CSCI 466: Networks

Lecture 5: Peer 2 Peer Networks (P2P), Content Distribution Networks (CDN)

Reese Pearsall

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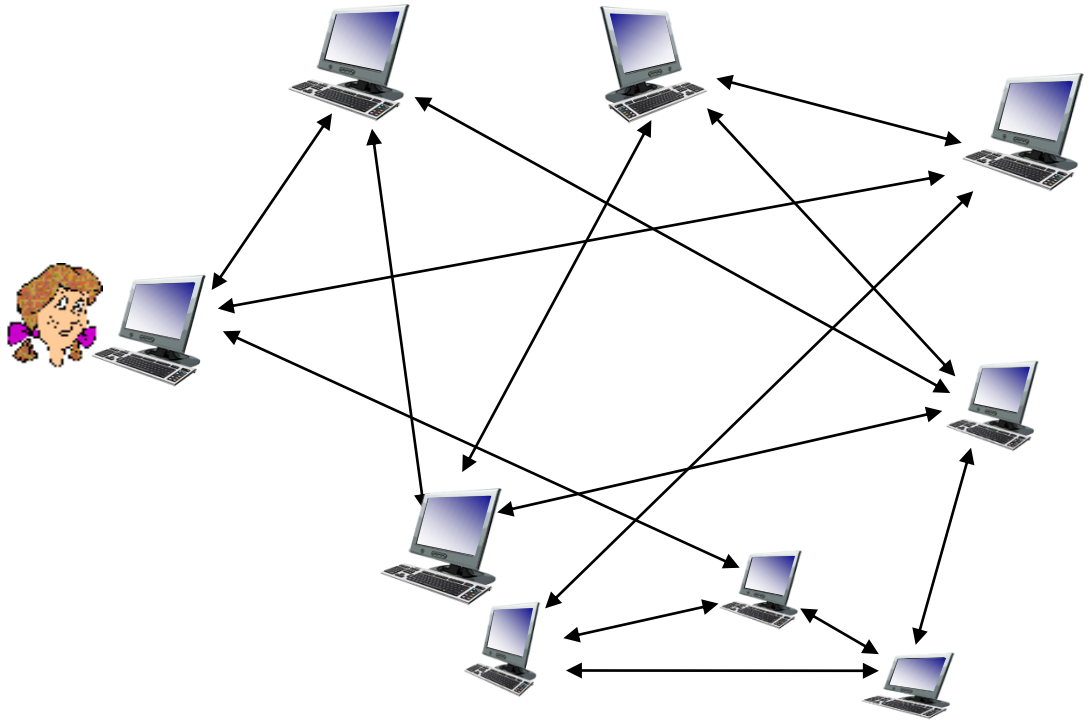
*All images are stolen from the internet

Announcements

there are no announcements

P2P Networks

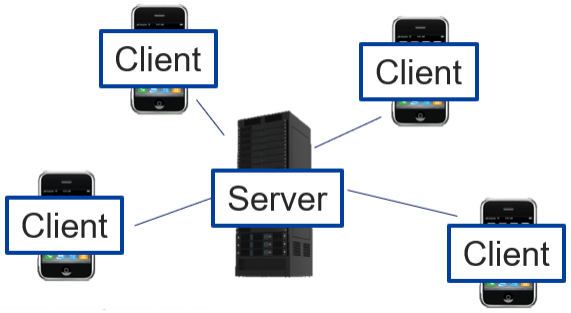
- No always-on server
- Arbitrary end systems directly communicate
- Peers are intermittently connected and change IP addresses



Time to distribute a file of size F to N clients

$$D_{P2P} = \max\left\{\frac{F}{u_s}, \frac{F}{d_{\min}}, \frac{NF}{u_s + \sum_{i=1}^{N} u_i}\right\}$$

Client-Server Architecture



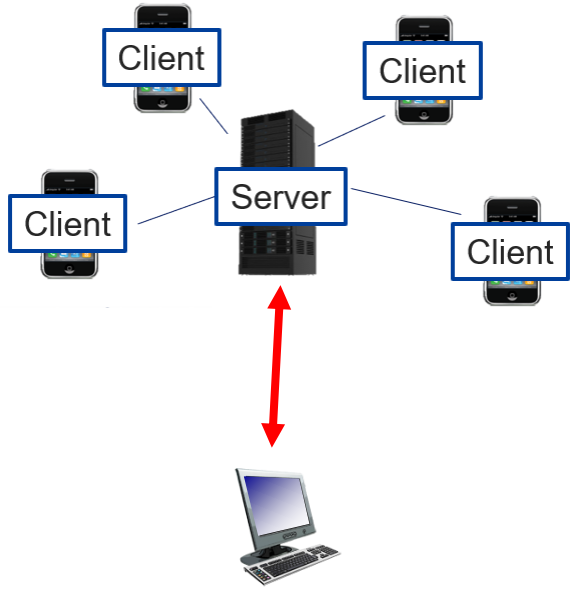
- Server can upload data at rate u_s
- Clients download data at rates $d_1, d_2, \ldots, d_N$

$$D_{CS} = \max\left\{\frac{NF}{u_s}, \frac{F}{d_{\min}}\right\}$$

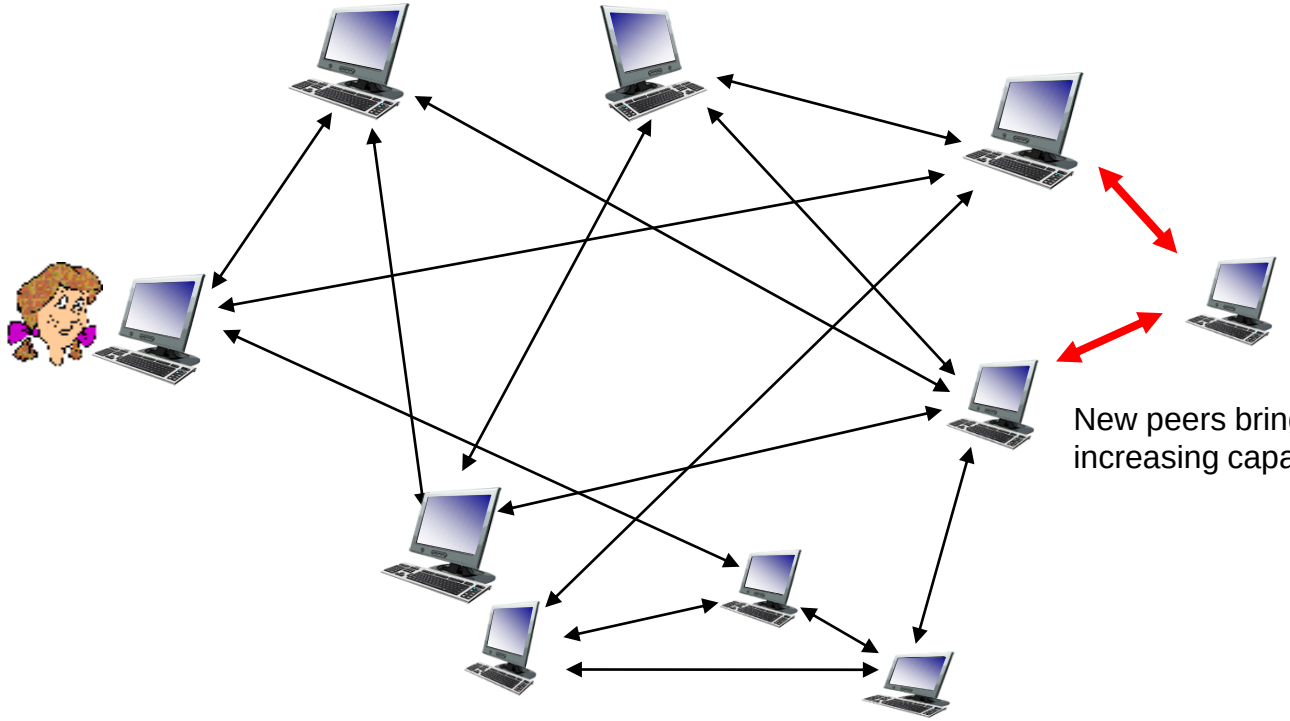
Time to distribute a file of size F to N clients

P2P Networks

Client-Server Architecture



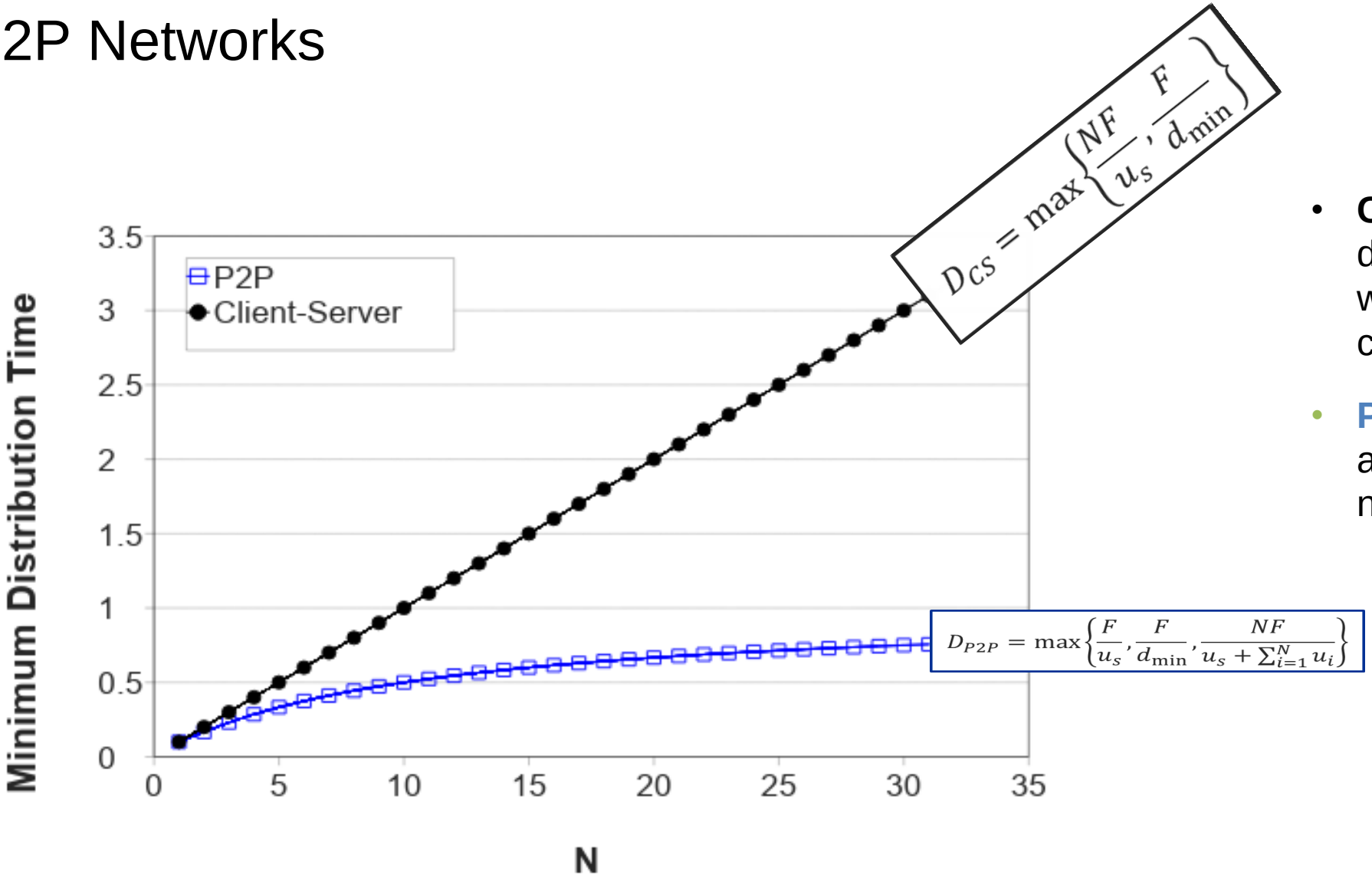
Existing clients have to share resources with new users



New peers are both a client and a server. There will not be a negative impact on current peers

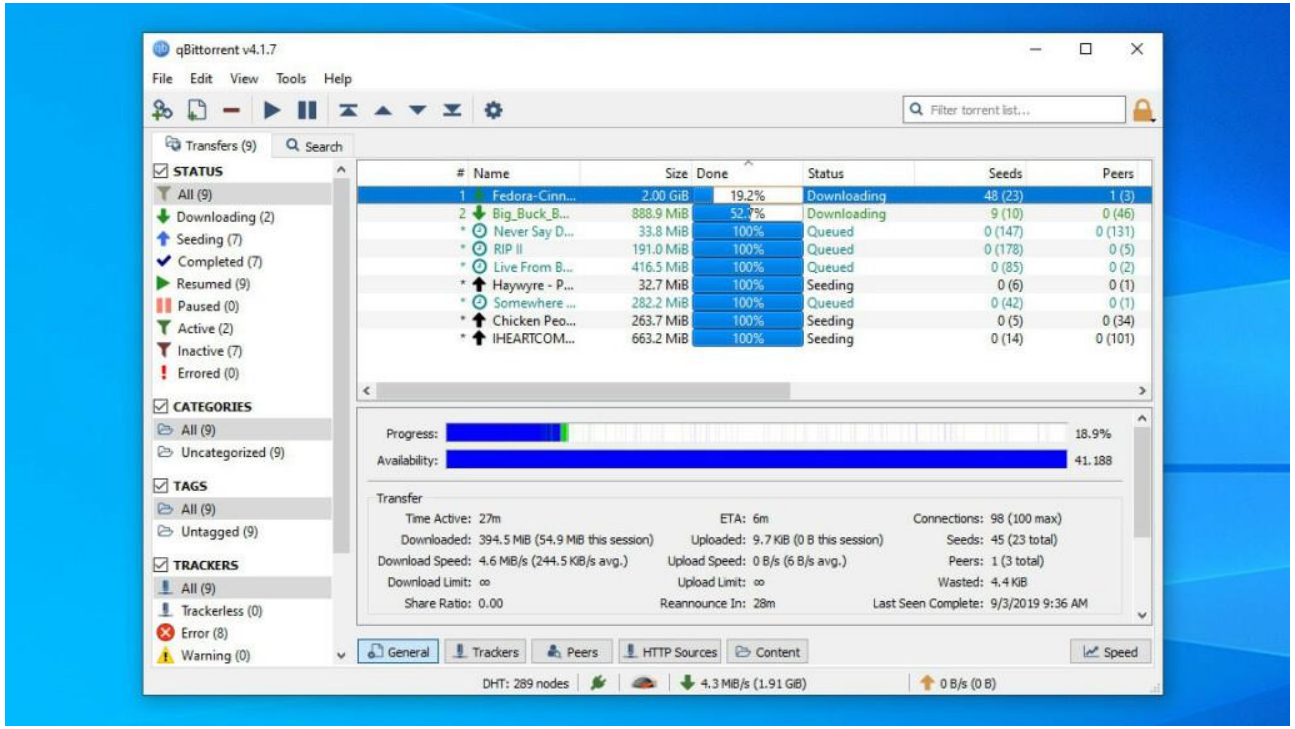
P2P architectures are *self-scaling*

P2P Networks



- **Client server** distribution time grows with the number of clients
- **P2P** distribution time approaches 1 hour as number of clients grows

P2P file distribution: BitTorrent



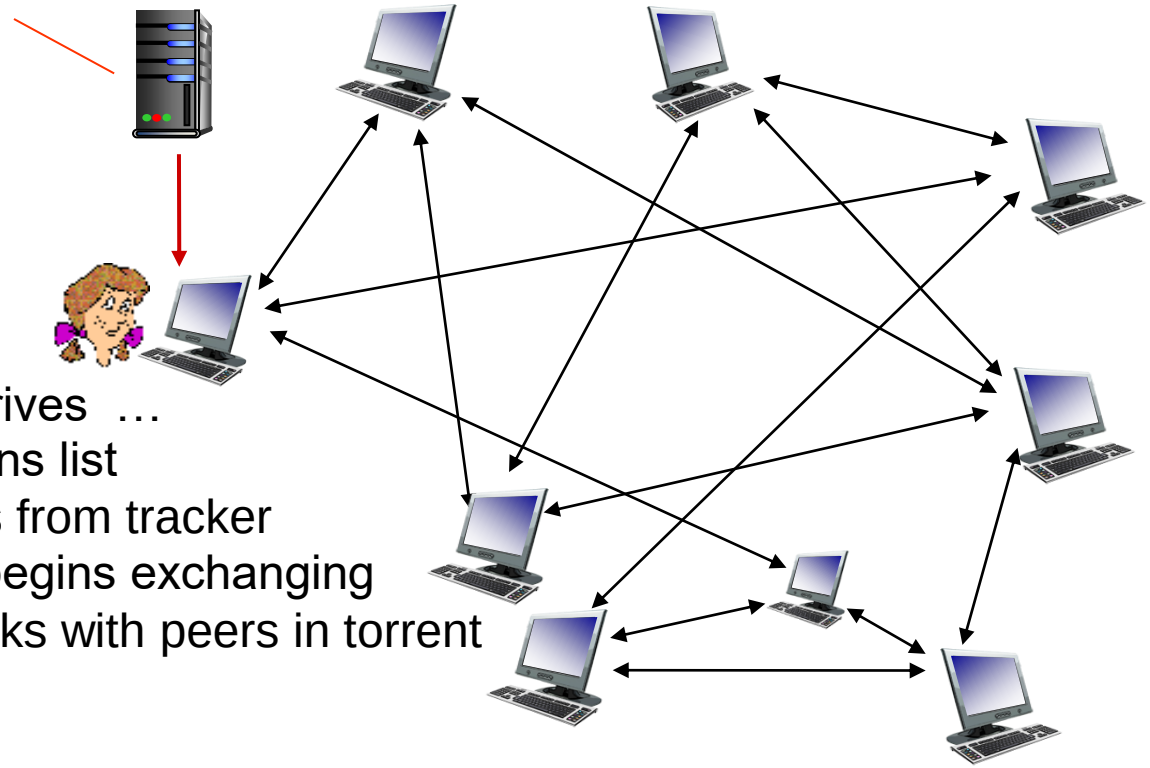
Service for sharing files over the internet in a decentralized fashion

P2P file distribution: BitTorrent

- Files are divided into 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

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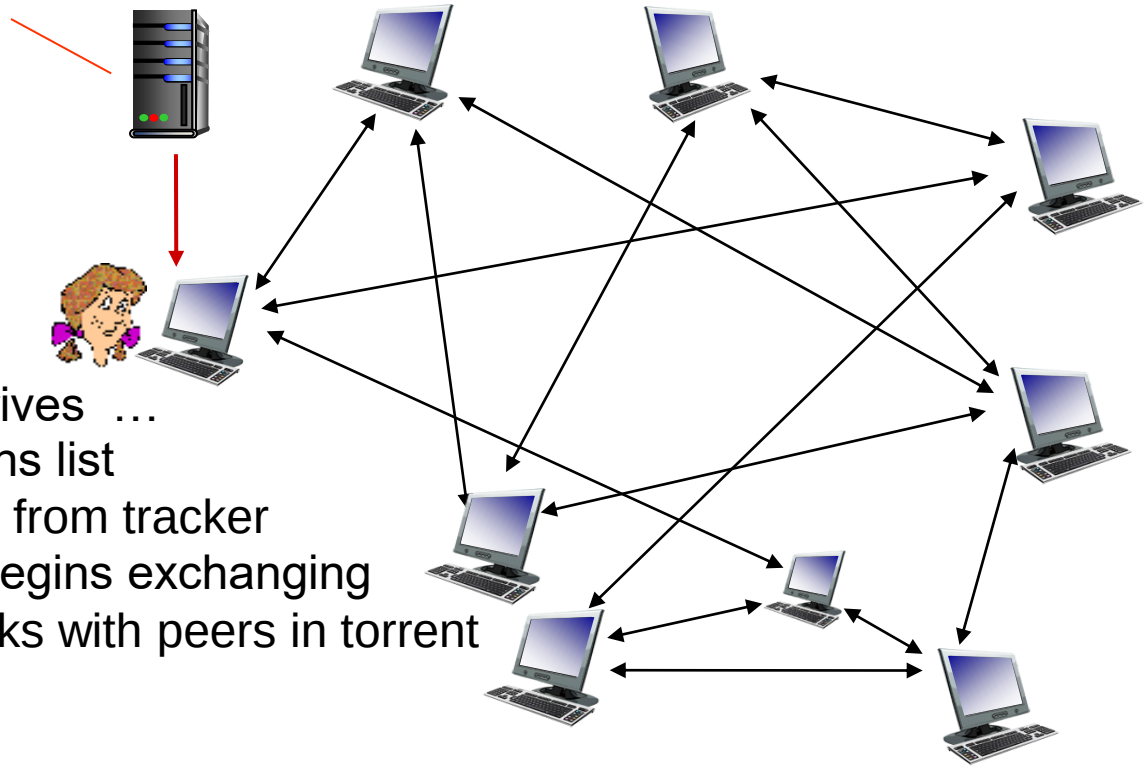

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torrent: group of peers exchanging chunks of a file

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")

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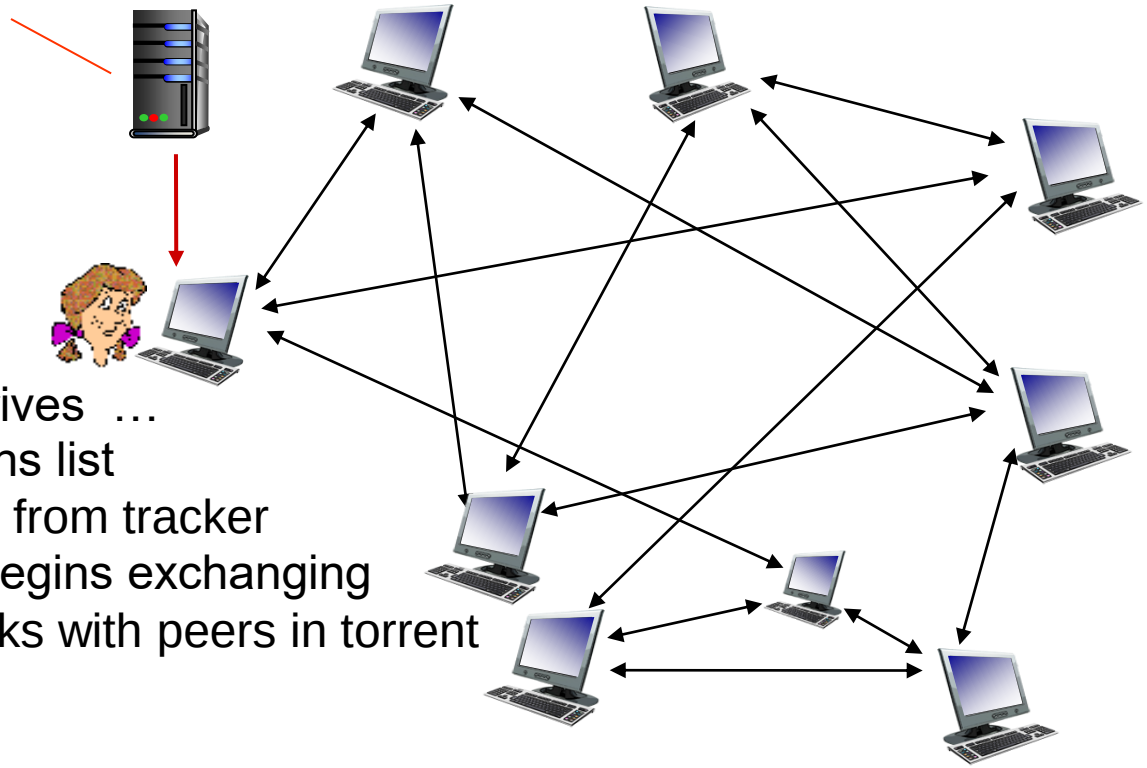

Alice arrives …
… obtains list
of peers from tracker
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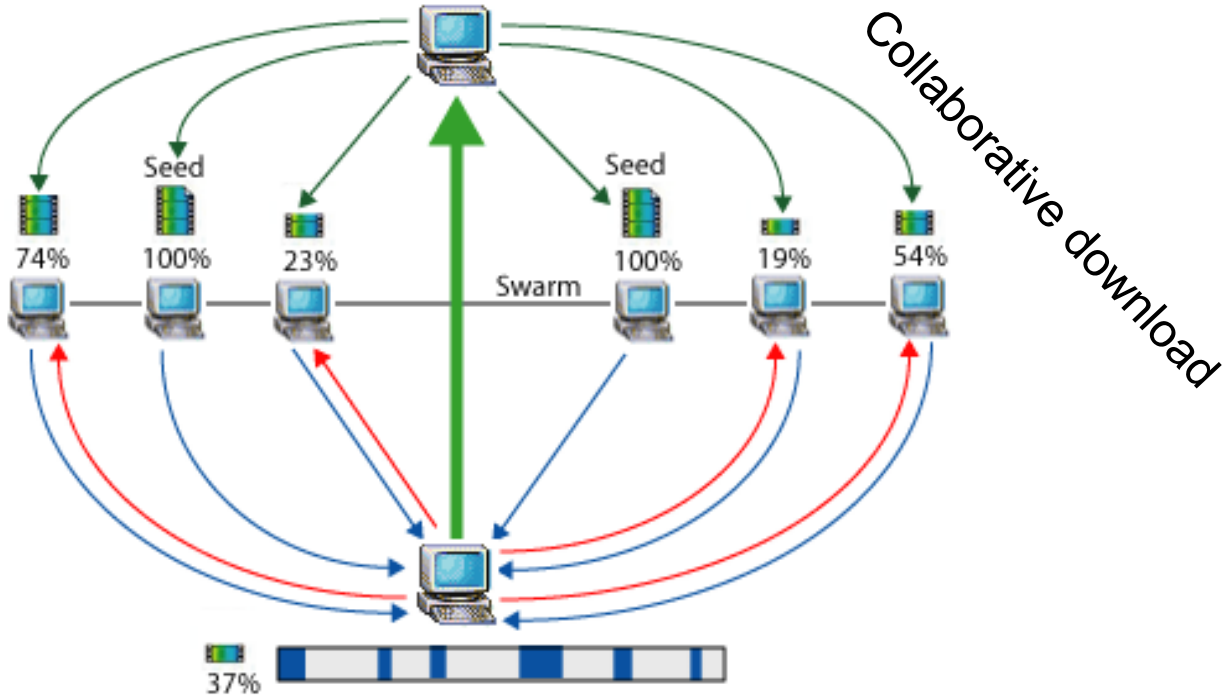
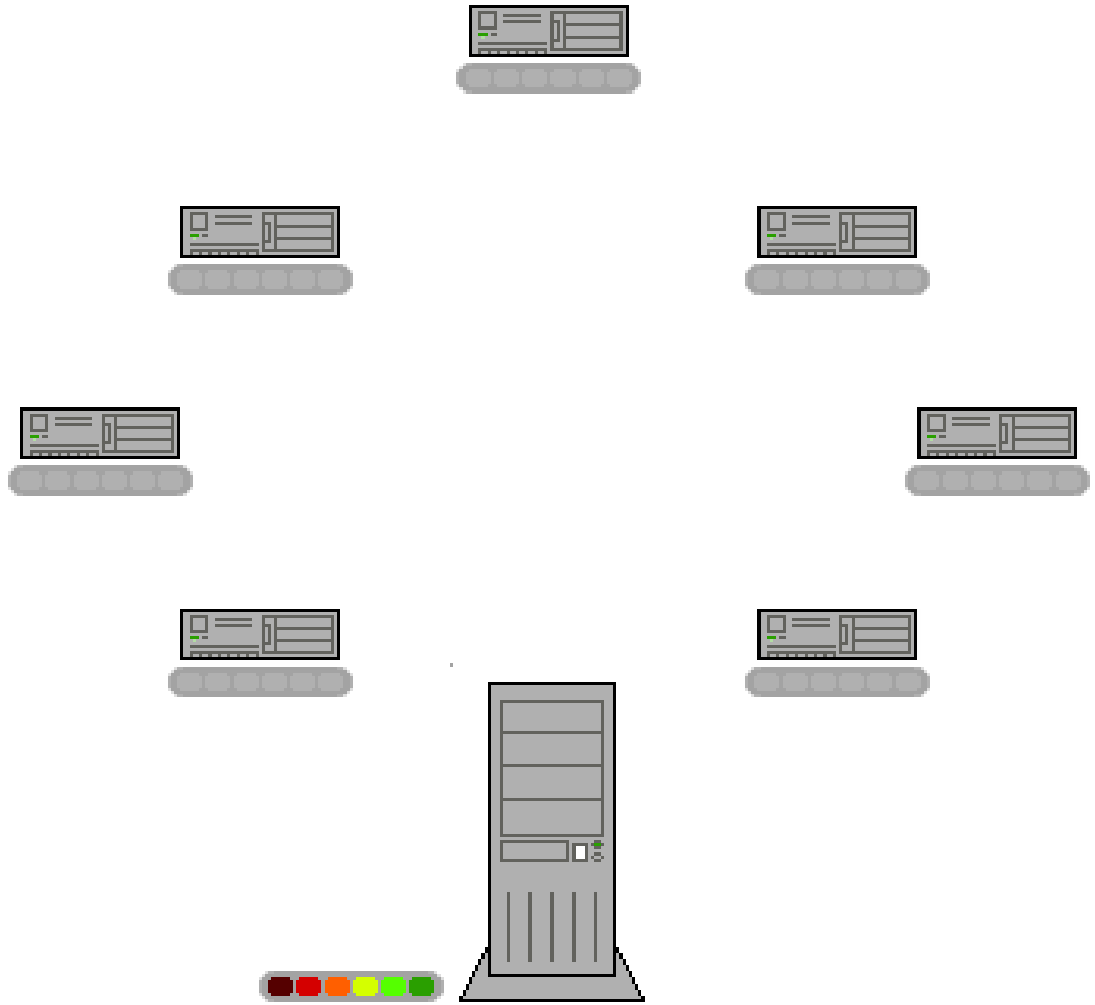
torrent: group of peers exchanging chunks of a file

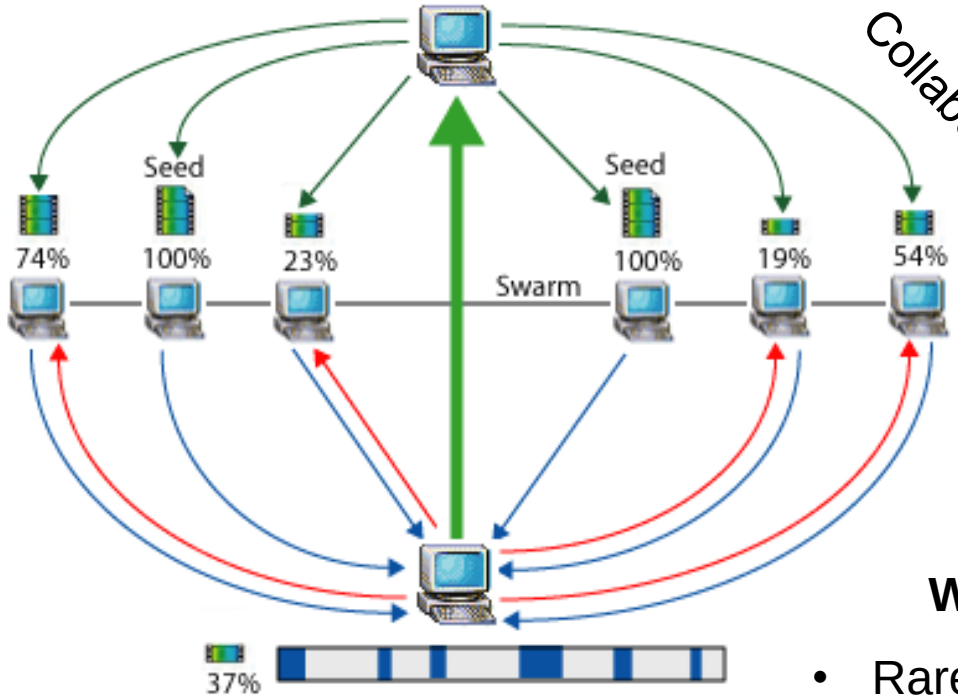
- while downloading, peer uploads chunks to other peers
- peer may change peers with whom it exchanges chunks
- *churn:* peers may come and go
- once peer has entire file, it may (selfishly) leave or (altruistically) remain in torrent

P2P file distribution: BitTorrent

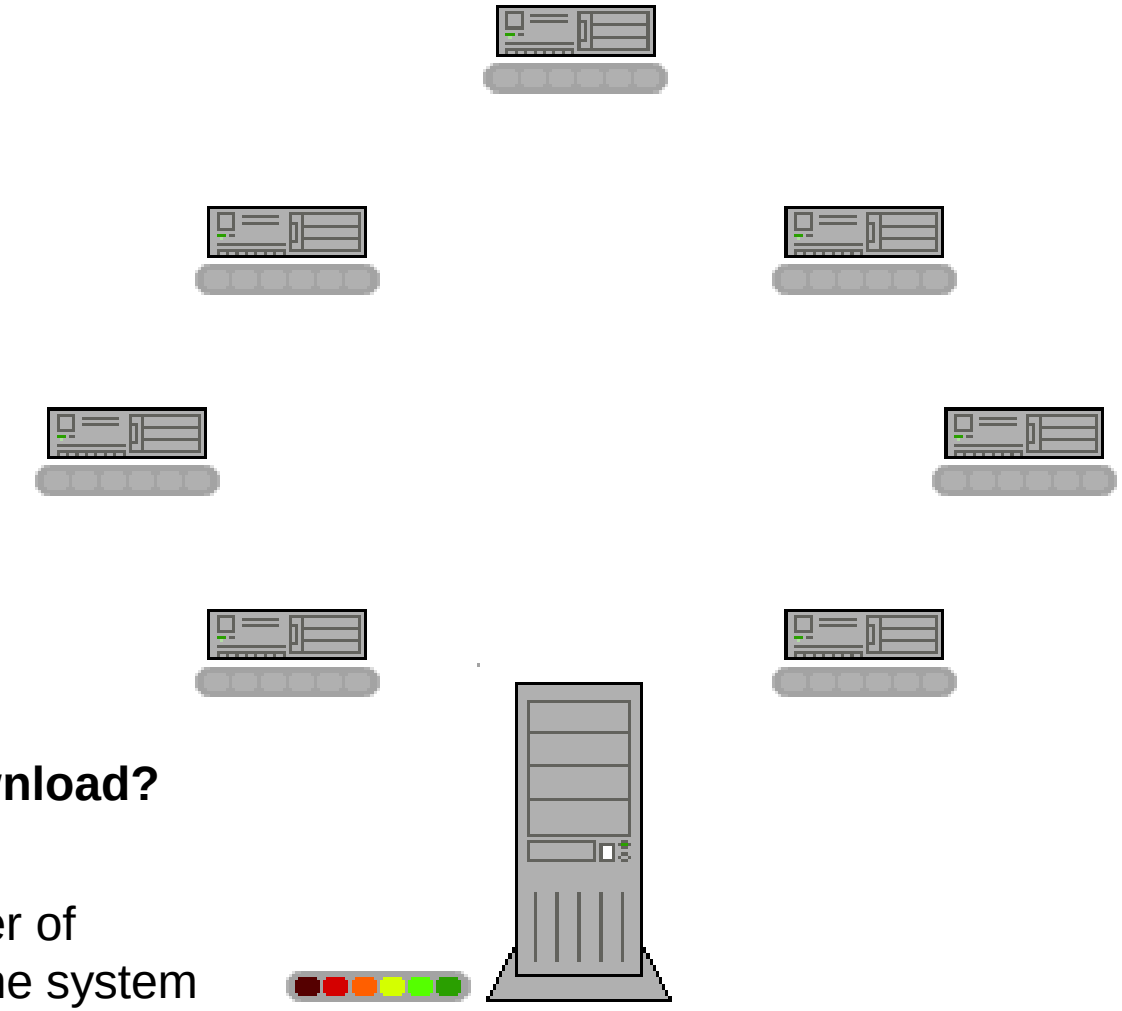




P2P file distribution: BitTorrent



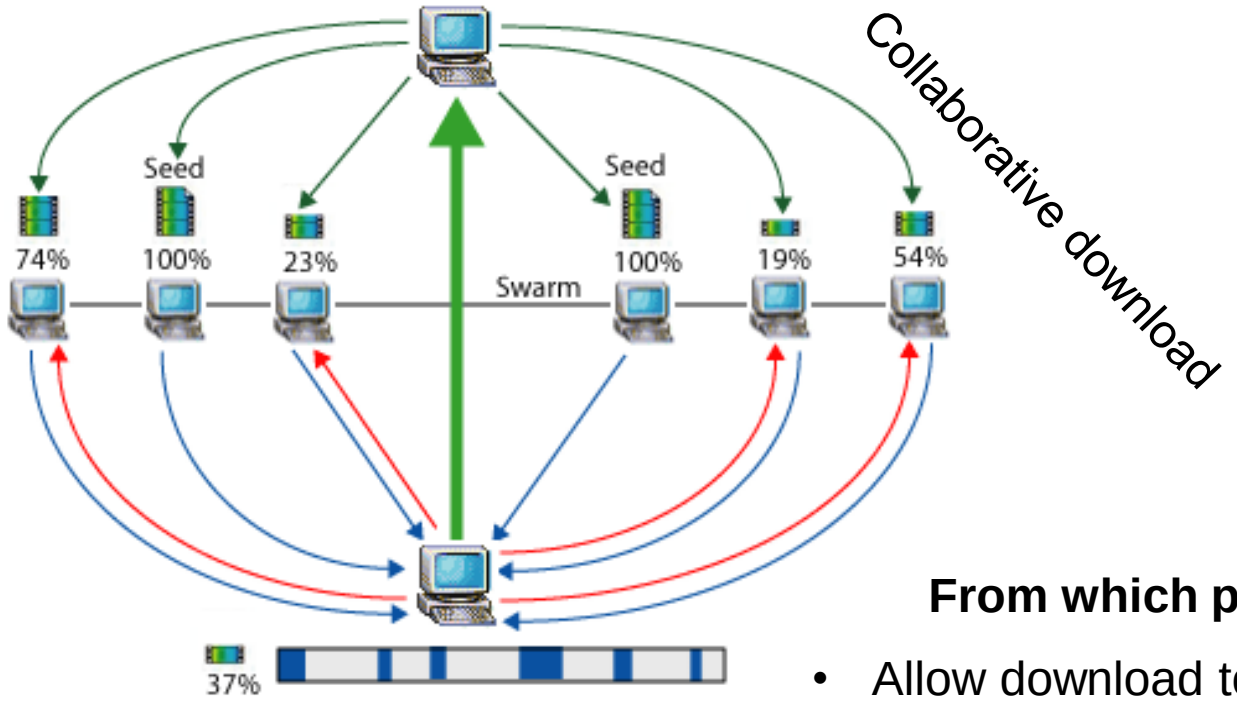
Collaborative download



Which chunks to download?

- Rarest first
- Try to equalize the number of copies of each chunk in the system

P2P file distribution: BitTorrent



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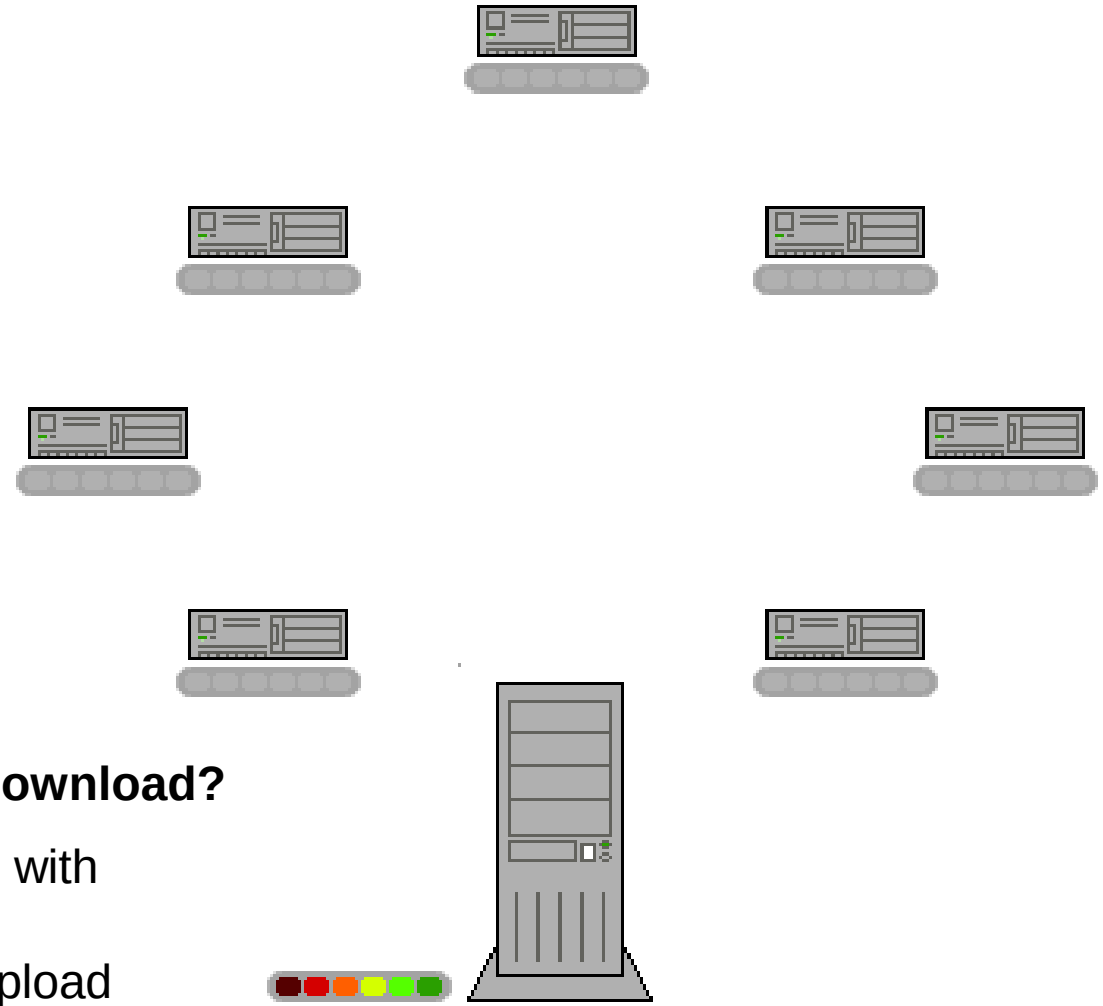


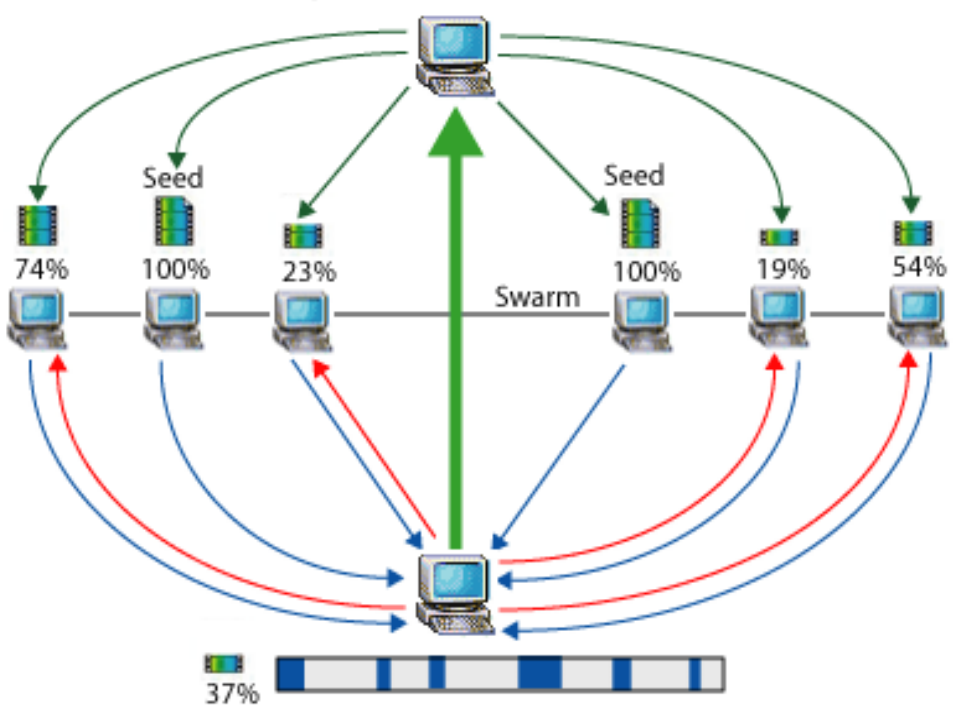
From which peers to download?

- Allow download to N peers with highest upload rates
- Allows peers with similar upload rates to find each other

P2P file distribution: BitTorrent

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



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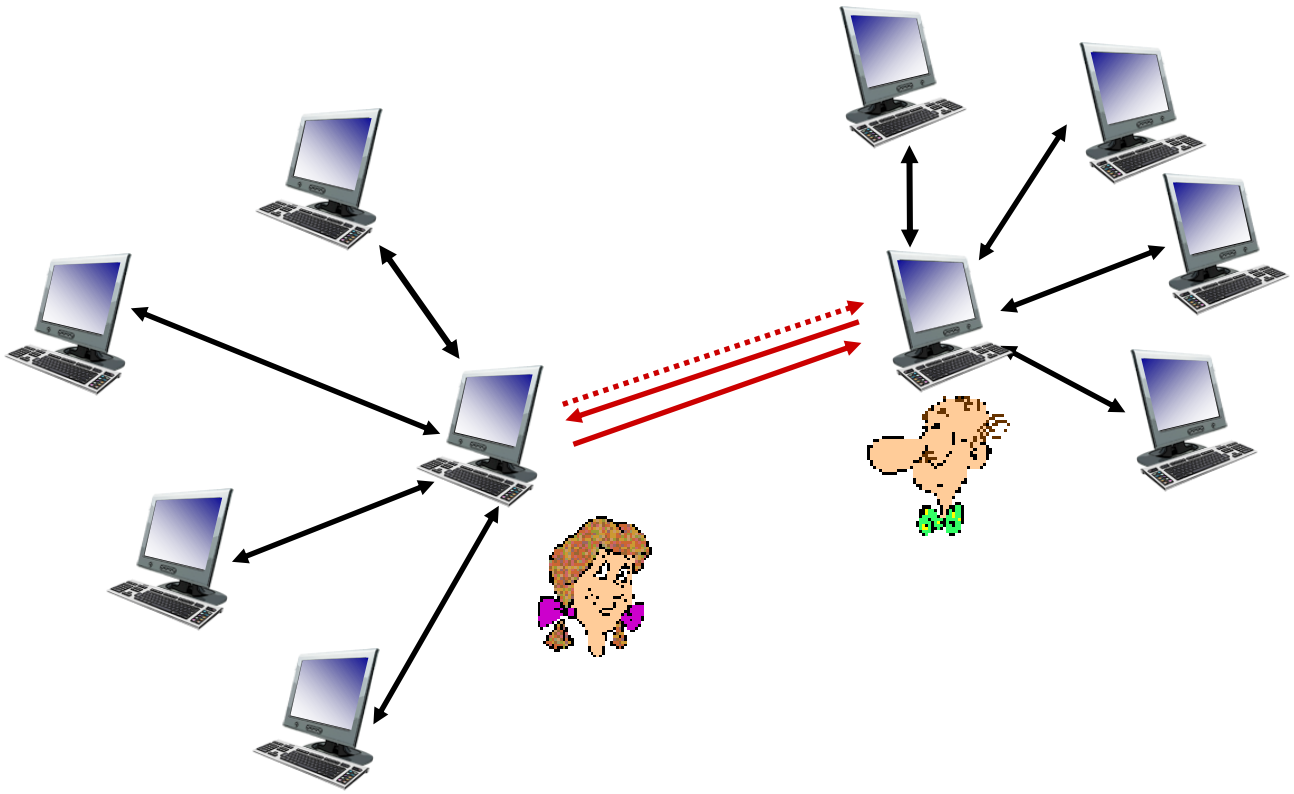


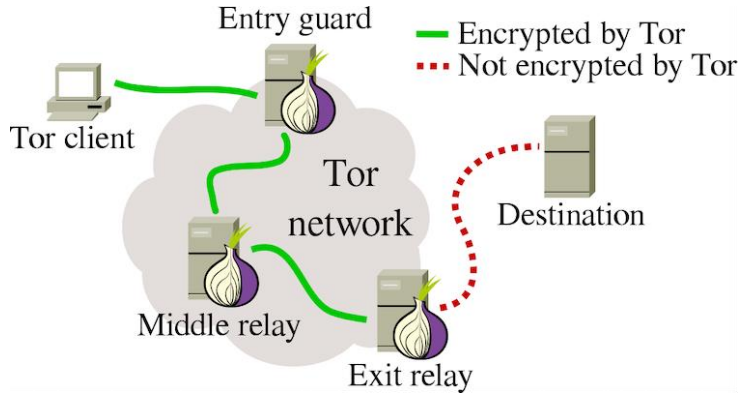
higher upload rate: find better trading partners, get file faster !

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

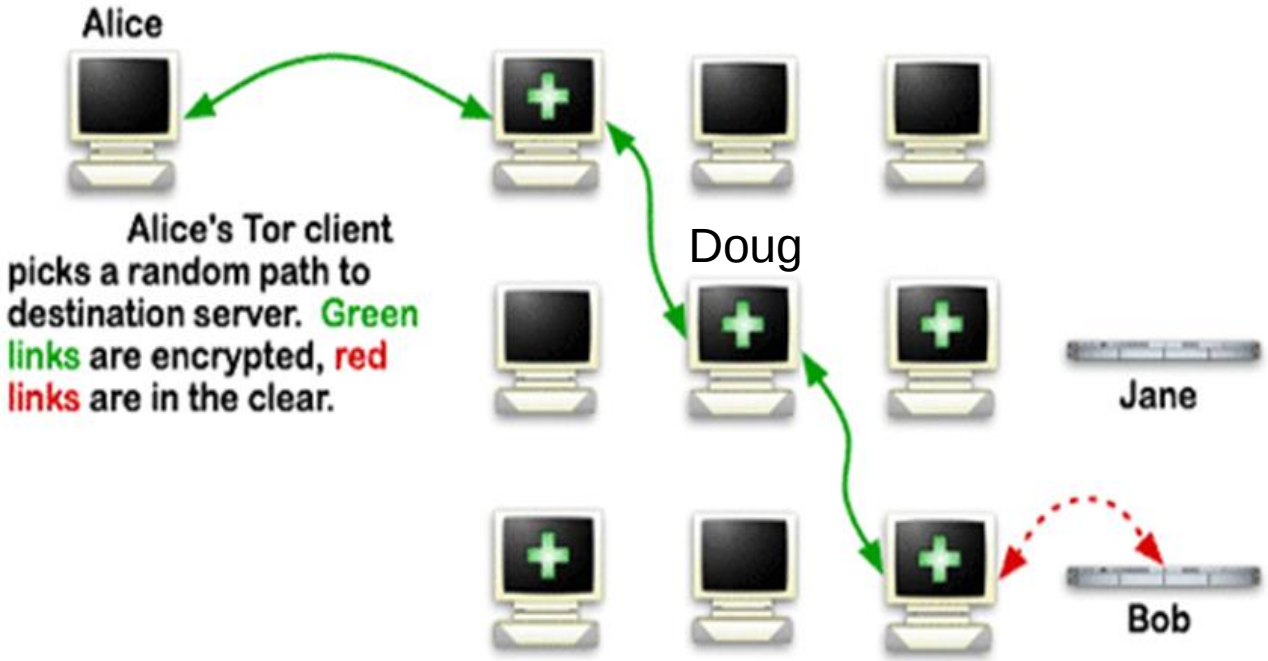
BitTorrent is referred to as a **unstructured** P2P

P2P file distribution mechanisms



To help with anonymity and privacy, some P2P may implement an onion router/TOR router

- Functionality
  - Sender obtains a set of router keys
  - Each router only knows next hop
  - Intermediate routers cannot read message



Structured P2P Example

Content is placed into the P2P network based on a Globally Unique Identifier (GUID)

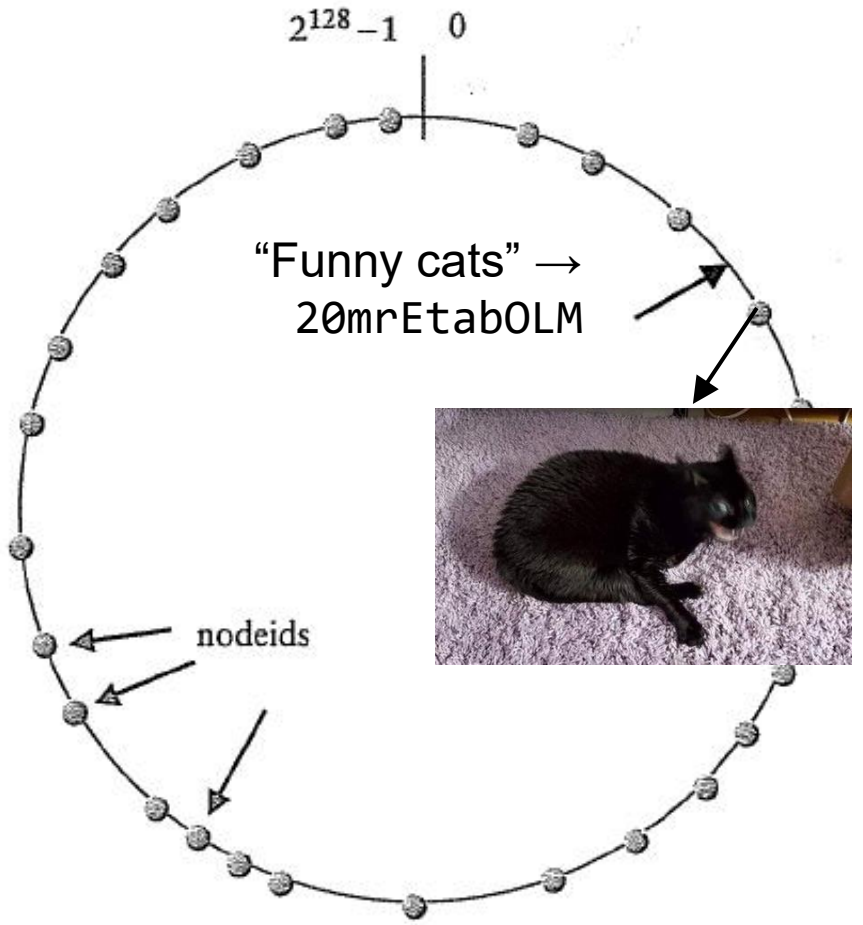
- GUID = H(key) where H is some hash function

P(H(a) = H(b)) is very low

- Distributed <key, value> search
- ➢ Fully Distributed and self-organzing

Distributed Hash Table (DHT)

- Join: join ring with GUID from public key
- Publish: put(GUID, value)
- Search/Fetch: value = get(GUID)



Each node maintains a link to the 4 **closest** neighbors and to nodes **half** way across the ring, **quarter** way across the ring, **eight** across the way…

O(logN)

Structured P2P Example

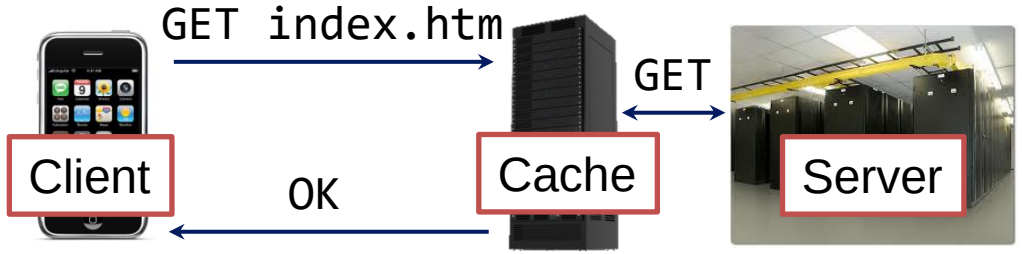
	Unstructured P2P	Structured P2P
Advantages	• Self-organizing • Naturally resilient to node failure	• Guaranteed to locate objects (if exist) • Time and complexity bounds • Low message overhead
Disadvantages	• Cannot offer guarantees on locating objects • Prone to excessive messaging that limits scalability	• Need to maintain complex overlays • High control traffic overhead in dynamic environments

CDNs

- video traffic: major consumer of Internet bandwidth
  - Netflix, YouTube: 37%, 16% of downstream residential ISP traffic
  - ~1B YouTube users, ~75M Netflix users
- challenge: scale - how to reach ~1B users?
  - single mega-video server won't work (why?)
- challenge: heterogeneity
  - different users have different capabilities (e.g., wired versus mobile; bandwidth rich versus bandwidth poor)
- *solution:* distributed, application-level infrastructure

CDNs

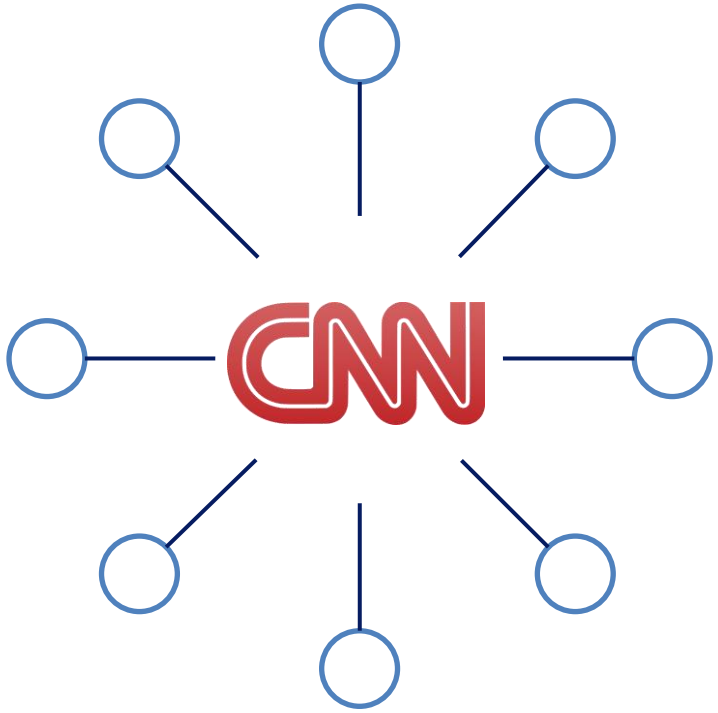
- Caching
  - Save previously delivered data
  - Subsequent requests served from cache on the browser, or in the access network
- Applications
  - Reduce response time for client request
  - Reduce ISP traffic costs
- Content distribution networks
  - Distributed caches
  - Web objects addressed to CDN server
  - CDN server fetches from content provider on first access



- Conditional GET
  - Cache: specify date of cached copy in HTTP request
    `If-modified-since: <date>`
  - Server: response contains no object if cached copy is up-to-date:
    `HTTP/1.0 304 Not Modified`

CDNs

- Challenge:
  - How to stream content to millions of users?
- Option 1:
  - Single mega-datacenter
  - Pros: Simple
  - Cons:
    - Single point of failure
    - Point of network congestion
    - Long path to distant clients
    - Multiple copies of video sent over outgoing link



CDNs

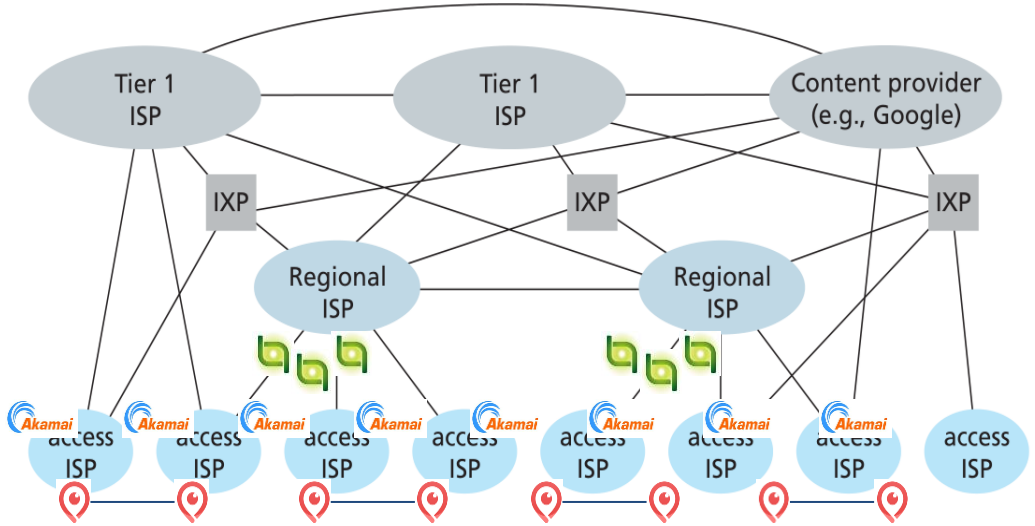
- Option 2:
  - Store/serve multiple copies of videos at multiple geographically distributed sites

A **content delivery network (CDN)** refers to a geographically distributed group of cache servers which work together to provide fast delivery of Internet content. **(not a web host)**

34 DNS lookups

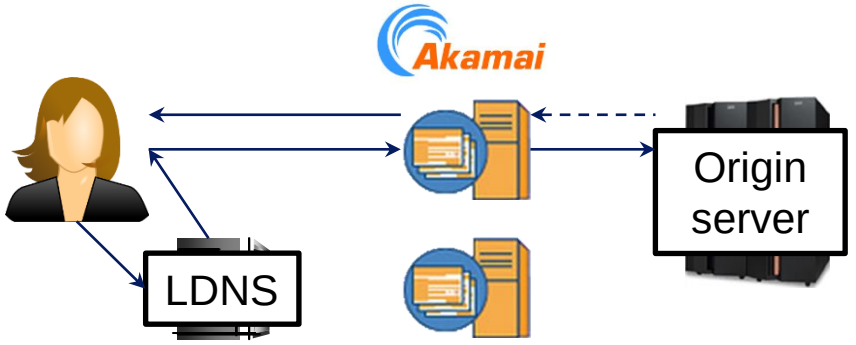
204 HTTP requests

520 KB of data downloaded



amazon web services™ Akamai Level(3) COMMUNICATIONS Google™

56% of domains resolve to a CDN

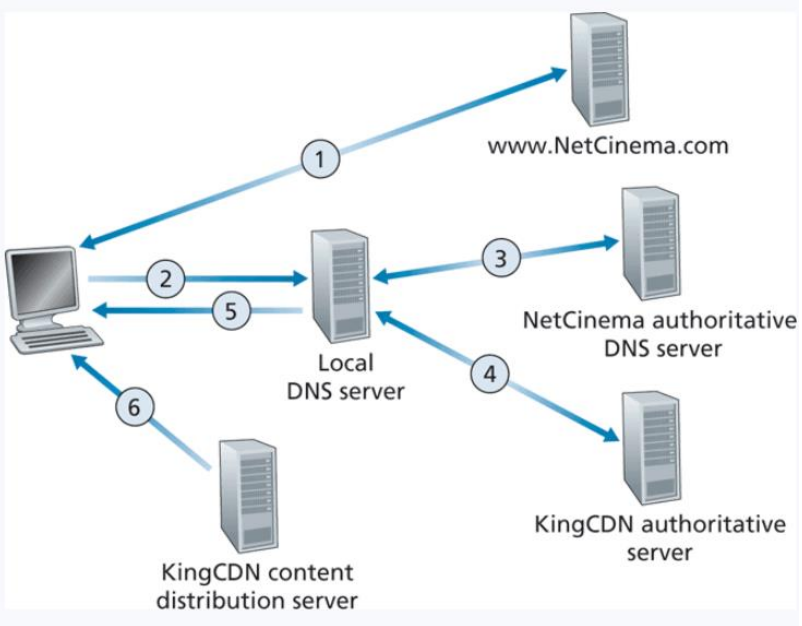


CDNs

https://**cdn**.discordapp.com/attachments/101763035
8621143110/1017849417216294972/unknown.png

CDNs

- Challenge: how does CDN DNS select “good” CDN node to stream to client
  - Pick CDN node **geographically** closest to client’s local DNS
  - Pick CDN node with **shortest delay** (or min # hops) to client (CDN nodes periodically ping access ISPs, reporting results to CDN DNS)



CDNs

In HTTP steaming, video is stored at an HTTP server and retrieved with a GET request

Frames are sent to a client buffered and played back after a certain threshold

All clients receiving the same encoding of the video despite widely different bandwidth

CDNs

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All clients receiving the same encoding of the video despite widely different bandwidth

Dynamic Adaptive Streaming over HTTP (DASH)- video is encoded into several different versions

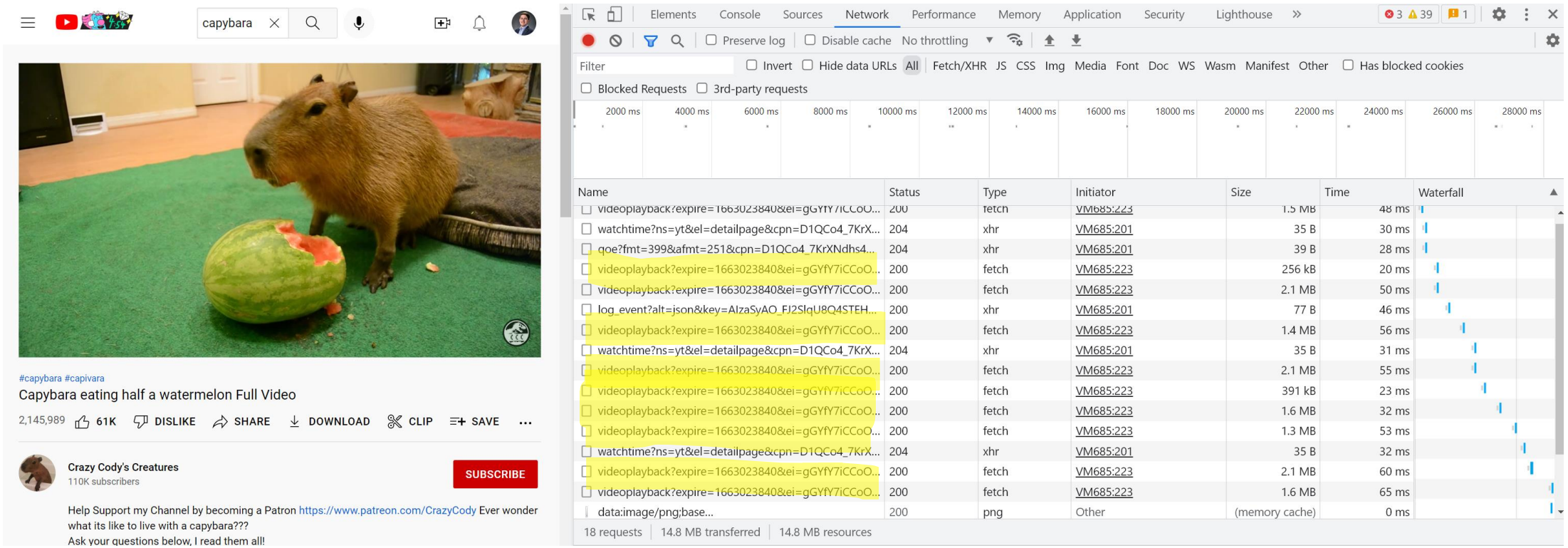
- Different encoding rate, different quality, etc

Clients dynamically request chunks of video segments every few seconds via GET requests

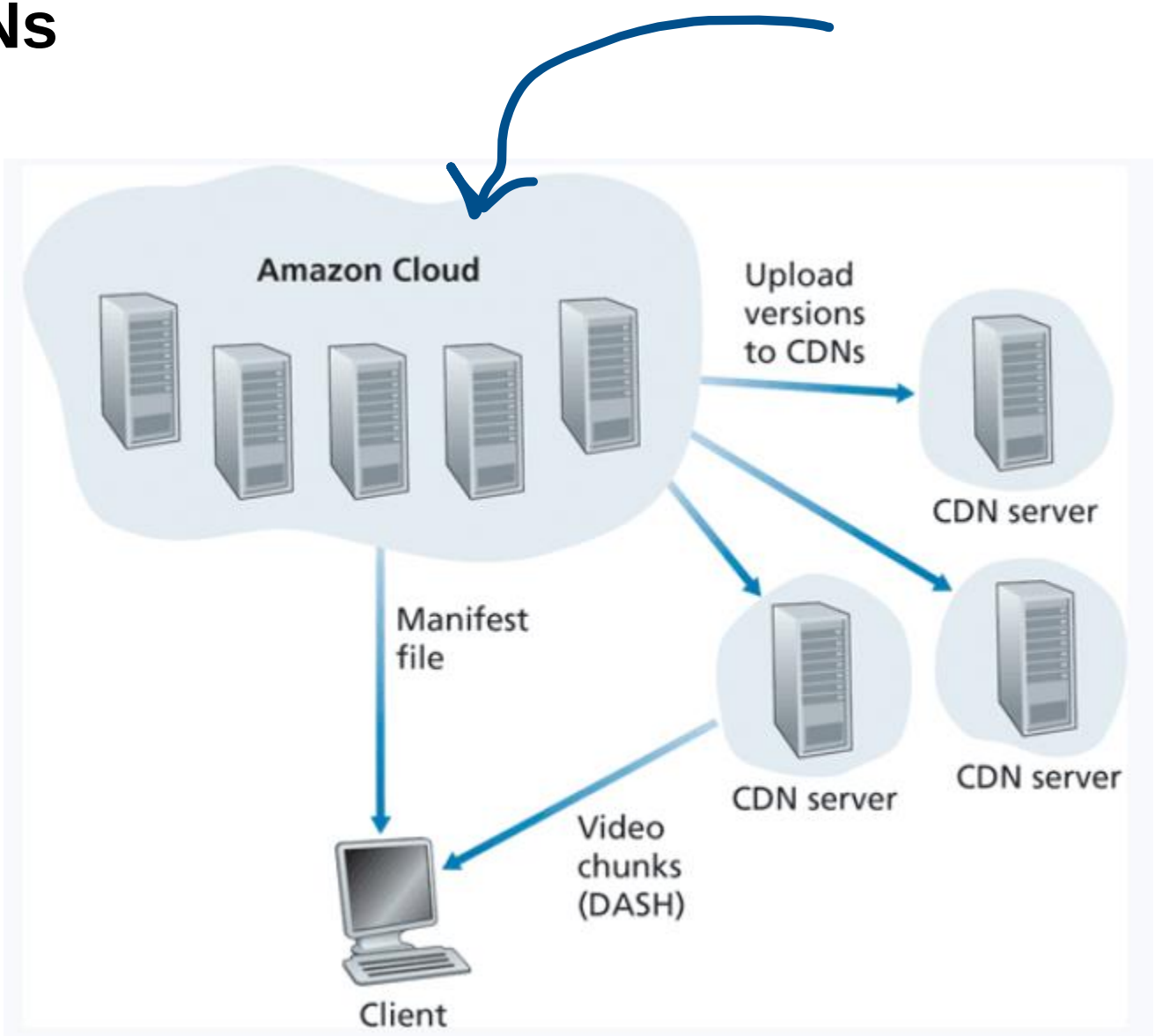
- Is the current bandwidth good? → Retrieve good quality
- Is the current bandwidth bad? → Retrieve ok quality

CDNs

When streaming, you are consistently issuing GET requests

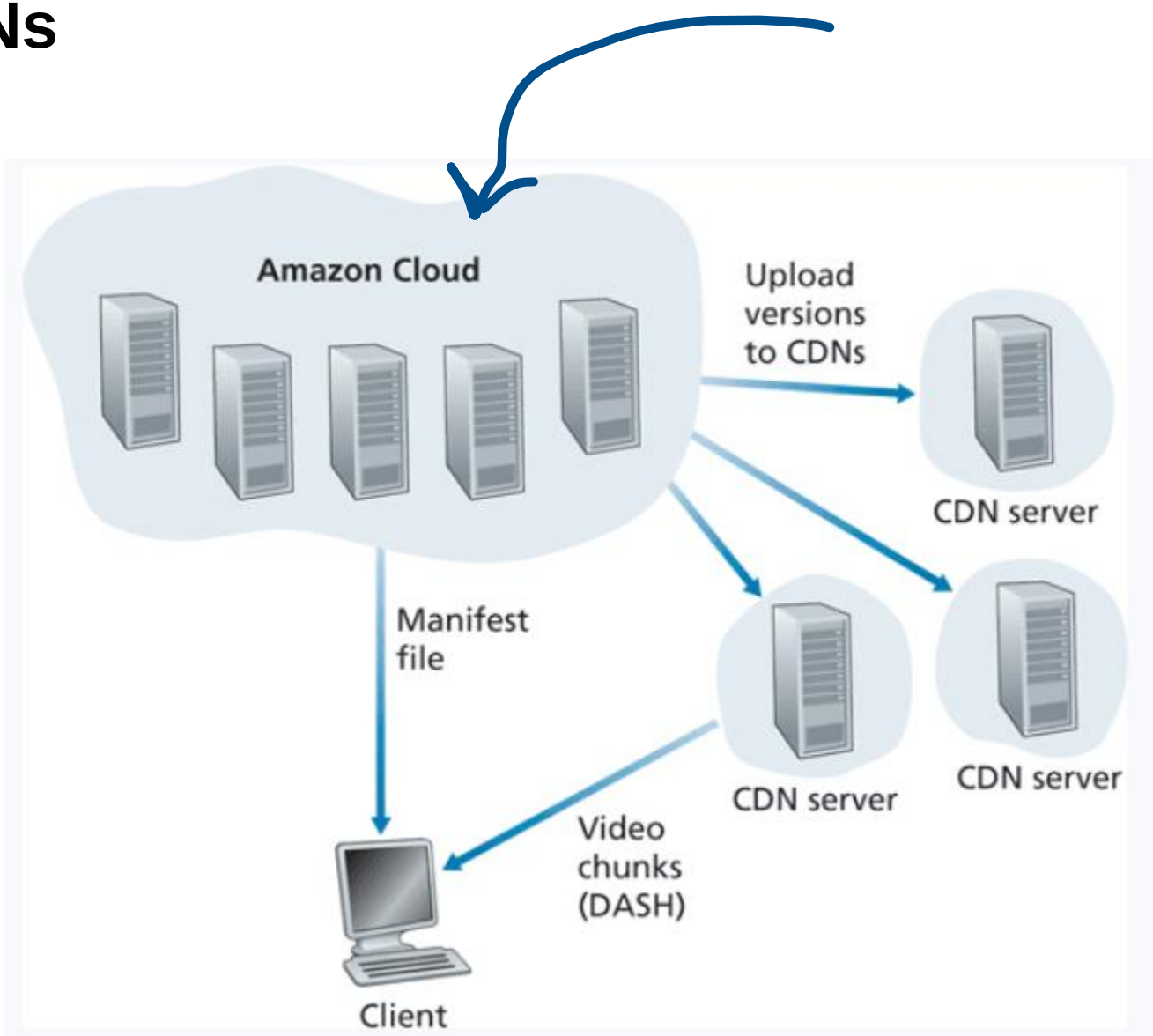


CDNs



Studio maser versions are uploaded to a private Amazon cloud

CDNs



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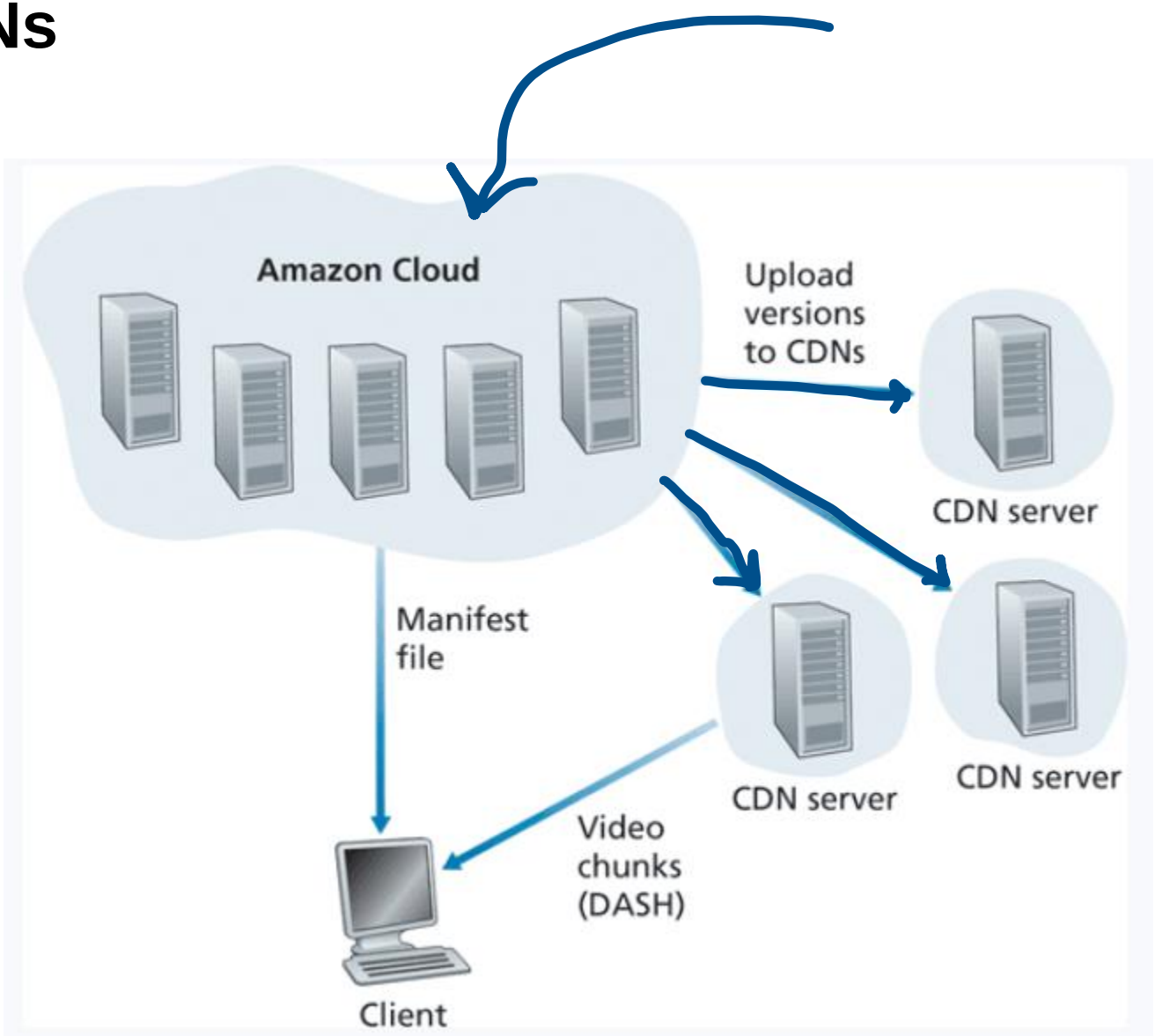
Videos are processed into many different formats, allowing for DASH

CDNs



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Versions are uploaded to Netflix's CDNs