50.012 Networks

Lecture 4: CDN and P2P

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Learning objectives

Understand the design of content distribution networks (CDN), including the design objectives, key design considerations, and various approaches.

Understand the peer-to-peer architecture: benefits, challenges, basic operations and incentive mechanism of BitTorrent.

Read: textbook Section 2.4, 2.5, 2.6

Content distribution networks

- *Challenge:* how to stream content (selected from millions of videos) to hundreds of thousands of *simultaneous* users?
  - Recall: they're highly heterogeneous, including locations, connectivity, etc.
- *Option 1:* single, large "mega-server"
  - point of network congestion
  - long path to distant clients
  - multiple copies of video sent over outgoing link (wastage)
  - single point of failure

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

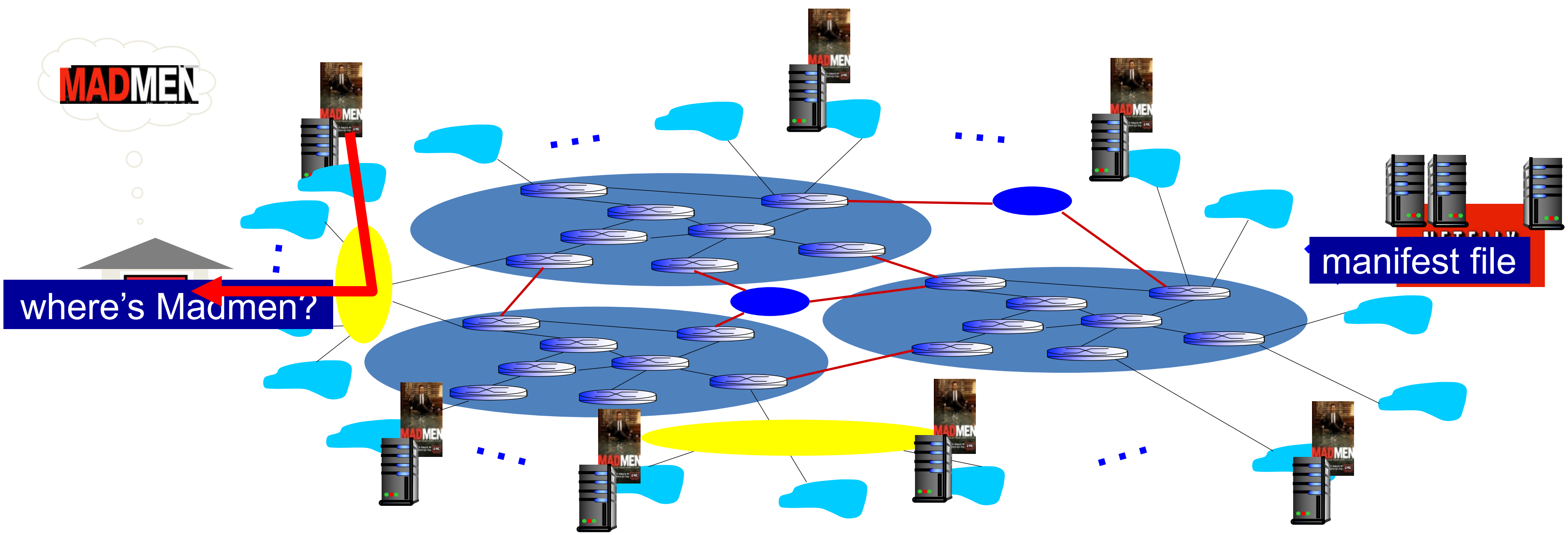
Content distribution networks

- *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)*

Content distribution networks

- CDN: stores copies of content at CDN nodes
  - e.g., Netflix stores copies of MadMen
- subscriber requests content from Netflix
  - directed to nearby CDN copy (based on mapping IP address of request to geographical location), retrieves content

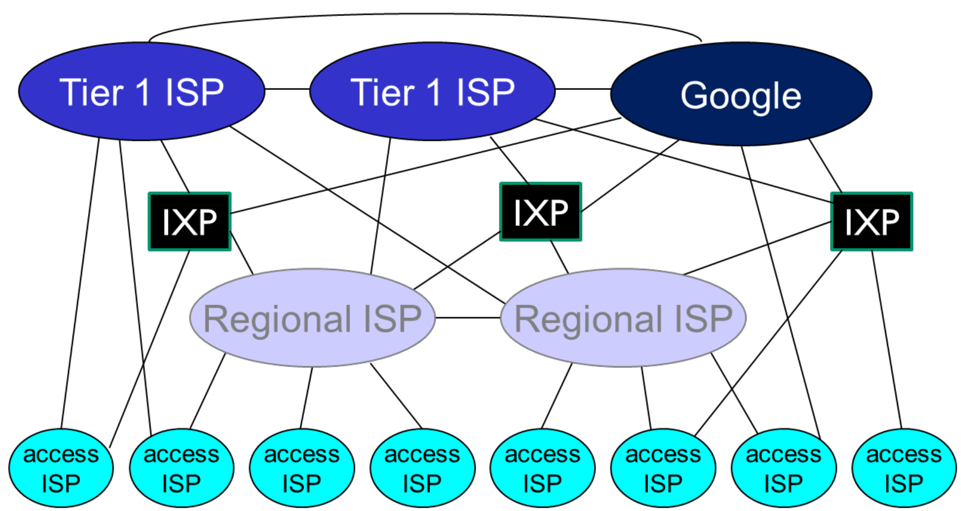


Questions for a CDN operator

- Where to put the servers?
- How to select the server?
- How to route the client to the server?
- How to replicate the content to the servers?

CDN Server Placement

- *Enter deep:* push CDN servers deep into many access ISPs
  - close to users
  - used by Akamai, 1700+ locations
- *Bring home:* smaller number (10's) of larger clusters in IXPs (Internet Exchange Points) near (but not within) access networks
  - used by Limelight



Types of CDN

- Commercial CDN
  - Akamai Technologies, Cloudflare, LimeLight
- Content provider’s own CDN
  - Google, netflix
- Telco CDN

Cluster (Server) Selection

- Geographically close
- Best performance: real-time measurement
- Lowest load: Load-balancing
- Cheapest: CDN may need to pay its provider ISP
- Any alive node: fault-tolerant

Content Access / Routing

- Naming (DNS)–based
- Application-driven
  - E.g., use HTTP redirect
  - Multiple connection setup, name lookups
- Routing (anycast)-based
  - Coarse-grained

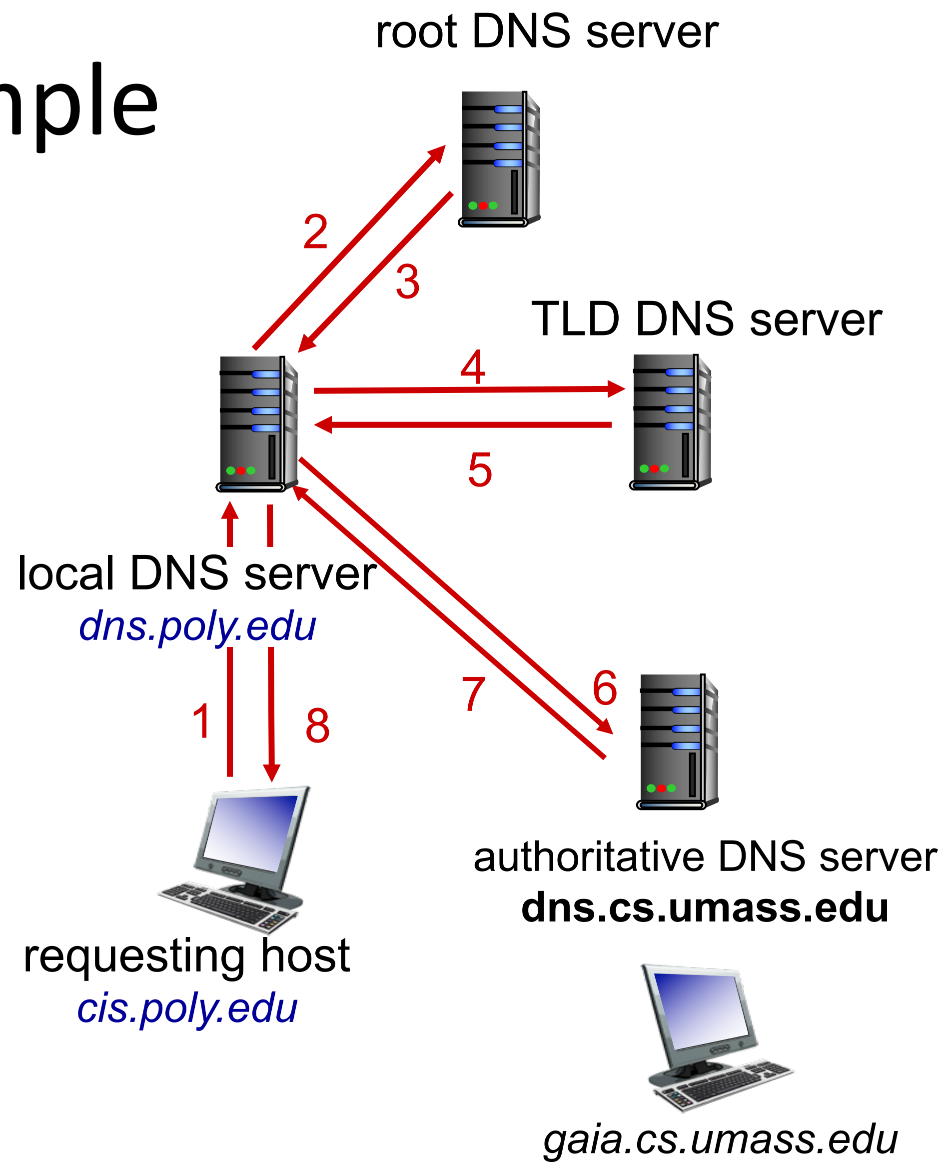
A quick recap of DNS
(Domain Name System)

DNS name resolution example

- host at cis.poly.edu wants IP address for gaia.cs.umass.edu

iterated query:

- contacted server replies with name of server to contact
- "I don't know this name, but ask this server"



DNS records

DNS: distributed database storing resource records (RR)

RR format: `(name, value, type, ttl)`

type=A

- **`name`** is hostname
- **`value`** is IP 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
- **`www.ibm.com`** is really **`servereast.backup2.ibm.com`**
- **`value`** is canonical name

type=MX

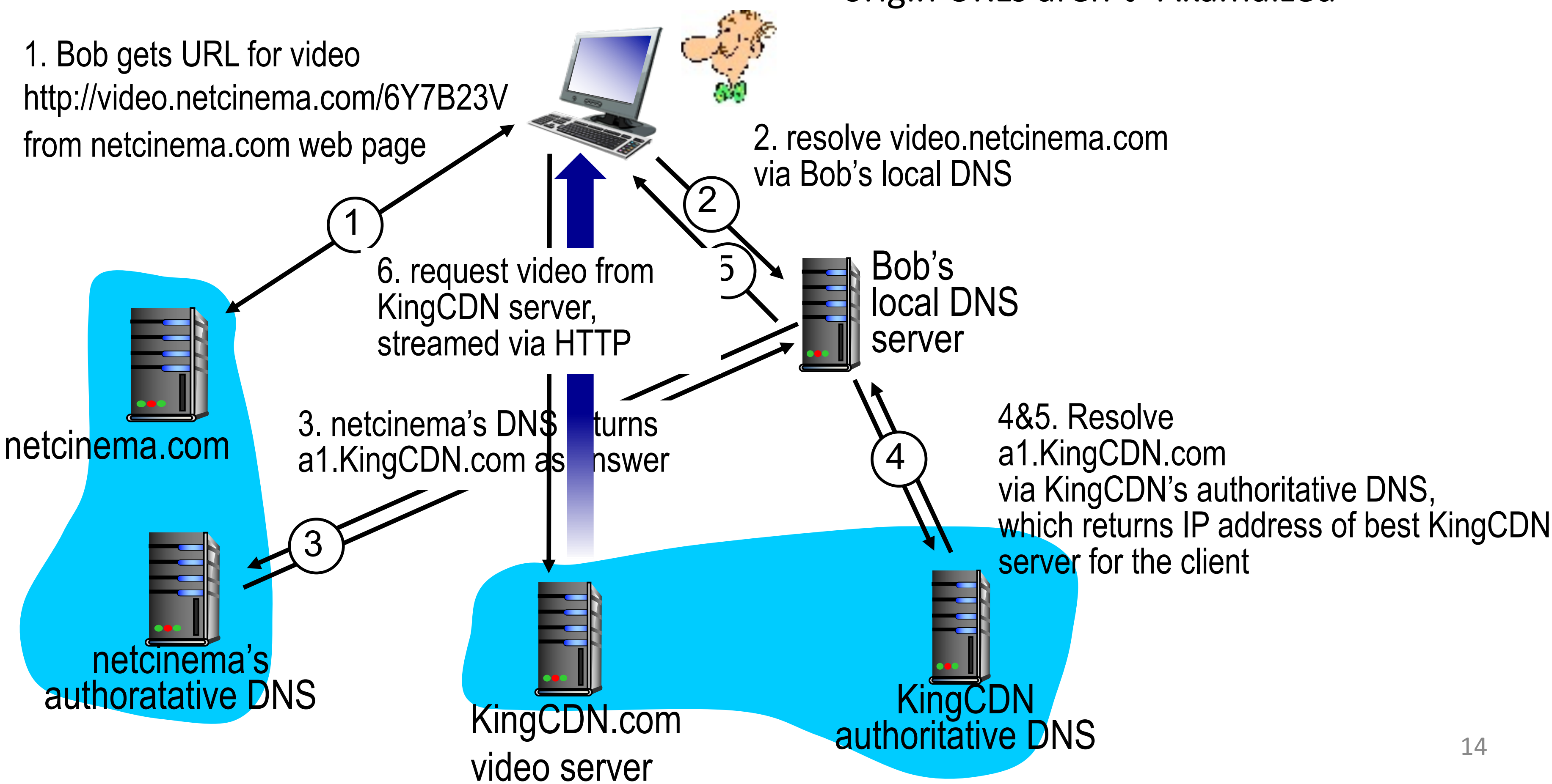
- **`value`** is name of mailserver associated with **`name`**

CDN content access by DNS redirect

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

- video stored in CDN run by KingCDN.com

Used by: third-party CDNs like Akamai, if origin URLs aren't "Akamaized"

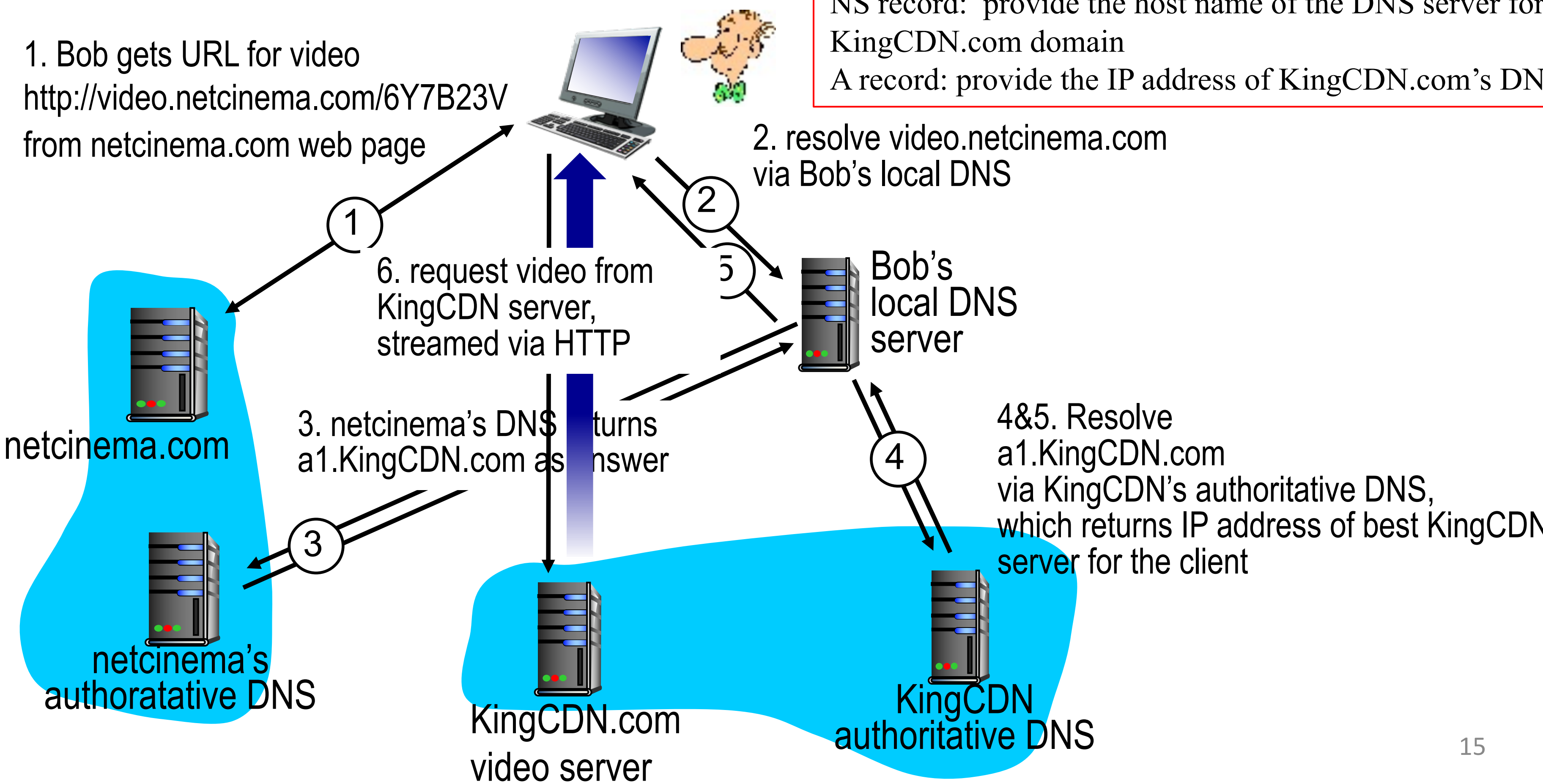


CDN content access by DNS redirect

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

- video stored in CDN run by KingCDN.com

The DNS records sent at step 3:
CNAME record: map video.netcinema.com to a1.KingCDN.com
NS record: provide the host name of the DNS server for the KingCDN.com domain
A record: provide the IP address of KingCDN.com's DNS s



Akamai Resource Locators (ARL)

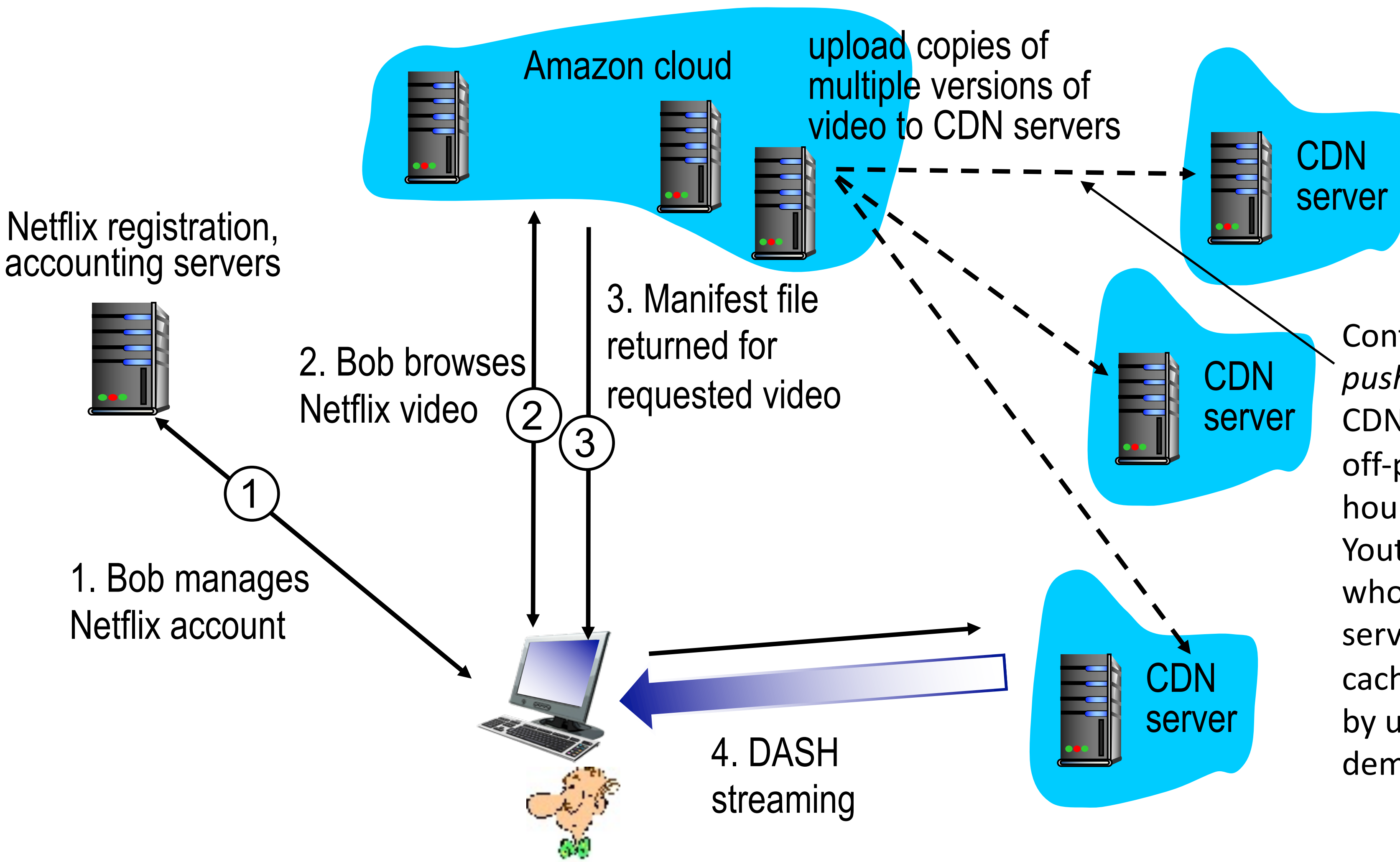
- Each customer has its dedicated domain name
  - E.g., a123.g.akamaitech.net
  - Akamai operates the authoritative DNS servers for these names
- The original server can "akamaize" the origin URL to ARL (Akamai Resource Locators)
  - E.g.,: <img src="http://sutd.edu.sg/img/welcome.gif"> becomes <img src ="http://a123.g.akamaitech.net/7/123/456/xobjdatax/sutd.edu.sg/img/welcome.gif">
- Client browser issues GET to CDN instead of origin server
- Read more:
  Akamai "Fast Internet Content Delivery with FreeFlow"

Case study: Netflix

- Netflix used to rely on third-party CDNs
  – Akamai, LimeLight, level-3
- It has built its private CDN for delivering videos
  – Still rely on Akamai for delivering web pages
  – Server placements: bring home (50+ IXP) + enter deep (free rack of servers for access ISPs)
- Netflix rack: 1 (access ISP) to 10+ (IXP) servers
  – Each server has multiple 10Gbps Ethernet ports, 100 Terabytes+ storage

Case study: Netflix

NB. CDN is owned (hence directly controlled) by Netflix: no need for previous DNS redirect



Content *pushed* to CDN during off-peak hours (cf. Youtube, whose CDN servers *pull* & cache content by user demand)

Content replication

	Mechanism	Pros.	Cons.
Netflix	Push		
Youtube	Pull		

Why the difference in their design?

Use of CDN

- DDoS Attack mitigation
- Handle flash crowds
- Web application firewalls (WAF)

Outline

Content distribution networks (CDN)

Peer-to-peer architecture

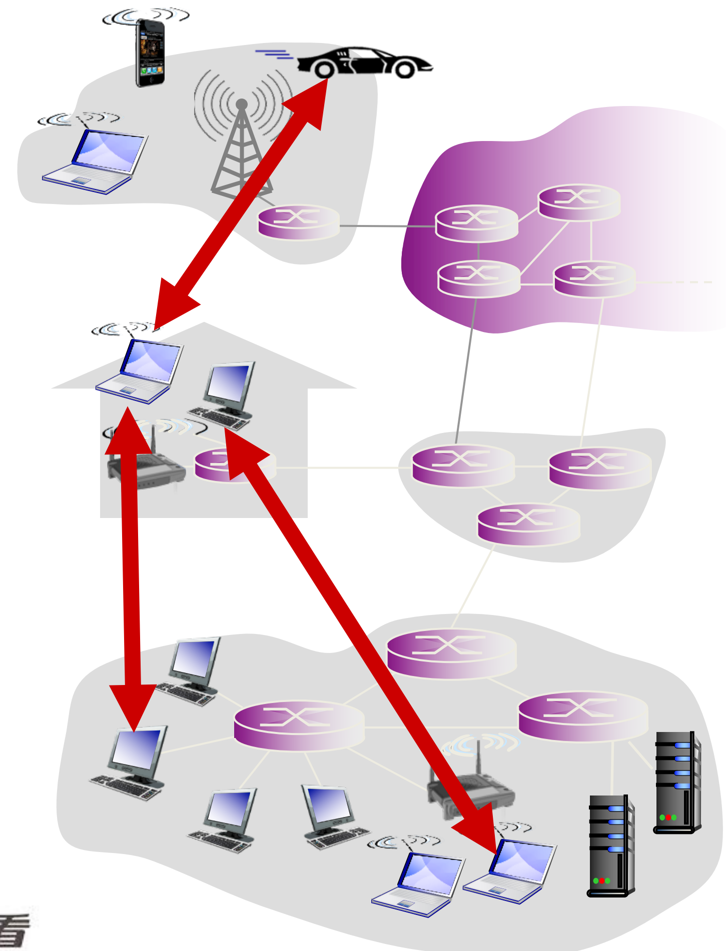
Pure P2P architecture

- *No* always-on server
- Arbitrary end systems (e.g., our laptops) directly communicate as peers
- Peers are intermittently connected and may change IP addresses

Examples:

- File (e.g., video) distribution (BitTorrent)
- Multimedia streaming (KanKan)
- VoIP (Skype)

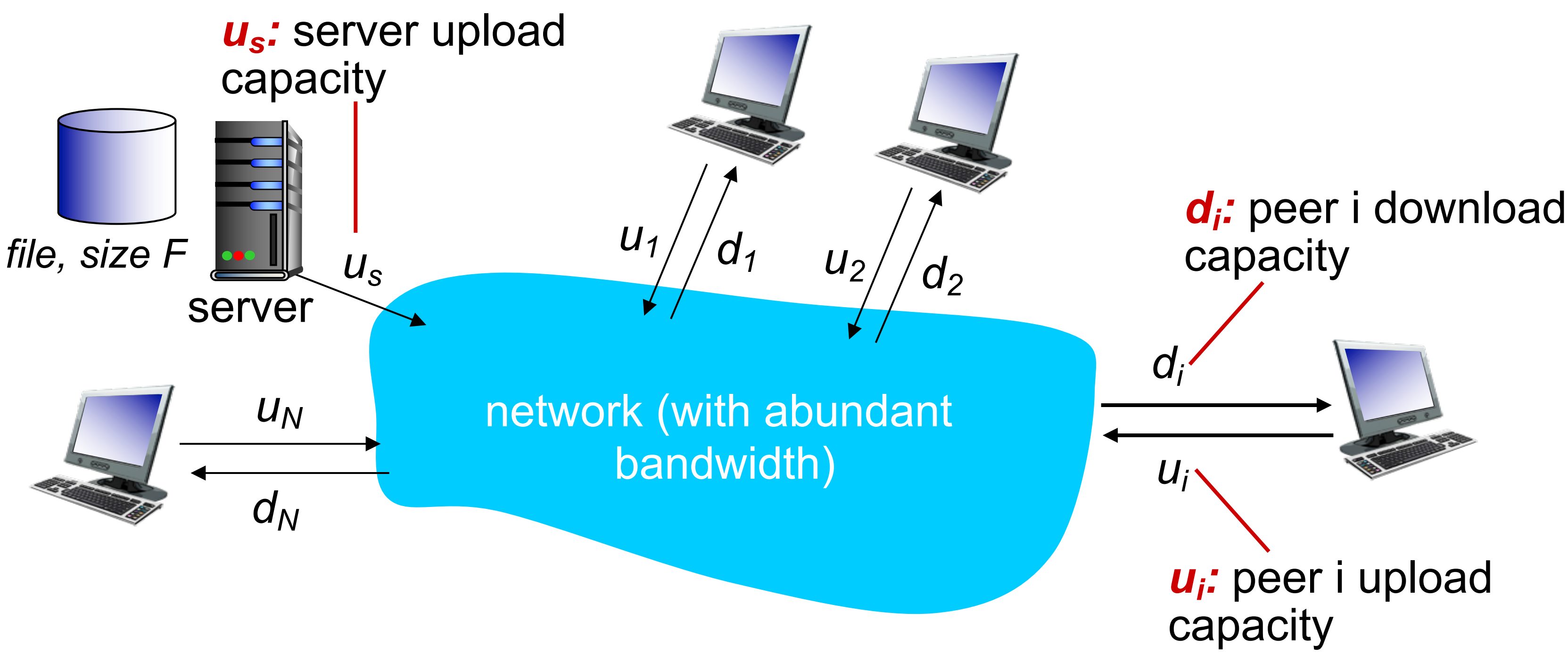
迅雷看看
www.kankan.com
网 络 高 清 影 院



File distribution: client-server vs P2P

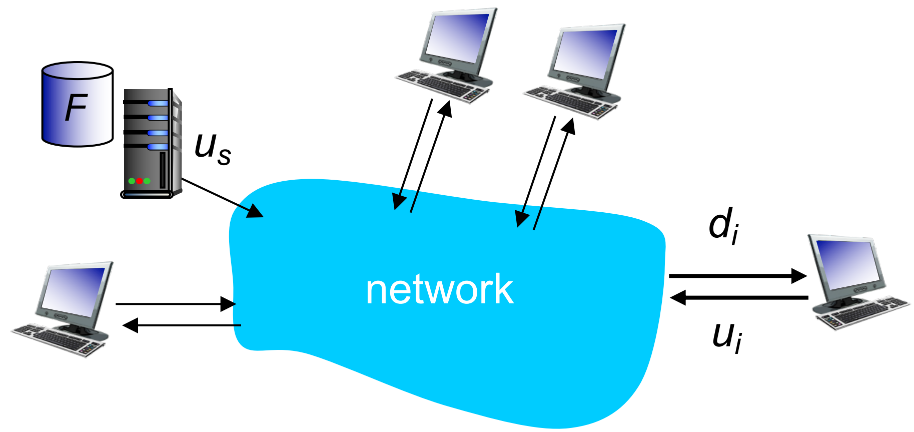
Question: How much time to distribute file (size *F*) from one server to *N* peers?

- peer upload/download capacity (access bandwidth) is limited resource, compared with core bandwidth



File distribution time (lower bound): 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}



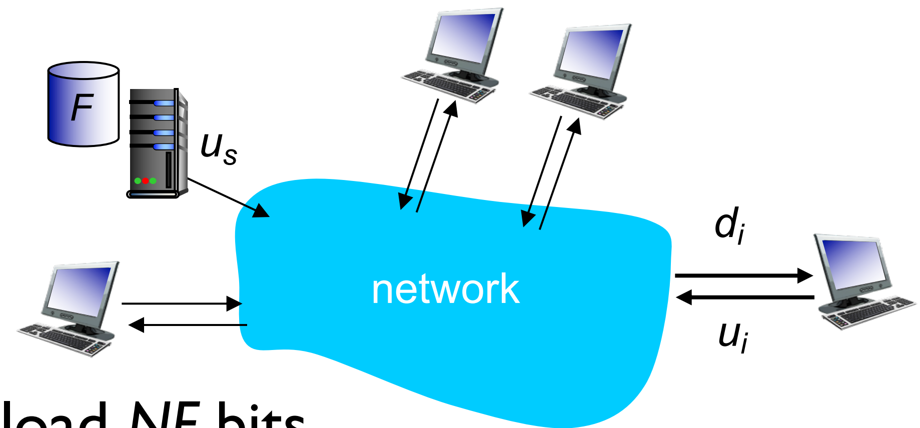
time to distribute F to N clients using client-server approach

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

increases linearly in N; susceptible to "flash crowds" particularly

File distribution time (lower bound): P2P

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



- *client:* each client must download a file copy
  - min client download time: F/d_{min}
- *clients:* as aggregate must download *NF* bits
  - implies upload of the same number of bits (*why?*)
  - max upload rate is $u_s + \Sigma u_i$ (if it's feasible to schedule the distribution to make all the uploads concurrently active)

time to distribute F to N clients using P2P approach

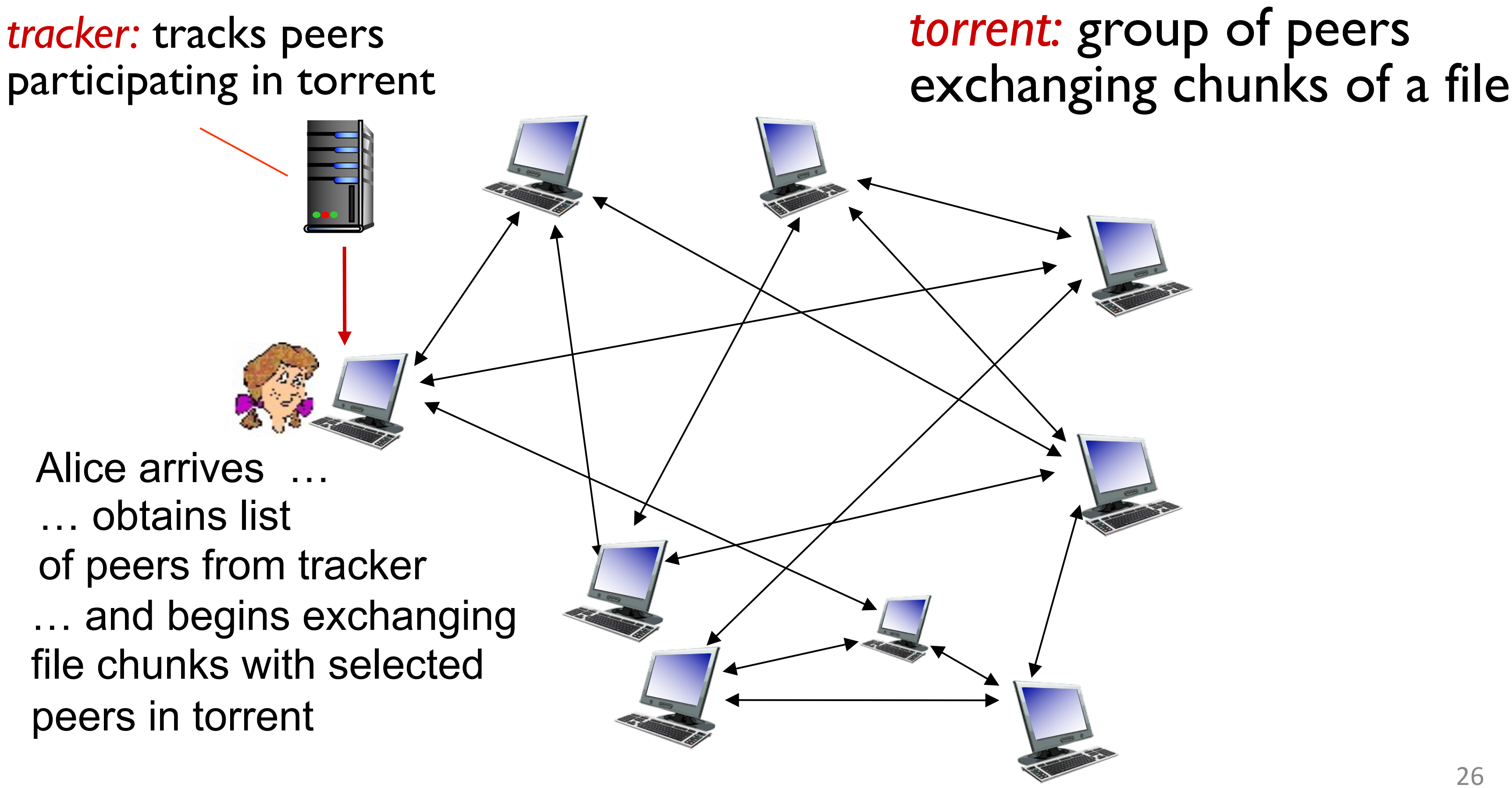
$$D_{P2P} \geq max\{F/u_s, F/d_{min}, NF/(u_s + \Sigma u_i)\}$$

increases linearly in *N* …

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

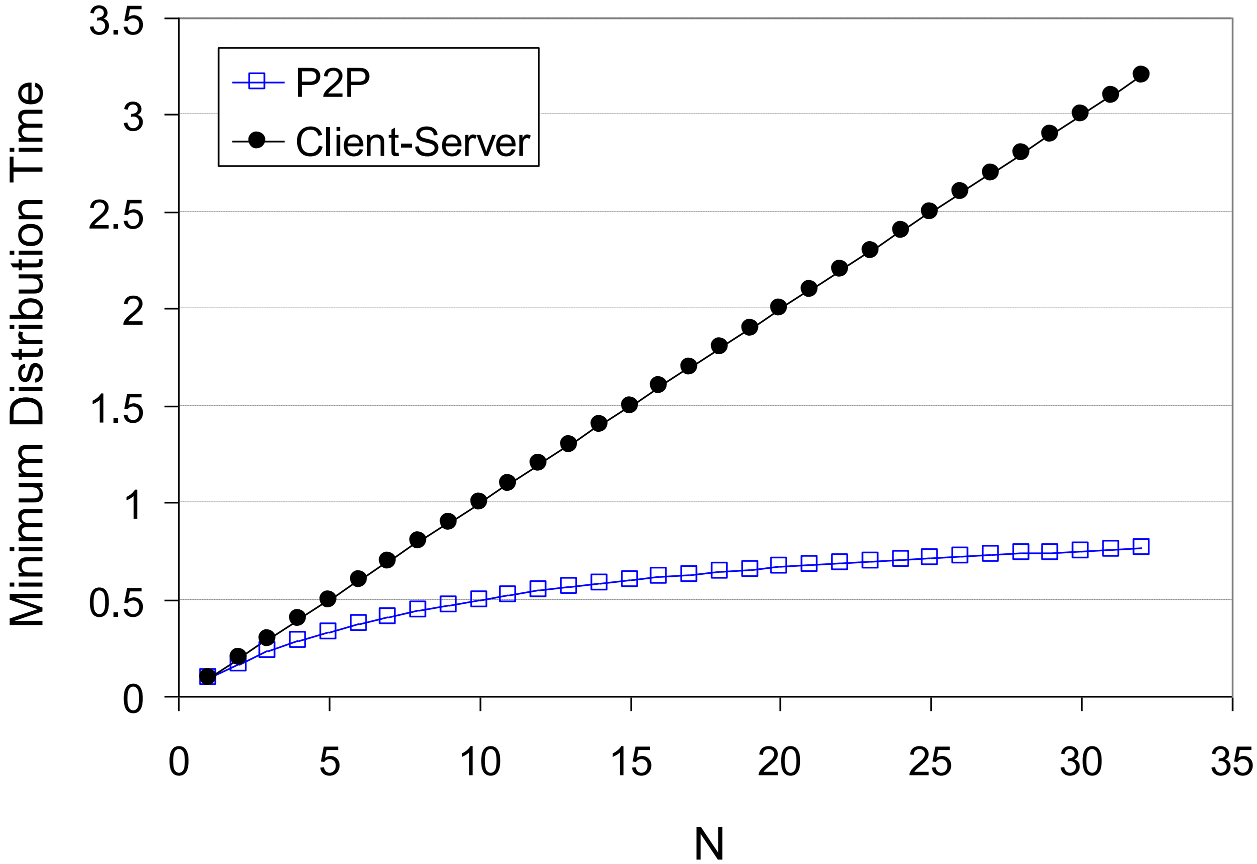
P2P file distribution: BitTorrent

- file divided into 256 kB chunks
- peers in torrent send/receive (trade) file chunks



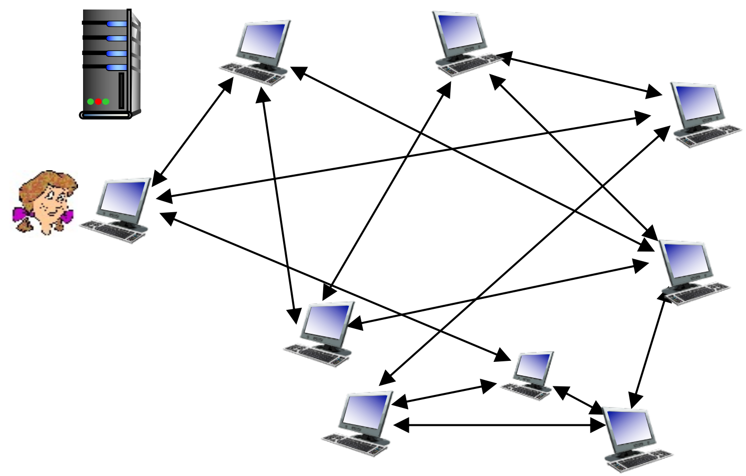
Client-server vs. P2P: example

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



P2P file distribution: BitTorrent

- Peer joining torrent:
  - initially 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 (highly dynamic & organic, *no a priori* set up reliable infrastructure)
- Once peer has entire file, it may (selfishly) leave or (altruistically) remain in torrent
  - peers ultimately interested in download
  - In general need *incentives* for them to provide upload (e.g., tit-for-tat)

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
  - Aim to make all the chunks equally available (they are equally important)

Sending chunks: tit-for-tat

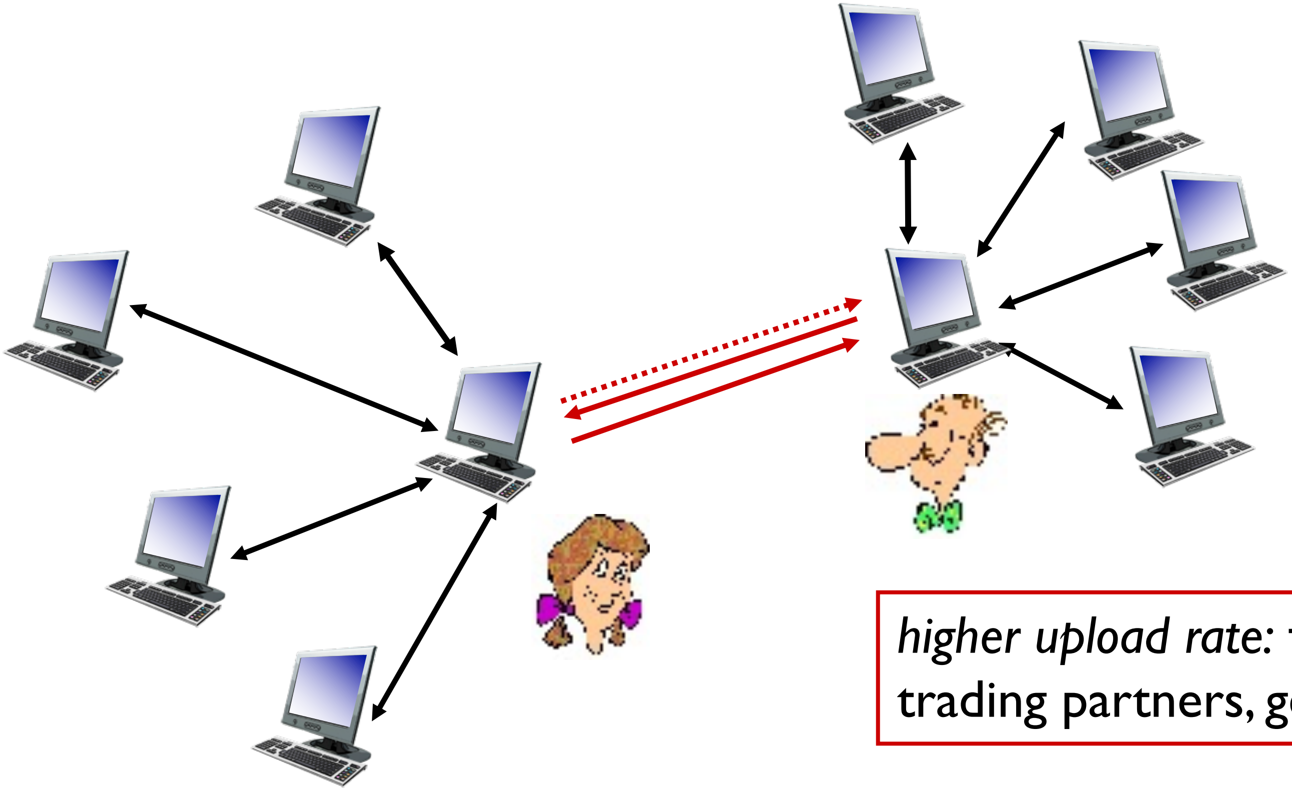
- Alice sends chunks to those four peers currently sending her chunks *at highest rate*
  - these 4 are "unchoked"
  - other peers are choked by Alice (do not receive chunks from her)
  - re-evaluate top 4 every10 secs
- every 30 secs: randomly select another peer, starts sending chunks
  - optimistically "unchoke" this peer: give chance of discovering an even better trading partner than the original top 4
  - 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 in turn becomes one of Alice's top-four providers



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