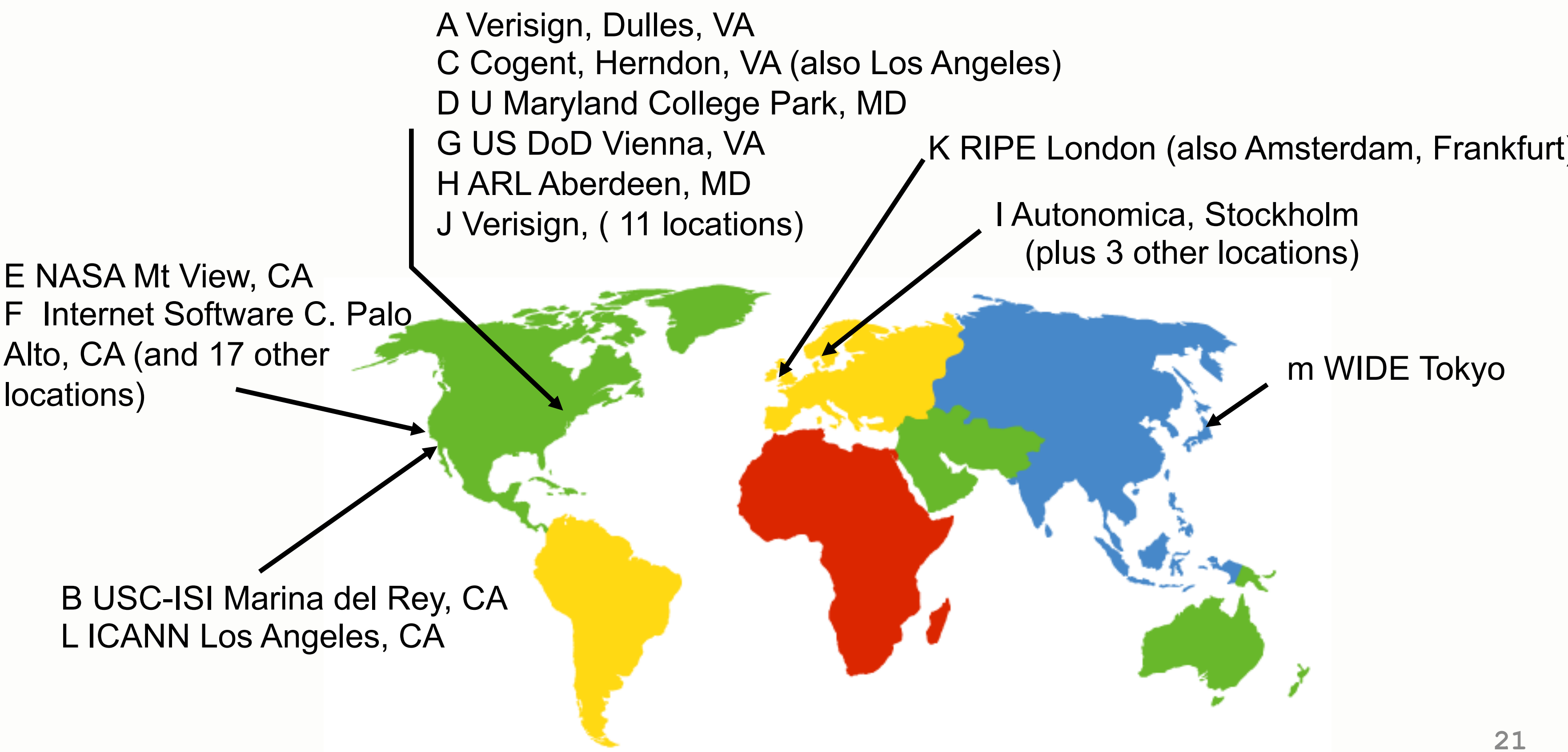
- Properties of DNS
  - Hierarchical name space divided into zones
  - Distributed over a collection of DNS servers
- Hierarchy of DNS servers
  - Root servers
  - Top-level domain (TLD) servers
  - Authoritative DNS servers
- Performing the translations
  - Local DNS servers and client resolvers

Distributed Hierarchical Database



DNS Root Servers

- 13 root servers (see http://www.root-servers.org/)
- Labeled A through M



TLD and Authoritative DNS Servers

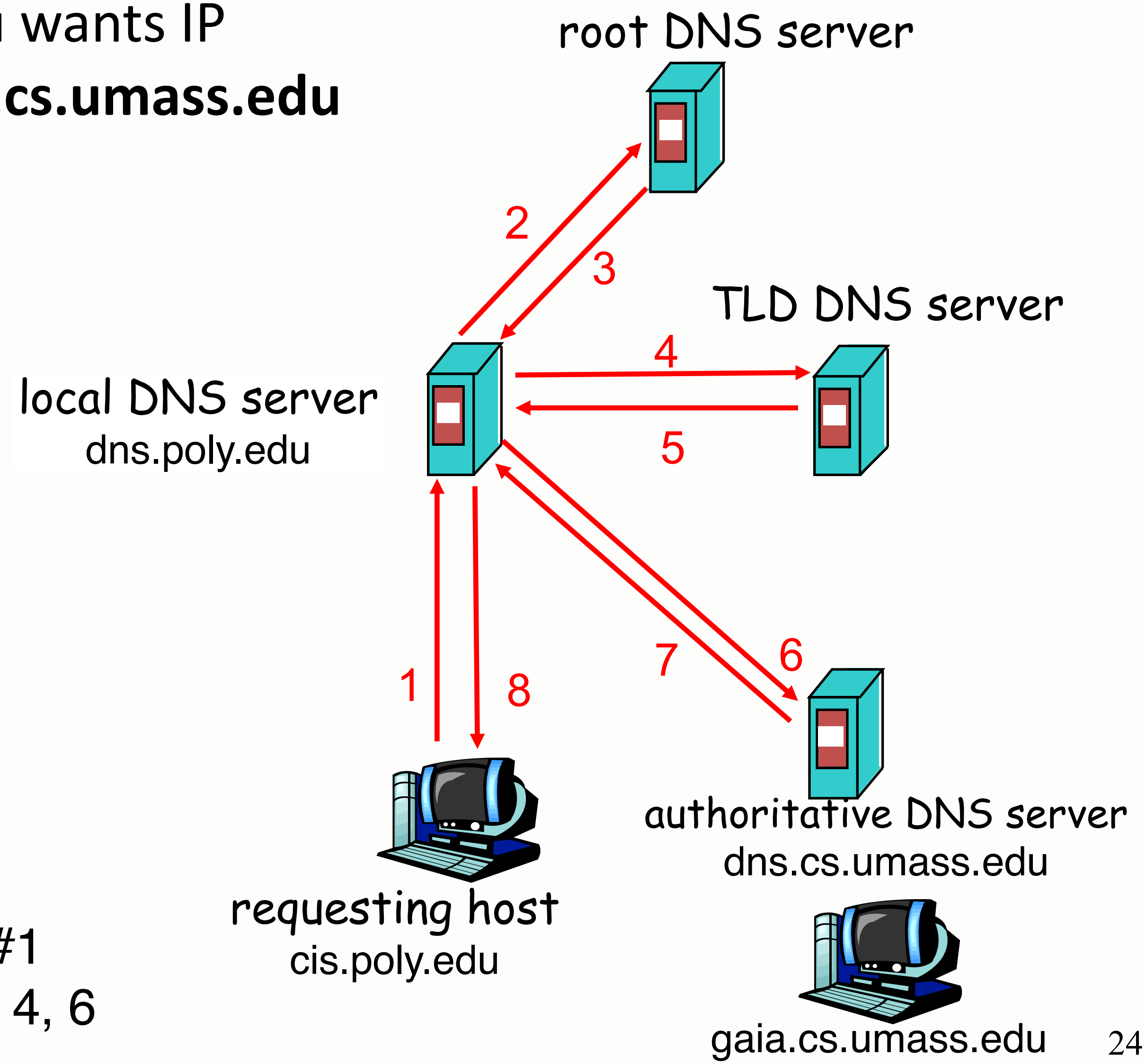
- Global Top-level domain (gTLD) servers
  - Generic domains (e.g., .com, .org, .edu)
  - Country domains (e.g., .uk, .fr, .ca, .jp)
  - Managed professionally (e.g., Verisign for .com .net)
- Authoritative DNS servers
  - Provide public records for hosts at an organization
  - For the organization's servers (e.g., Web and mail)
  - Can be maintained locally or by a service provider

Using DNS

- Local DNS server ("default name server")
  - Usually near the end hosts who use it
  - Local hosts configured with local server (e.g., /etc/resolv.conf) or learn the server via DHCP
- Client application
  - Extract server name (e.g., from the URL)
  - Do *gethostbyname()* or *getaddrinfo()* to get address
- Server application
  - Extract client IP address from socket
  - Optional *gethostbyaddr()* to translate into name

DNS Queries

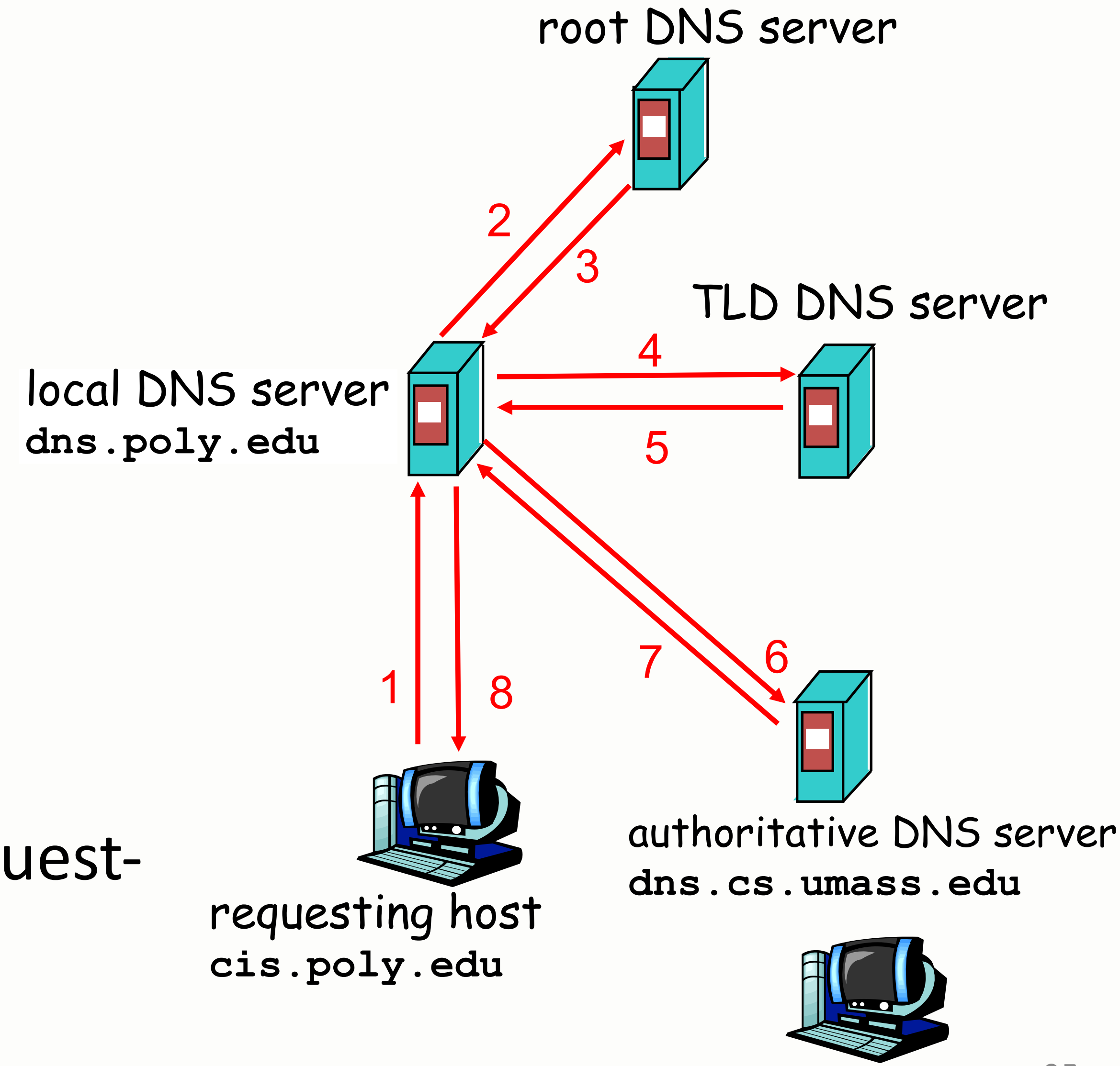
Host at cis.poly.edu wants IP address for **gaia.cs.umass.edu**



Recursive query: #1
Iterative queries: #2, 4, 6

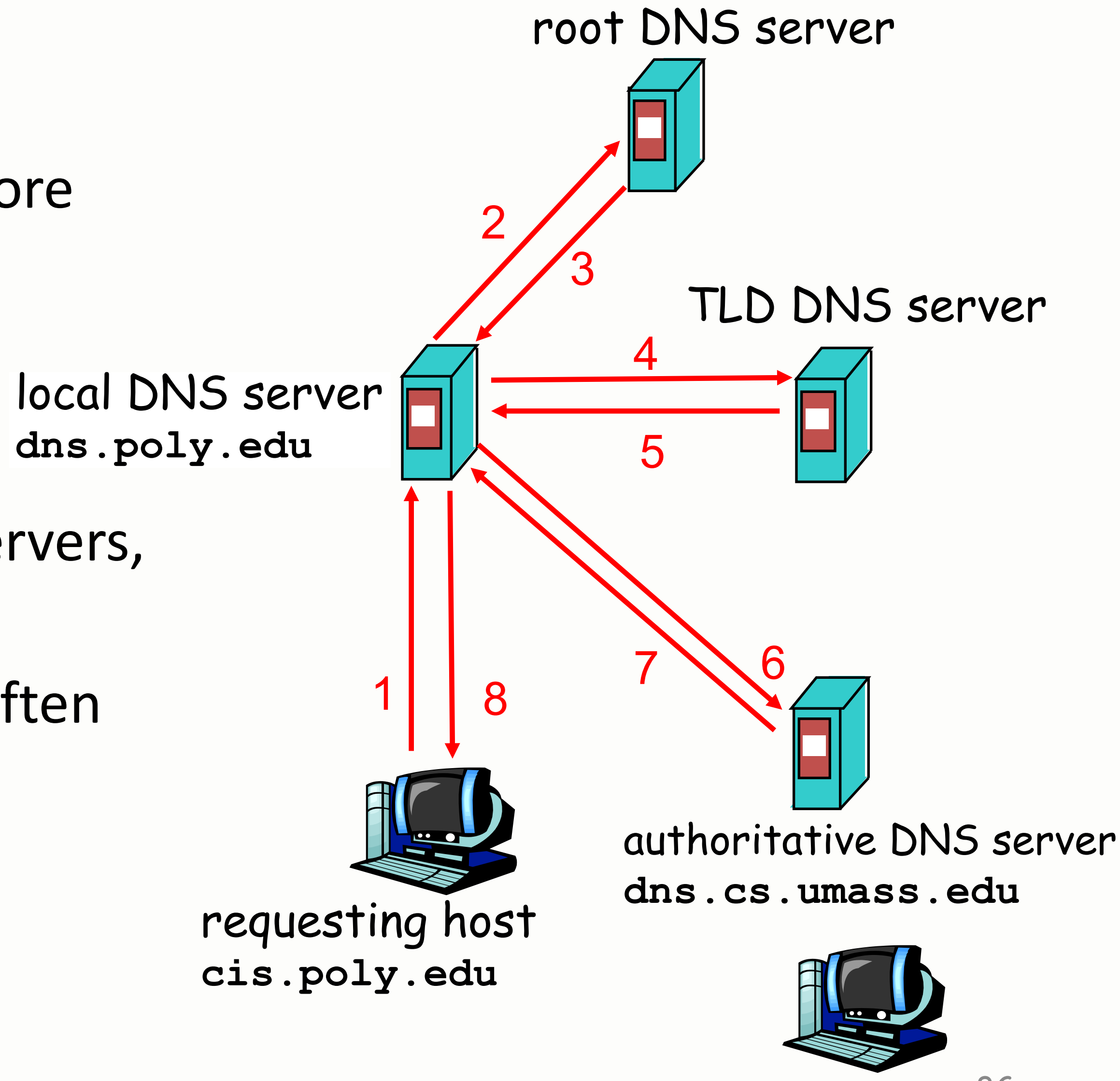
Recursive vs. Iterative Queries

- Recursive query
  - Ask server to get answer for you
  - E.g., request 1 and response 8
- Iterative query
  - Ask server who to ask next
  - E.g., all other request-response pairs



DNS Caching

- DNS query latency
  - E.g., 1 sec latency before starting a download
- Caching to reduce overhead and delay
  - Small # of top-level servers, that change rarely
  - Popular sites visited often
- Where to cache?
  - Local DNS server
  - Browser



DNS Cache Consistency

- Cache consistency
  - Ensuring cached data is up to date
- DNS design considerations
  - Cached data is “read only”
  - Explicit invalidation would be expensive
- Avoiding stale information
  - Responses include a “time to live” (TTL) field
  - Delete the cached entry after TTL expires

Setting the Time To Live (TTL)

- TTL trade-offs
  - Small TTL: fast response to change
  - Large TTL: higher cache hit rate
- Following the hierarchy
  - Top of the hierarchy: days or weeks
  - Bottom of the hierarchy: seconds to hours
- Tension in practice
  - Set low TTLs for load balancing and failover
  - Browsers cache for 15-60 seconds

Negative Caching

- Broken domain names are slow to resolve
  - Misspellings like www.cnn.comm and www.cnnn.com
  - These can take a long time to fail the first time
- Remember things that *don't* work
  - Good to remember that they don't work
  - … so the failure takes less time in the future
- But don't remember for *too* long
  - Use a time-to-live to expire

DNS Reliability

- DNS servers are replicated
  - Name service available if at least one replica is up
  - Queries can be load balanced between replicas
- Retransmission of lost queries
  - No response to a query? Try again!
- Try alternate servers on timeout
  - Exponential back-off when retrying same server

Conclusions

- Network names
  - To identify remote end-points
  - Readability? Format? Length? Hierarchy?
  - Hostnames, IP addresses, and MAC addresses
- Network directories
  - Key-value stores to map name to address
  - Flooding (ARP), local copy, central server
  - Hierarchical (DNS) or non-hierarchical (DHT)
- More on protocol layers in a few weeks!