CSCI-1680
CDN & P2P

Chen Avin

Based partly on lecture notes by Scott Shenker and John Jannotti andRodrigo Fonseca

And “Computer Networking: A Top Down Approach” - 6th edition

Last time

- **DNS & DHT**
- **Today: P2P & CND**
  - P2P Benefits
  - Bit Torrent & Skype
  - Caching & Content Distribution Networks

Content distribution networks

- ***challenge:*** **how to stream content (selected from millions of videos) to hundreds of thousands of simultaneous users?**

- ***option 1:*** **single, large "mega-server"**
  - single point of failure
  - point of network congestion
  - long path to distant clients
  - multiple copies of video sent over outgoing link

….quite simply: this solution *doesn't scale*

Content distribution networks

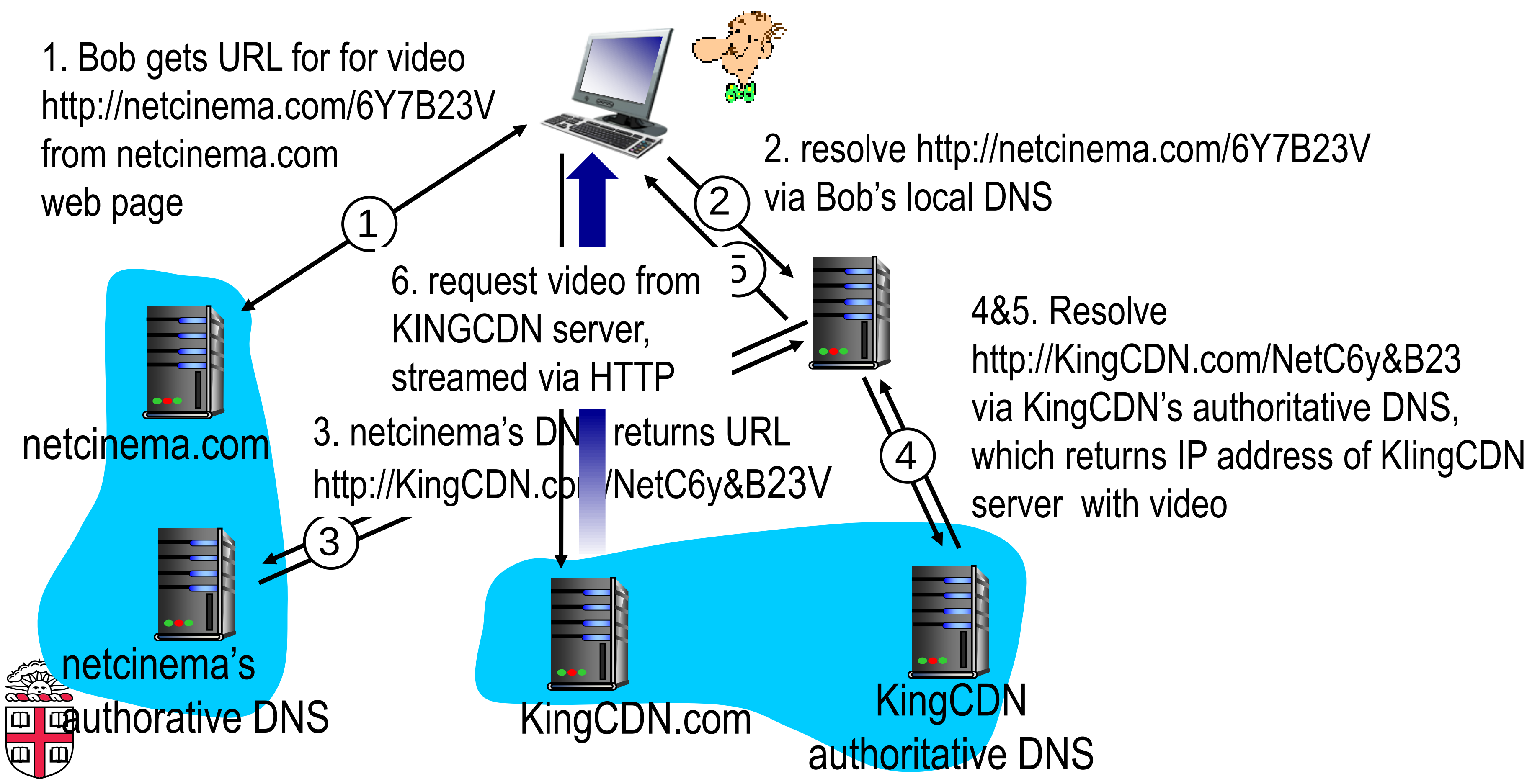
- ***challenge:*** **how to stream content (selected from millions of videos) to hundreds of thousands of simultaneous users?**

- ***option 2:*** **store/serve multiple copies of videos at multiple geographically distributed sites *(CDN)***
  - *enter deep:* push CDN servers deep into many access networks
    - close to users
    - used by Akamai, 1700 locations
  - *bring home:* smaller number (10's) of larger clusters in POPs near (but not within) access networks
    - used by Limelight

CDN: “simple” content access scenario

Bob (client) requests video http://netcinema.com/6Y7B23V

- video stored in CDN at http://KingCDN.com/NetC6y&B23V



CDN cluster selection strategy

- ***challenge:*** **how does CDN DNS select "good" CDN node to stream to client**
  - pick CDN node geographically closest to client
  - pick CDN node with shortest delay (or min # hops) to client (CDN nodes periodically ping access ISPs, reporting results to CDN DNS)
  - IP anycast
- ***alternative:*** **let *client* decide - give client a list of several CDN servers**
  - client pings servers, picks "best"
  - Netflix approach

How Akamai works

- **Akamai has cache servers deployed close to clients**
  – Co-located with many ISPs
- **Challenge: make same domain name resolve to a proxy close to the client**
- **Lots of DNS tricks. BestBuy is a customer**
  – Delegate name resolution to Akamai (via a CNAME)
- **From Brown:**

```
dig www.bestbuy.com
;; ANSWER SECTION:
www.bestbuy.com.        3600  IN    CNAME    www.bestbuy.com.edgesuite.net.
www.bestbuy.com.edgesuite.net. 21600 IN    CNAME    a1105.b.akamai.net.
a1105.b.akamai.net.     20    IN    A        198.7.236.235
a1105.b.akamai.net.     20    IN    A        198.7.236.240
```

  – Ping time: 2.53ms
- **From Berkeley, CA:**

```
a1105.b.akamai.net.     20    IN    A        198.189.255.200
a1105.b.akamai.net.     20    IN    A        198.189.255.207
```

  – Ping time: 3.20ms

DNS Resolution

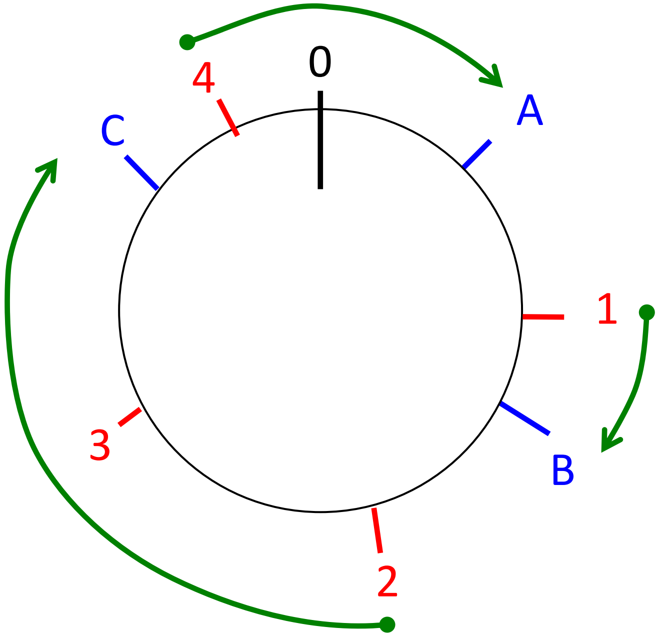
```
dig www.bestbuy.com
;; ANSWER SECTION:
www.bestbuy.com.         3600  IN   CNAME   www.bestbuy.com.edgesuite.net.
www.bestbuy.com.edgesuite.net. 21600 IN   CNAME   a1105.b.akamai.net.
a1105.b.akamai.net.      20    IN   A       198.7.236.235
a1105.b.akamai.net.      20    IN   A       198.7.236.240
;; AUTHORITY SECTION:
b.akamai.net.            1101  IN   NS      n1b.akamai.net.
b.akamai.net.            1101  IN   NS      n0b.akamai.net.
;; ADDITIONAL SECTION:
n0b.akamai.net.          1267  IN   A       24.143.194.45
n1b.akamai.net.          2196  IN   A       198.7.236.236
```

- **n1b.akamai.net finds an edge server close to the client’s local resolver**
  - Uses knowledge of network: BGP feeds, traceroutes. *Their secret sauce…*

What about the content?

- **Say you are Akamai**
  - Clusters of machines close to clients
  - Caching data from many customers
  - Proxy fetches data from *origin* server first time it sees a URL
- **Choose cluster based on client network location**
- **How to choose server within a cluster?**
- **If you choose based on client**
  - Low hit rate: N servers in cluster means N cache misses per URL

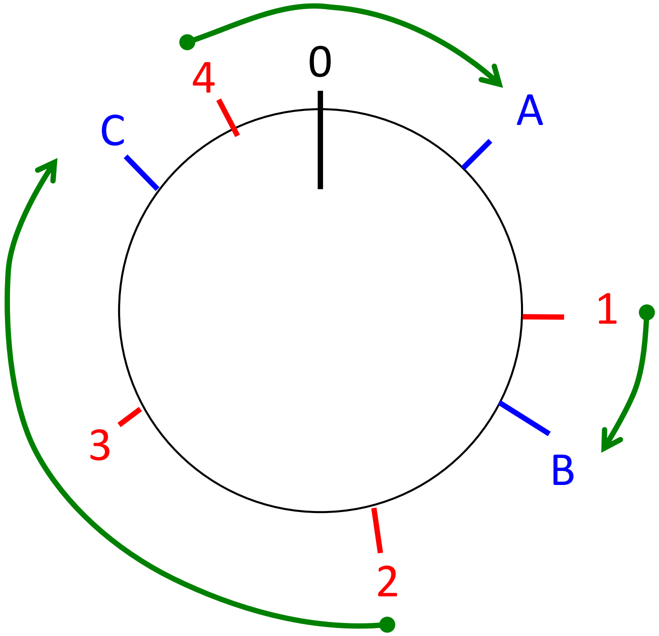
Consistent Hashing [Karger et al., 99]



Object	Cache
1	B
2	C
3	C
4	A

- **URLs and Caches are mapped to points on a circle using a hash function**
- **A URL is assigned to the closest cache clockwise**
- **Minimizes data movement on change!**
  - When a cache is added, only the items in the preceding segment are moved
  - When a cache is removed, only the next cache is affected

Consistent Hashing [Karger et al., 99]



Object	Cache
1	B
2	C
3	C
4	A

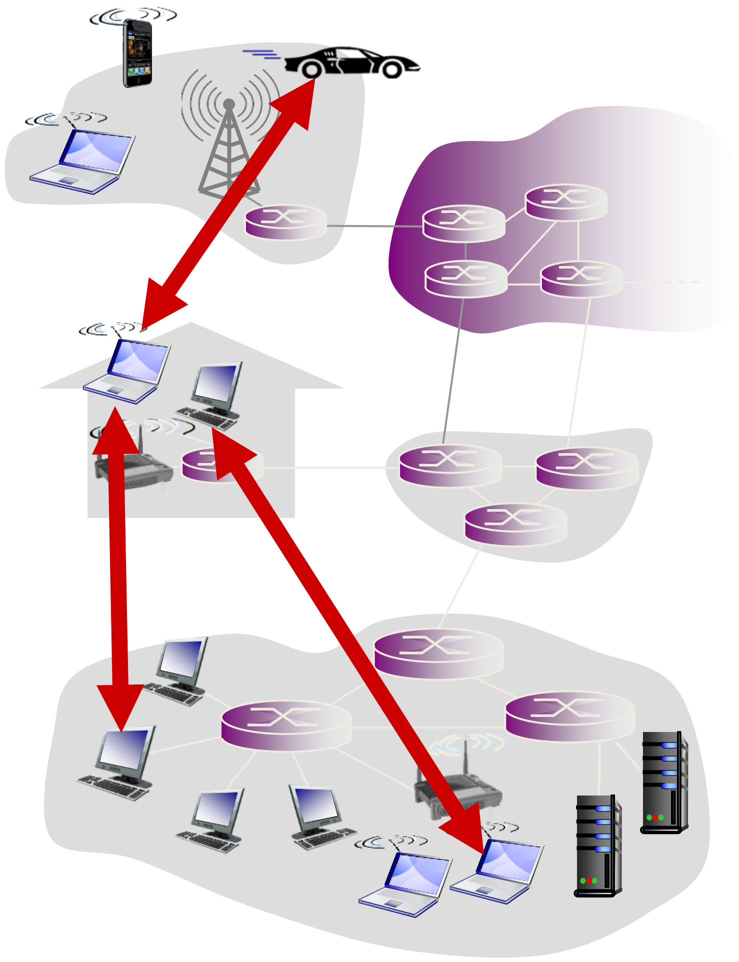
- **Minimizes data movement**
  - If 100 caches, add/remove a proxy invalidates ~1% of objects
  - When proxy overloaded, spill to successor
- **Can also handle servers with different capacities. How?**
  - Give bigger proxies more random points on the ring

Pure P2P architecture

- *no* always-on server
- arbitrary end systems directly communicate
- peers are intermittently connected and change IP addresses

examples:

- file distribution (BitTorrent)
- Streaming (KanKan)
- VoIP (Skype)



Peer-to-Peer Systems

- **How did it start?**
  - A killer application: file distribution
  - Free music over the Internet! (*not exactly legal…*)
- **Key idea: share storage, content, and bandwidth of individual users**
  - Lots of them
- **Big challenge: coordinate all of these users**
  - In a scalable way (not NxN!)
  - With changing population (aka *churn*)
  - With no central administration
  - With no trust
  - With large heterogeneity (content, storage, bandwidth,…)

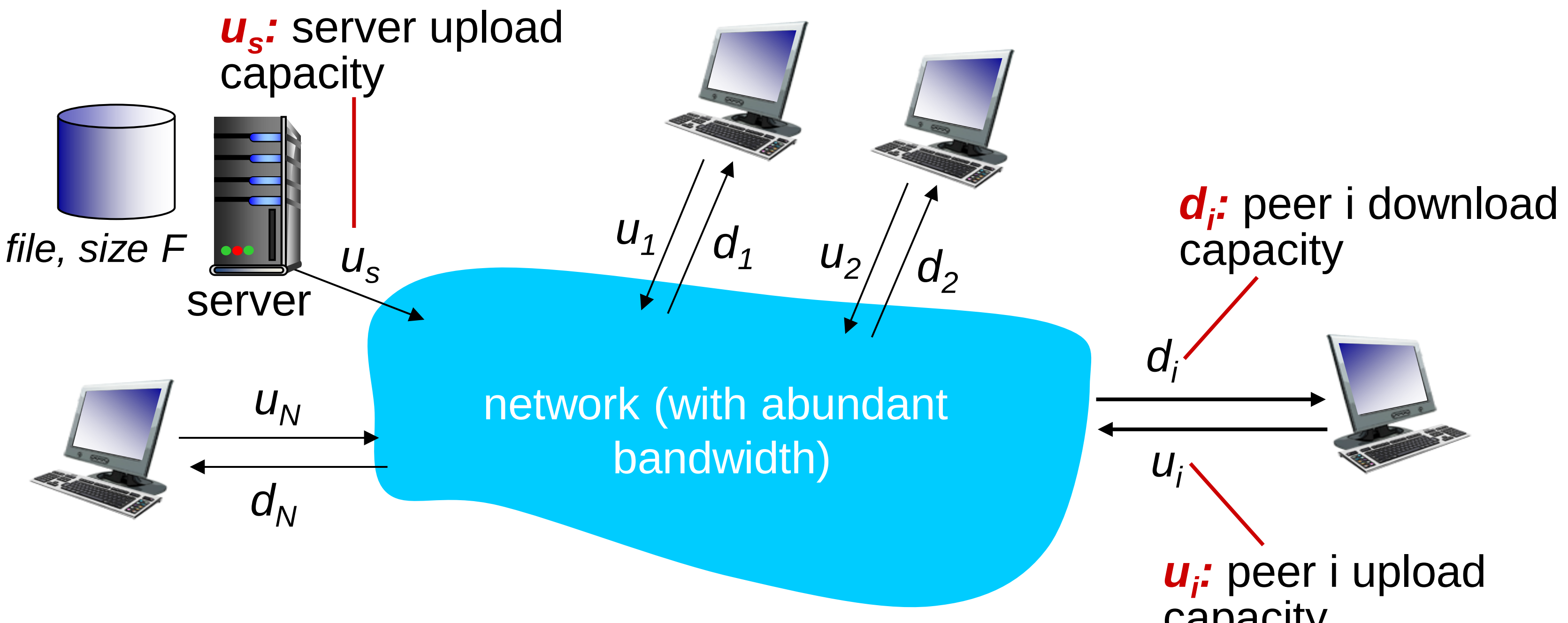
3 Key Requirements

- **P2P Systems do three things:**
- **Help users determine what they want**
  - Some form of search
  - P2P version of Google
- **Locate that content**
  - Which node(s) hold the content?
  - P2P version of DNS (map name to location)
- **Download the content**
  - Should be efficient
  - P2P form of Akamai

File distribution: client-server vs P2P

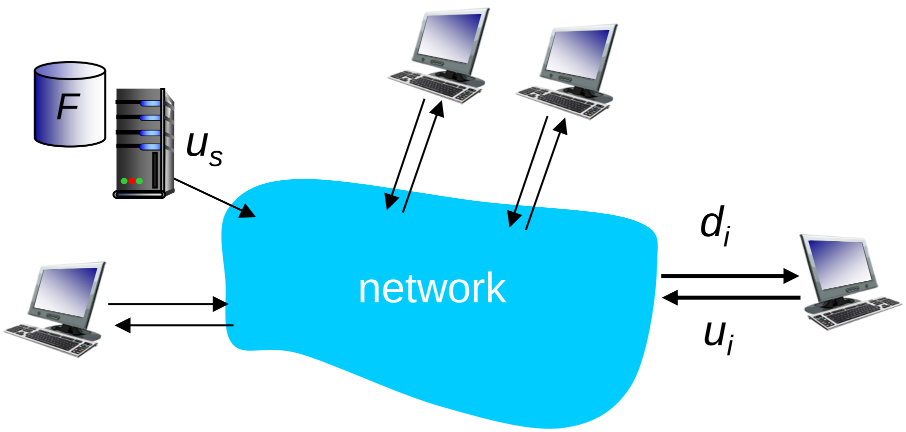
Question: **how much time to distribute file (size *F*) from one server to *N* *peers*?**

- peer upload/download capacity is limited resource



File distribution time: client-server

- ***server transmission:*** **must sequentially send (upload) *N* file copies:**
  - time to send one copy: F/u_s
  - time to send N copies: NF/u_s



- *client:* each client must download file copy
  - d_{min} = min client download rate
  - min client download time: F/d_{min}

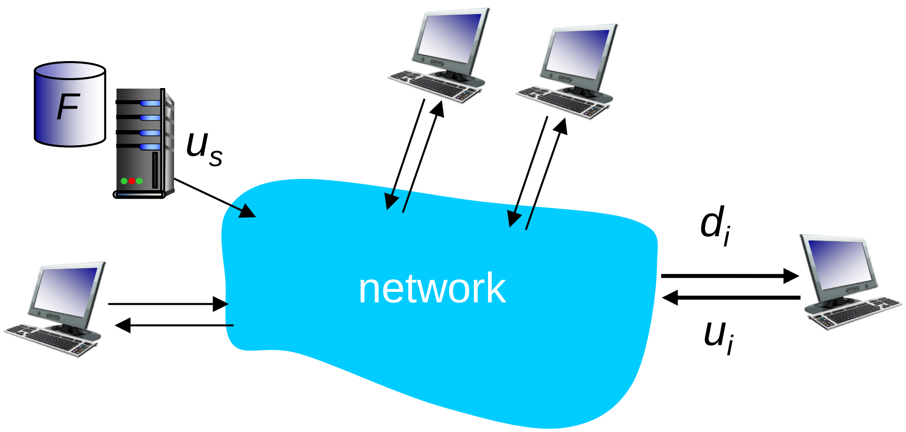
time to distribute F to N clients using client-server approach

$$D_{c-s} \geq max\{NF/u_{s,},F/d_{min}\}$$

increases linearly in N

File distribution time: P2P

- ***server transmission:*** **must upload at least one copy**
  - time to send one copy: F/u_s



- *client:* each client must download file copy
  - min client download time: F/d_{min}
- *clients:* as aggregate must download *NF* bits
  - max upload rate (limting max download rate) is $u_s + \Sigma u_i$

time to distribute F to N clients using P2P approach

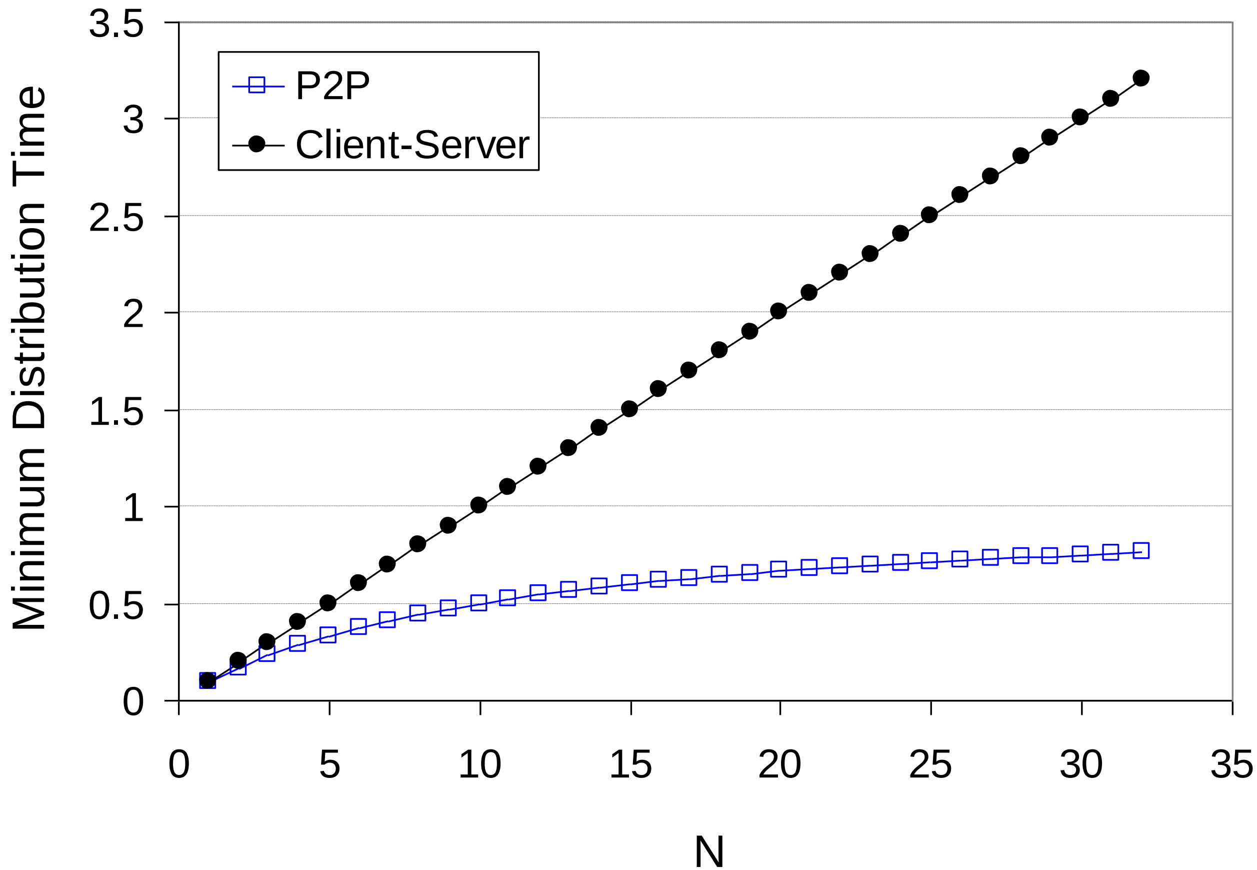
$$D_{P2P} \geq max\{F/u_{s,}, F/d_{min,}, NF/(u_s + \Sigma u_i)\}$$

increases linearly in *N* …

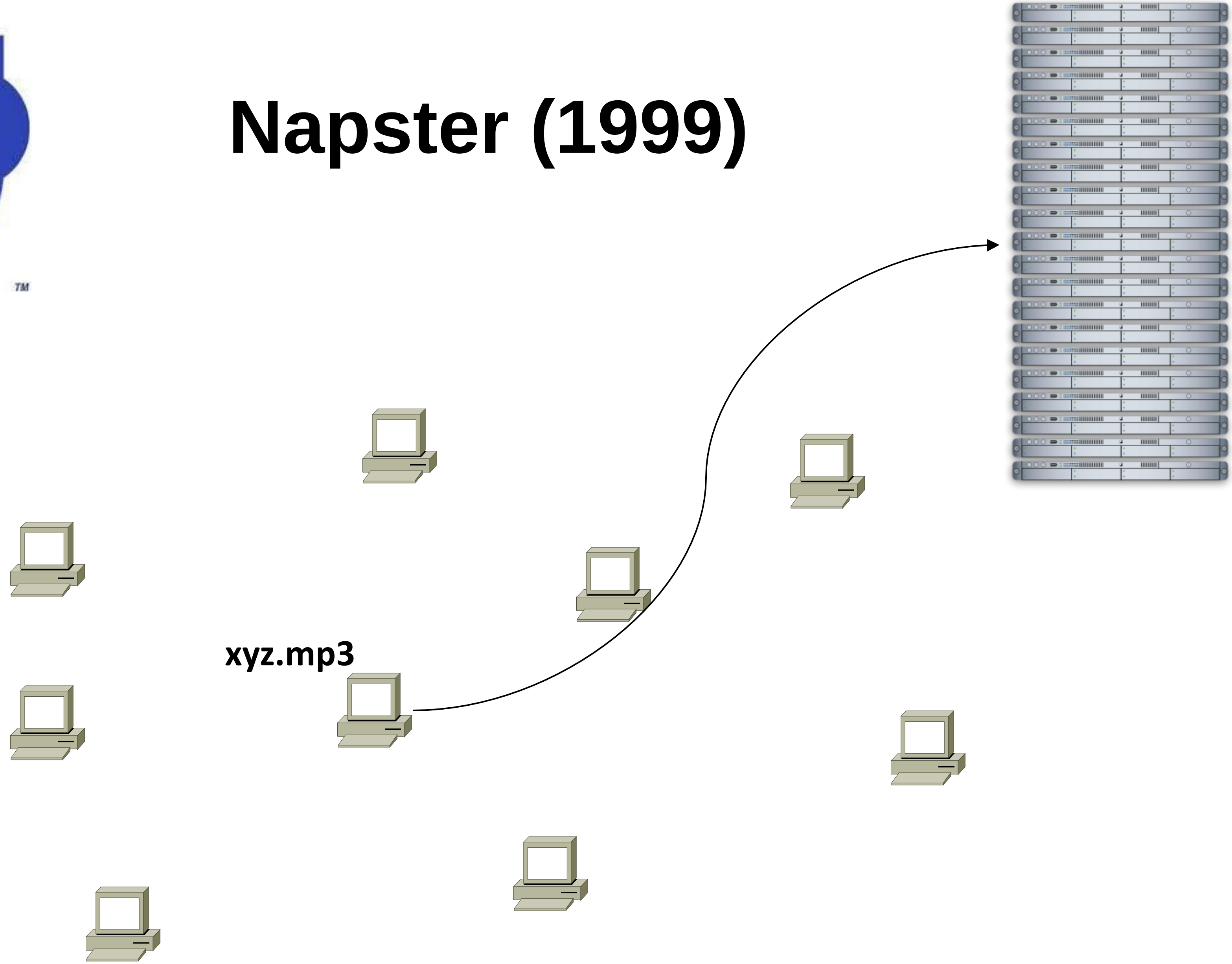
… but so does this, as each peer brings service capacity

Client-server vs. P2P: example

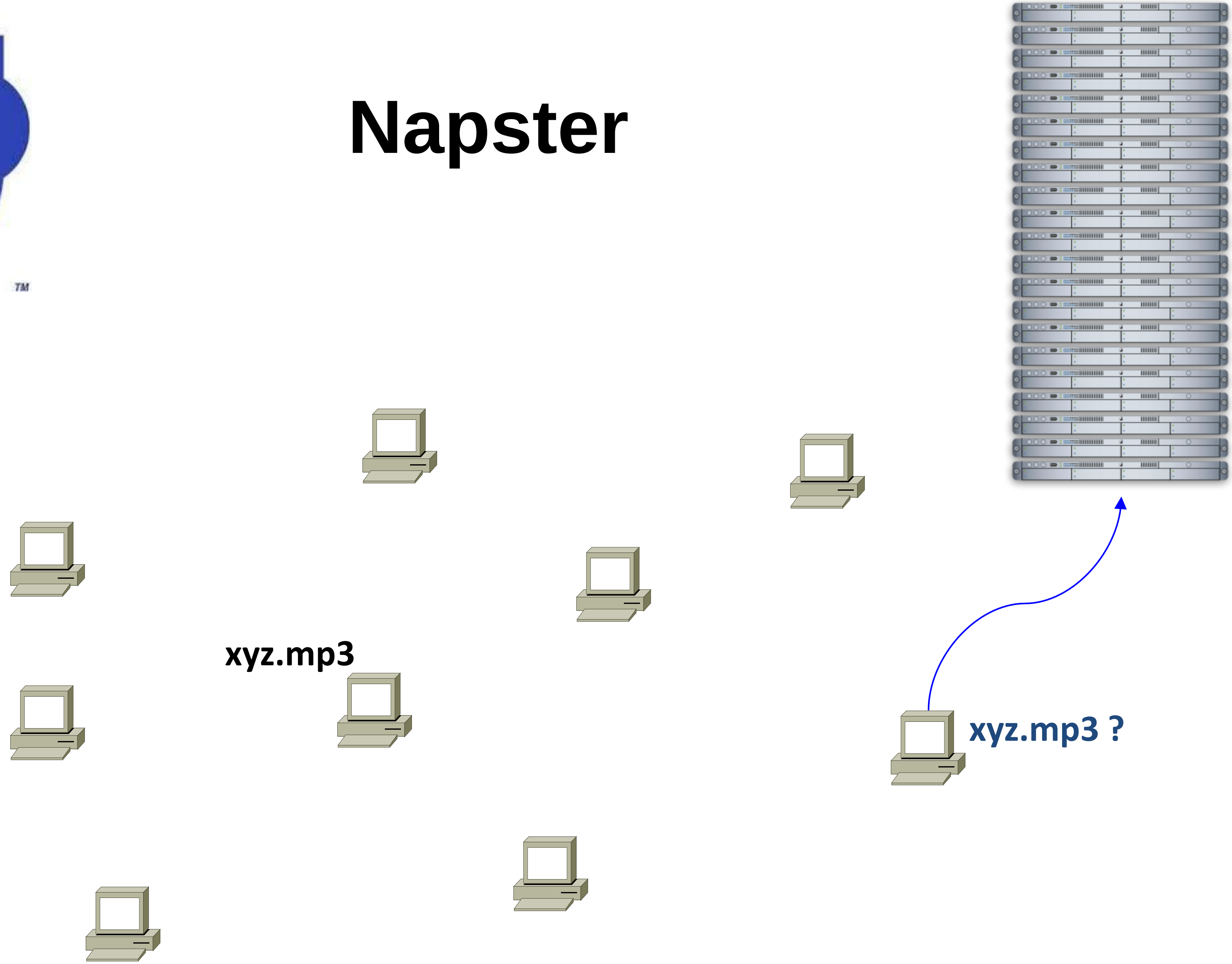
client upload rate = u, F/u = 1 hour, $u_s = 10u$, $d_{min} \geq u_s$



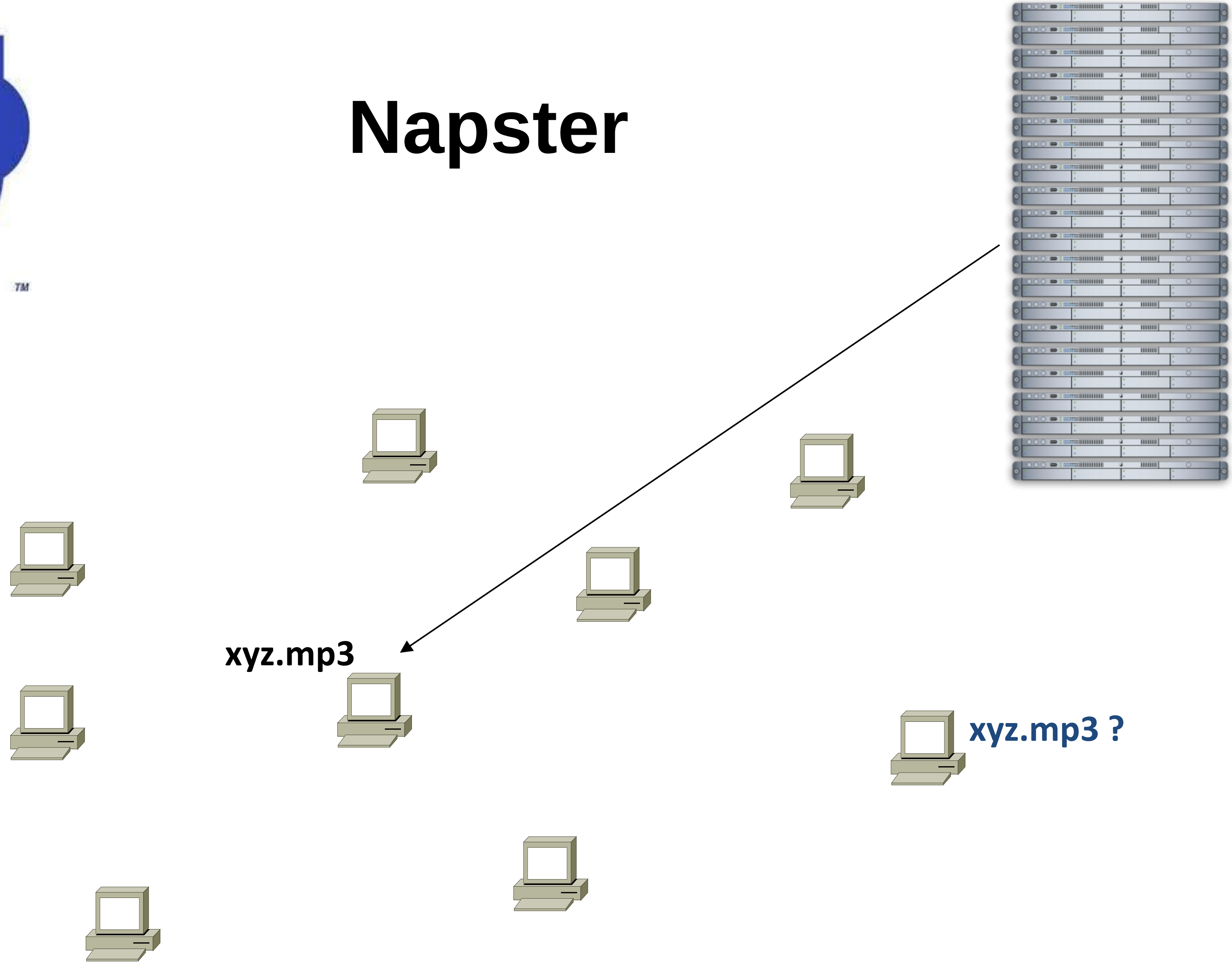
Napster (1999)



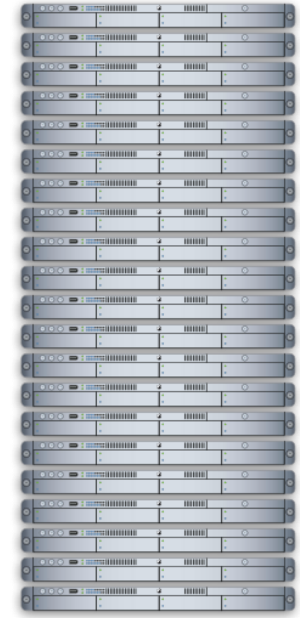
Napster

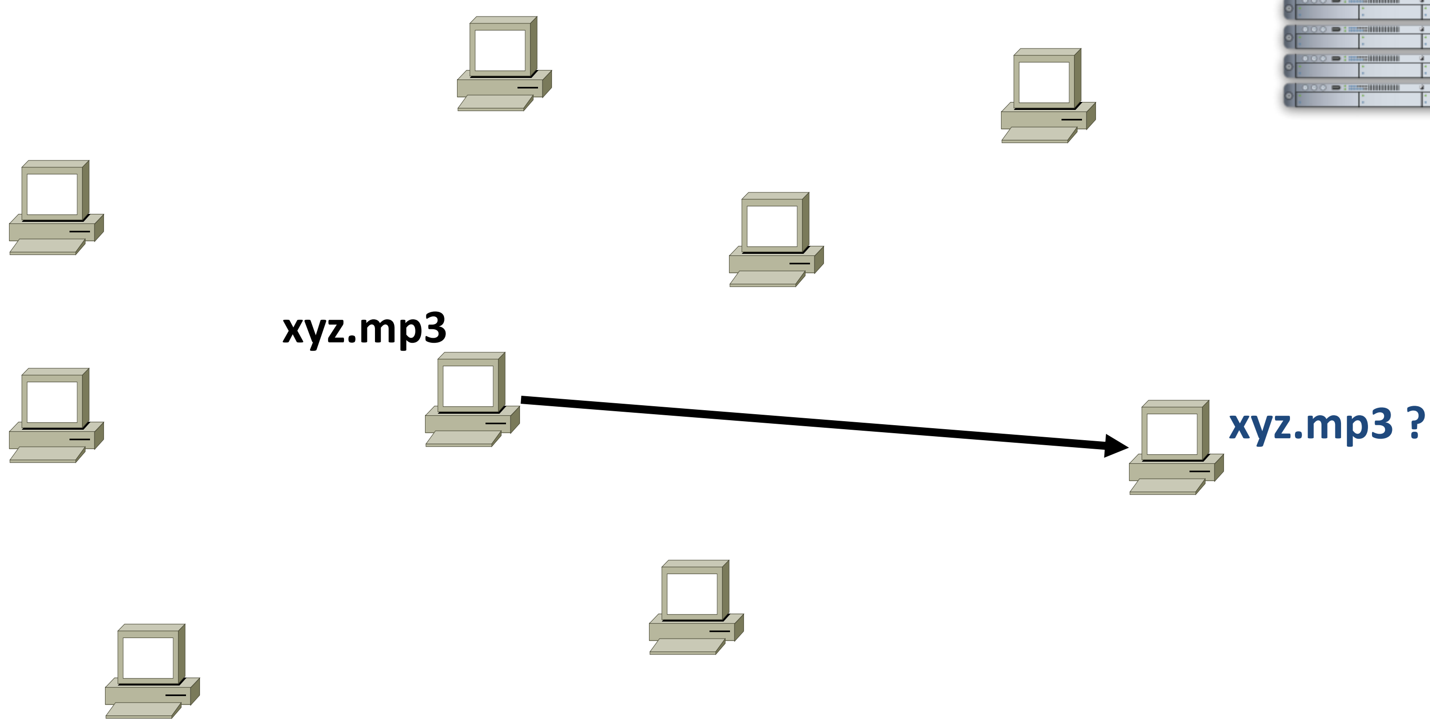


Napster



Napster



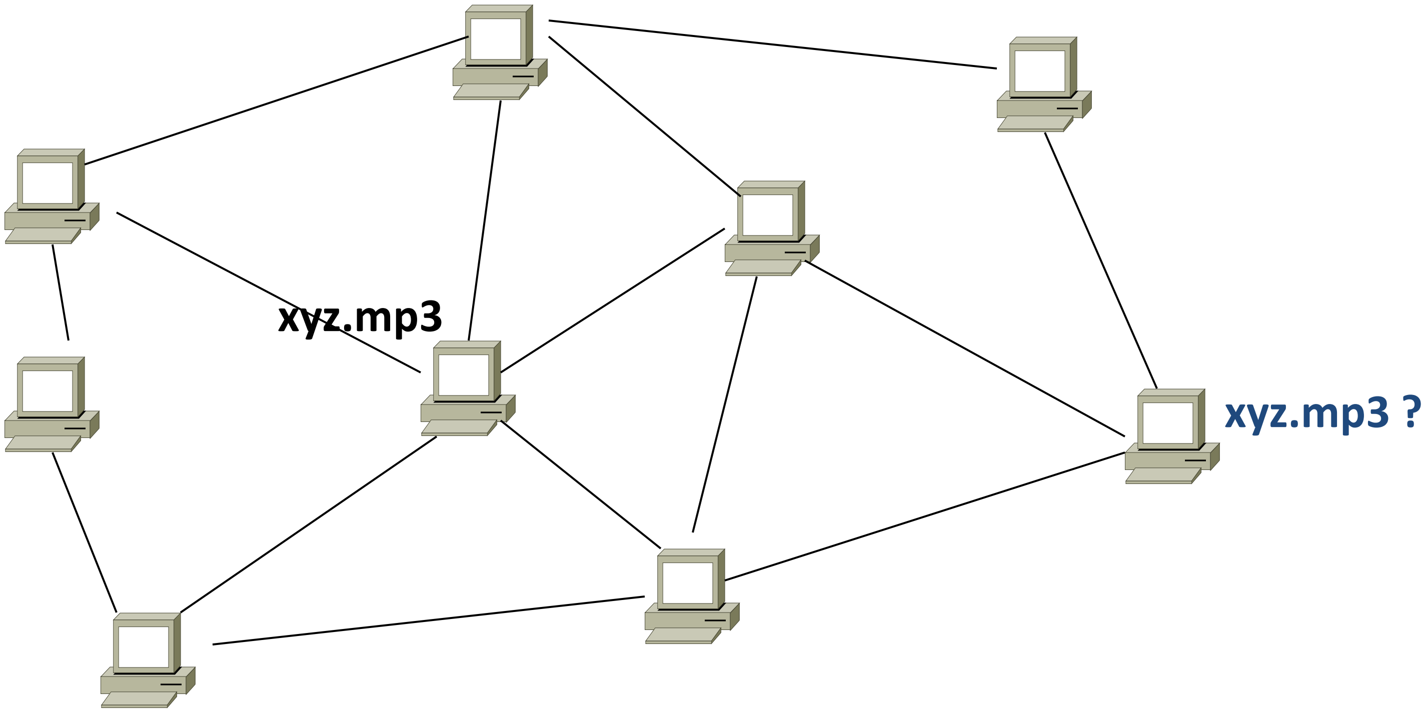


Napster

- **Search & Location: central server**
- **Download: contact a peer, transfer directly**
- **Advantages:**
  - Simple, advanced search possible
- **Disadvantages:**
  - Single point of failure (technical and … legal!)
  - The latter is what got Napster killed

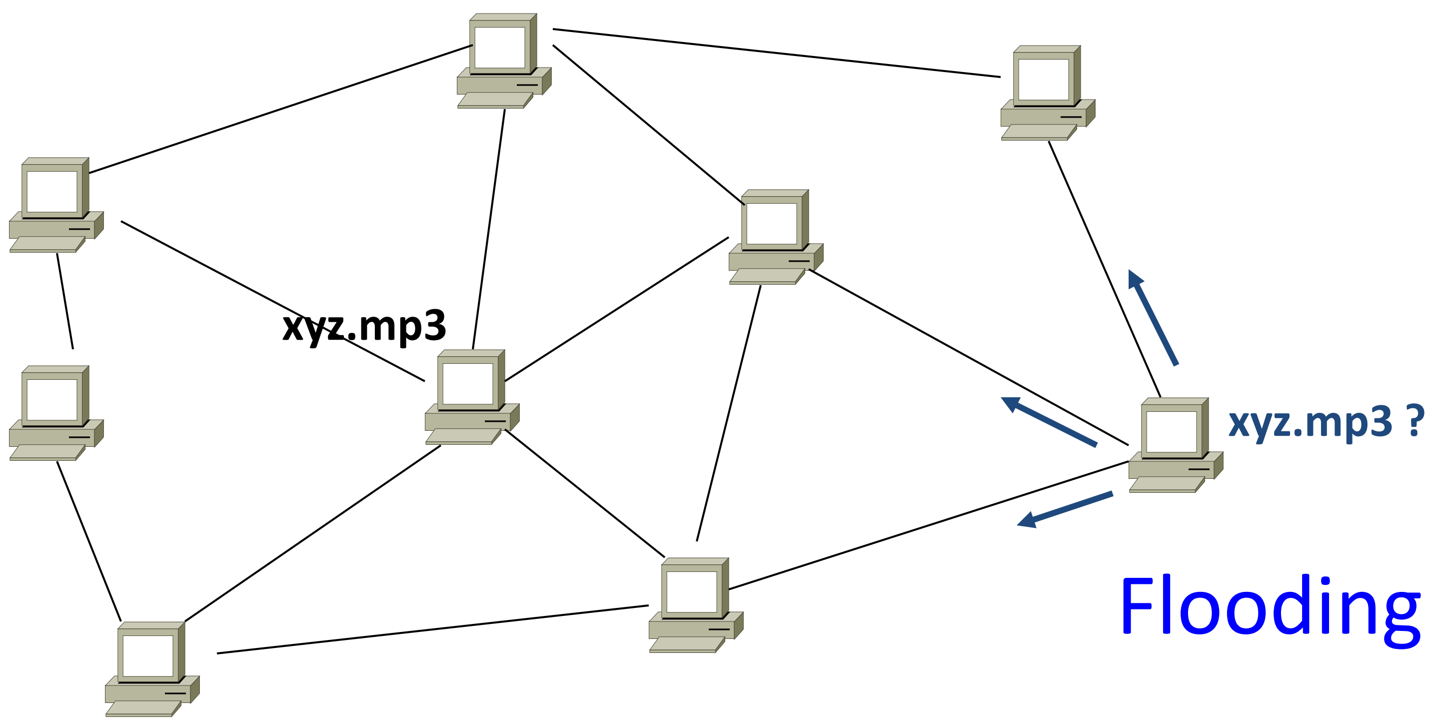
Gnutella: Flooding on Overlays (2000)

- **Search & Location: flooding (with TTL)**
- **Download: direct**

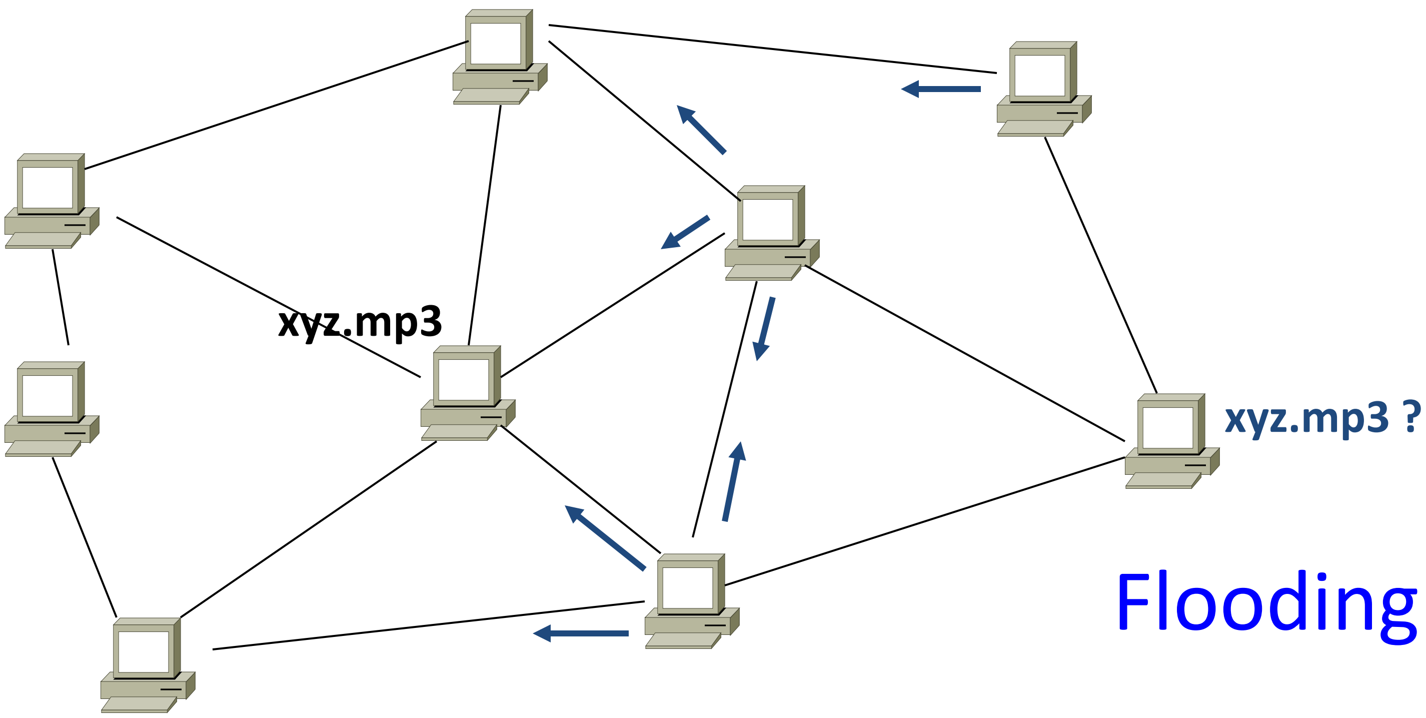


An "unstructured" *overlay network*

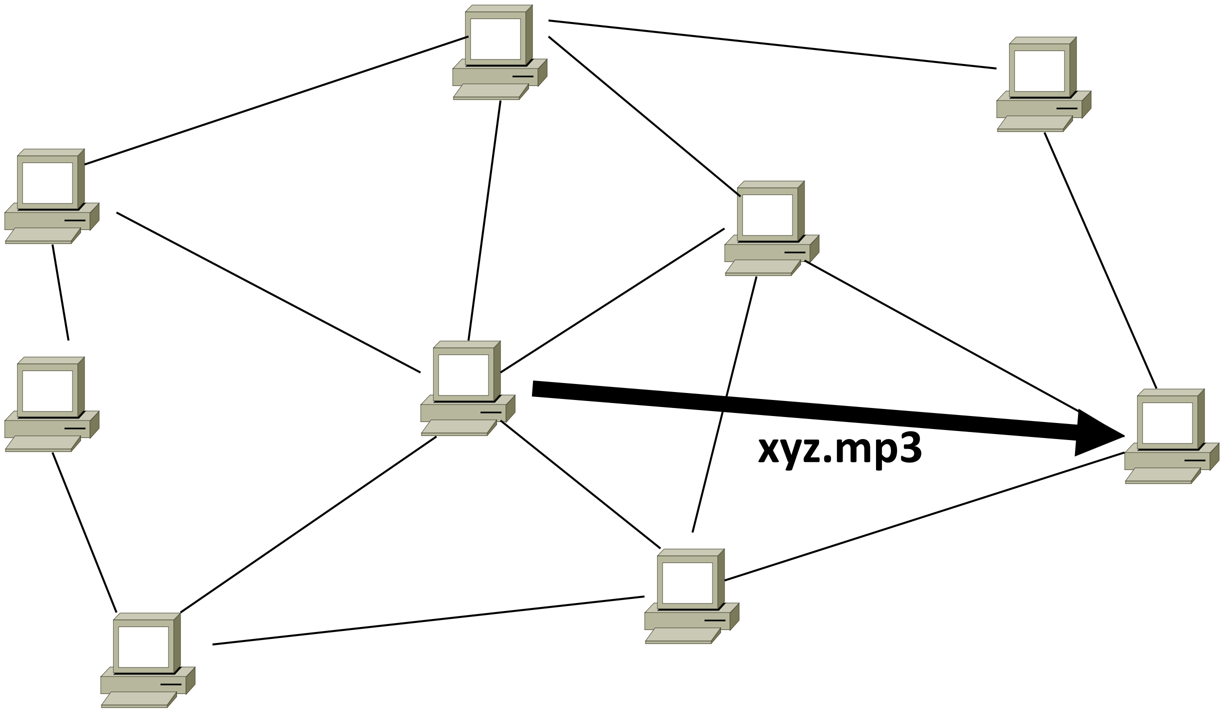
Gnutella: Flooding on Overlays



Gnutella: Flooding on Overlays

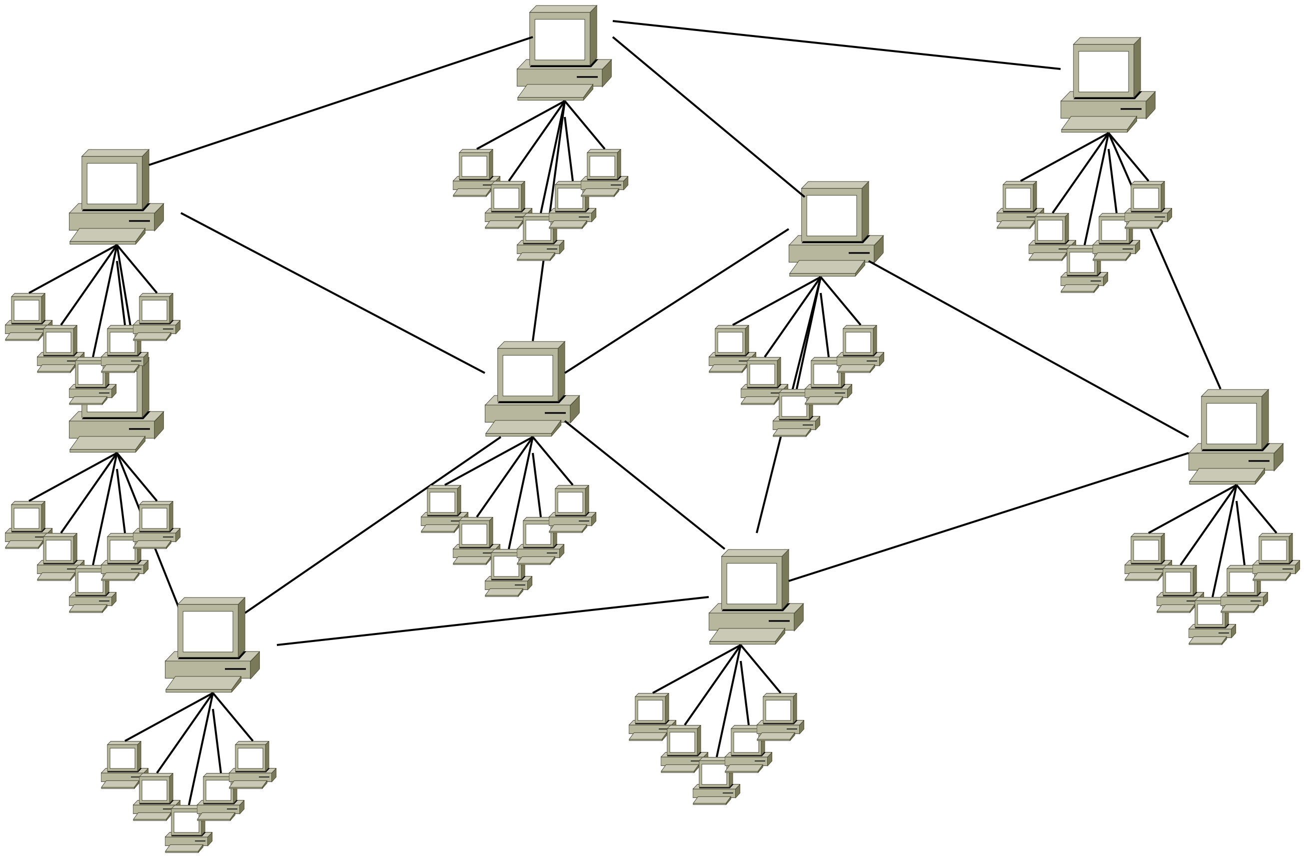


Gnutella: Flooding on Overlays



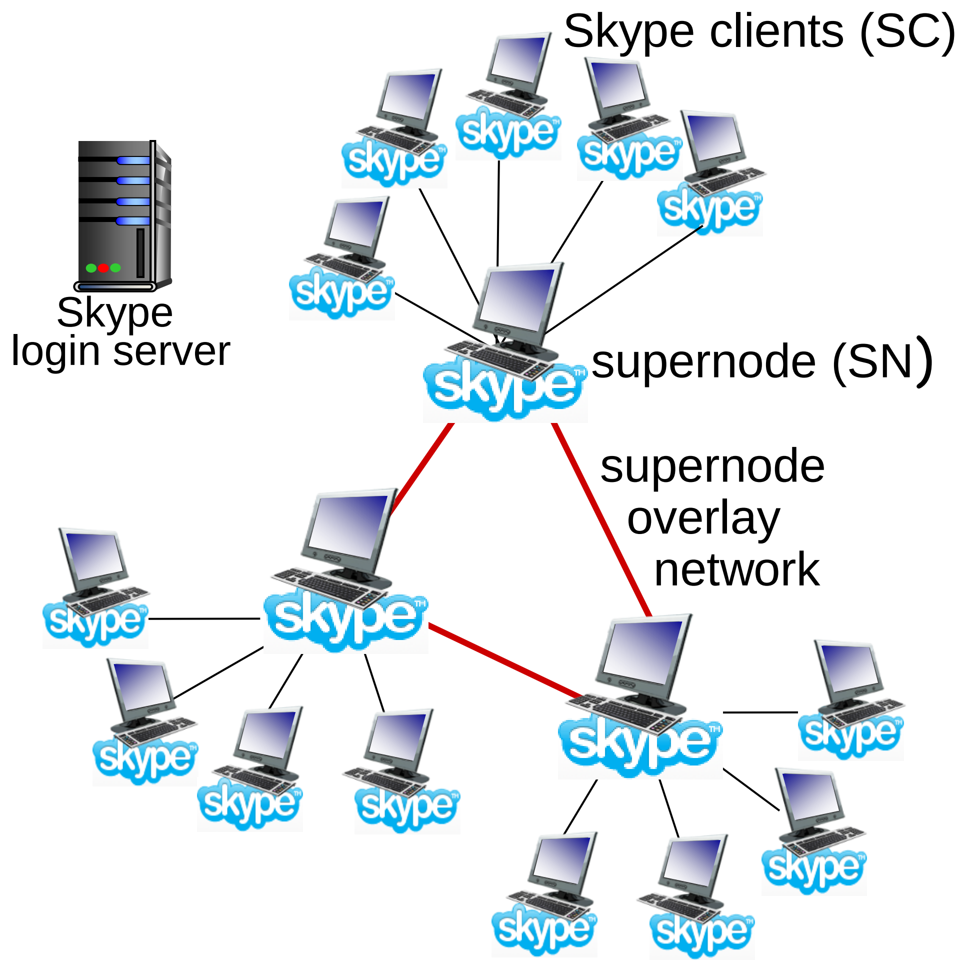
KaZaA: Flooding w/ Super Peers (2001)

- **Well connected nodes can be installed (KaZaA) or self-promoted (Gnutella)**



Voice-over-IP: Skype

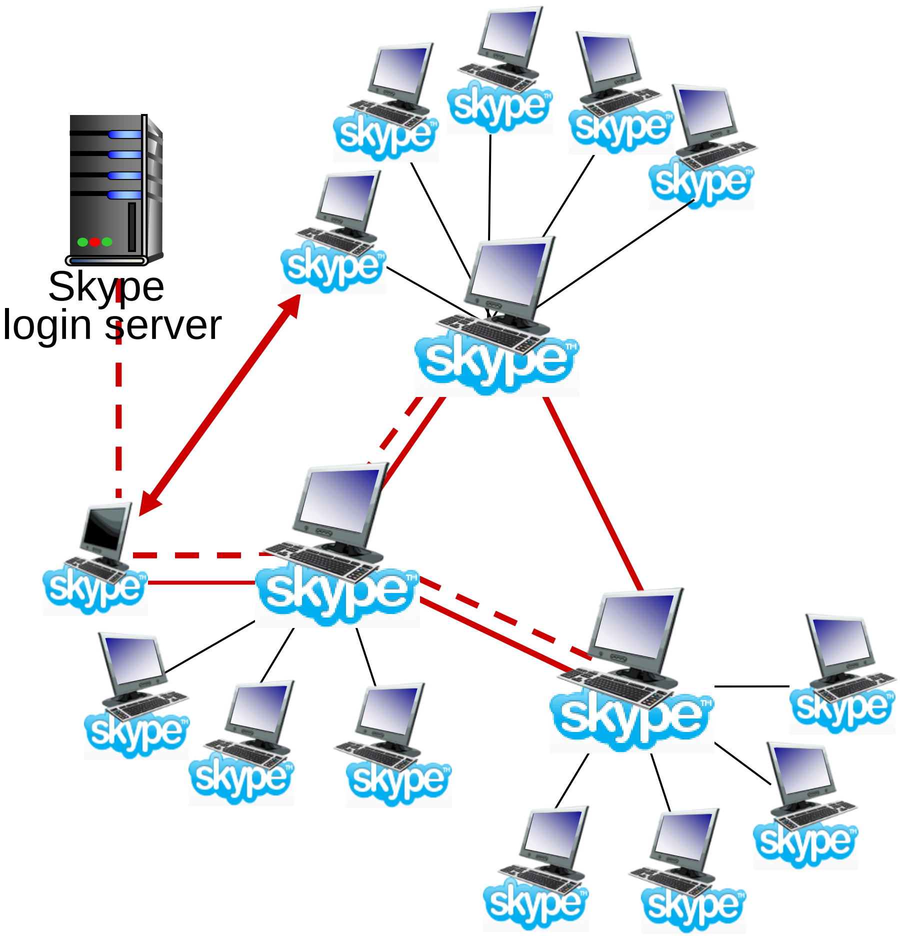
- **proprietary application-layer protocol (inferred via reverse engineering)**
  - encrypted msgs
- **P2P components:**
  - clients: skype peers connect directly to each other for VoIP call
  - super nodes (SN): skype peers with special functions
  - overlay network: among SNs to locate SCs
  - login server



P2P voice-over-IP: skype

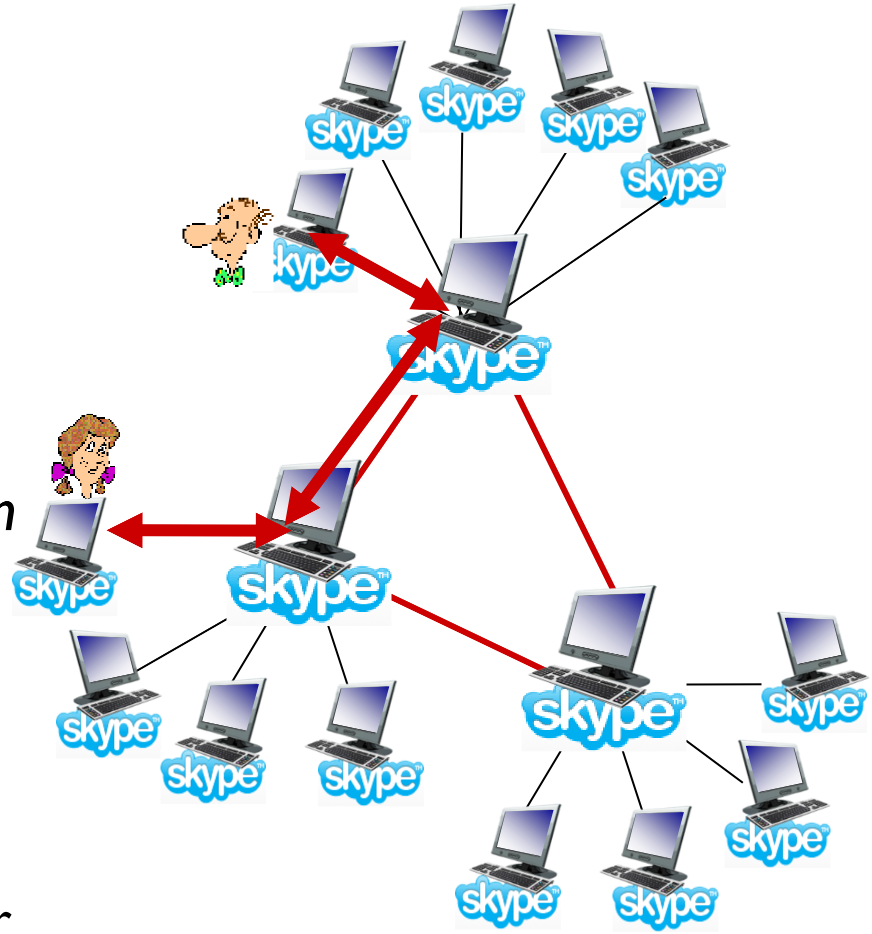
skype client operation:

1. joins skype network by contacting SN (IP address cached) using TCP
2. logs-in (usename, password) to centralized skype login server
3. obtains IP address for callee from SN, SN overlay
   - or client buddy list
4. initiate call directly to callee



Skype: peers as relays

- ***problem:*** **both Alice, Bob are behind "NATs"**
  - NAT prevents outside peer from initiating connection to insider peer
  - inside peer *can* initiate connection to outside
- *relay solution: Alice, Bob maintain open connection to their SNs*
  - Alice signals her SN to connect to Bob
  - Alice's SN connects to Bob's SN
  - Bob's SN connects to Bob over open connection Bob initially initiated to his SN



Lessons and Limitations

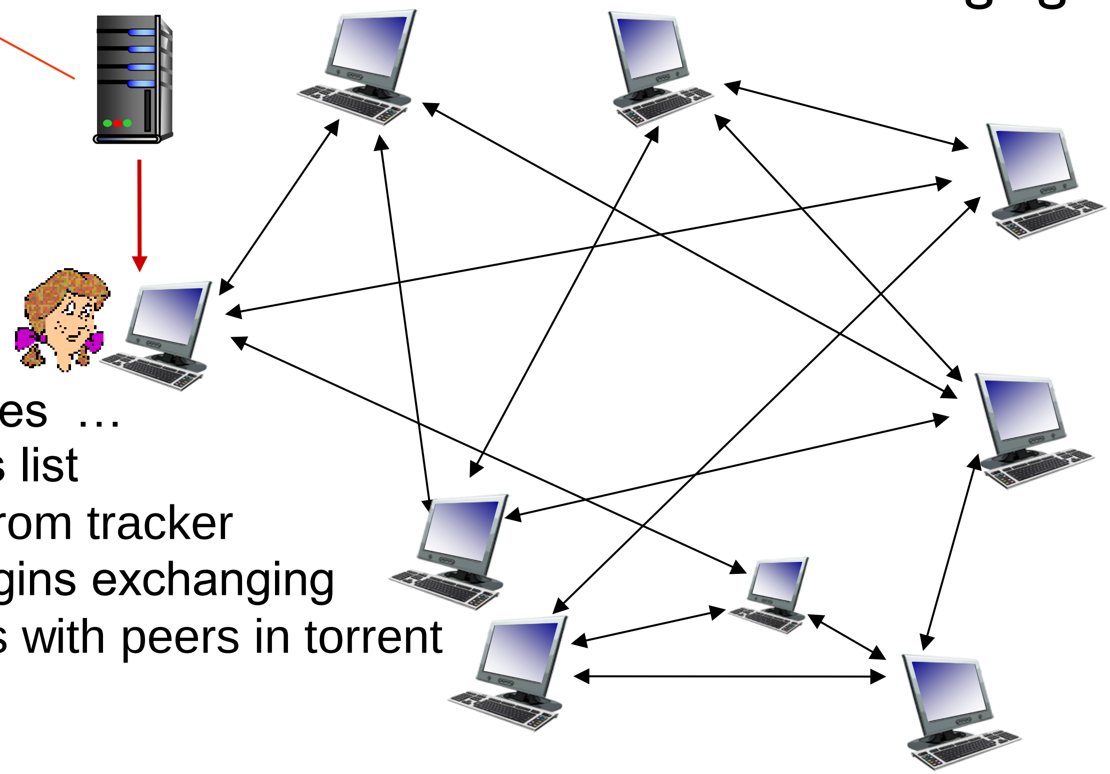
- **Client-server performs well**
  - But not always feasible
- **Things that flood-based systems do well**
  - Organic scaling
  - Decentralization of visibility and liability
  - Finding popular stuff
  - Fancy *local* queries
- **Things that flood-based systems do poorly**
  - Finding unpopular stuff
  - Fancy *distributed* queries
  - Vulnerabilities: data poisoning, tracking, etc.
  - Guarantees about anything (answer quality, privacy, etc.)

P2P file distribution: BitTorrent

- file divided into 256Kb chunks
- peers in torrent send/receive file chunks

tracker: tracks peers participating in torrent

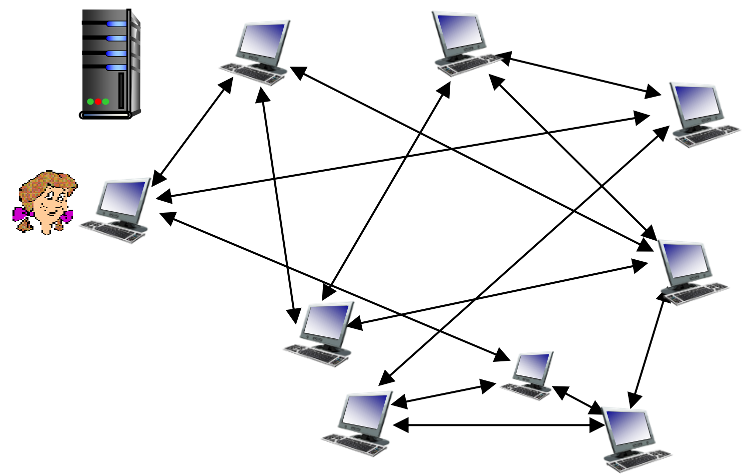
torrent: group of peers exchanging chunks of a file



Alice arrives …
… obtains list
of peers from tracker
… and begins exchanging
file chunks with peers in torrent

P2P file distribution: BitTorrent

- **peer joining torrent:**
  - has no chunks, but will accumulate them over time from other peers
  - registers with tracker to get list of peers, connects to subset of peers ("neighbors")



- while downloading, peer uploads chunks to other peers
- peer may change peers with whom it exchanges chunks
- *churn:* peers may come and go
- once peer has entire file, it may (selfishly) leave or (altruistically) remain in torrent

BitTorrent: requesting, sending file chunks

requesting chunks:

- at any given time, different peers have different subsets of file chunks
- periodically, Alice asks each peer for list of chunks that they have
- Alice requests missing chunks from peers, rarest first

sending chunks: tit-for-tat

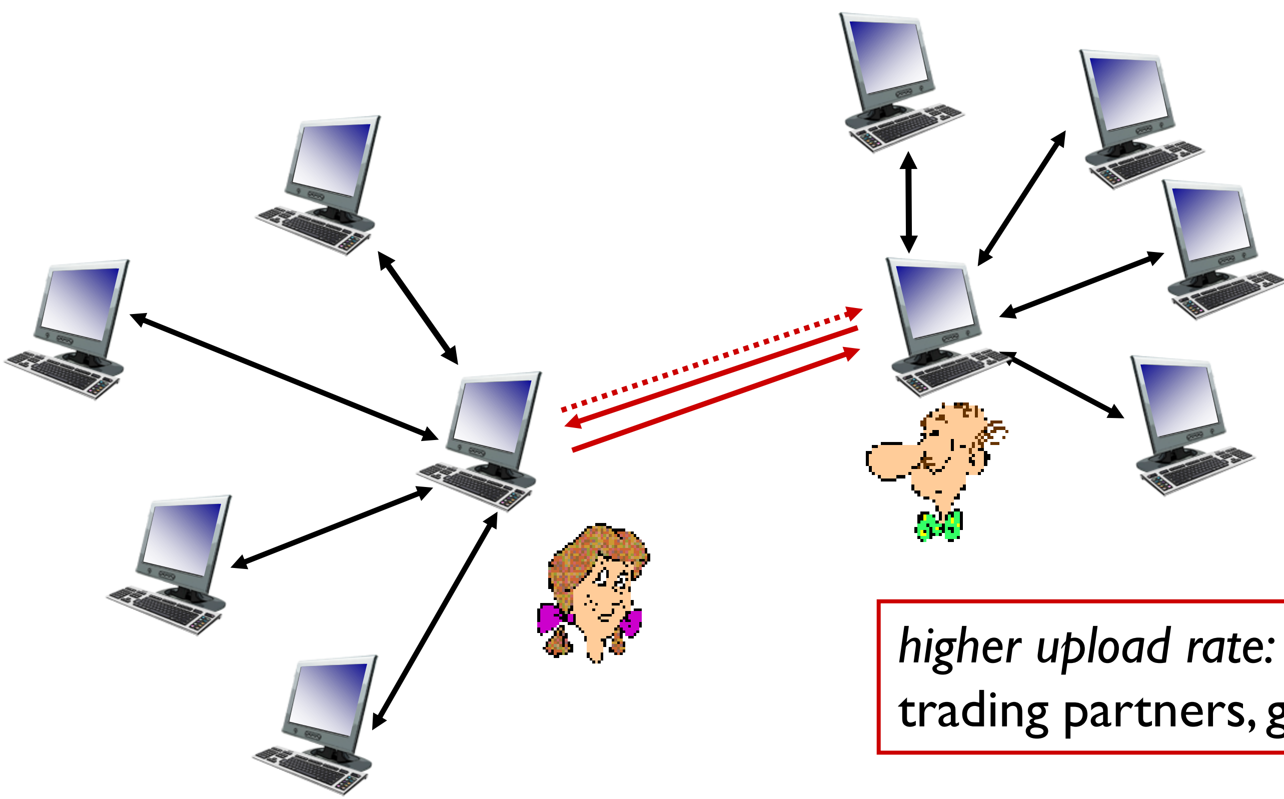
- Alice sends chunks to those four peers currently sending her chunks *at highest rate*
  - other peers are choked by Alice (do not receive chunks from her)
  - re-evaluate top 4 every10 secs
- every 30 secs: randomly select another peer, starts sending chunks
  - "optimistically unchoke" this peer
  - newly chosen peer may join top 4

BitTorrent: tit-for-tat

(1) Alice "optimistically unchokes" Bob

(2) Alice becomes one of Bob's top-four providers; Bob reciprocates

(3) Bob becomes one of Alice's top-four providers



higher upload rate: find better trading partners, get file faster !