Reti di Elaboratori

Corso di Laurea in Ingegneria Informatica

Università degli Studi di Roma "La Sapienza"

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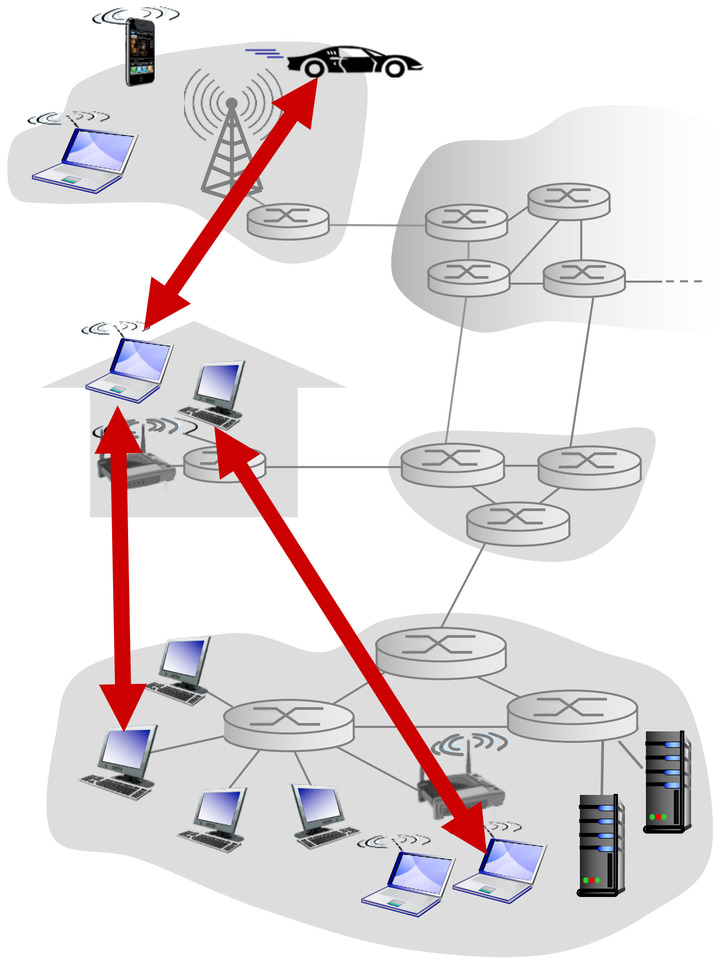
Chapter 2: outline

Pure P2P architecture

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

examples:

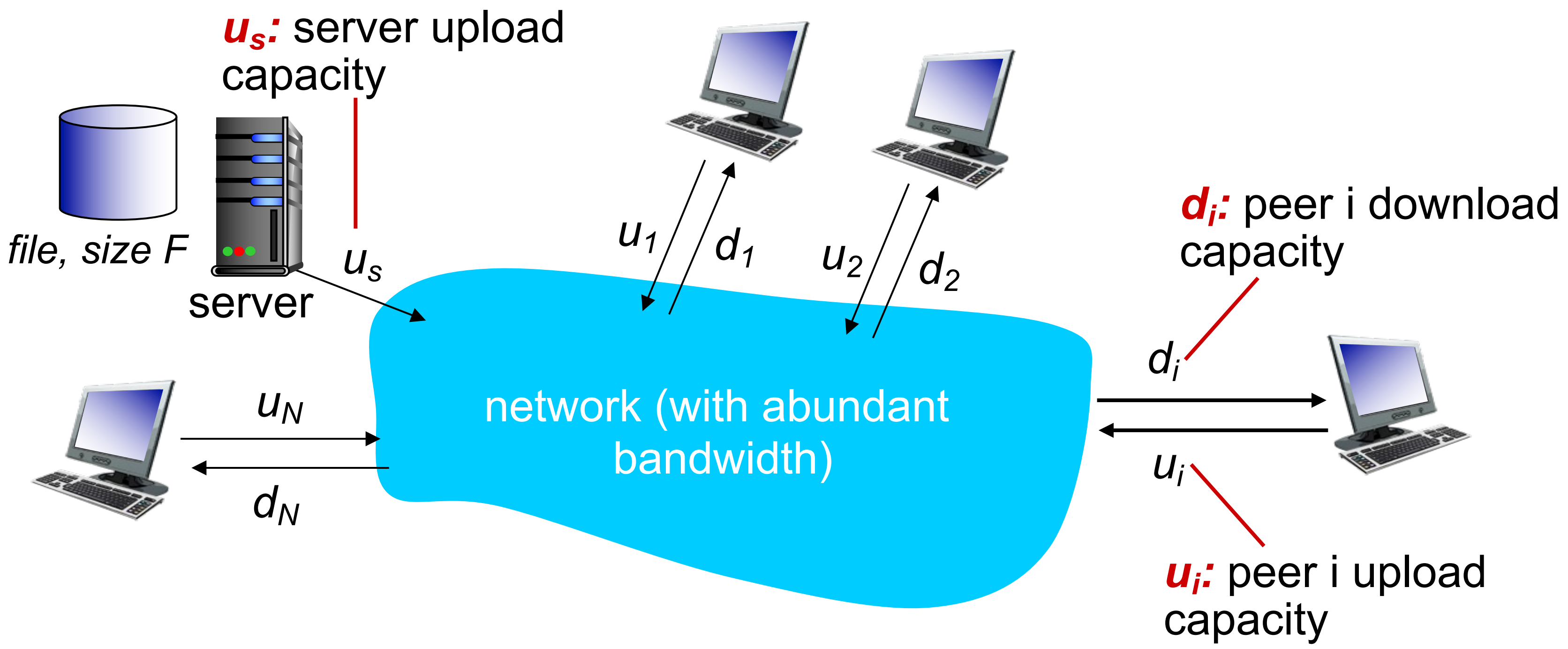
- file distribution (BitTorrent)
- Streaming (KanKan)
- VoIP (Skype)



File distribution: client-server vs P2P

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

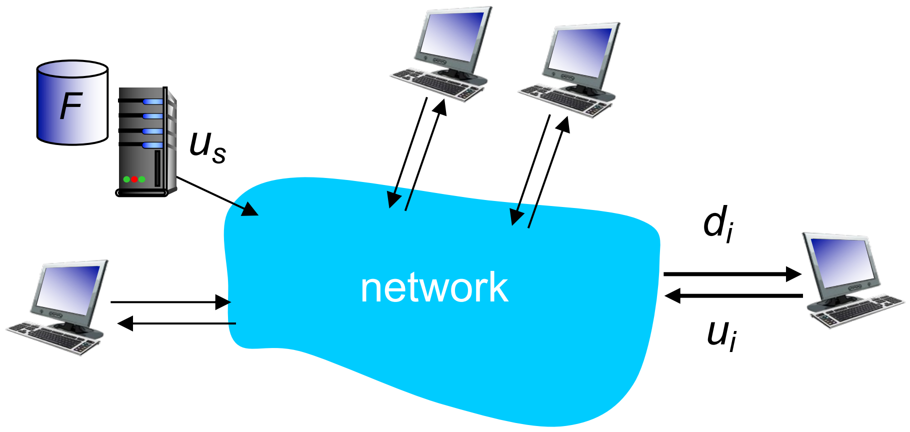
- peer upload/download capacity is limited resource



u_s: server upload capacity
file, size F
server
u_s
u_1
d_1
u_2
d_2
d_i: peer i download capacity
d_i
u_N
d_N
network (with abundant bandwidth)
u_i
u_i: peer i upload capacity

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}



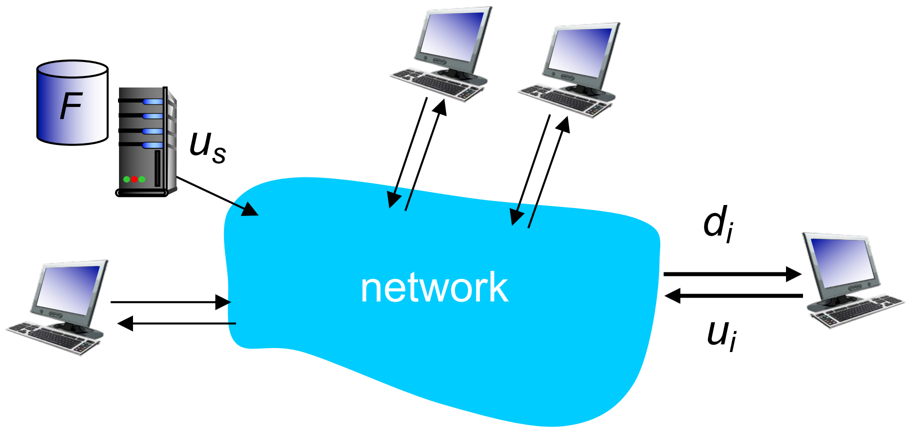
time to distribute F to N clients using client-server approach

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

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 (limiting max download rate) is $u_s + \Sigma u_i$

time to distribute F to N clients using P2P approach

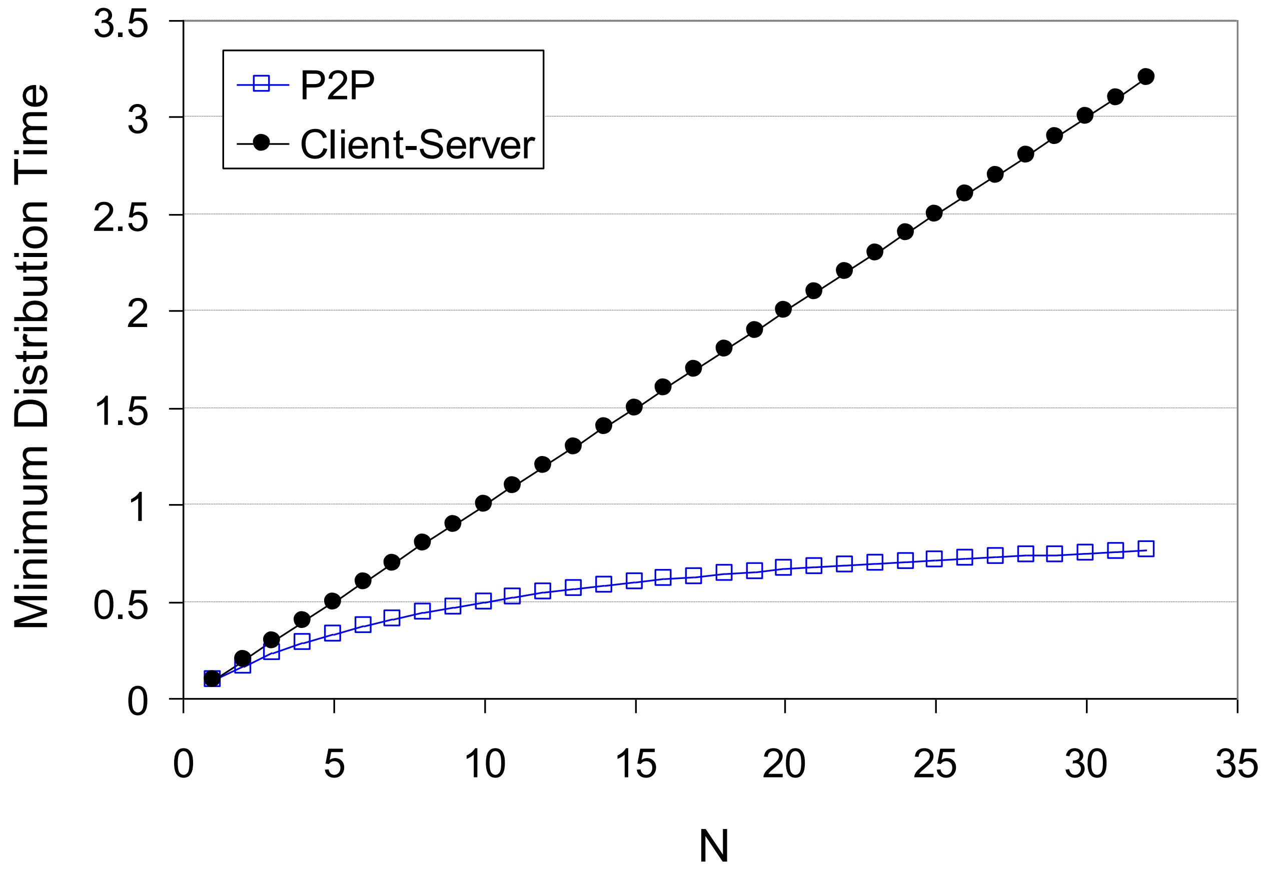
$$D_{P2P} \geq max\{F/u_s,,F/d_{min,},NF/(u_s + \Sigma u_i)\}$$

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, $u_s = 10u$, $d_{min} \geq u_s$

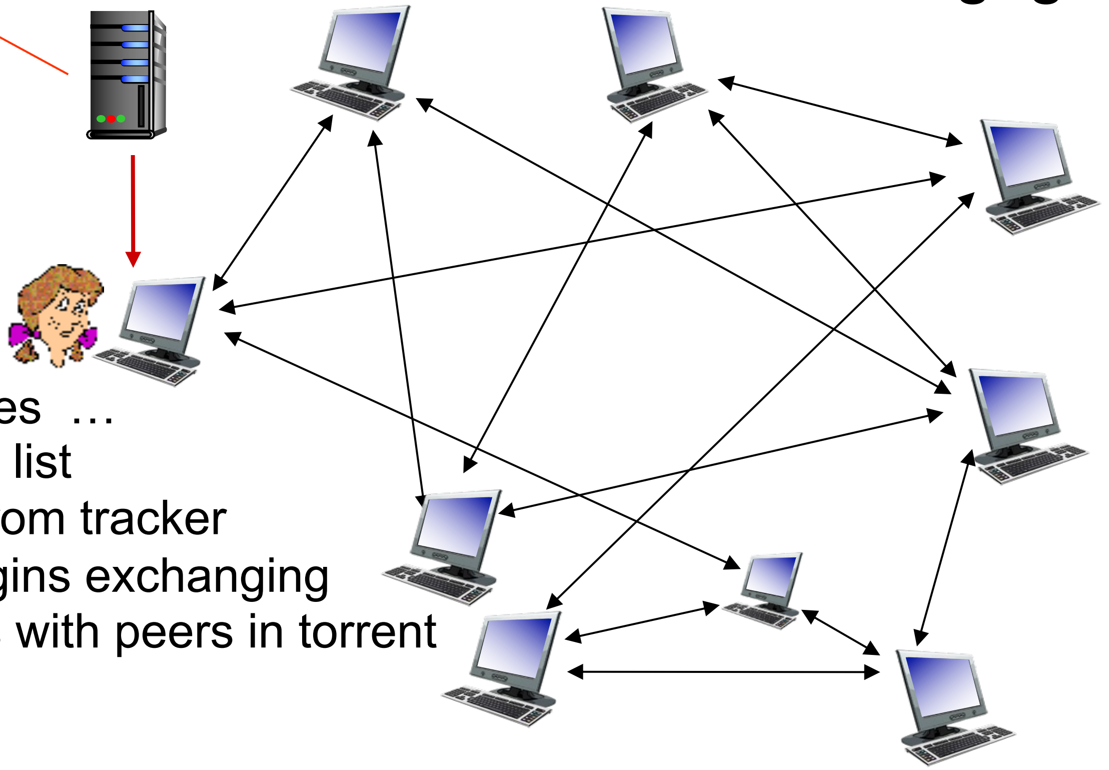


P2P file distribution: BitTorrent

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

tracker: tracks peers participating in torrent

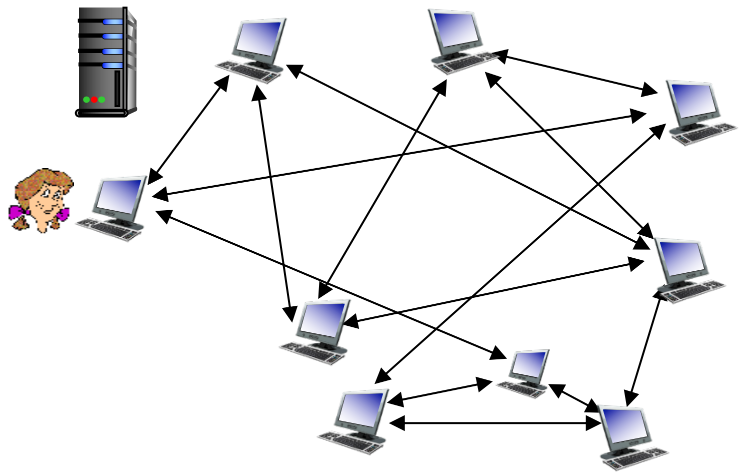
torrent: group of peers exchanging chunks of a file



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

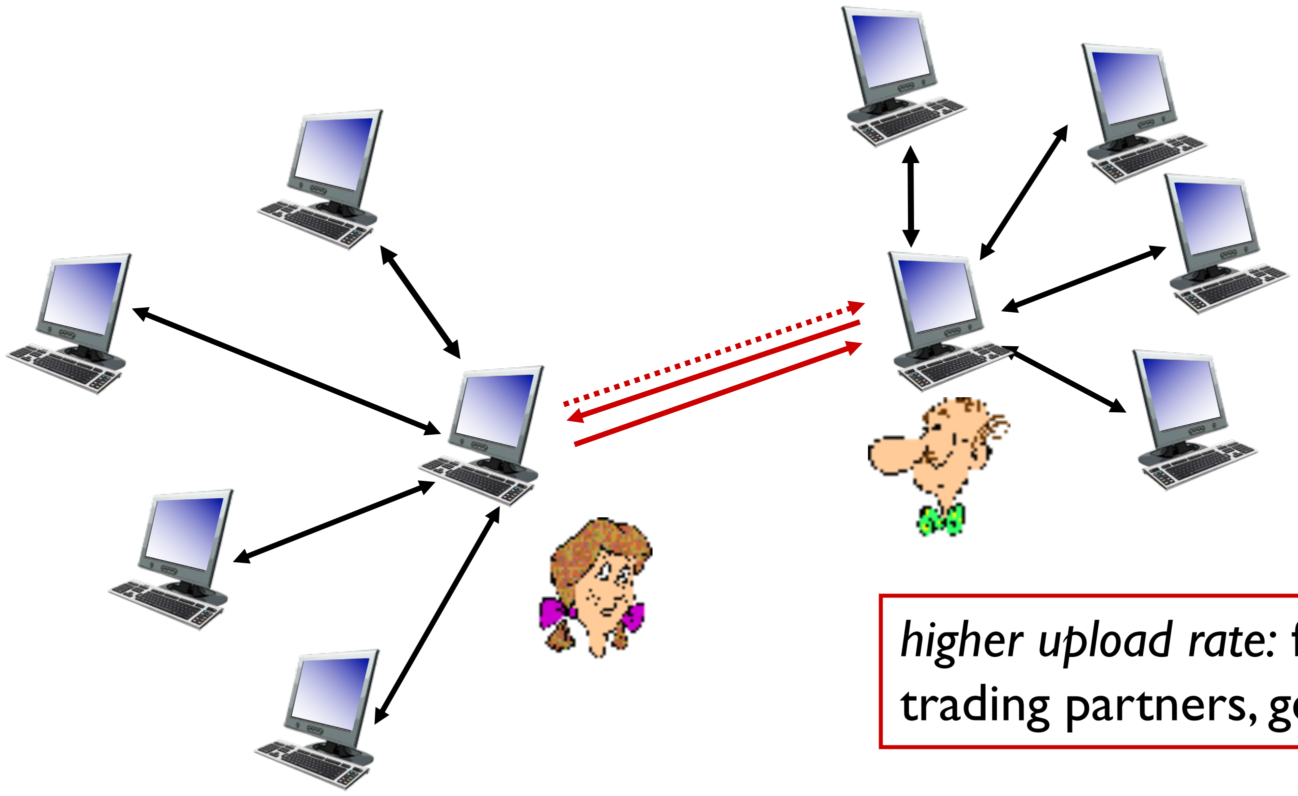
- Alice sends chunks to those four peers currently sending her chunks *at highest rate*
  - other peers are choked by Alice (do not receive chunks from her)
  - re-evaluate top 4 every10 secs
- every 30 secs: randomly select another peer, starts sending chunks
  - "optimistically unchoke" this peer
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

Content distribution networks

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

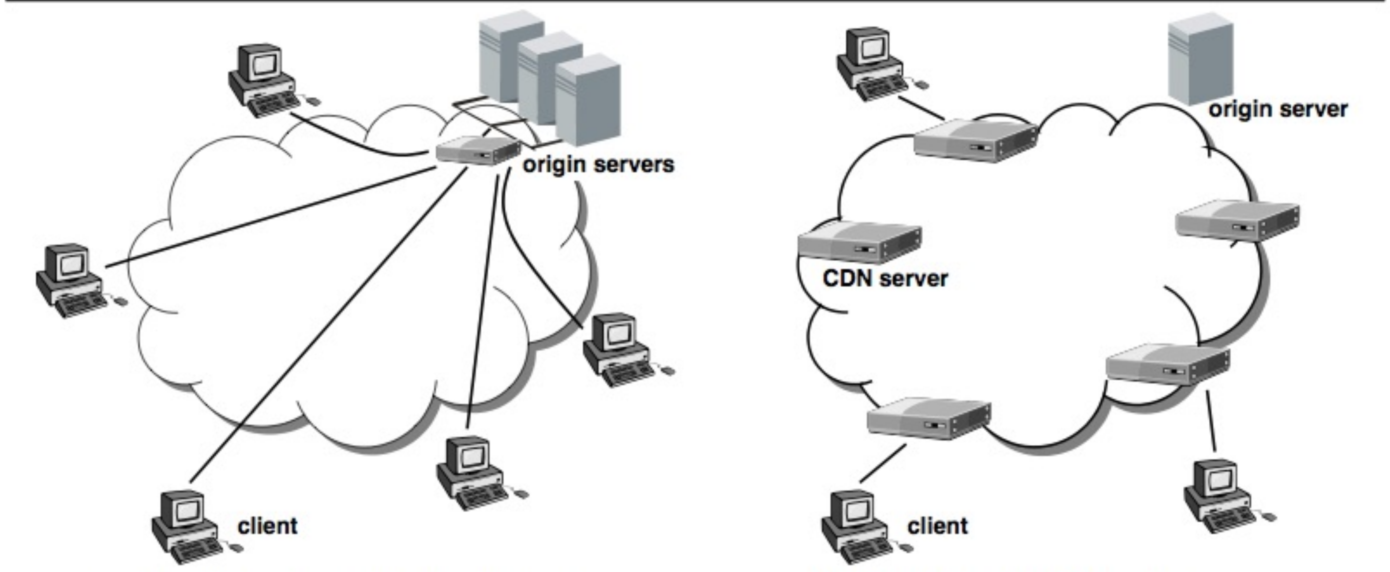
- *option 1:* single, large "mega-server"
  - single point of failure
  - point of network congestion
  - long path to distant clients
  - multiple copies of video sent over outgoing link

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

Content Delivery Networks

- We have seen the extensive use of caching for reducing latencies in resolving names and accessing web content
- Is this enough?
  - Origin servers may still have to be accessed to maintain consistency
- Caching
  - What to cache
  - How to maintain consistency
  - How to invalidate or update in case an inconsistency is detected
- More here:http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.73.586&rep=rep1&type=pdf

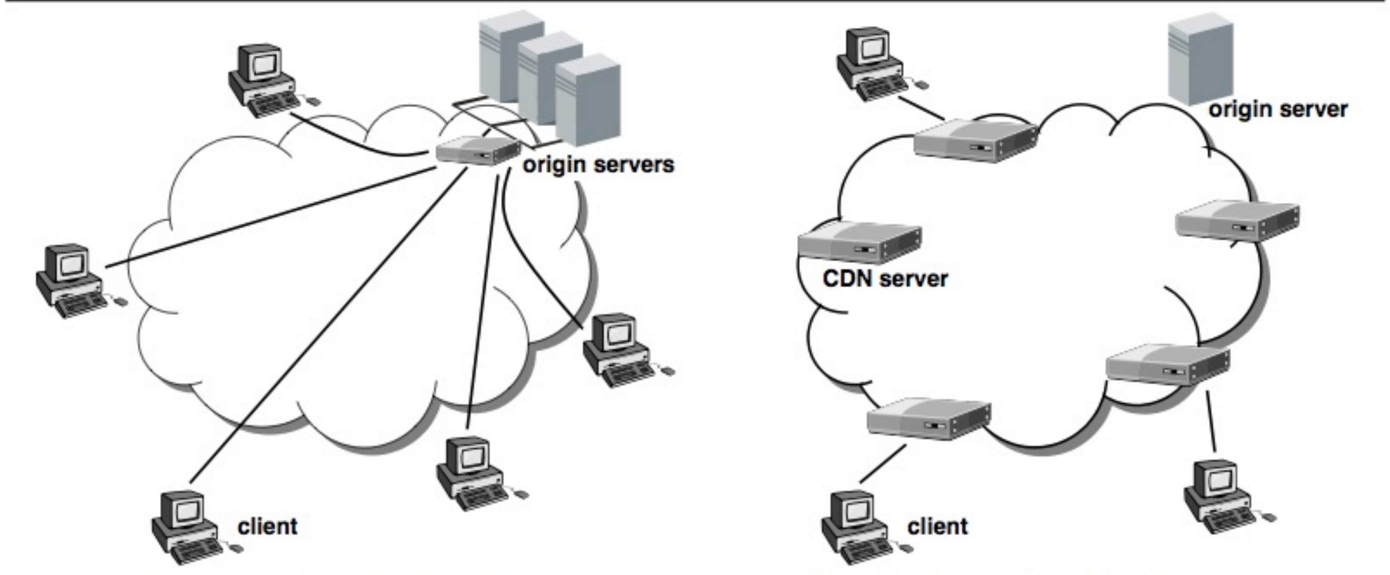
Content Delivery Networks



(a) Traditional centralized architecture (b) Distributed CDN architecture

- improving client-perceived response time by bringing content closer to the network edge, and thus closer to end-users
- off-loading work from origin servers by serving larger objects, such as images and multimedia, from multiple CDN servers
- reducing content provider costs by reducing the need to invest in more powerful servers or more bandwidth as user population increases

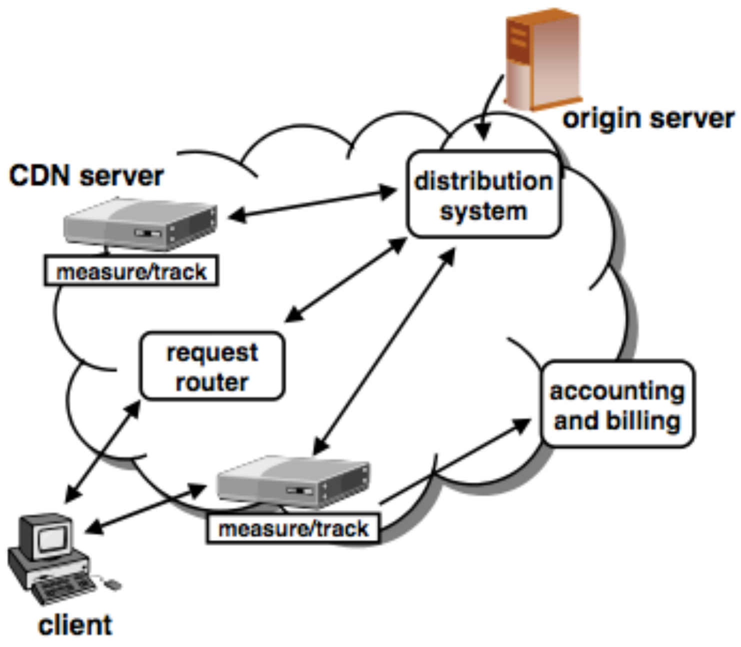
Content Delivery Networks



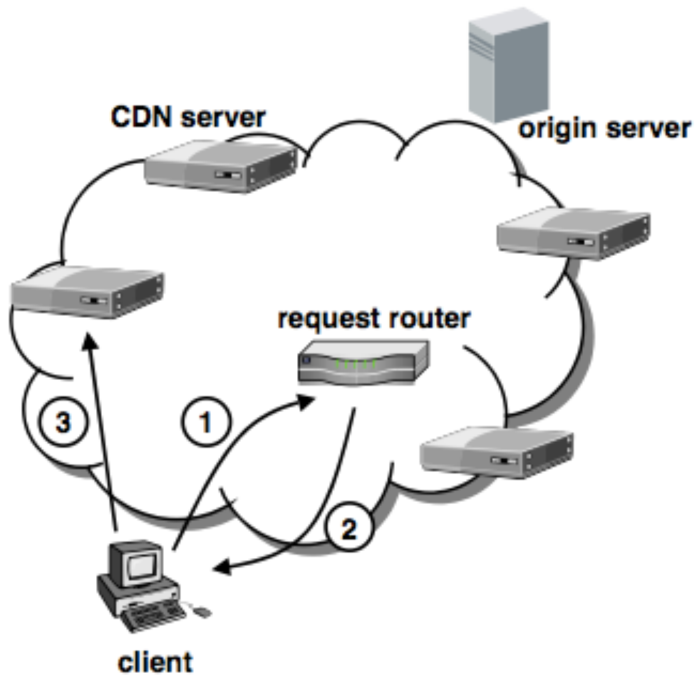
(a) Traditional centralized architecture (b) Distributed CDN architecture

- improving site availability by replicating content in many distributed locations

Content Delivery Networks

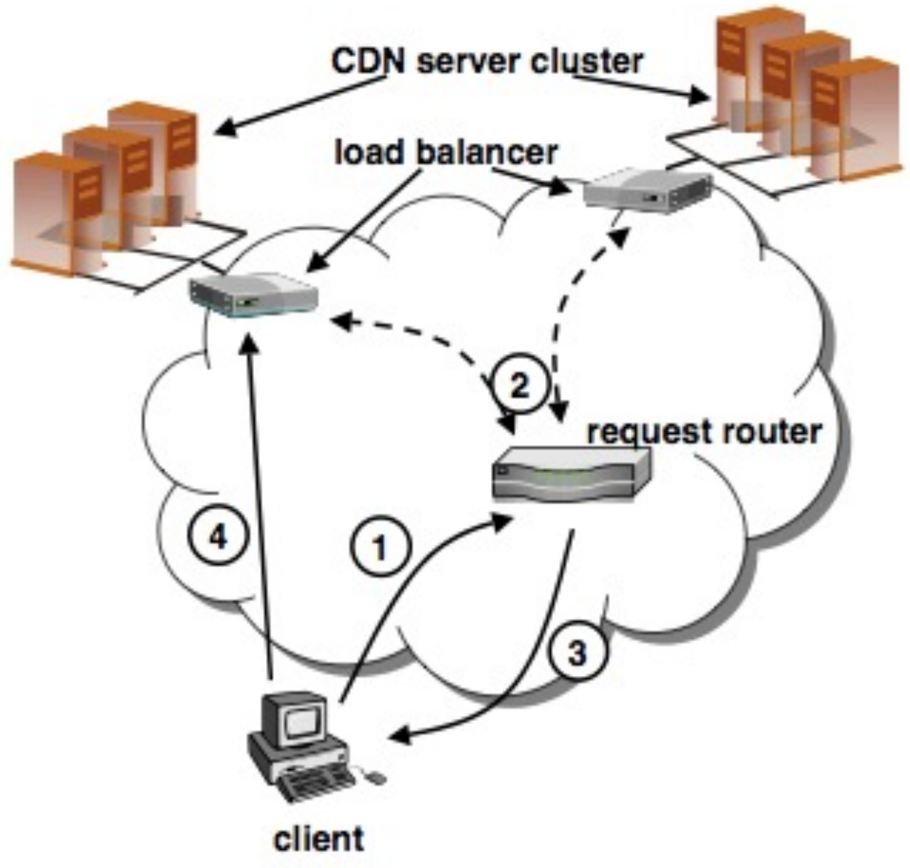


(a) CDN architectural elements



(b) CDN request-routing

Content Delivery Networks



- HTTP Redirect
- DNS Redirect

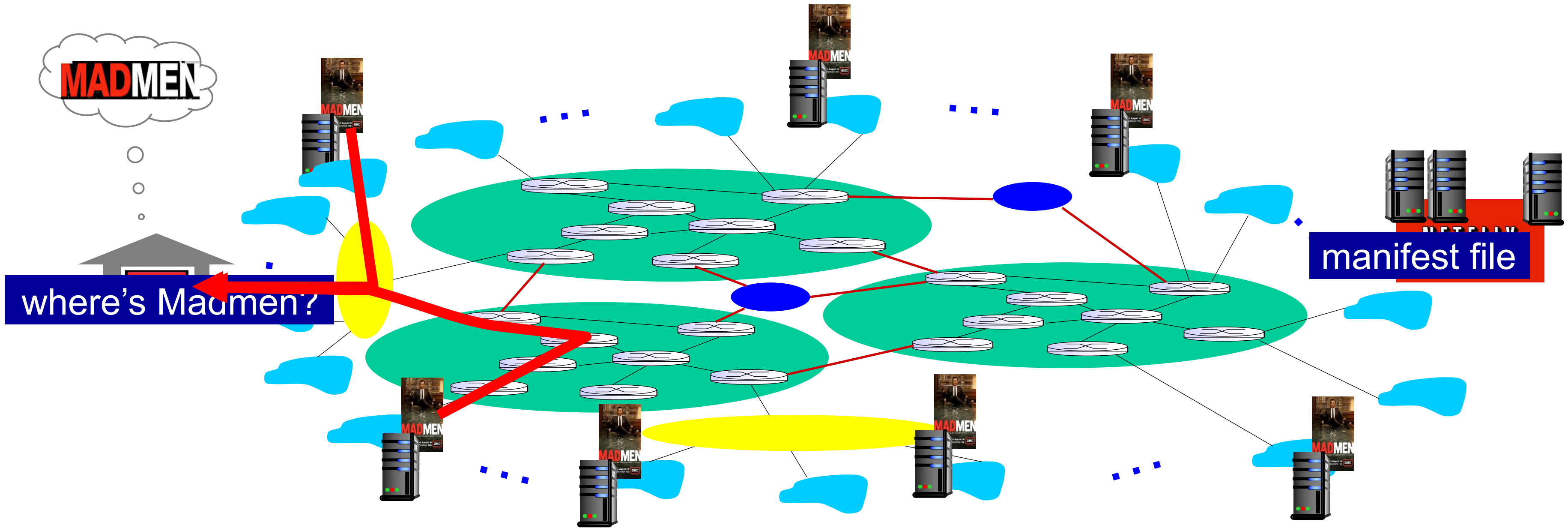
Content distribution networks

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

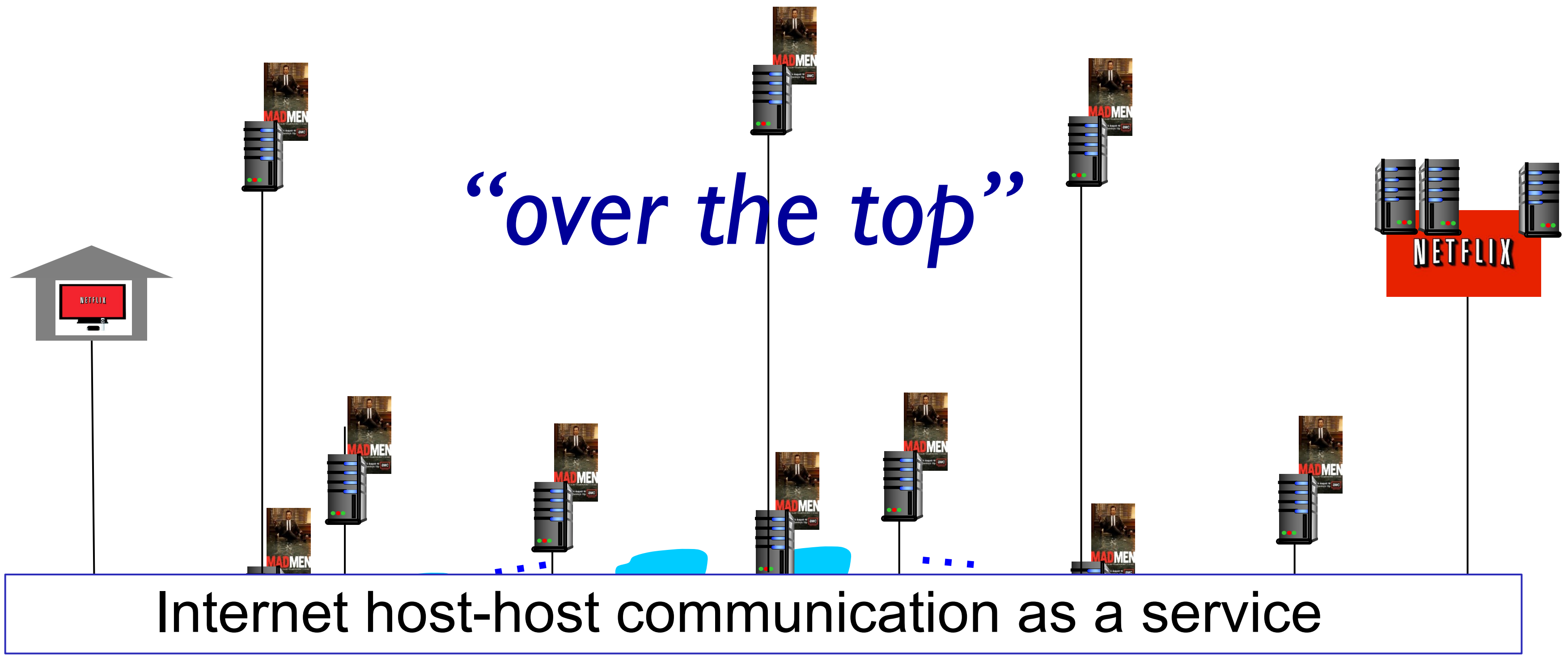
- *option 2:* store/serve multiple copies of videos at multiple geographically distributed sites *(CDN)*
  - *enter deep:* push CDN servers deep into many access networks
    - close to users
    - used by Akamai, 1700 locations
  - *bring home:* smaller number (10's) of larger clusters in POPs near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

Content Distribution Networks (CDNs)

- CDN: stores copies of content at CDN nodes
  - e.g. Netflix stores copies of MadMen
- subscriber requests content from CDN
  - directed to nearby copy, retrieves content
  - may choose different copy if network path congested



Content Distribution Networks (CDNs)



OTT challenges: coping with a congested Internet

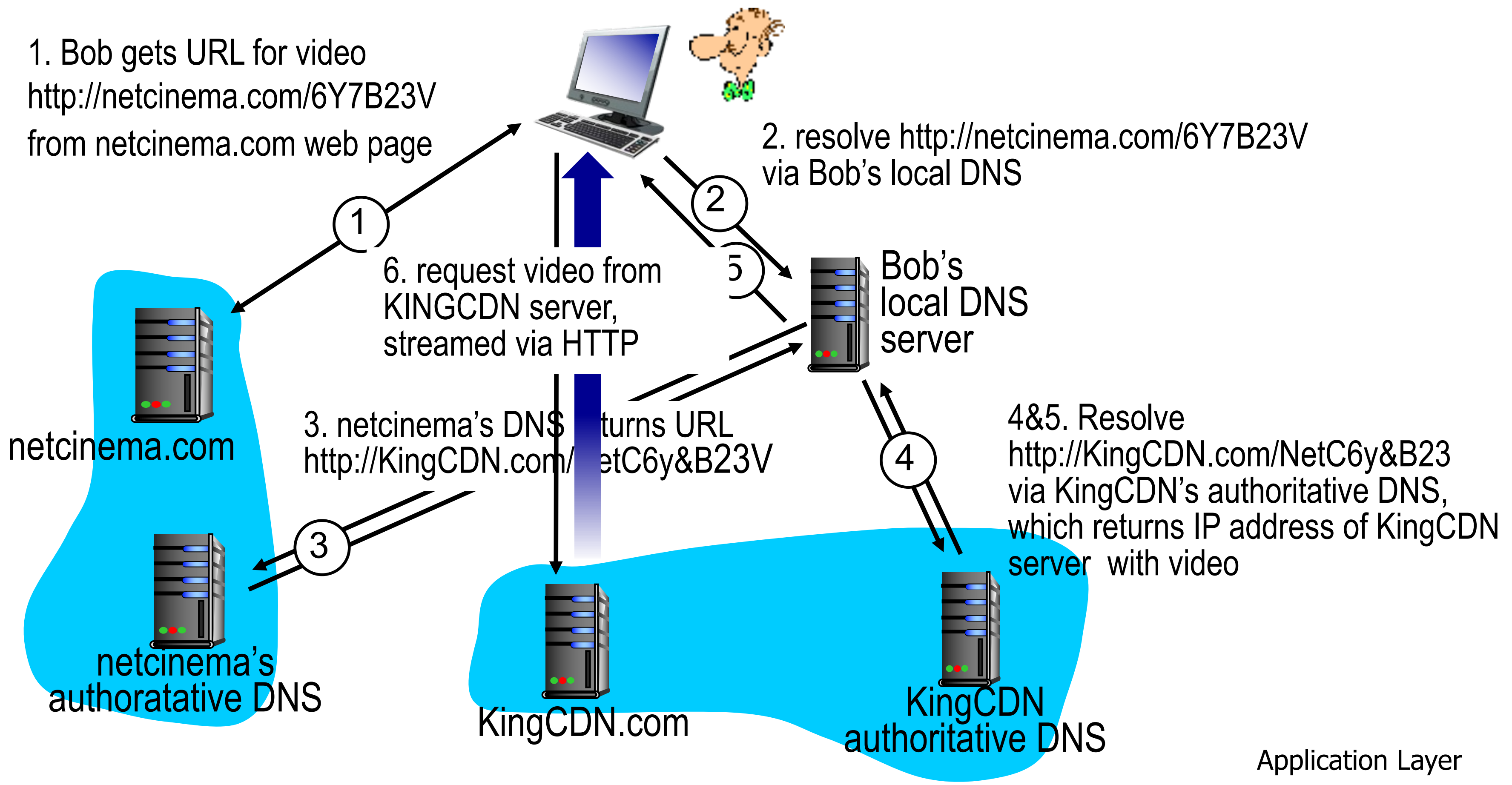
- from which CDN node to retrieve content?
- viewer behavior in presence of congestion?
- what content to place in which CDN node?

more .. in chapter 7

CDN content access: a closer look

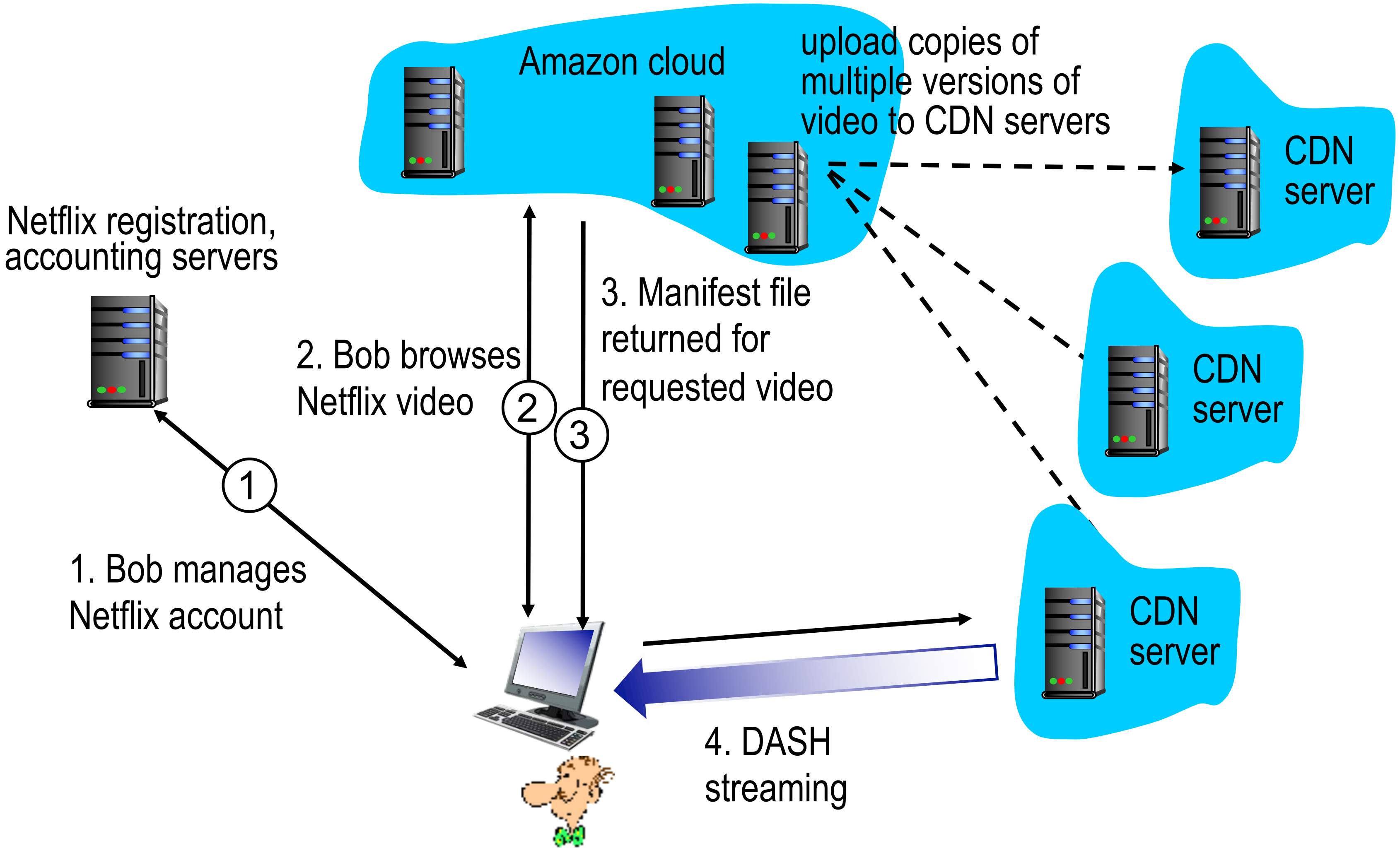
Bob (client) requests video http://netcinema.com/6Y7B23V

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



1. Bob gets URL for video http://netcinema.com/6Y7B23V from netcinema.com web page
2. resolve http://netcinema.com/6Y7B23V via Bob's local DNS
1
2
5
Bob's local DNS server
6. request video from KINGCDN server, streamed via HTTP
3. netcinema's DNS returns URL http://KingCDN.com/NetC6y&B23V
3
4
4&5. Resolve http://KingCDN.com/NetC6y&B23 via KingCDN's authoritative DNS, which returns IP address of KingCDN server with video
netcinema.com
netcinema's authoratative DNS
KingCDN.com
KingCDN authoritative DNS

Case study: Netflix


Amazon cloud
upload copies of multiple versions of video to CDN servers
CDN server
CDN server
CDN server
Netflix registration, accounting servers
2. Bob browses Netflix video
2
3
3. Manifest file returned for requested video
1
1. Bob manages Netflix account
4. DASH streaming

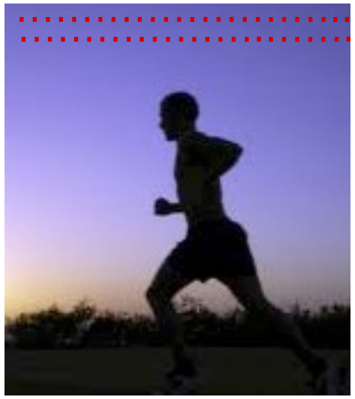
Video Streaming and CDNs: context

- 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

Multimedia: video

- video: sequence of images displayed at constant rate
  - e.g., 24 images/sec
- digital image: array of pixels
  - each pixel represented by bits
- coding: use redundancy *within* and *between* images to decrease # bits used to encode image
  - spatial (within image)
  - temporal (from one image to next)

spatial coding example: instead of sending *N* values of same color (all purple), send only two values: color value (*purple*) *and number of repeated values* (N)



frame *i*

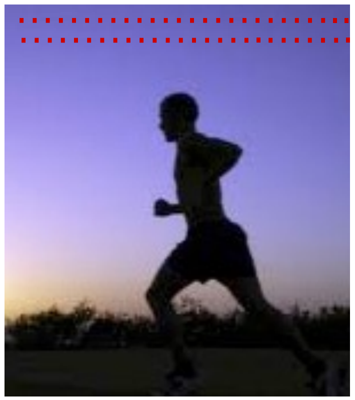
temporal coding example: instead of sending complete frame at i+1, send only differences from frame i

frame *i+1*

Multimedia: video

- CBR: (constant bit rate): video encoding rate fixed
- VBR: (variable bit rate): video encoding rate changes as amount of spatial, temporal coding changes
- examples:
  - MPEG 1 (CD-ROM) 1.5 Mbps
  - MPEG2 (DVD) 3-6 Mbps
  - MPEG4 (often used in Internet, < 1 Mbps)

spatial coding example: instead of sending *N* values of same color (all purple), send only two values: color value (*purple*) *and number of repeated values* (N)



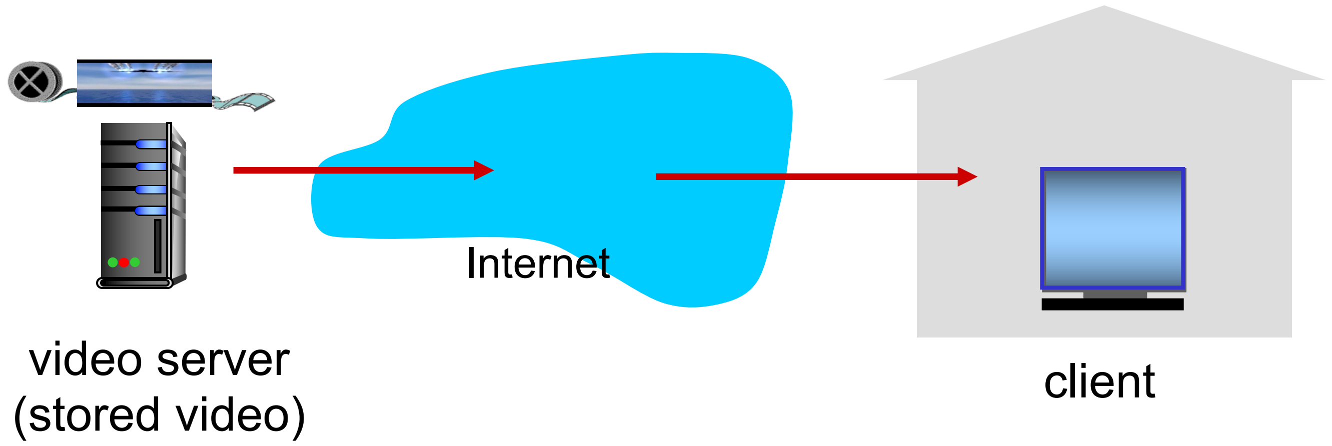
frame *i*

temporal coding example: instead of sending complete frame at i+1, send only differences from frame i

frame *i+1*

Streaming stored video:

simple scenario:



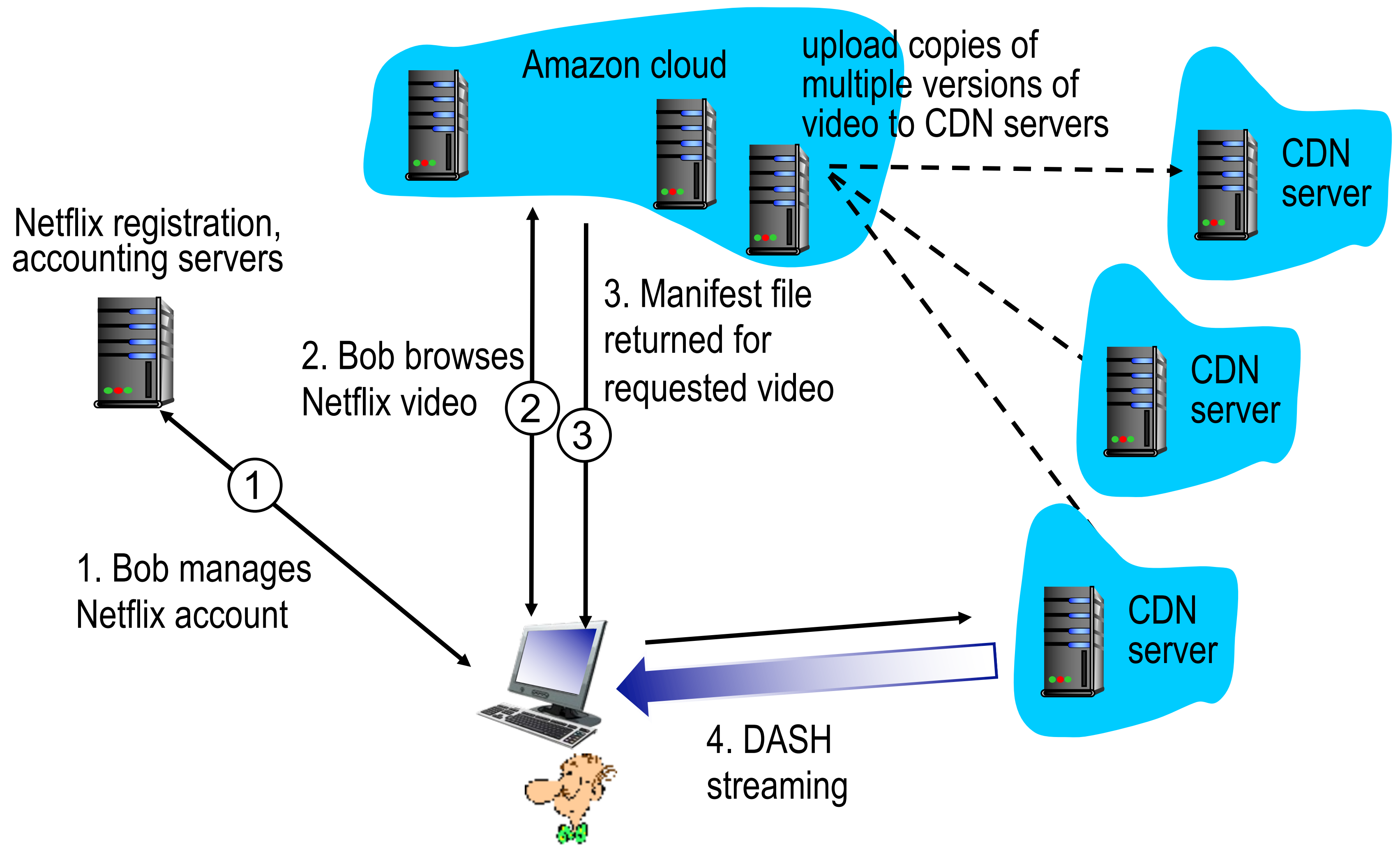
Streaming multimedia: DASH

- *DASH: D*ynamic, *A*daptive *S*treaming over *H*TTP
- *server:*
  - divides video file into multiple chunks
  - each chunk stored, encoded at different rates
  - *manifest file:* provides URLs for different chunks
- *client:*
  - periodically measures server-to-client bandwidth
  - consulting manifest, requests one chunk at a time
    - chooses maximum coding rate sustainable given current bandwidth
    - can choose different coding rates at different points in time (depending on available bandwidth at time)

Streaming multimedia: DASH

- *DASH: Dynamic, Adaptive Streaming over HTTP*
- *"intelligence"* at client: client determines
  - *when* to request chunk (so that buffer starvation, or overflow does not occur)
  - *what encoding rate* to request (higher quality when more bandwidth available)
  - *where* to request chunk (can request from URL server that is "close" to client or has high available bandwidth)

Case study: Netflix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