Peer-to-Peer File Sharing

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COS 461: Computer Networks

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Server Distributing a Large File

- Sending an F-bit file to N receivers
  - Transmitting NF bits at rate $u_s$
  - ... takes at least $NF/u_s$ time

- Receiving the data at the slowest receiver
  - Slowest receiver has download rate $d_{\text{min}} = \min_i(d_i)$
  - ... takes at least $F/d_{\text{min}}$ time

- Download time: $\max\{NF/u_s, F/d_{\text{min}}\}$

Speeding Up the File Distribution

- Increase the server upload rate
  - Higher link bandwidth at the server
  - Multiple servers, each with their own link

- Alternative: have the receivers help
  - Receivers get a copy of the data
  - ... and redistribute to other receivers
  - To reduce the burden on the server
### Peers Help Distributing a Large File

Components of distribution latency:
- Server must send each bit: min time \( F/u_i \)
- Slowest peer must receive each bit: min time \( F/d_{\min} \)

Upload time using all upload resources:
- Total number of bits: \( NF \)
- Total upload bandwidth \( u_i + \text{sum}(u_j) \)

Total: \( \max\{F/u_i, F/d_{\min}, NF/(u_i+\text{sum}(u_j))\} \)

### Peer-to-Peer is Self-Scaling

- Download time grows slowly with \( N \)
  - Client-server: \( \max\{NF/u, F/d_{\min}\} \)
  - Peer-to-peer: \( \max\{F/u_i, F/d_{\min}, NF/(u_i+\text{sum}(u_j))\} \)
- But...
  - Peers may come and go
  - Peers need to find each other
  - Peers need to be willing to help each other

### Locating the Relevant Peers

Three main approaches:
- Central directory (Napster)
- Query flooding (Gnutella)
- Hierarchical overlay (Kazaa, modern Gnutella)

Design goals:
- Scalability
- Simplicity
- Robustness
- Plausible deniability
Peer-to-Peer Networks: Napster

- Napster history: the rise
  - 1/99: Napster version 1.0
  - 5/99: company founded
  - 12/99: first lawsuits
  - 2000: 80 million users

- Shawn Fanning, Northeastern freshman

- Napster history: the fall
  - Mid 2001: out of business due to lawsuits
  - Mid 2001: dozens of decentralized P2P alternatives
  - 2003: growth of pay services like iTunes

Napster Directory Service

- Client contacts Napster (via TCP)
  - Provides a list of music files it will share
  - ... and Napster’s central server updates the directory

- Client searches on a title or performer
  - Napster identifies online clients with the file
  - ... and provides their IP addresses

- Client requests the file from the chosen supplier
  - Supplier transmits the file to the client
  - Both client and supplier report status to Napster

Napster Properties

- Server’s directory continually updated
  - Always know what music is currently available
  - Point of vulnerability for legal action

- Peer-to-peer file transfer
  - No load on the server
  - Plausible deniability for legal action (but not enough)

- Bandwidth
  - Suppliers ranked by apparent bandwidth and response time

Napster: Limitations of Directory

- File transfer is decentralized, but locating content is highly centralized
  - Single point of failure
  - Performance bottleneck
  - Copyright infringement

- So, later P2P systems were more distributed
  - Gnutella went to the other extreme...
Peer-to-Peer Networks: Gnutella

- Gnutella history
  - 2000: J. Frankel & T. Pepper released Gnutella
  - Soon after: many other clients (e.g., Morpheus, Limewire, Bearshare)
  - 2001: protocol enhancements, e.g., “ultrapeers”

- Query flooding
  - Join: contact a few nodes to become neighbors
  - Publish: no need!
  - Search: ask neighbors, who ask their neighbors
  - Fetch: get file directly from another node

Gnutella: Search by Flooding
Gnutella: Pros and Cons

• Advantages
  – Fully decentralized
  – Search cost distributed
  – Processing per node permits powerful search semantics

• Disadvantages
  – Search scope may be quite large
  – Search time may be quite long
  – High overhead, and nodes come and go often

Lessons and Limitations

• Client-Server performs well
  – But not always feasible: Performance not often key issue!

For the following, you should choose a system that’s
(A) Flood-based (B) DHT-based (C) Either (D) Neither

– Organic scaling
– Decentralization of visibility and liability
– Finding popular stuff
– Finding unpopular stuff
– Fancy local queries
– Fancy distributed queries
– Prevent data poisoning
– Performance guarantees

Peer-to-Peer Networks: KaZaA

• KaZaA history
  – 2001: created by Dutch company (Kazaa BV)
  – Single network called FastTrack used by other clients as well
  – Eventually protocol changed so others could no longer use it

• Super-node hierarchy
  – Join: on start, the client contacts a super-node
  – Publish: client sends list of files to its super-node
  – Search: queries flooded among super-nodes
  – Fetch: get file directly from one or more peers
**“Ultra/super peers” in KaZaA and later Gnutella**

- KaZaA: MoFvaFon for Super-Nodes
  - Query consolidation
    - Many connected nodes may have only a few files
    - Propagating query to a sub-node may take more
time than for the super-node to answer itself
  - Stability
    - Super-node selection favors nodes with high up-time
    - How long you’ve been on is a good predictor of how
long you’ll be around in the future

**Peer-to-Peer Networks: BitTorrent**

- BitTorrent history
  - 2002: B. Cohen debuted BitTorrent
- Emphasis on efficient fetching, not searching
  - Distribute same file to many peers
  - Single publisher, many downloaders
- Preventing free-loading
  - Incentives for peers to contribute

**BitTorrent: Simultaneous Downloads**

- Divide file into many chunks (e.g., 256 KB)
  - Replicate different chunks on different peers
  - Peers can trade chunks with other peers
  - Peer can (hopefully) assemble the entire file
- Allows simultaneous downloading
  - Retrieving different chunks from different peers
  - And uploading chunks to peers
  - Important for very large files
BitTorrent: Tracker

- **Infrastructure node**
  - Keeps track of peers participating in the torrent
  - Peers registers with the tracker when it arrives

- **Tracker selects peers for downloading**
  - Returns a random set of peer IP addresses
  - So the new peer knows who to contact for data

- **Can have “trackerless” system**
  - Using distributed hash tables (DHTs)
BitTorrent: Overall Architecture

Web Server
Tracker

Peer [Leech] Downloader

Peer [Seed]

Peer [Leech]

Web Server
Tracker

Get-announce
Response-peer list
Get announce
with list of peers

Peer [Leech] Downloader

Peer [Seed]

Peer [Leech]

**BitTorrent: Chunk Request Order**
- Which chunks to request?
  - Could download in order
  - Like an HTTP client does
- Problem: many peers have the early chunks
  - Peers have little to share with each other
  - Limiting the scalability of the system
- Problem: eventually nobody has rare chunks
  - E.g., the chunks need the end of the file
  - Limiting the ability to complete a download
- Solutions: random selection and rarest first

**BitTorrent: Rarest Chunk First**
- Which chunks to request first?
  - Chunk with fewest available copies (i.e., rarest chunk)
- Benefits to the peer
  - Avoid starvation when some peers depart
- Benefits to the system
  - Avoid starvation across all peers wanting a file
  - Balance load by equalizing # of copies of chunks

**Free-Riding in P2P Networks**
- Vast majority of users are free-riders
  - Most share no files and answer no queries
  - Others limit # of connections or upload speed
- A few “peers” essentially act as servers
  - A few individuals contributing to the public good
  - Making them hubs that basically act as a server
- BitTorrent prevent free riding
  - Allow the fastest peers to download from you
  - Occasionally let some free loaders download

**Bit-Torrent: Preventing Free-Riding**
- Peer has limited upload bandwidth
  - And must share it among multiple peers
  - Tit-for-tat: favor neighbors uploading at highest rate
- Rewarding the top four neighbors
  - Measure download bit rates from each neighbor
  - Reciprocate by sending to the top four peers
- Optimistic unchoking
  - Randomly try a new neighbor every 30 seconds
  - So new neighbor has a chance to be a better partner
BitTyrant: Gaming BitTorrent

- BitTorrent can be gamed, too
  - Peer uploads to top N peers at rate 1/N
  - E.g., if N=4 and peers upload at 15, 12, 10, 9, 8, 3
  - ... peer uploading at rate 9 gets treated quite well
- Best to be the Nth peer in the list, rather than 1st
  - Offer just a bit more bandwidth than low-rate peers
  - And you’ll still be treated well by others
- BitTyrant software  http://bittyrant.cs.washington.edu/
  - Uploads at higher rates to higher-bandwidth peers

Conclusions

- Finding the appropriate peers
  - Centralized directory (Napster)
  - Query flooding (Gnutella)
  - Super-nodes (KaZaA)
- BitTorrent
  - Distributed download of large files
  - Anti-free-riding techniques
- Great example of how change can happen so quickly in application-level protocols