CS 352 The Application Layer

Lecture 3.1, Spring 2020 http://www.cs.rutgers.edu/~sn624/352

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Application-layer Protocol

- Types of messages exchanged,
 - e.g., request, response
- Message format:
 - Syntax: what fields in messages & how fields are delineated
 - Semantics: meaning of information in fields
- Actions: when and how processes send & respond to messages

Public-domain protocols:

- defined in RFCs
- allows for interoperability
- e.g., HTTP, SMTP
- Proprietary protocols:
- e.g., Skype

Application Addresses

- We usually think of an application executing on a single endpoint
- However, applications can reside on, say, 2 different endpoints connected by a network
- In order to communicate, need to identify the communicating parties
 - Telephone network: phone number (10 digits)
- Computer network: IP address
 - IPv4 (32 bits) 128.6.24.78
 - IPv6 (128 bits) 2001:4000:A000:C000:6000:B001:412A:8000
- Suppose there is more than one networked program executing on a nost
 - In addition to host address, we need one more address
 - "Which Program to talk to?"
- The identity for an application: port number (+ IP addr)

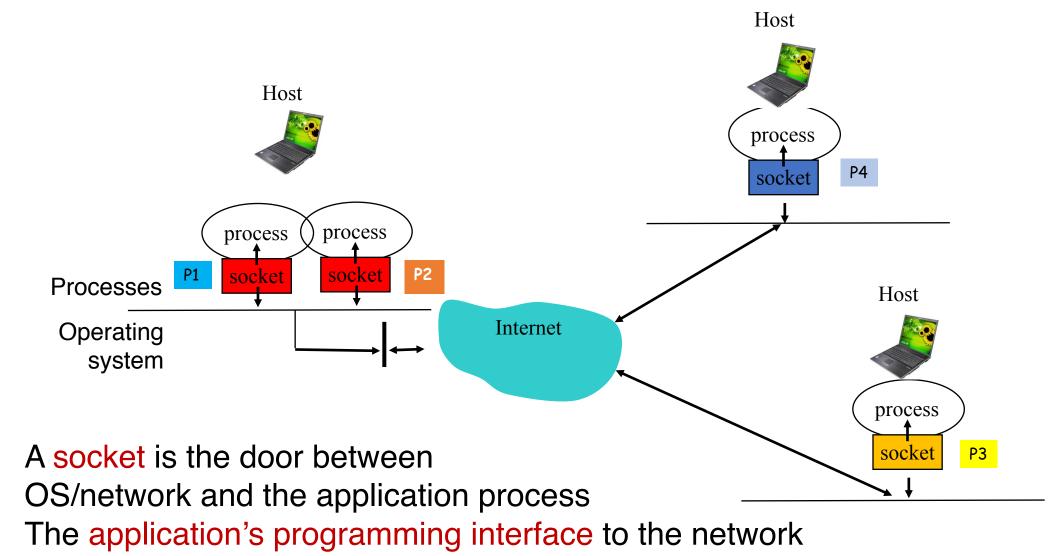
App / person (port #)

Host /

house (IP

address)

IP address & port number



An app-layer connection is a 4-tuple

Host: IP address B

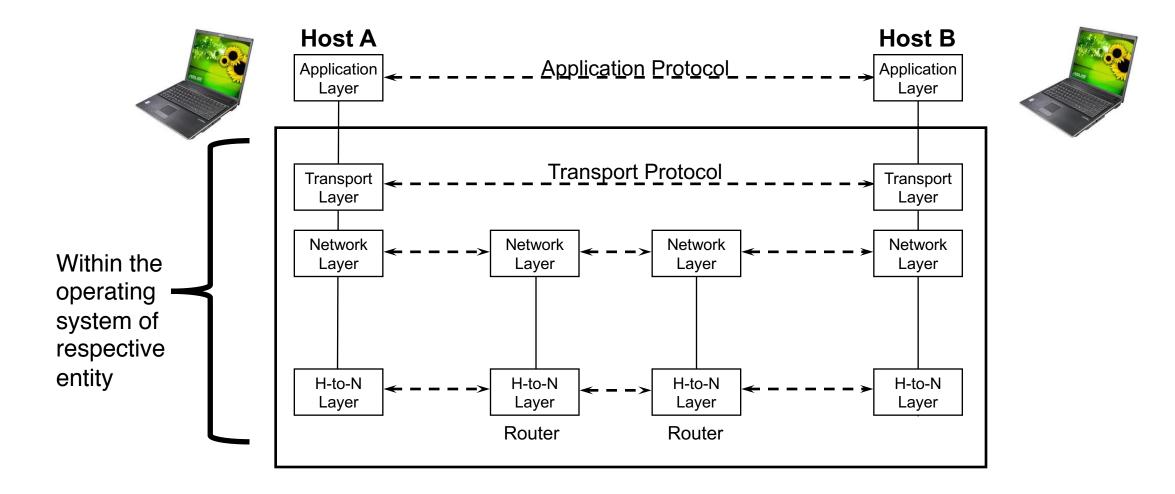
Host:: IP address A process socket process process socket socket Host: IP address C Internet process socket Connection := $(IP_S, Port_S, IP_D, Port_D)$

(S = source, D = destination)

App-layer connections

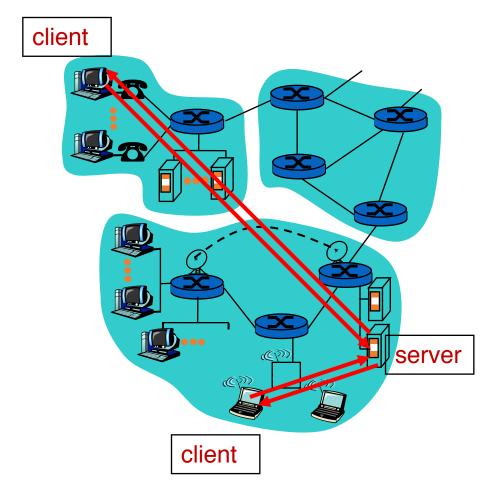
• A small demo

Recall: Apps rely on services by lower layers



Common Architectures of Applications

Client-server architecture



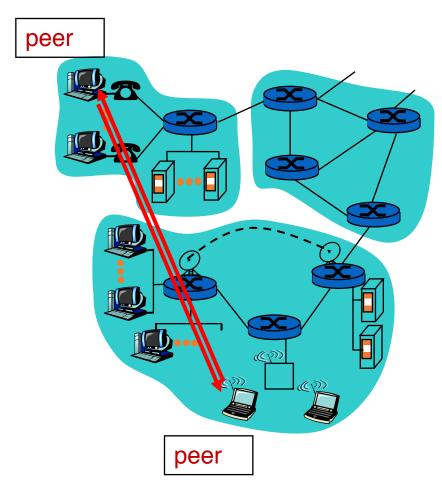
Server:

- always-on endpoint
- "permanent" IP address
- server farms ("data centers") for scaling

Clients:

- communicate with server
- may be intermittently connected
- may have dynamic IP addresses
- do not communicate directly with each other
- The web (HTTP) works this way.
- Many mobile apps work this way (e.g., Instagram)

Peer-to-peer (P2P) architecture



• Peers:

- Intermittently connected hosts
- Directly talking to each other

Little to no reliance on always-up servers

- Examples: BitTorrent, Skype
- Today, many applications use a hybrid model
 - Example: Skype "supernodes"

Going forward: A few applications

- Domain Name System
- The web: HTTP
- Mail
- File transfer

CS 352 Domain Name System

Lecture 3.2, Spring 2020 http://www.cs.rutgers.edu/~sn624/352

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"You have my name. Can you lookup my address?"

Domain Name System (DNS)

• Problem statement:

- Average brain can easily remember 7 digits for a few names
- On average, IP addresses have 12 digits
- We need an easier way to remember IP addresses
- Solution:
 - Use alphanumeric names to refer to hosts. Called host names or domain names
 - Example: cs.rutgers.edu
 - We need a directory: add a service to map between alphanumeric host names and binary IP addresses
 - We call this process Address Resolution

Types of Directories

- Directories map a *name* to an *address*
- Simplistic designs
 - Central directory
 - Ask everyone (e.g., flooding)
 - Tell everyone (e.g., push to a file like /etc/hosts)

Scalable distributed designs

- Hierarchical namespace (e.g., Domain Name System (DNS))
- Flat name space (e.g., Distributed Hash Table)



Simple DNS

- What if every host has a local directory?
- /etc/hosts.txt
 - How things worked in the early days of the Internet!
- What if hosts moved around? How do you keep this up to date?

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Simple DNS

DOMAIN NAME	IP ADDRESS	
www.yahoo.com	98.138.253.109	
cs.rutgers.edu	128.6.4.2	
www.google.com	74.125.225.243	
www.princeton.edu	128.112.132.86	

<Client IP, CPort, DNS server IP, 53>



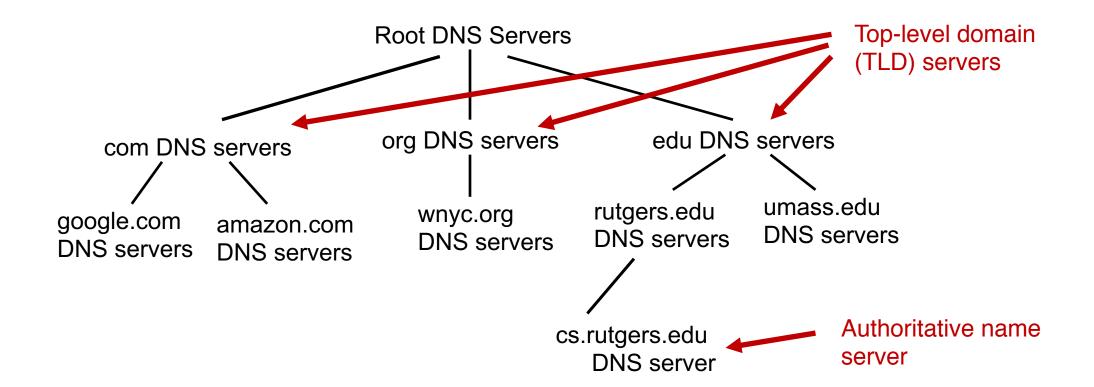
QUERY I STD QUERY I cs.rutgers.edu

<DNS server, 53, Client IP, Cport>

RESPONSE I STD QUERY I 128.6.4.2

- Key idea: Implement a server that looks up a table.
- Will this scale?
 - Every new host needs to be entered in this table
 - Performance: can the server serve billions of Internet users
 - Failure: what if the server or the database crashes?
 - How to secure this server?

Distributed and hierarchical database



RFC 1034: Distribution through hierarchy enables scaling

DNS Protocol

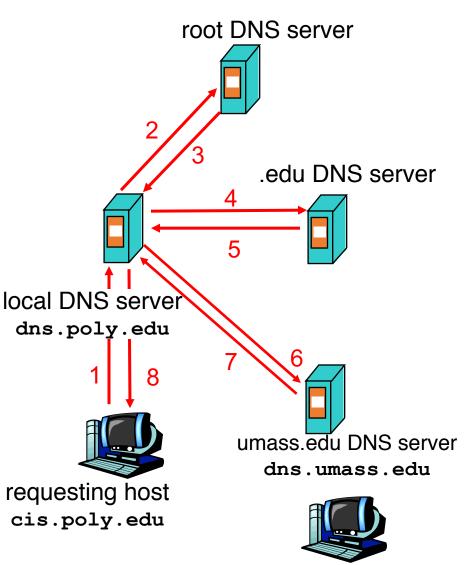
- Client and Server
- Client connects to Port 53 on server
- Assume DNS server IP known
- Two types of messages
 - Queries
 - Responses
- Type of Query (OPCODE) methods
 - Standard query (0x0)
 - e.g., Request IP address for a given domain name
 - Updates (0x5)
 - Provide a binding of IP address to domain name
- Each type has a common message format that follows the header

DNS Protocol

- When client wants to know an IP address for a host name
 - Client sends a DNS query to the "local" name server in its network
 - If name server contains the mapping, it returns the IP address to the client
 - Otherwise, the name server forwards the request to the root name server
 - The request works its way down the tree toward the host until it reaches a name server with the correct mapping

Example

- Host at cis.poly.edu wants IP
 address for gaia.cs.umass.edu
- Local DNS server
- Root DNS server
- TLD DNS server
- Authoritative DNS server

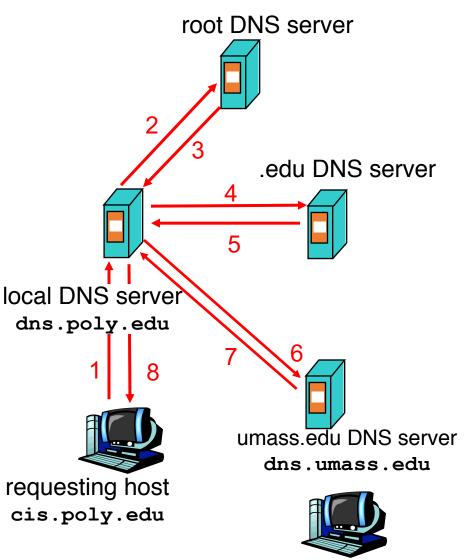


gaia.cs.umass.edu

Query type

Iterative query:

- Contacted server replies with name of server to contact
- "I don't know this name, but ask this server"
- Queries are iterative for the local DNS server



gaia.cs.umass.edu

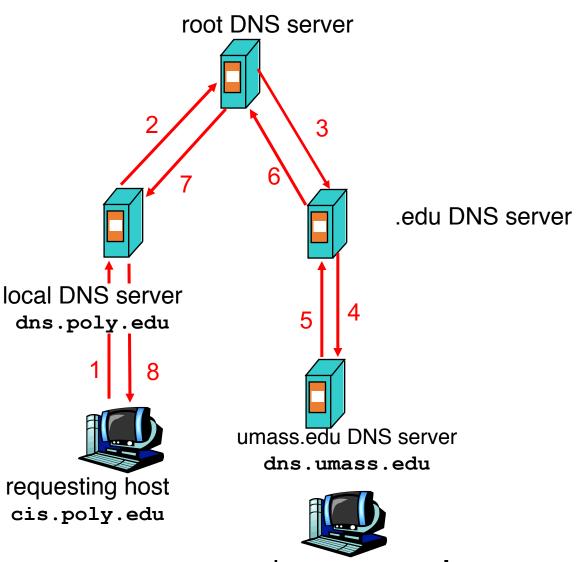
Query type

Recursive query:

 Puts burden of name resolution on the contacted name server

Problem: think about the root DNS server.

• Must it answer every DNS query?



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DNS in action

• A small demo

CS 352 DNS Records

Lecture 3.3, Spring 2020 http://www.cs.rutgers.edu/~sn624/352

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DNS records

DNS: distributed database storing resource records (RR)

RR format: (name, type, class, ttl, addr)

Type=A

name is hostname value is IP address

Type=AAAA

- ✤ name is hostname
- value is IPv6 address
- Type=NS
 - **name** is domain (e.g. foo.com)
 - **value** is hostname of authoritative name server for this domain

Type=CNAME

- name is alias name for some "canonical" (the real) name e.g., www.ibm.com is really
 - servereast.backup2.ibm.com
- * value is canonical name

Type=MX

 value is name of mailserver associated with name

DNS Record example

	NAME	Design.cs.rutgers.edu
RRs in response	ТҮРЕ	А
to query	CLASS	IN
	TTL	1 day(86400)
	ADDRESS	192.26.92.30

records for	NAME	Cs.rutgers.edu
authoritative	ТҮРЕ	NS
servers	CLASS	IN
Information about	TTL	1 day(86400)
nameserver	NSDNAME	Ns-lcsr.rutgers.edu

DNS serves as a general repository of information for the Internet!

DNS record types

• A small demo

DNS caching and updating records

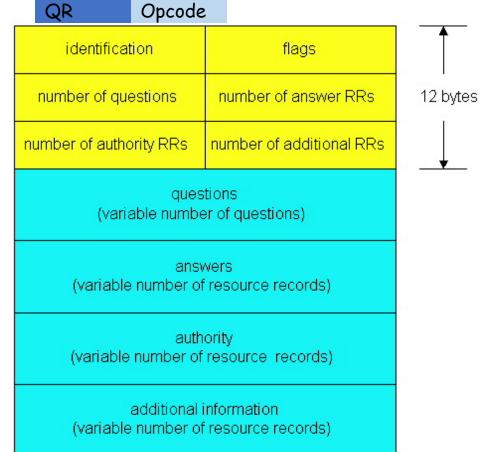
- Once (any) name server learns a name to IP address mapping, it *caches* the mapping
 - Cache entries timeout (disappear) after some time
 - TLD servers typically cached in local name servers
 - In practice, root name servers aren't visited often

DNS protocol messages

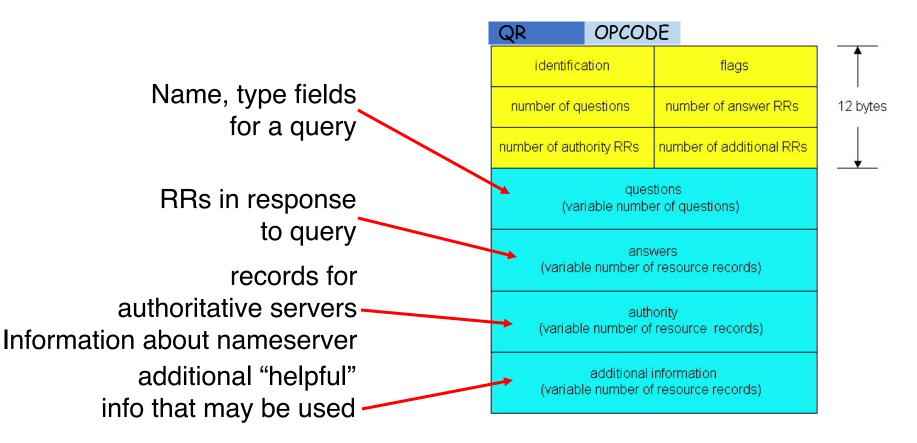
DNS protocol : query and reply messages, both with same message format

Message header

- QR = 0 for Query, 1 for response
- Opcode= 0 standard
- identification: 16 bit # for query, reply to query uses same #
- flags:
 - Authoritative answer
 - recursion desired
 - recursion available
 - reply is authoritative



DNS protocol, messages



Bootstrapping DNS

- How does a host contact the name server if all it has is the domain name and no (name server) IP address?
- IP address of at least 1 nameserver (usually, a local resolver) must be known a priori
- The name server may be bootstrapped "statically", e.g.,
 - File /etc/resolv.conf in unix
 - Start -> settings-> control panel-> network ->TCP/IP -> properties in windows
- ... or with another protocol!
 - DHCP: Dynamic Host Configuration Protocol (more on this later)

Summary of DNS

- Hostname to IP address translation via a global network of servers
- Use Multiple layers of indirection
 - Hierarchically scale
 - Good performance (load distribution)
 - Resilient to local transient failure
- Additional load distribution can happen at each level (e.g., TLD server)
- Uses caching all over for better performance
- DNS can be used to implement useful primitives atop domain names:
- Example: Scaling large web services, e.g., google search
- Domain-authoritative server will return an address from a pool of IP addresses, for example from Google's server "farm"

Some themes and observations on DNS

- Request/response nature of the protocol
- How messages are structured: simple, text-based protocol
 Similarly in HTTP, SMTP, FTP
- Caching is an effective method to improve performance