

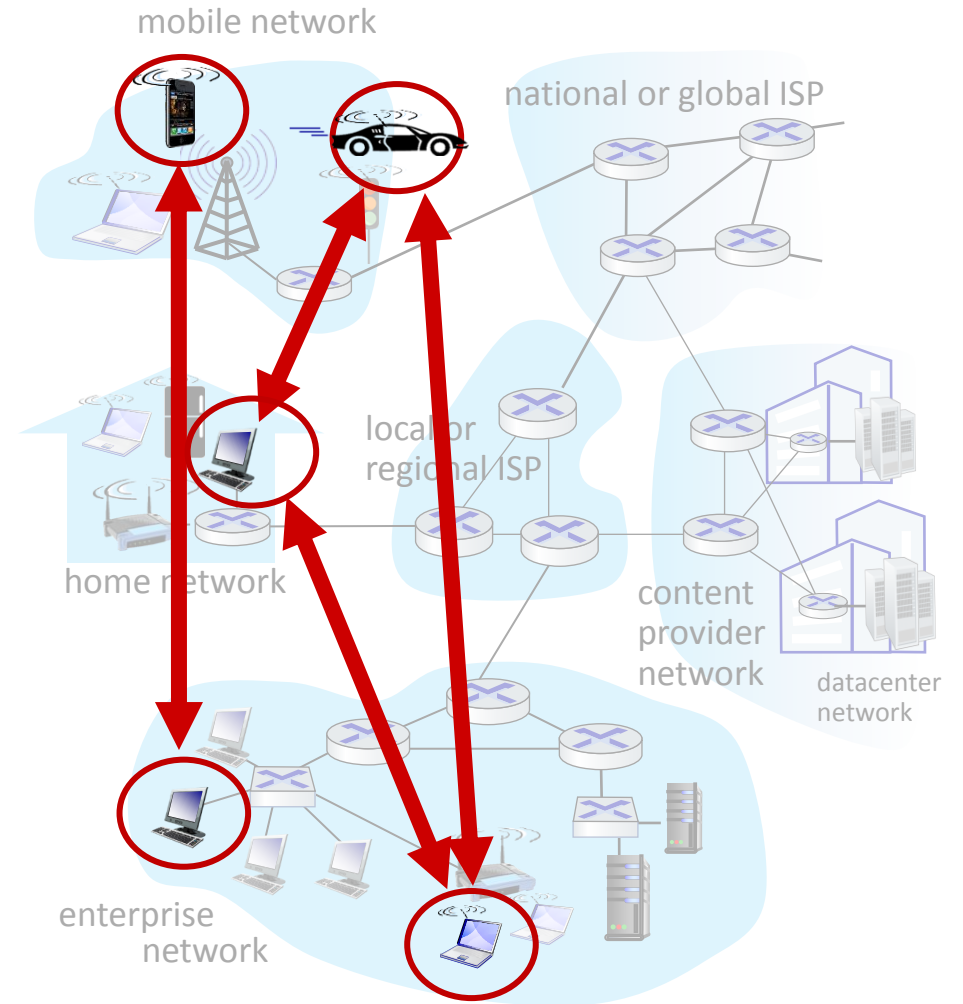
Application Layer: Overview

- Principles of network applications
- Web and HTTP
- E-mail, SMTP, IMAP
- The Domain Name System DNS
- P2P applications
- video streaming and content distribution networks
- socket programming with UDP and TCP



Peer-to-peer (P2P) architecture

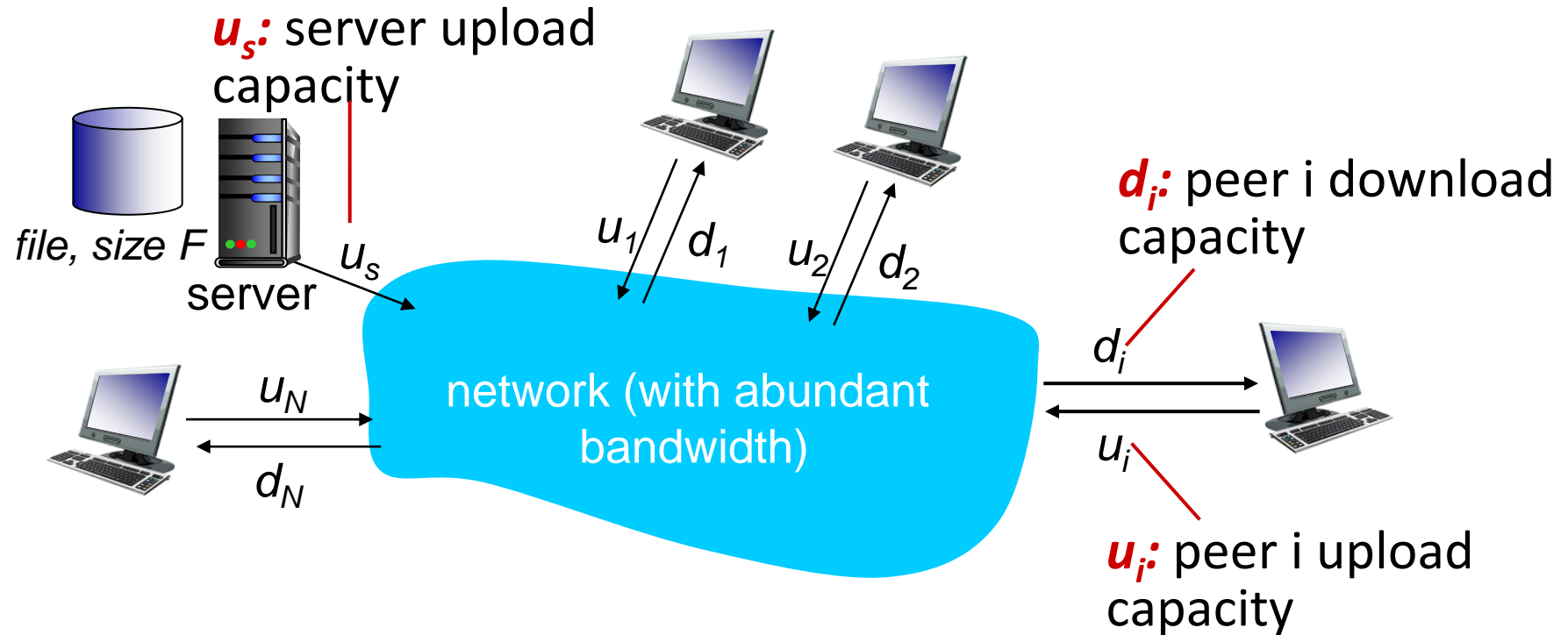
- *no* always-on server
- arbitrary end systems directly communicate
- peers request service from other peers, provide service in return to other peers
 - *self scalability* – new peers bring new service capacity, and new service demands
- peers are intermittently connected and change IP addresses
 - complex management
- examples: P2P file sharing (BitTorrent), streaming (KanKan), VoIP (Skype)



File distribution: client-server vs P2P

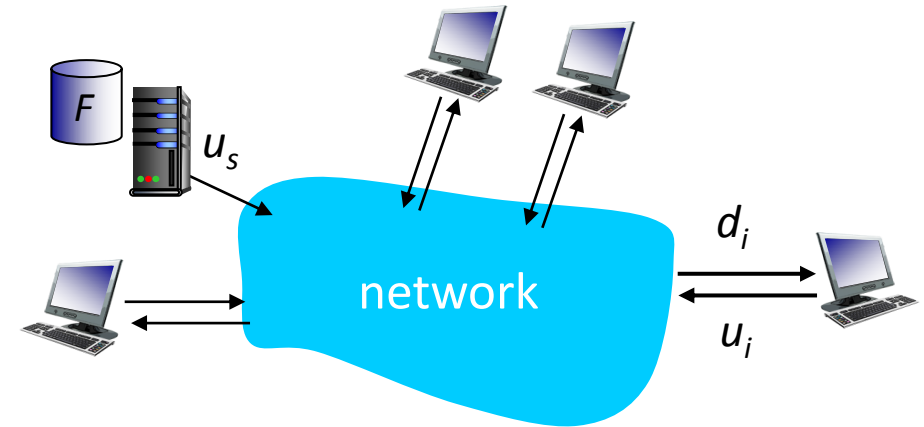
Q: how much time to distribute file (size F) from one server to N peers?

- 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}



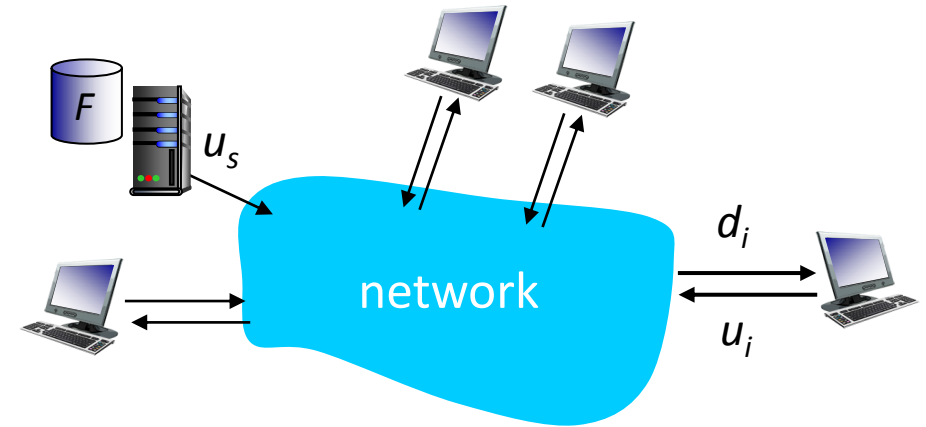
*time to distribute F
to N clients using
client-server approach*

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

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



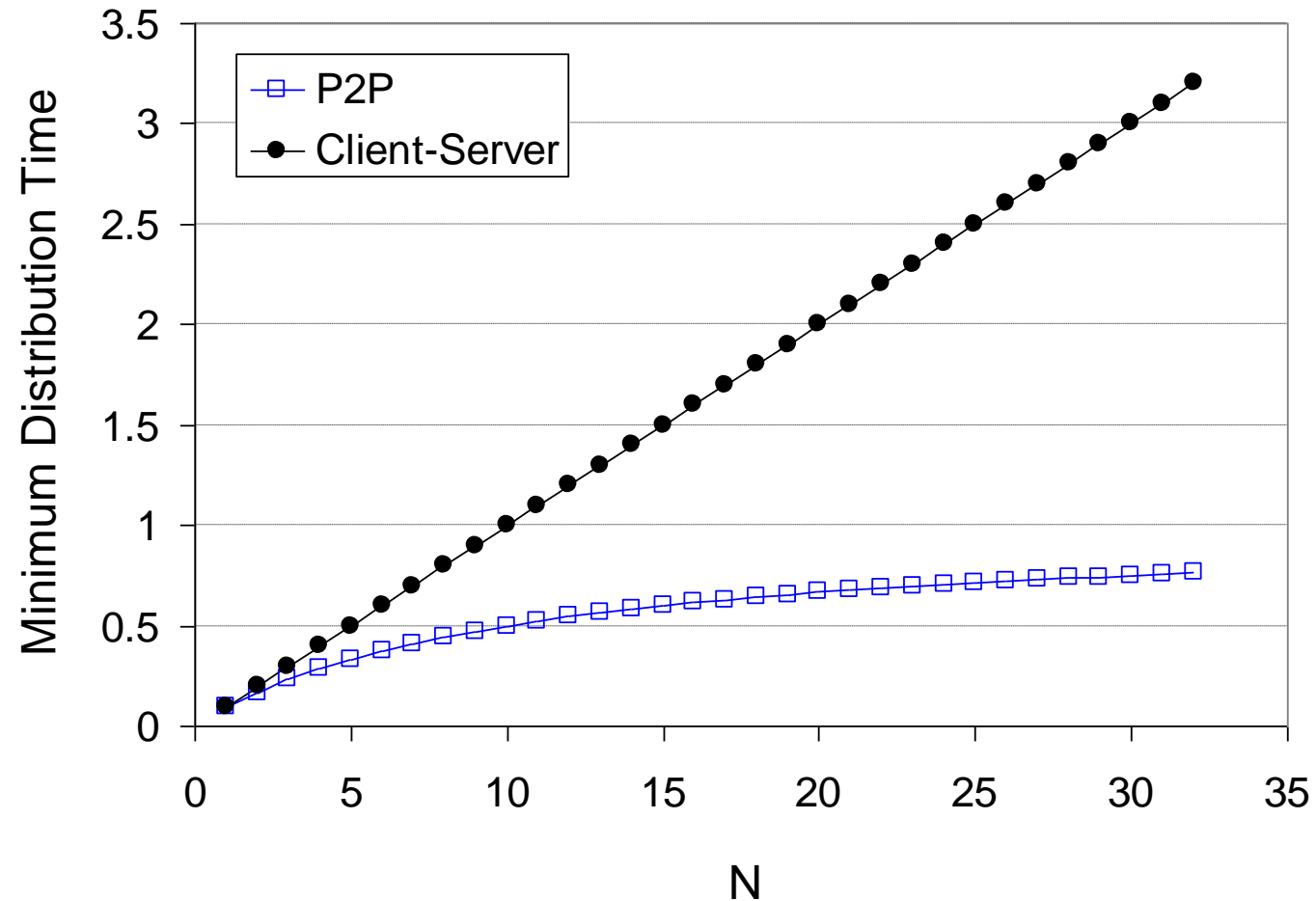
time to distribute F
to N clients using
P2P approach

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

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

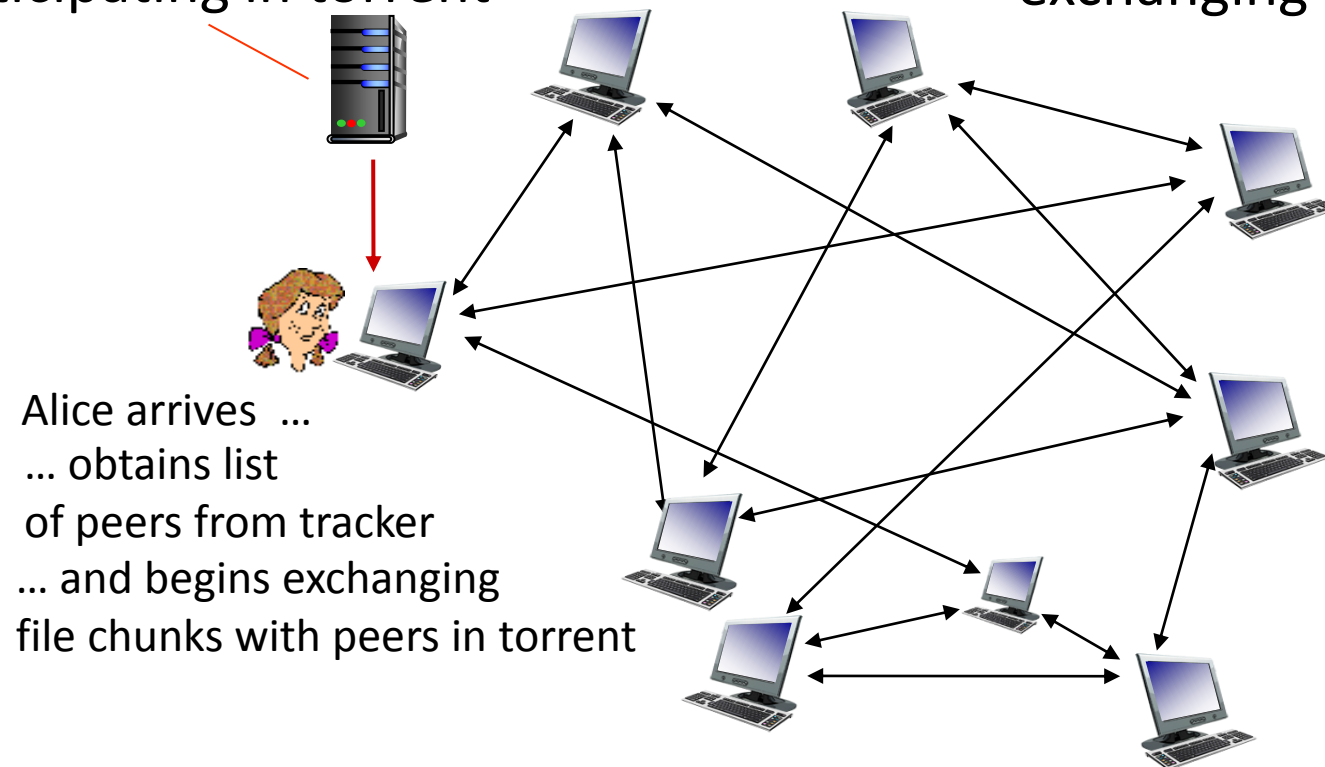


P2P file distribution: BitTorrent

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

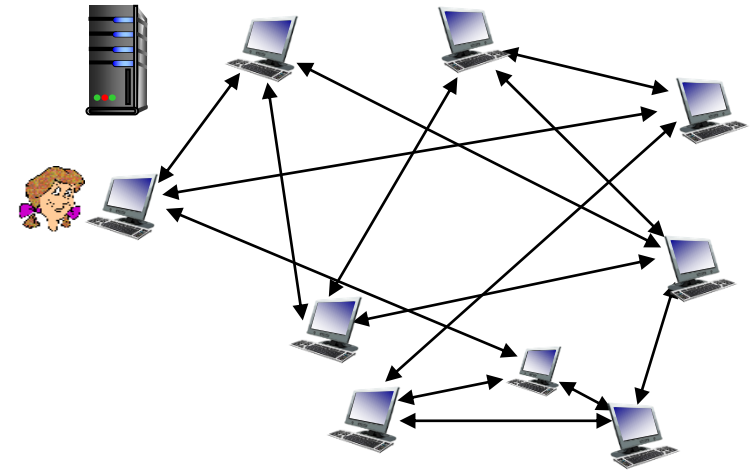
tracker: tracks peers participating in torrent

torrent: group of peers exchanging chunks of a file



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 every 10 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

