Network Applications and Application-Layer Protocols

Network applications:
- running in end systems (hosts)
- distributed, communicating using network
- use communication services provided by lower layer protocols (TCP, UDP)

Application-layer comm. protocols:
- define comm. interface between application components
- open protocol - components implemented independently can inter-operate

Web and HTTP

- **Web**: the application for distributed publishing and viewing of content
- **Client/server model**
  - **server**: hosts published content and sends the content upon request
  - **client**: requests, receives, and displays content
- **HTTP**: the comm. protocol supporting the web
  - request/response format

Plain Text Headers

HTTP headers are plain text.
TCP/UDP/IP/Ethernet headers are binary.

Issues:
- Efficiency
- Portability
- Easy for human understanding, debugging
Performance of HTTP Persistency

TCP per-connection overhead:
- Connection establishment
- Congestion control: slow start

Non-persistent HTTP (1.0)
- At most one object is sent over a TCP connection.
- Pays TCP per-connection overhead for each object.

Persistent HTTP (1.1)
- Multiple objects can be sent over single TCP connection between the browser and web server.

Additional Example Applications
- Remote console
  - Components: host machine and console client
  - Comm. protocol: SSH
- Electronic mail
  - Components: mail servers and mail readers
  - Comm. protocol: SMTP, POP3, IMAP
- Domain name system (DNS)
- Network file system (NFS)
- Peer-to-peer content sharing (Gnutella, BitTorrent)
  - ...

Electronic Mail

Two types of components:
- Mail servers
  - mailbox contains incoming messages for users
  - message queue of outgoing (to be sent) mail messages
- User agents
  - a.k.a. “mail reader”
  - composing, editing, reading mail messages
  - e.g., pine, Outlook, Web browser

Two types of protocols:
- Mail transfer protocol
  - from sender agent to the receiver’s mail server
  - SMTP (simple mail transfer protocol)
- Mail access protocol
  - the receiver pulls mails from server to agent
  - POP, IMAP, proprietary prot.
SMTP Interaction between mail servers at cs.rochester.edu (client) and gmail.com (server)

S: 220 gmail.com
C: HELO cs.rochester.edu
S: 250 Hello cs.rochester.edu, pleased to meet you
C: MAIL FROM: <alice@cs.rochester.edu>
S: 250 alice@cs.rochester.edu... Sender ok
C: RCPT TO: <bob@gmail.com>
S: 250 bob@gmail.com ... Recipient ok
C: DATA
S: 354 Enter mail, end with "." on a line by itself
C: Do you like ketchup?
C: How about pickles?
C: .
S: 250 Message accepted for delivery
C: QUIT
S: 221 gmail.com closing connection

Try SMTP Interaction Yourself

- telnet servername 25
- see 220 reply from server
- enter HELO, MAIL FROM, RCPT TO, DATA, QUIT cmds

This lets you
- send email without using a normal email client
- ...

Mail Access Protocols

- SMTP: delivery to receiver’s server and stored there
- Mail access protocol: retrieval from server
  - POP3: Post Office Protocol
    - authorization and download
  - IMAP: Internet Mail Access Protocol
    - manipulation of stored messages on server
  - Proprietary: Gmail, etc.

DNS: Domain Name System

- People: multiple identifiers
  - SSN – good for machine bookkeeping, indexing
  - name – human friendly, easy to remember
- Internet hosts:
  - IP address - used for addressing, routing on the Internet
  - “name”, e.g., cycle1.cs.rochester.edu - human friendly
  - map between IP addresses and names?
- DNS query: find the IP address for a given name
  - not part of Internet as a network
  - ease of use for Internet applications
  - “ssh cycle1.cs.rochester.edu” vs. “ssh 128.151.67.99”
Domain Name System: Overview

- Distributed database
  - Implemented with collaboration of many name servers distributed all over the network
- DNS queries
  - Name lookup: find the IP address for a given name
  - Others: find mail server for a domain, ipv4/v6 address mapping, ...

DNS: Decentralized and Hierarchical

- Decentralized
  - a large number of servers/sites work together
- Why not centralize DNS?
  - performance bottleneck
  - single point of failure
  - can only be close to few hosts => long latency to many others
- Hierarchical/partitioned
  - there are different types of name servers in charge of different mappings
  - What if massively replicating it?
    - high overhead of maintaining consistency: hard to make any changes on the data

Types of Name Servers

- Local name server (defined for a particular group of hosts):
  - each organization often has a local (default) name server
  - used when one of the hosts in its domain initiates a DNS query
  - first stop for a DNS query
- Authoritative name server (defined for a particular group of hosts):
  - maintain "IP address — name" mapping for a group of hosts so it can answer DNS query for these hosts
  - used when one of the hosts in its domain is the target of a DNS query
  - last stop for a DNS query (if ever reached)
  - often the same as local name server for an organization
- Each local NS may not know all authoritative NSes
  - something is missing ...

Root Name Servers

- Root name server (defined globally)
  - bridging between local NSs and authoritative NSes
  - contacted by local name server that cannot resolve name
- What it does:
  - contacts authoritative name server
  - gets result and returns it to the requesting local name server

[Map of root name servers]
DNS Query in Action

- Host `surf.kai.com` wants IP addr. of `xyz.cs.rochester.edu`
  1. Contacts its local DNS server, `dns.kai.com`
  2. `dns.kai.com` contacts root NS
  3. Root NS contacts authoritative name server, `dns.cs.rochester.edu`

*Note* that the destination host is not involved in the lookup.

Intermediate Name Servers

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

Iterative Queries

- **Recursive query**: puts burden of name resolution on contacted name server
- **Iterative query**: contacted server replies with name of server for next contact
  - “I don’t know this name, but ask this server”

What is the real difference here?

DNS Caching

- Once a name server learns mapping, it *caches* mapping
  - Next query for the same name can be answered directly
  - Can be at any step of the name lookup (even at end host), but not at root name server
- Cache entries timeout (and removed) after some time
  - As long as a day; as short as a few minutes
- Timeout is necessary because the mapping can change
  - Switch Web server to a more powerful machine ⇒ change the mapping between `www.cs.rochester.edu` to IP address of the new machine
  - Load balancing
DNS Properties

- Scalability
  - poor scalability at the few root name servers
  - made more scalable by iterative queries and caching
- Reliability
  - problems at (even a single) root name server(s) can cause big problem
  - again, caching helps improve reliability
- Consistency
  - DNS caching is replication without consistency guarantee
  - only feasible for stable name-IP address mapping, may not be suitable for more dynamic information

TCP vs. UDP

- We saw applications:
  - Web/HTTP
  - Email/SMTP/POP3/IMAP
  - DNS
- They build on some transport services.
  - TCP or UDP?

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