CS 43: Computer Networks

P2P, BitTorrent

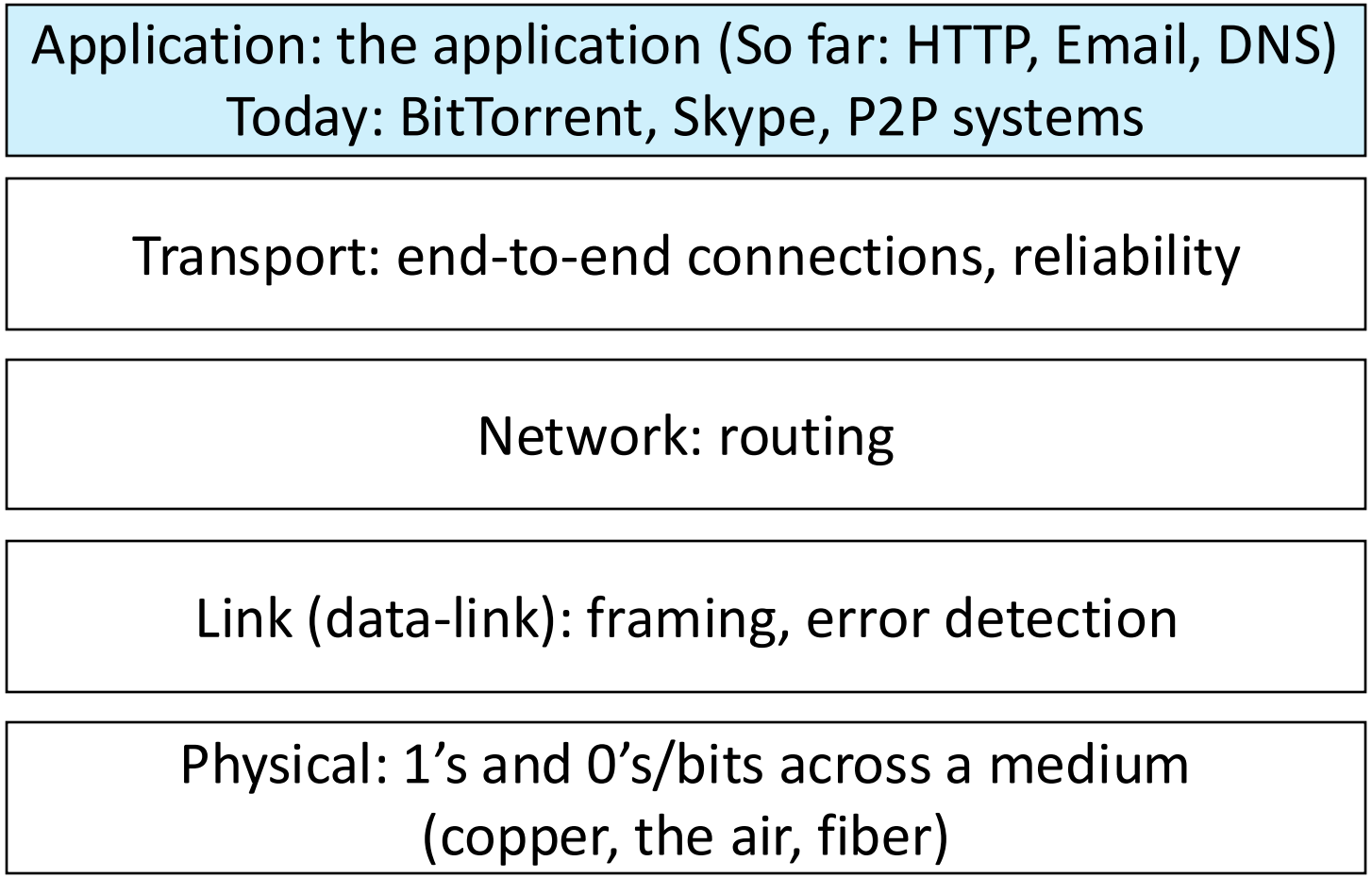
October 06, 2025

Slides adapted from Kurose & Ross, Vasanta Chaganti, Kevin Webb

Today

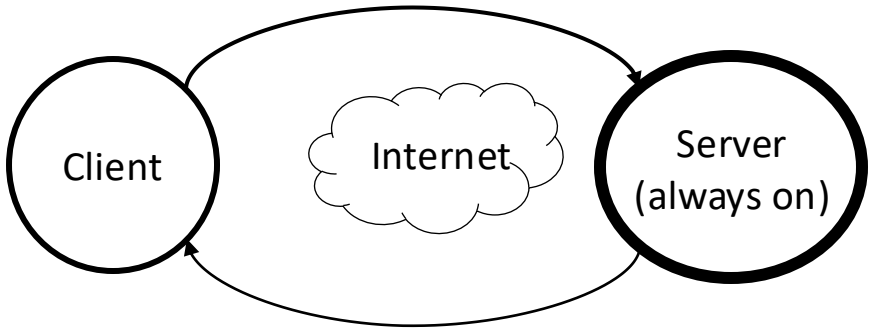
- P2P vs Client-Server applications
- P2P examples
  - Napster
- BitTorrent
  - Cooperative file transfers

Where we are

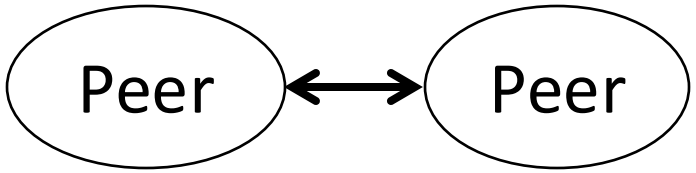

Application: the application (So far: HTTP, Email, DNS)
Today: BitTorrent, Skype, P2P systems
Transport: end-to-end connections, reliability
Network: routing
Link (data-link): framing, error detection
Physical: 1's and 0's/bits across a medium
(copper, the air, fiber)

Designating roles to an endpoint

Client-server architecture

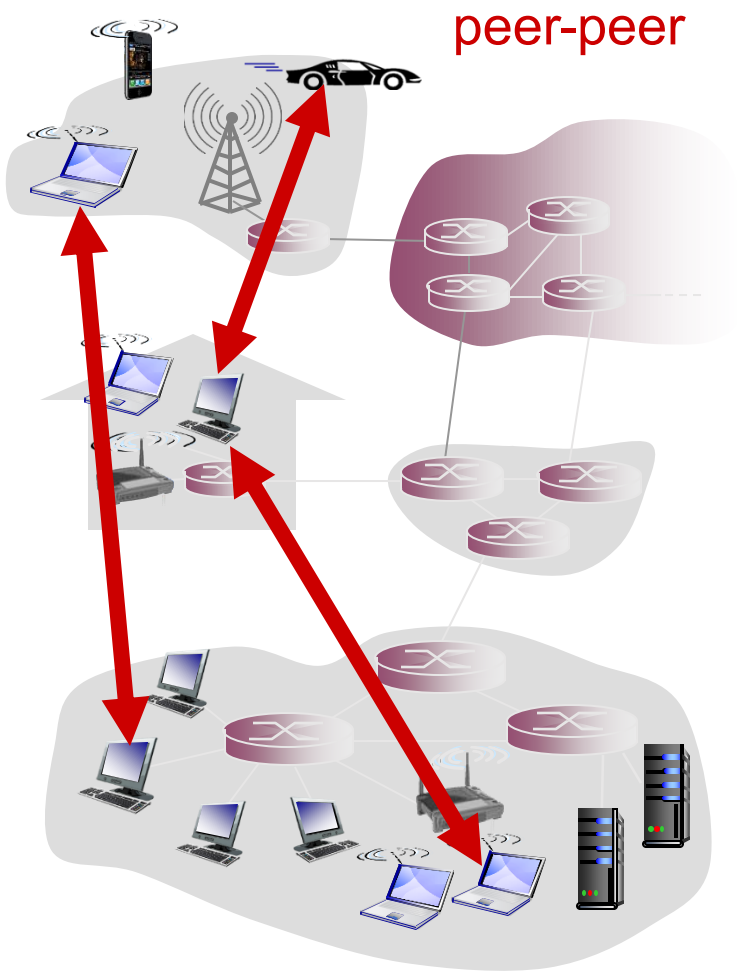


Peer-to-peer architecture



Peer-to-Peer Architecture

- no always-on server
- A peer talks directly with another peer
  - Symmetric responsibility (unlike client/server)
- peers request service from other peers, provide service in return to other peers
  - self scalability – new peers bring new service capacity, as well as new service demands
- peers are intermittently connected and change IP addresses
  - complex management



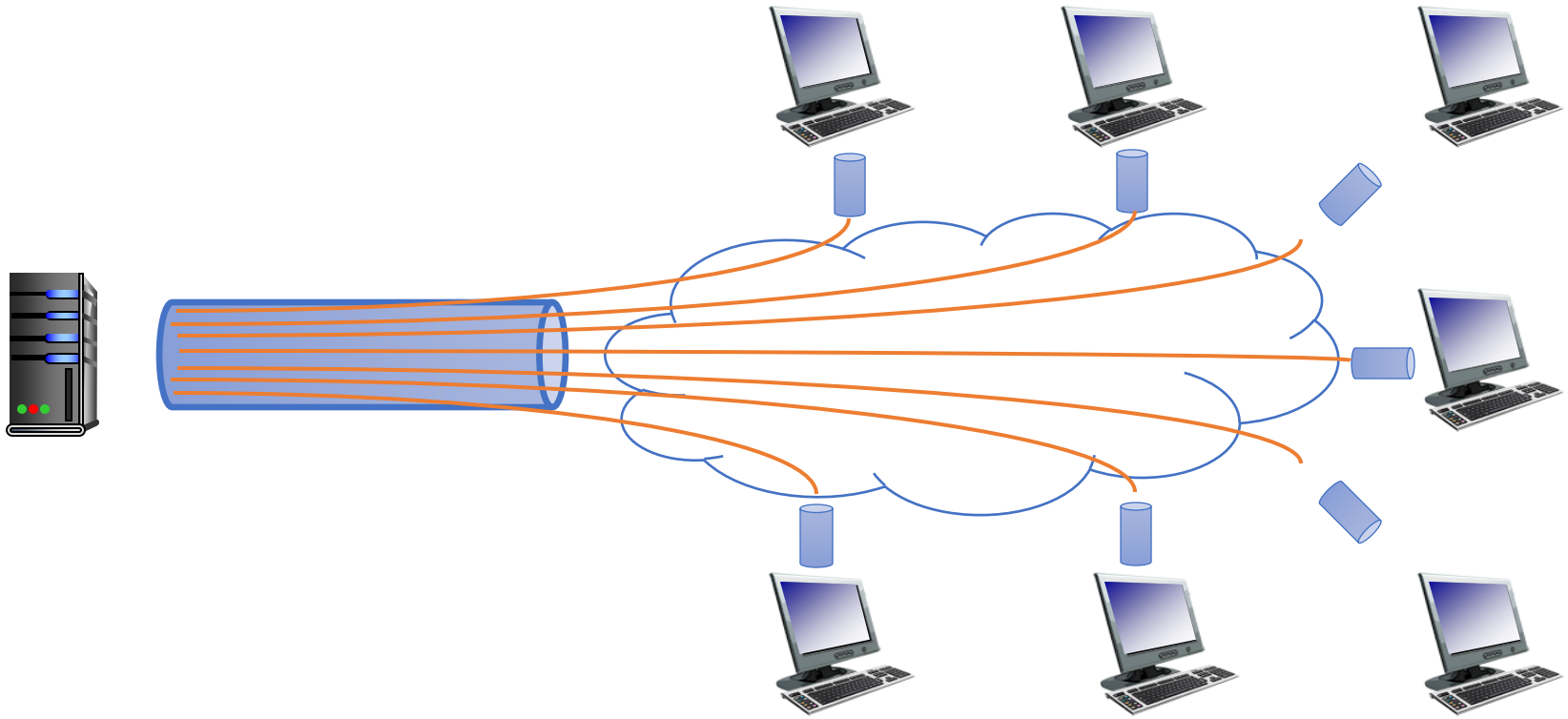
File Transfer Problem

- You want to distribute a file to a large number of people as quickly as possible.

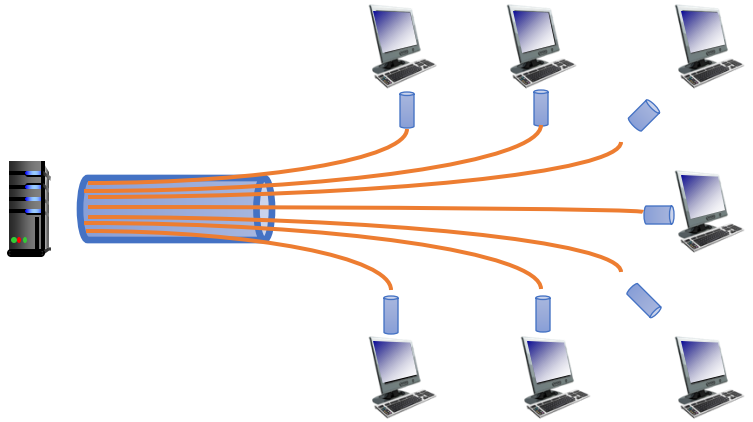
Traditional Client/Server

- Many clients, 1 (or more) server(s)
- Web servers, DNS, file downloads, video streaming

Traditional Client/Server

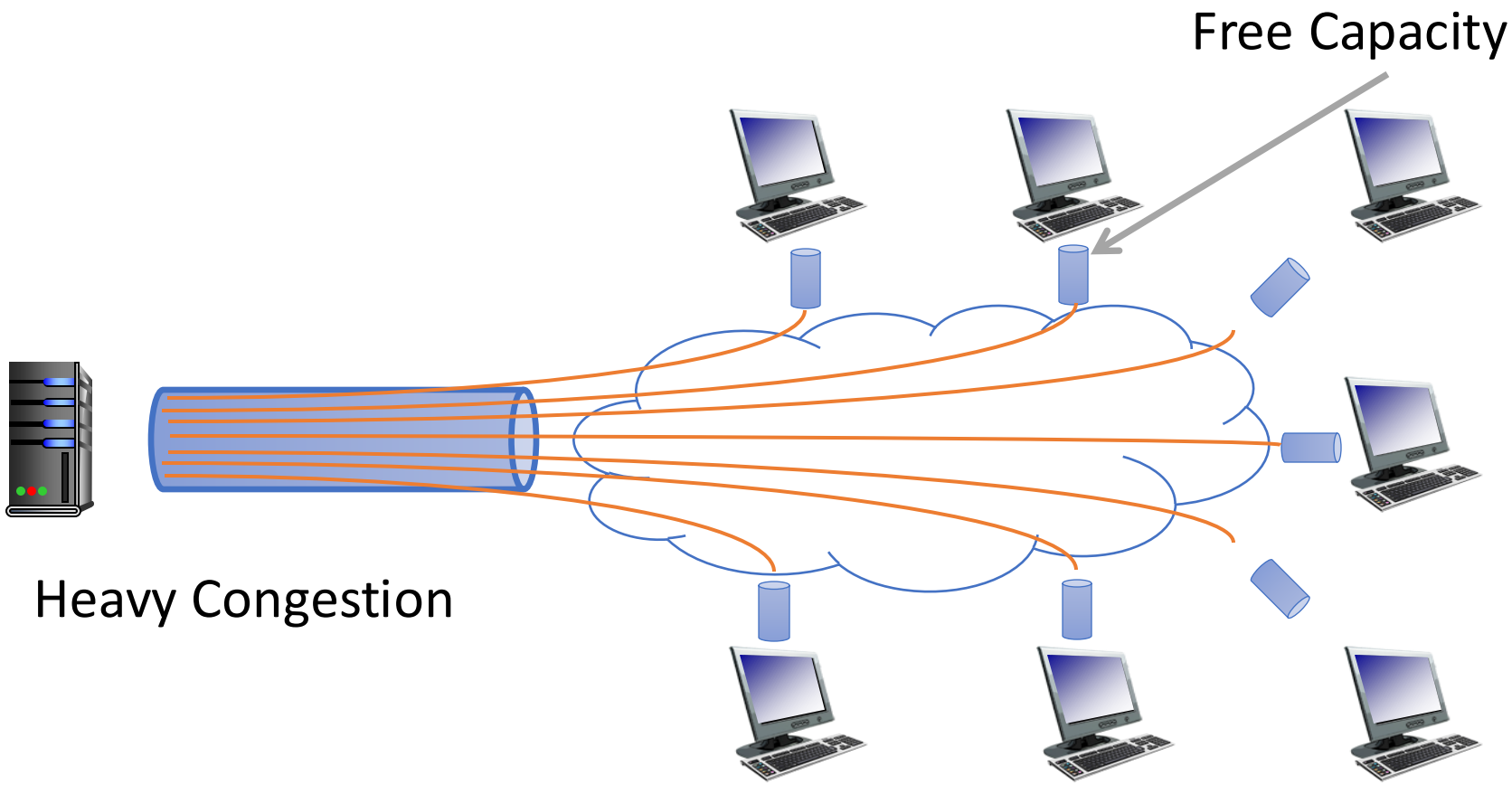


What is the biggest problem you run into with the traditional C/S model?

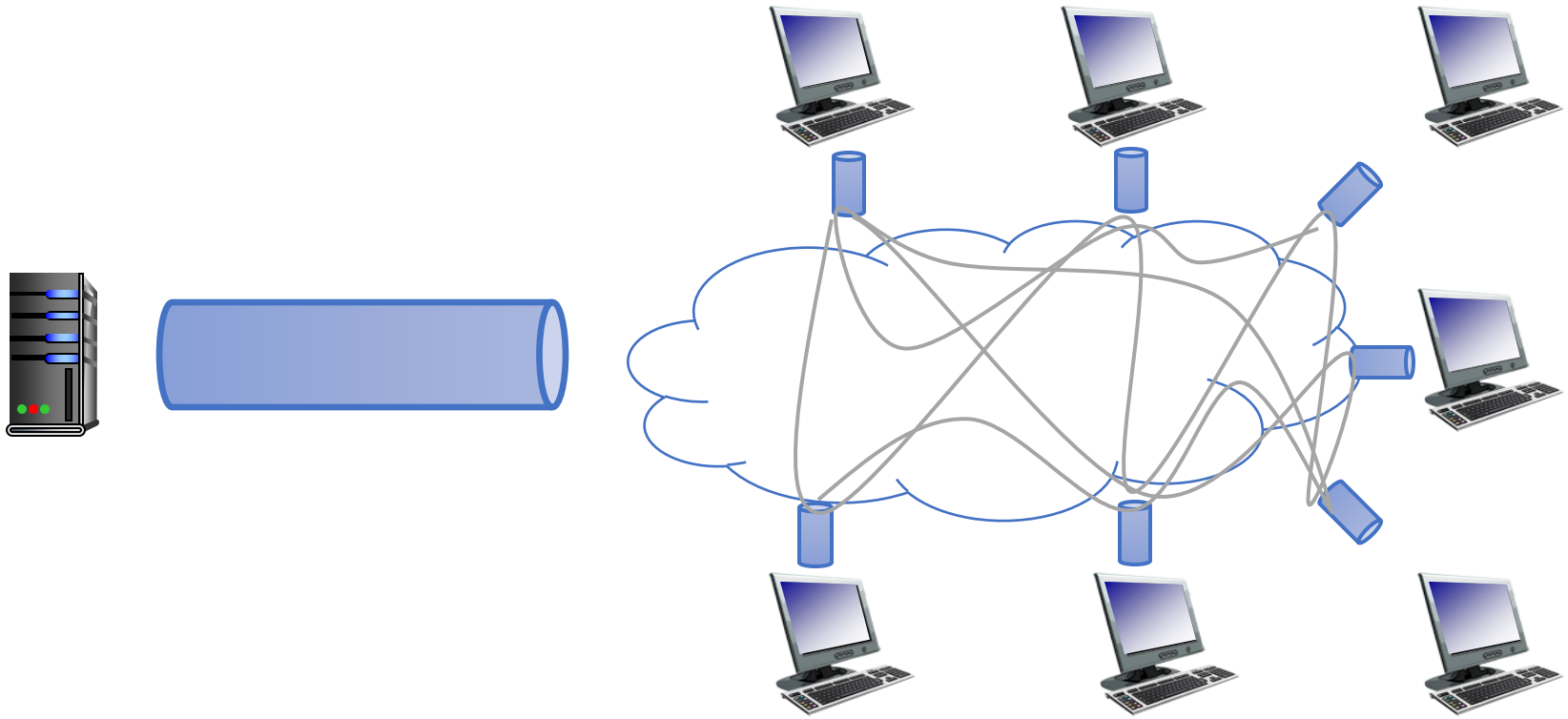


A. Scalability (how many end-hosts can you support?)
B. Reliability (what happens on failure?)
C. Efficiency (fast response time)

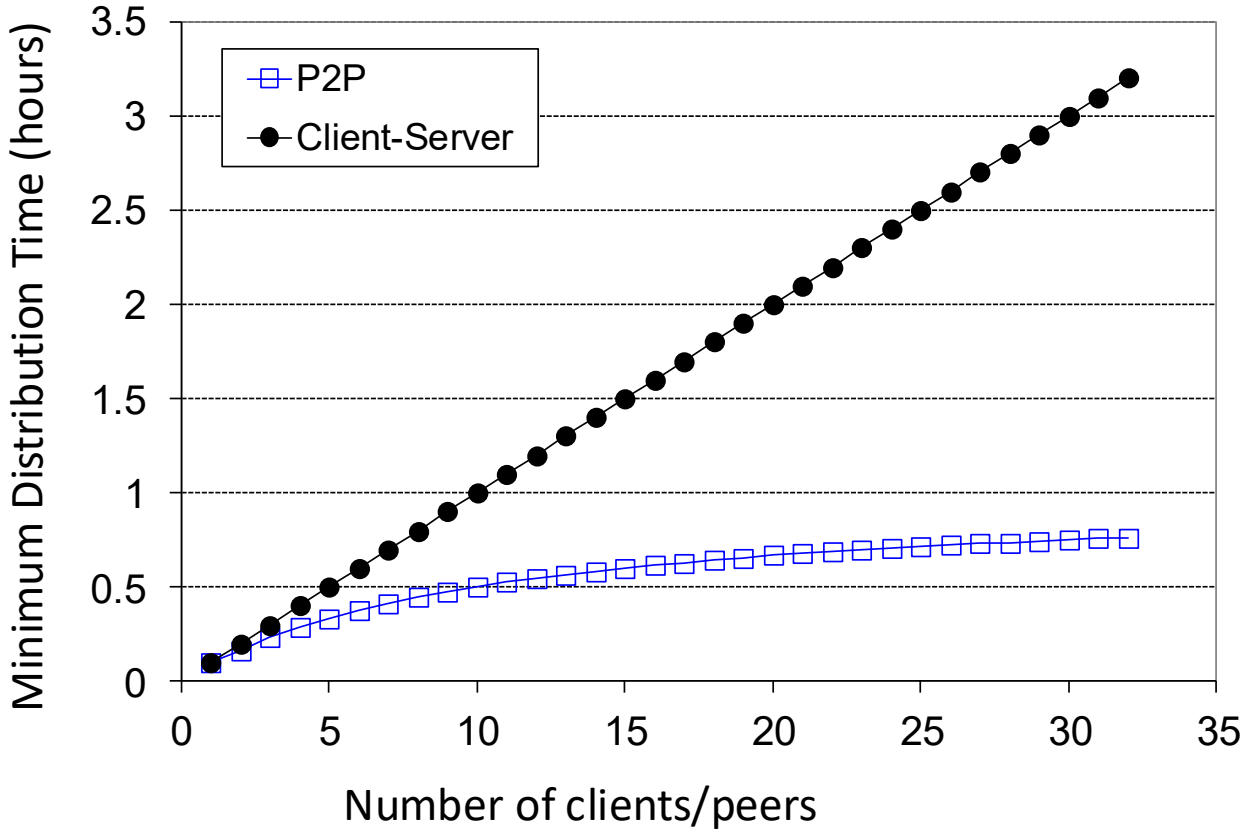
Traditional Client/Server



P2P Solution



Client-server vs. P2P: example



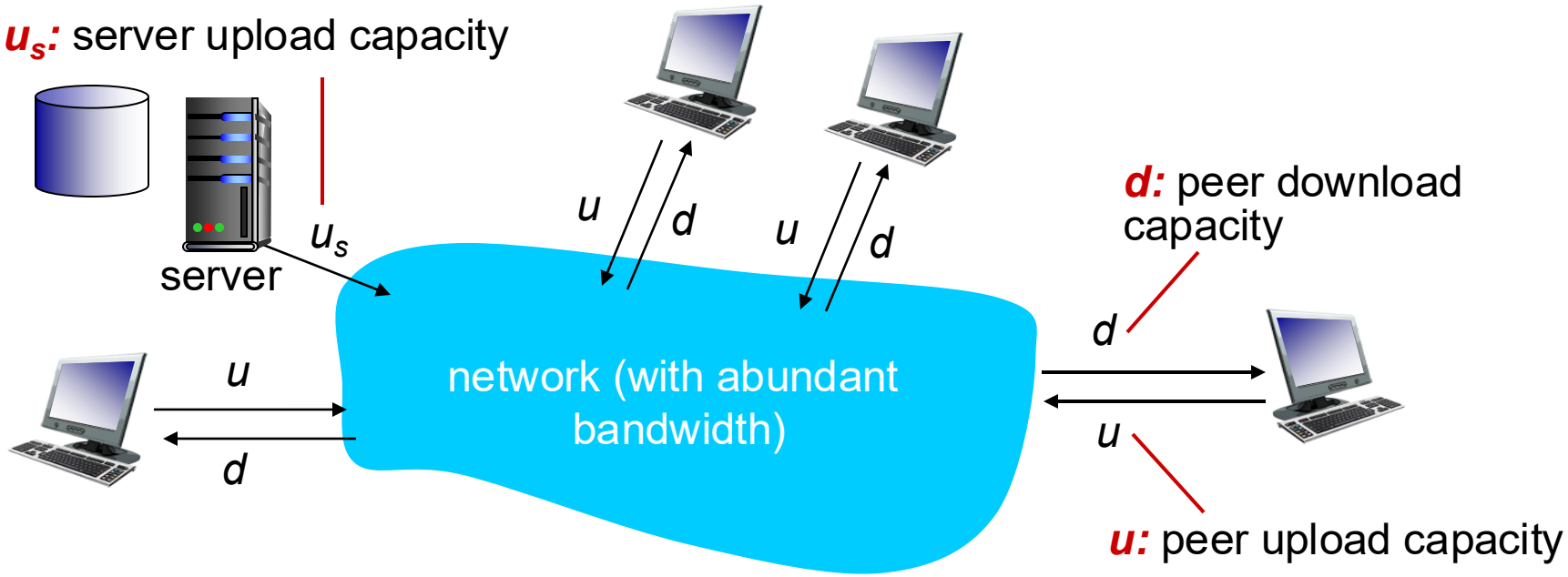
In a peer-to-peer architecture, are there clients and servers?

A. Yes

B. No

File size = 6 Gbits = 6000 Mb (megabits)
Number of peers = 10
Server upload rate of u_s = 100 Mbps (megabits per second)
Peer upload rate of u = 20Mbps
Peer download rate of d = 50Mbps

Worksheet Question



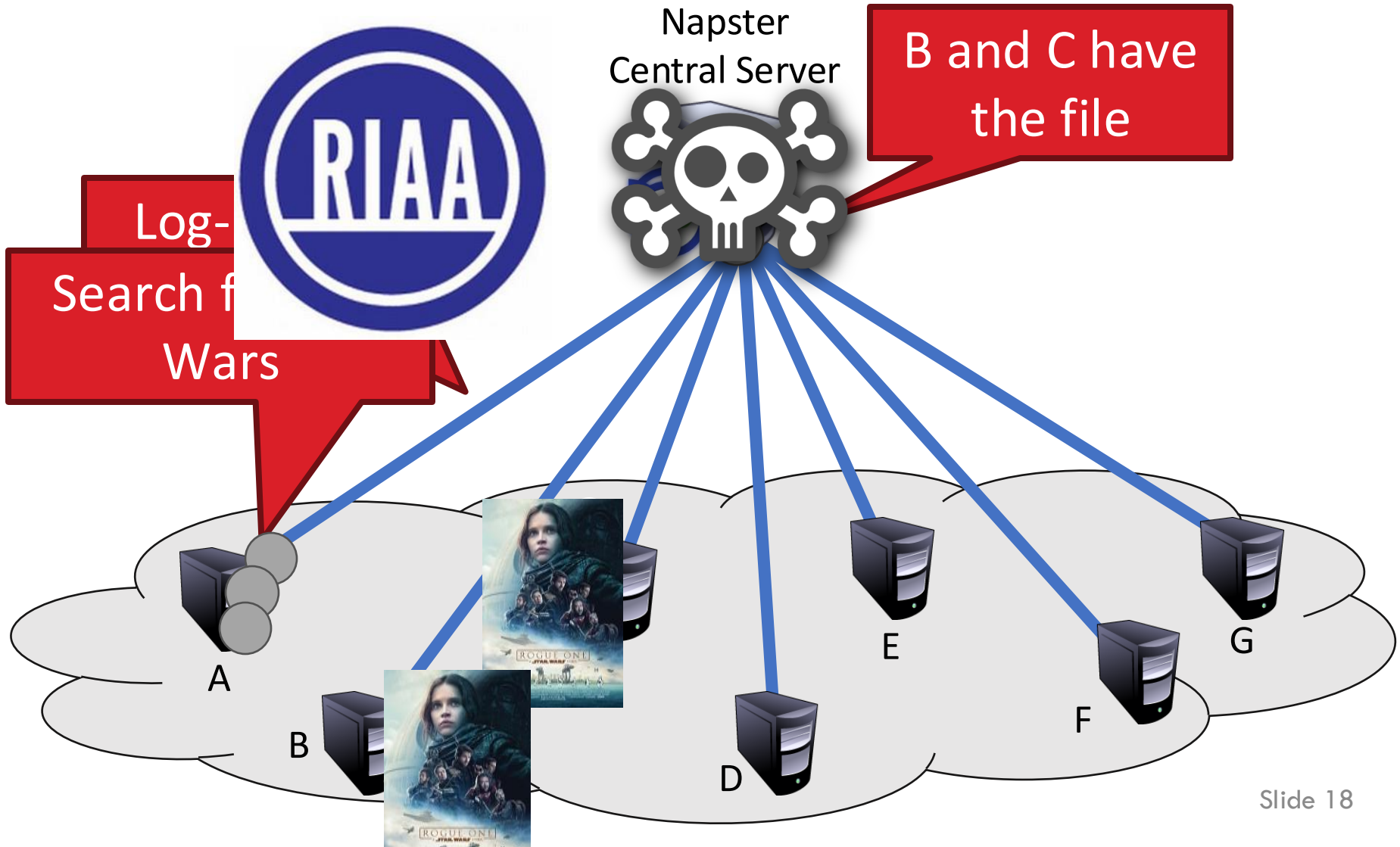
C/S Model

- Minimum time to distribute the file = max(time to upload the file, time to download the file)
- Time to upload the file = NF/u_s = 6000*10/100 = 600s
- Time to download the file = 6000/50 = 120s
- Min time = 600s.

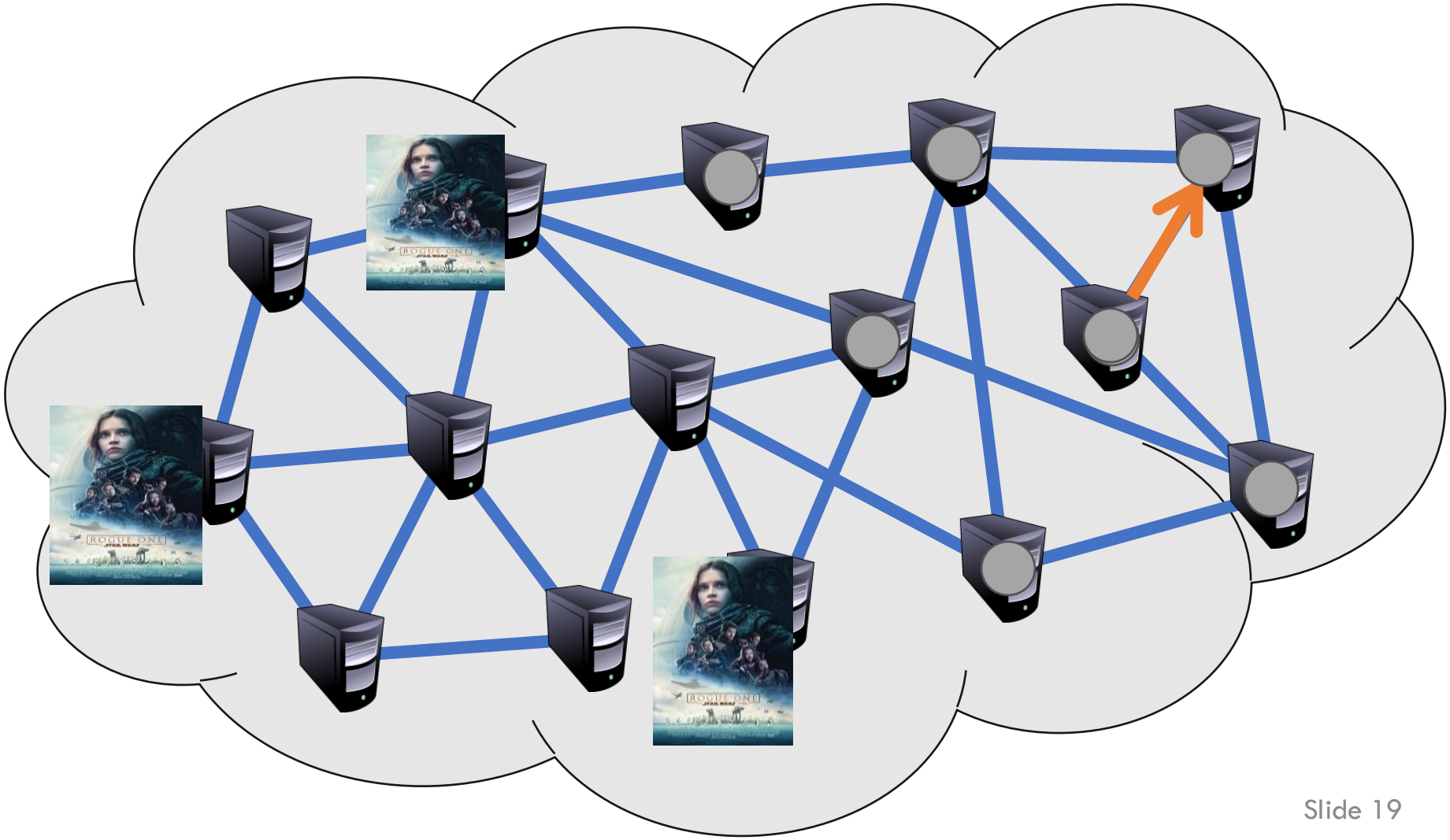
P2P Model

- Minimum time to distribute the file = max(time to upload the file, time to download the file)
- Time to upload the file from the server = F/u_s = 6000/100 = 60s
- Time to upload from peers to every other peer 6000*10/(100+20*10) = 200s
- Time to download the file = 6000/50 = 120s
- Min time = 200s

Napster Architecture

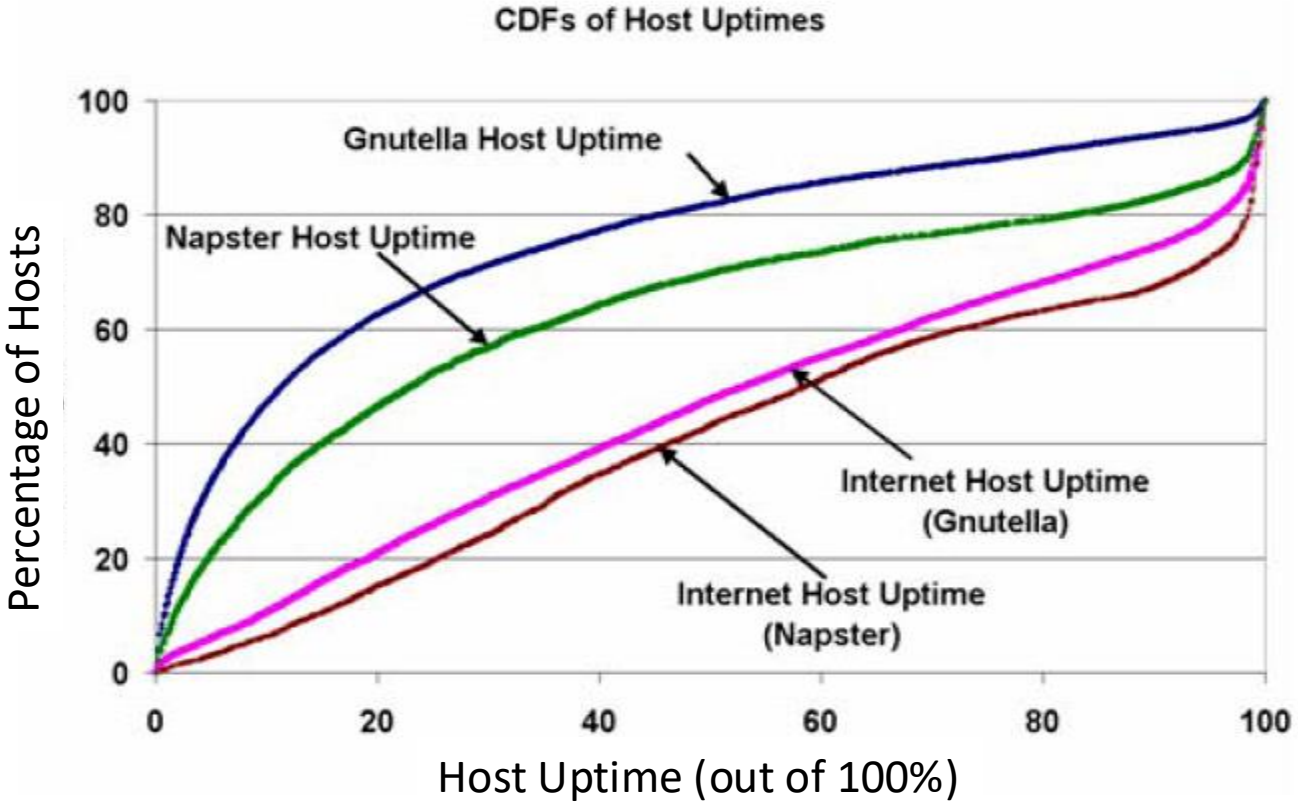


File Search via Flooding in Gnutella



Peer Lifetimes: Highly available?

"only 20% of the peers in each system had an IP-level uptime of 93% or more."



Sessions are short ~60 minutes

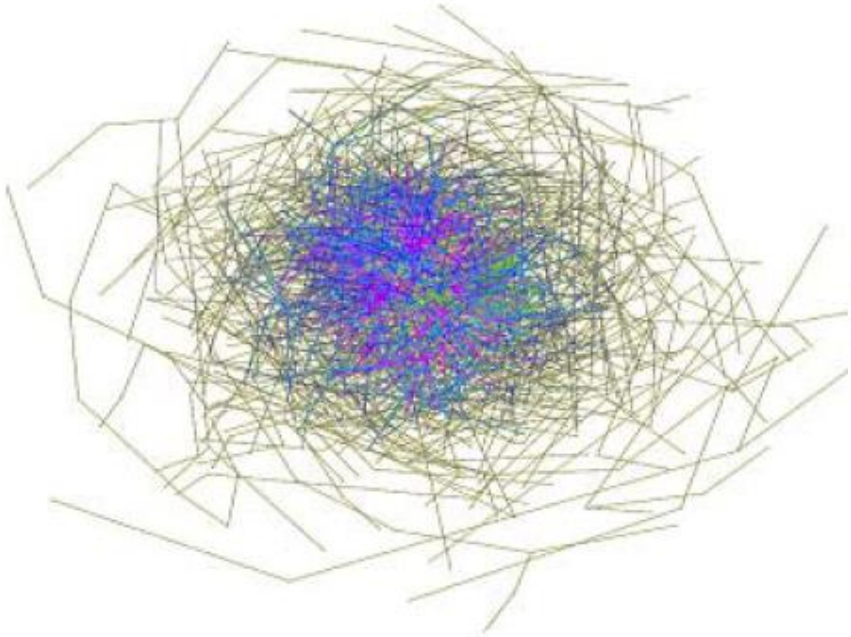
Hosts are frequently offline

Study of host uptime and application uptime (MMCN 2002)

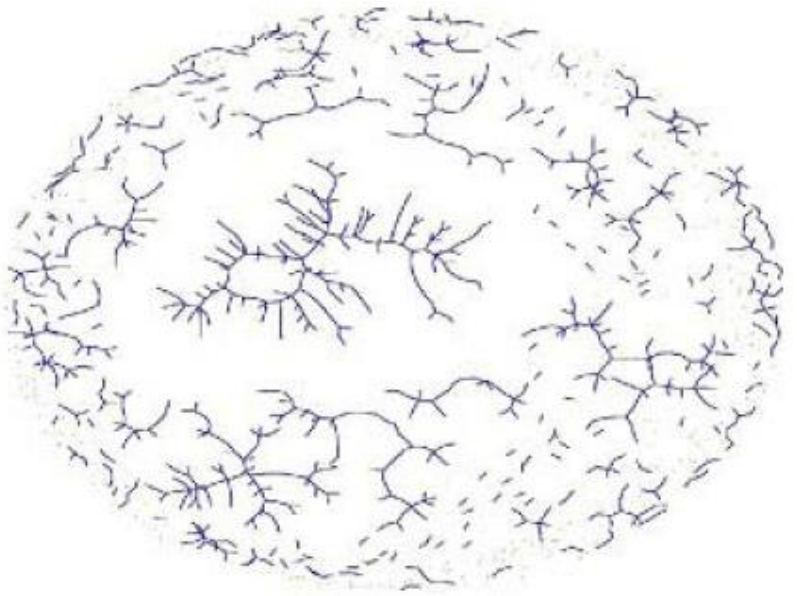
Resilience to Failures and Attacks

- Previous studies (Barabasi) show interesting dichotomy of resilience for "scale-free networks"
  - Resilient to random failures, but not attacks

- Here's what it looks like for Gnutella



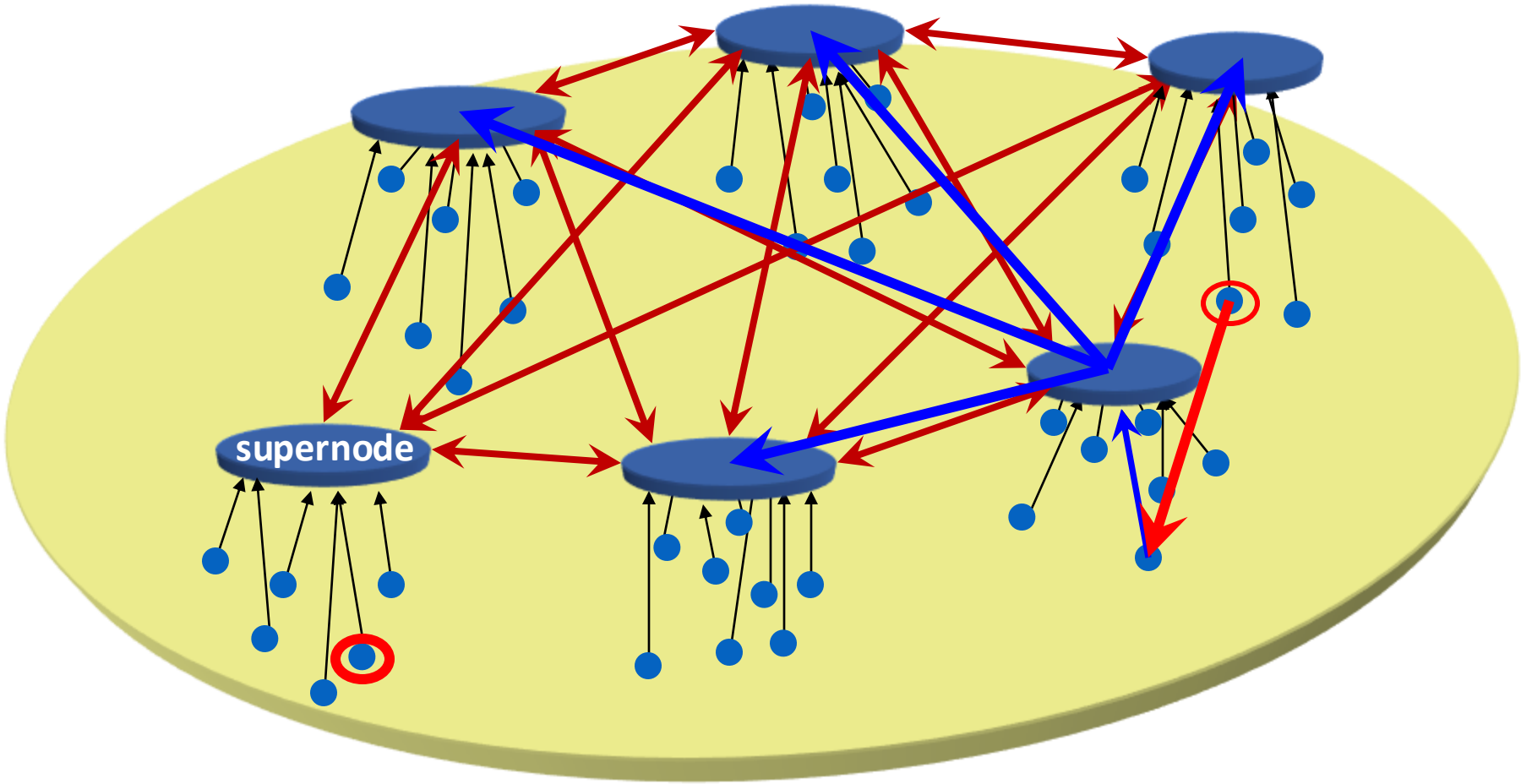
1771 Peers in Feb, 2001



After top 4% of peers are removed
After random 30% of peers removed

Hierarchical P2P Networks

- FastTrack network (Kazaa, Grokster, Morpheus, Gnutella++)



Skype: P2P VoIP

- P2P client supporting VoIP, video, and text based conversation, buddy lists, etc.
  - Overlay P2P network consisting of ordinary and Super Nodes (SN)

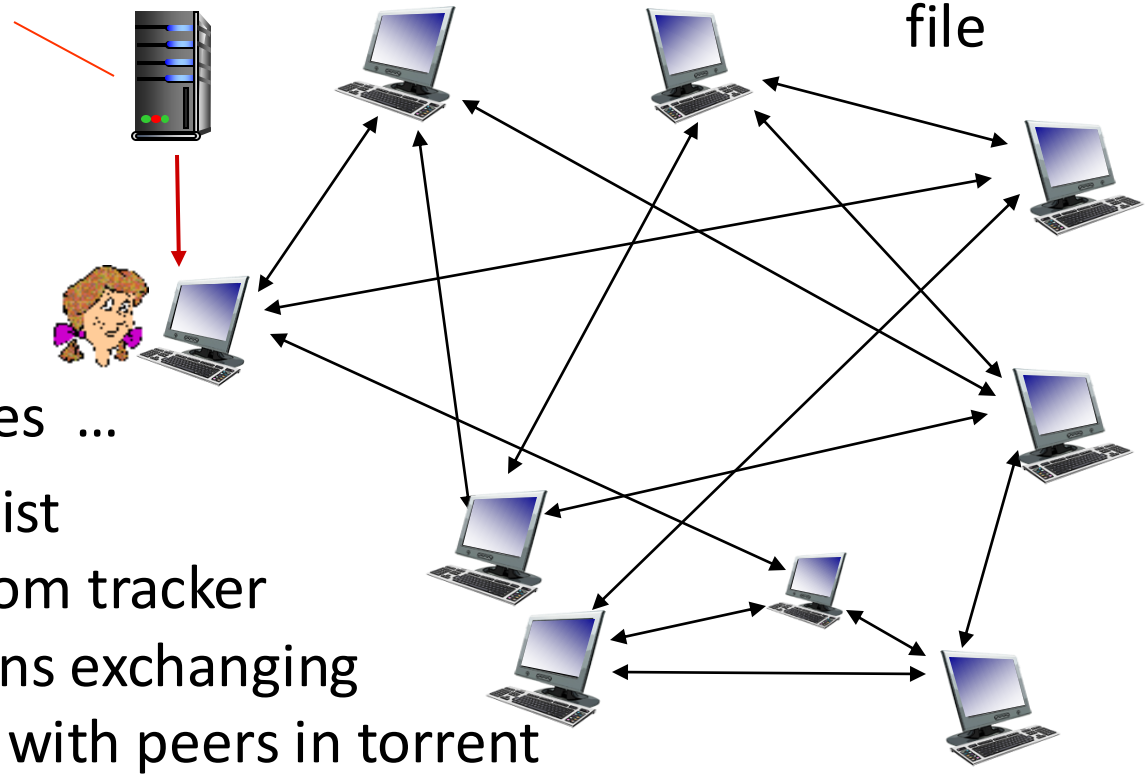
- Each user registers with a central server
  - User information propagated in a decentralized fashion

P2P file distribution: BitTorrent

- File divided into chunks (commonly 256 KB)
- 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

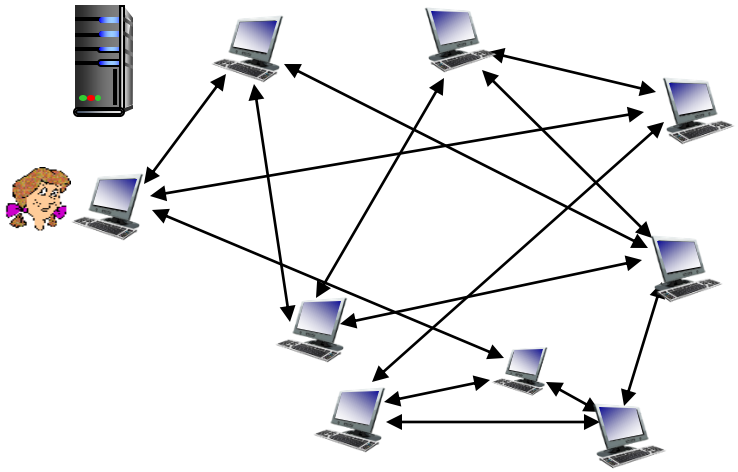
.torrent files

- Contains address of tracker for the file
  - Where can I find other peers?

- Contain a list of file chunks and their cryptographic hashes
  - This ensures pieces are not modified

BitTorrent : Peer Joining

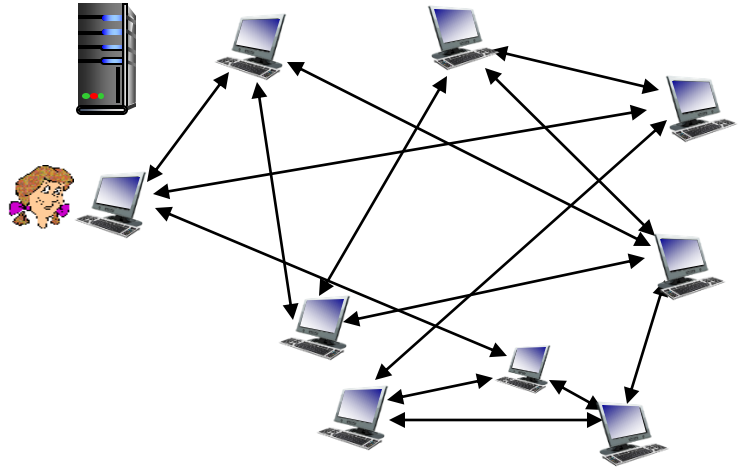
- has no chunks, but will accumulate them over time from other peers
- registers with tracker to get list of peers, connects to subset of peers ("neighbors")



P2P file distribution: BitTorrent

- While downloading, peer uploads chunks to other peers

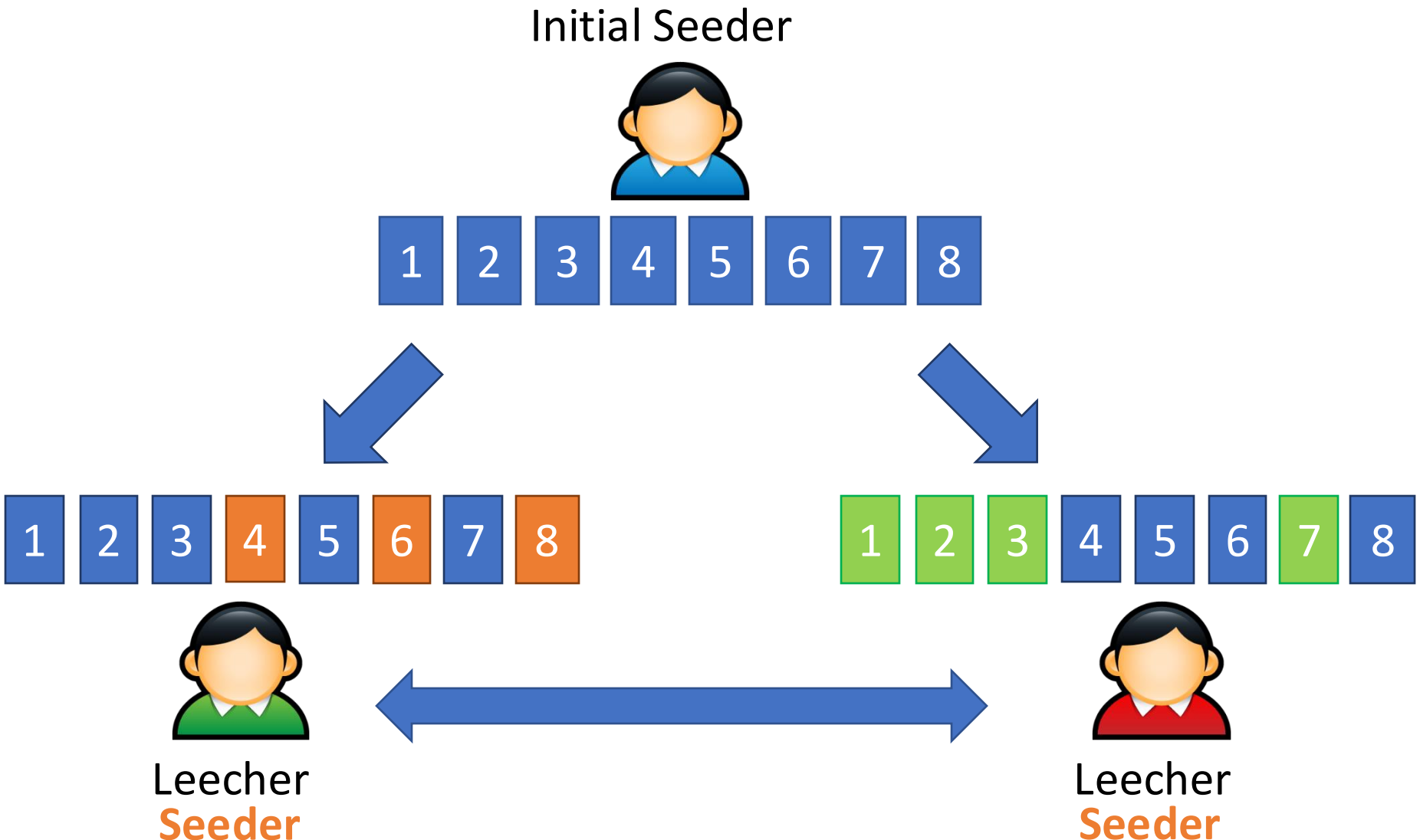
- *Churn:* peers may come and go
  - Peer may change peers with whom it exchanges chunks



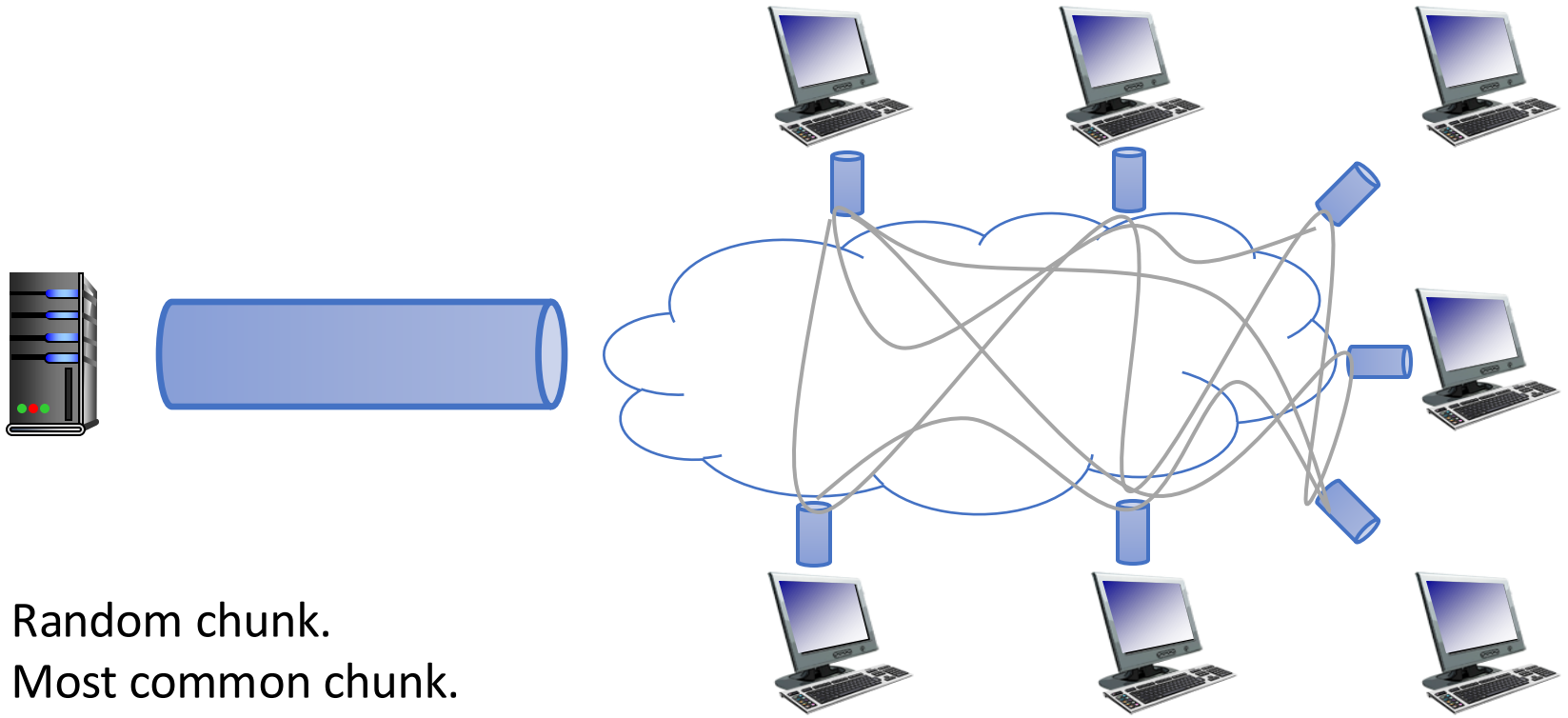
Requesting Chunks

- At any given time, peers have different subsets of file chunks.
- Periodically, ask peers for list of chunks that they have.
- Once peer has entire file, it may (selfishly) leave or (altruistically) remain in torrent

Sharing Pieces

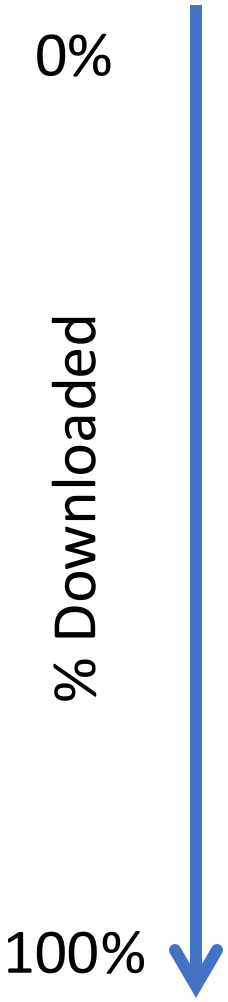


If you're trying to receive a file, which chunk should you request next?



A. Random chunk.
B. Most common chunk.
C. Least common chunk.
D. Some other chunk.
E. It doesn't matter.

Requesting Chunks



- Bootstrap: random selection
  - Initially, you have no pieces to trade
  - Essentially, beg for free pieces at random
- Steady-state: rarest piece first
  - Ensures that common pieces are saved for last
- Endgame
  - Simultaneously request final pieces from multiple peers
  - Cancel connections to slow peers
  - Ensures that final pieces arrive quickly

Sending Chunks: tit-for-tat

- A node sends chunks to those four peers currently sending it chunks at highest rate
  - other peers are choked (do not receive chunks)
  - re-evaluate top 4 every ~10 secs

- Every 30 seconds: randomly select another peer, start sending chunks
  - "optimistically unchoke" this peer
  - newly chosen peer may join top 4

Academic Interest in BitTorrent

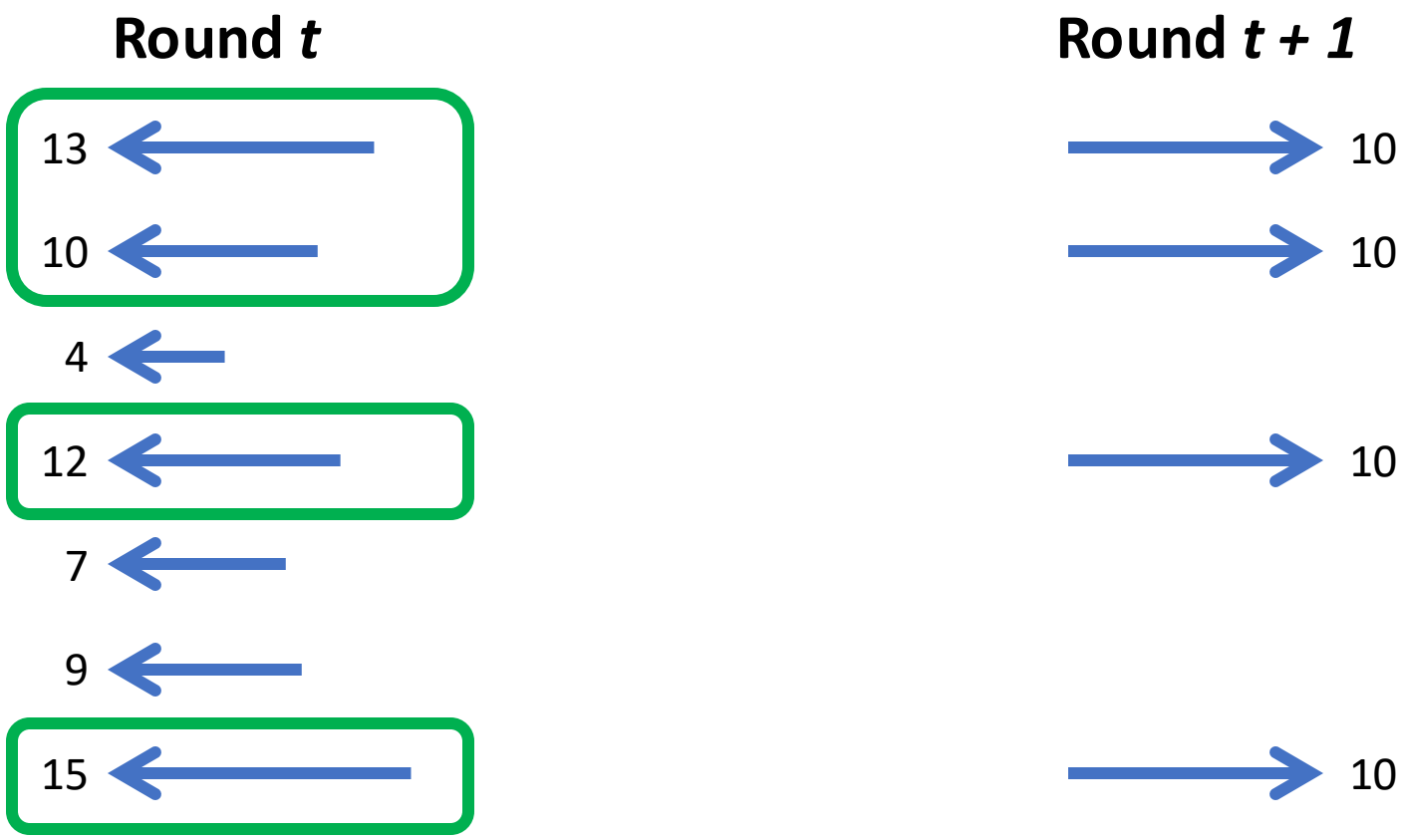
- BitTorrent was enormously successful
  - Large user base
  - Lots of aggregate traffic
  - Invented relatively recently

- Research
  - Modifications to improve performance
  - Modeling peer communications (auctions)
  - Gaming the system (BitTyrant)

Incentives to Upload

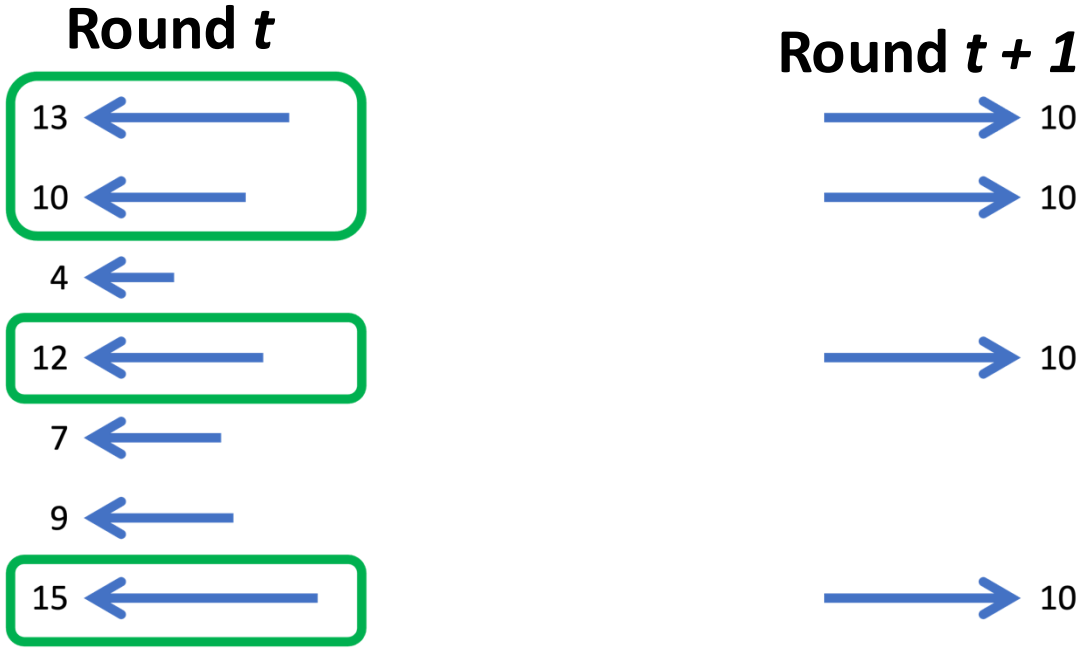
- Every round, a BitTorrent client calculates the number of pieces received from each peer
  - The peers who gave the most will receive pieces in the next round
  - These decisions are made by the unchoker
- Assumption
  - Peers will give as many pieces as possible each round
  - Based on bandwidth constraints, etc.
- Can an attacker abuse this assumption?

Unchoker Example



Abusing the Unchoker

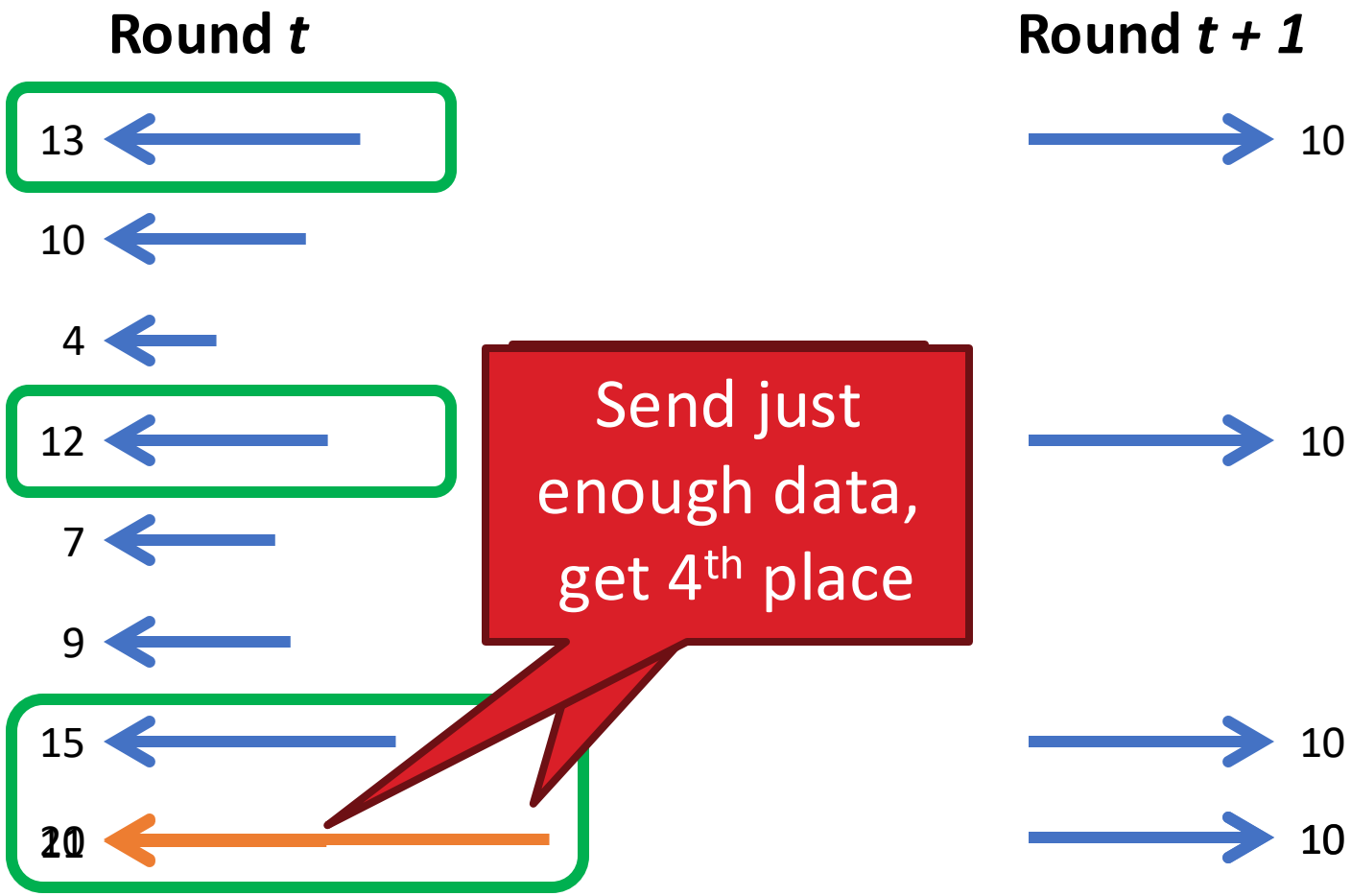
- What if you really want to download from someone?



A. Send more data than the top 1 peer
B. Send more data than the top 4 peer
C. Send less data than the top 3 peers
D. Send some other combination

Abusing the Unchocker

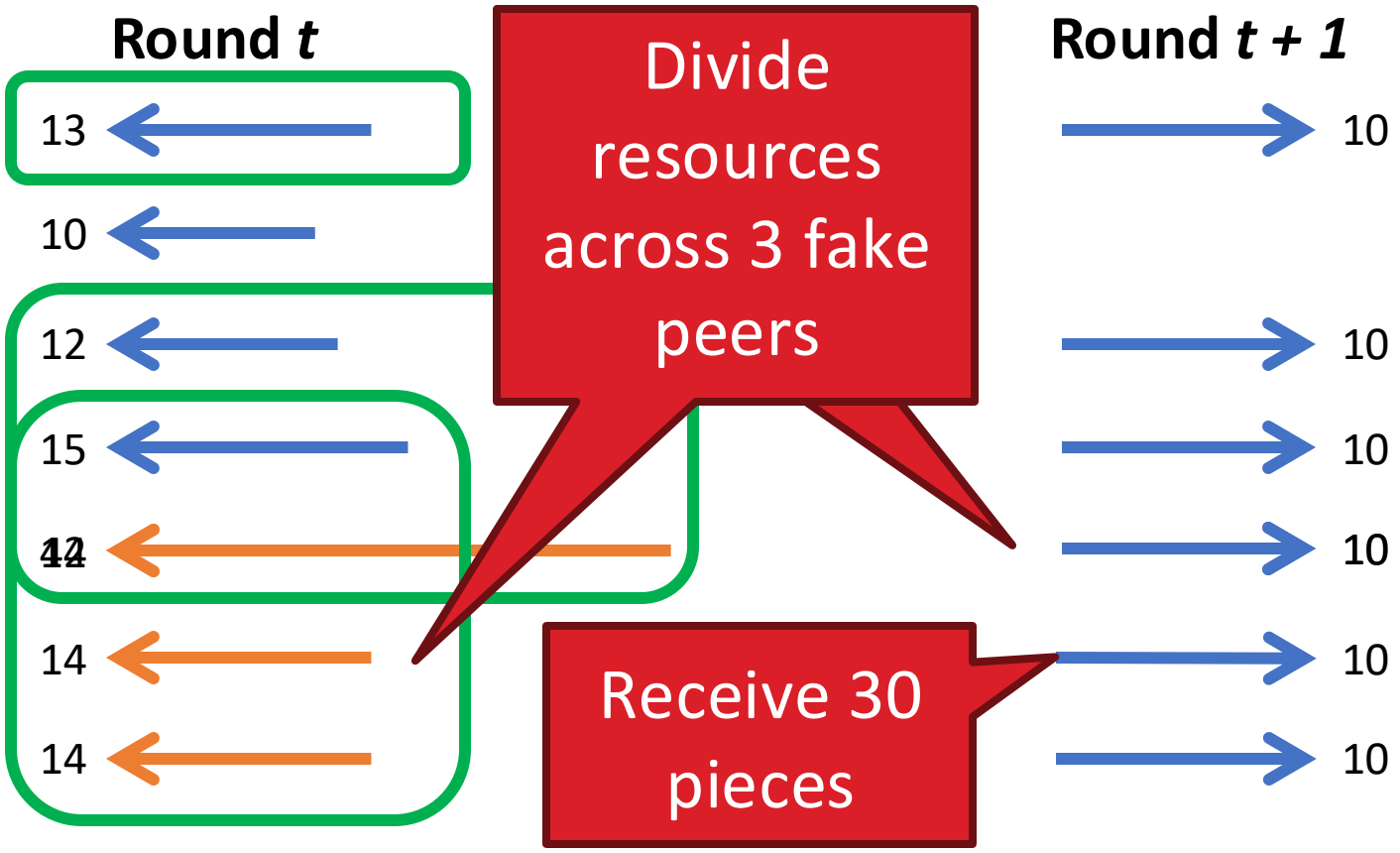
- What if you really want to download from someone?



BitTyrant

- Piatek et al. 2007
  - Implements the “come in last strategy”
  - Essentially, an unfair unchoker
  - Faster than stock BitTorrent (For the Tyrant user!)

Sybil Attack



Total Capacity = 42

Summary

- Application Layer: P2P
  - Symmetric responsibility
  - Self-scalability
  - No central authority
- Different flavors:
  - hybrid, hierarchical, completely decentralized
- Incentivize peers using game theory
  - choice of chunk to download
  - tit-for-tat model
  - other optimizations possible