Overlay graphs

- Edges are TCP connections or pointer to an IP address
- Edges maintained by periodic “are you alive” messages.
- Typically new edge established when a neighbor goes down
- New nodes BOOTSTRAP
- Structured vs Unstructured

Structured overlays

- Edges arranged in a preplanned manner.
- DNS is an example of a structured overlay (but not P2P)
- Mostly still in the research stage – so has not made it to the textbook!

Challenge: locating content

- Gnutella-type search – expensive, no guarantee, need many cached copies for technique to work well.
- Directed search – assign particular nodes to hold particular content (or pointers to it).

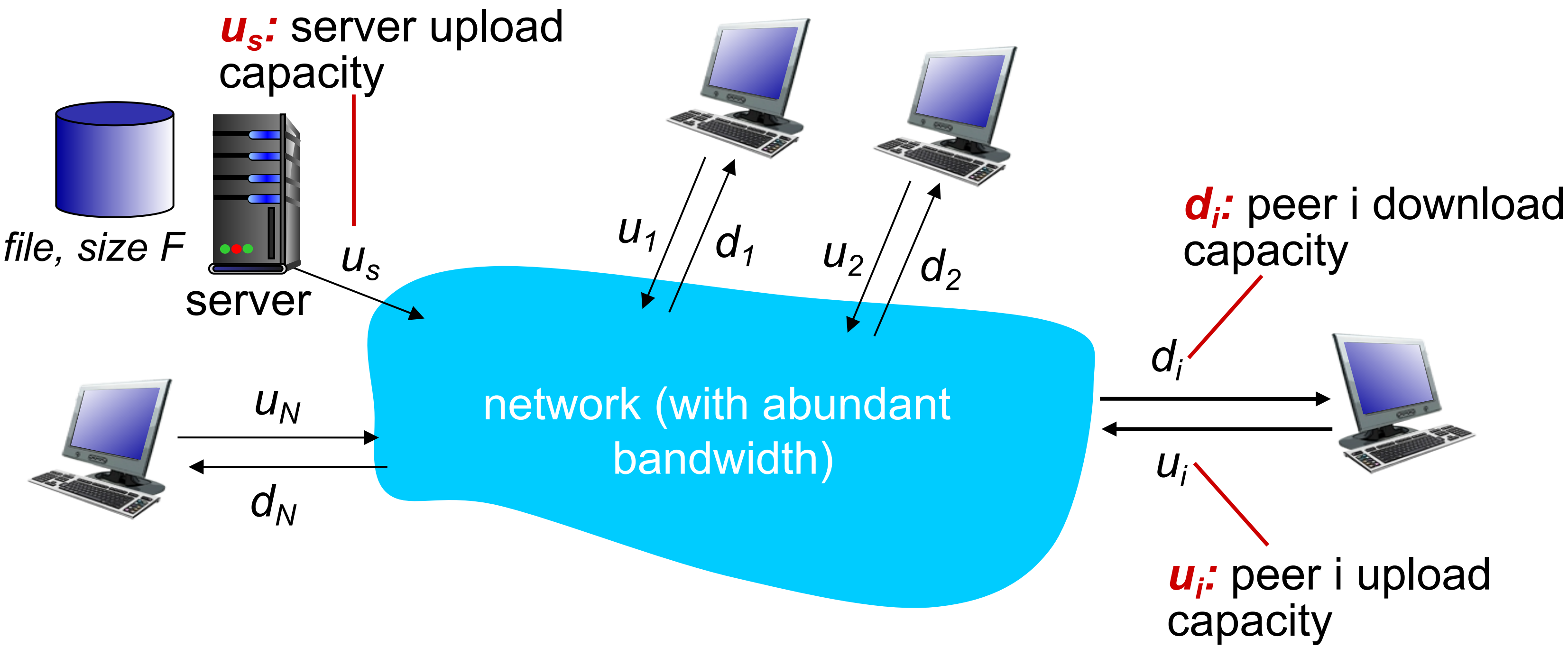
- Problems: Distributed

Handling join/leave

File distribution: client-server vs P2P

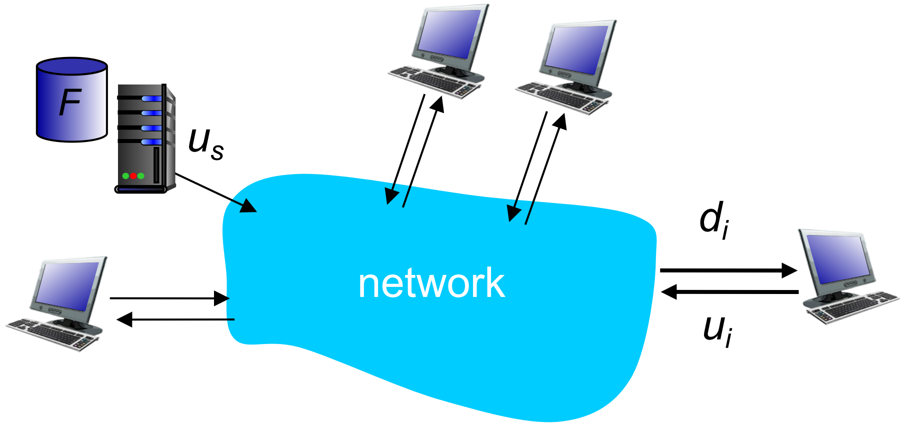
Question: how much time to distribute file (size *F*) from one server to *N* *peers*?

- peer upload/download capacity is limited resource



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}



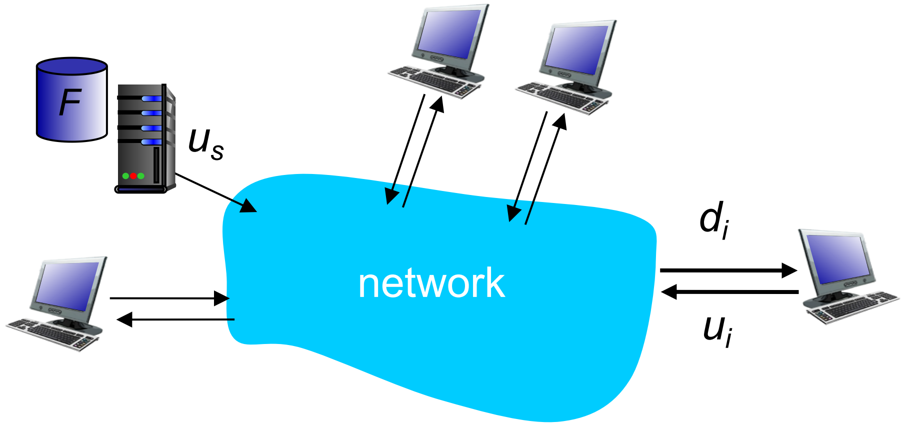
time to distribute F to N clients using client-server approach

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

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

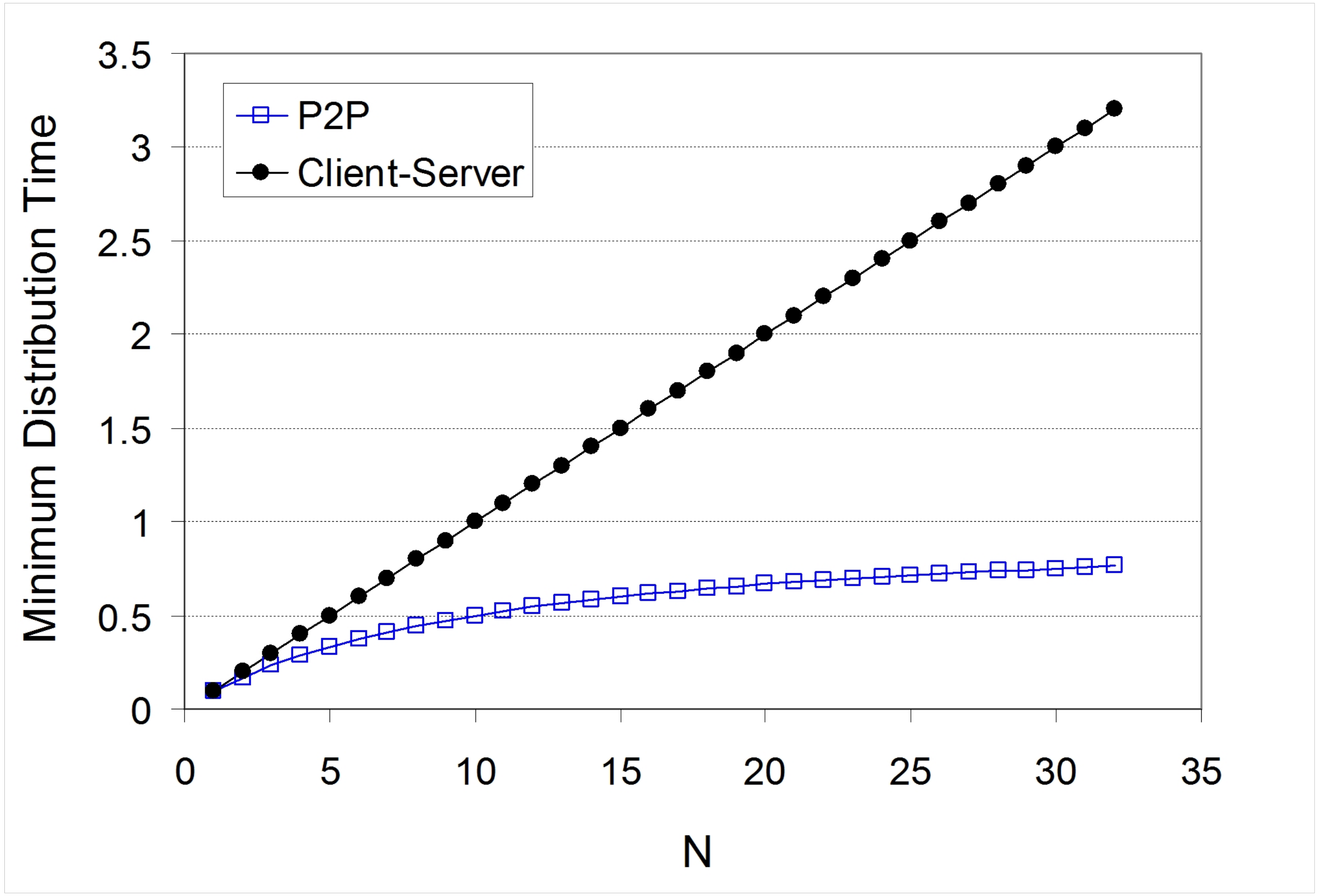
time to distribute F to N clients using P2P approach	$$D_{P2P} \geq max\{F/u_s, F/d_{min}, NF/(u_s + \Sigma u_i)\}$$

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

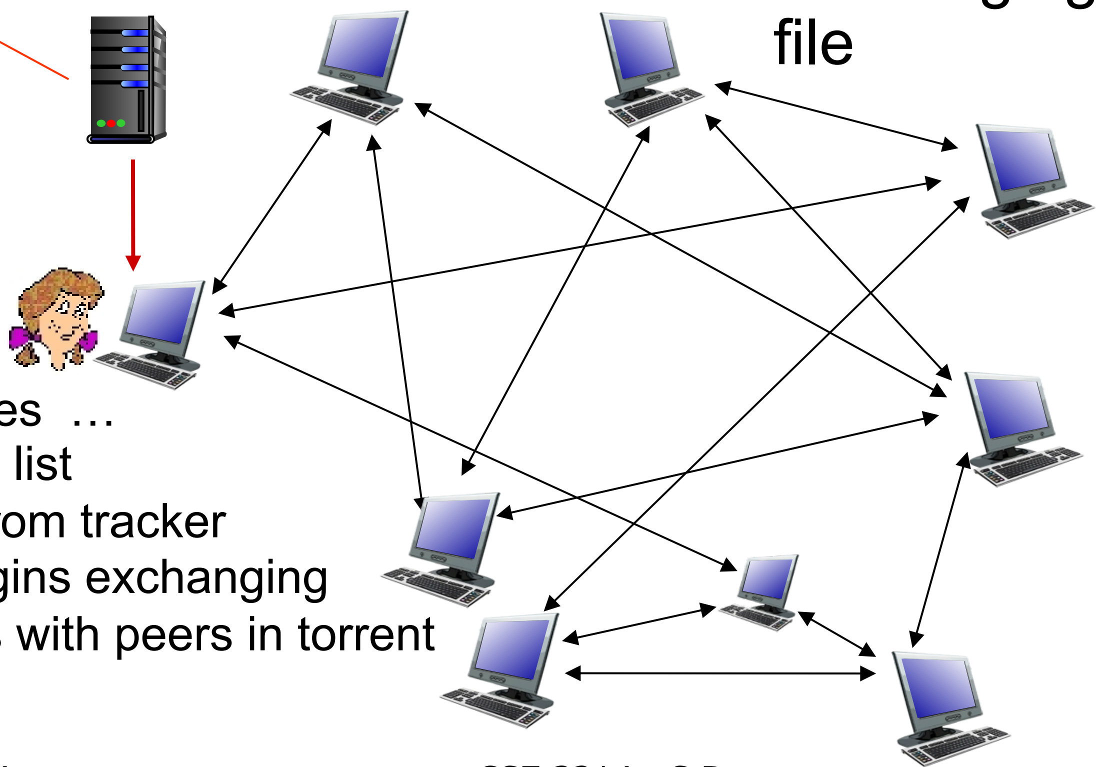


P2P file distribution: BitTorrent

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

tracker: tracks peers participating in torrent

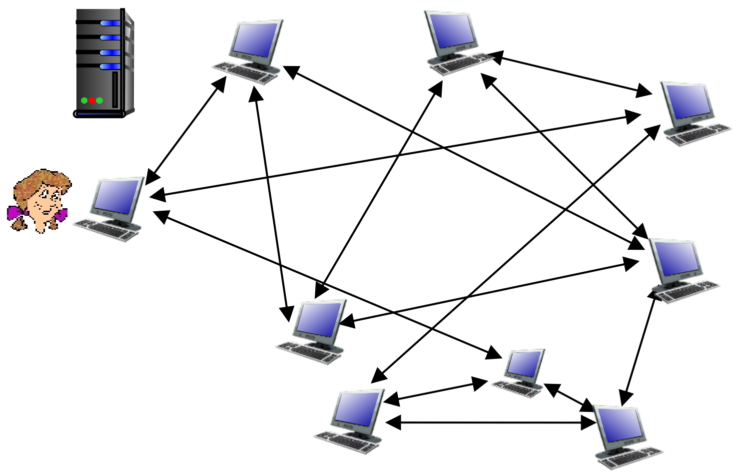
torrent: group of peers exchanging chunks of a file



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

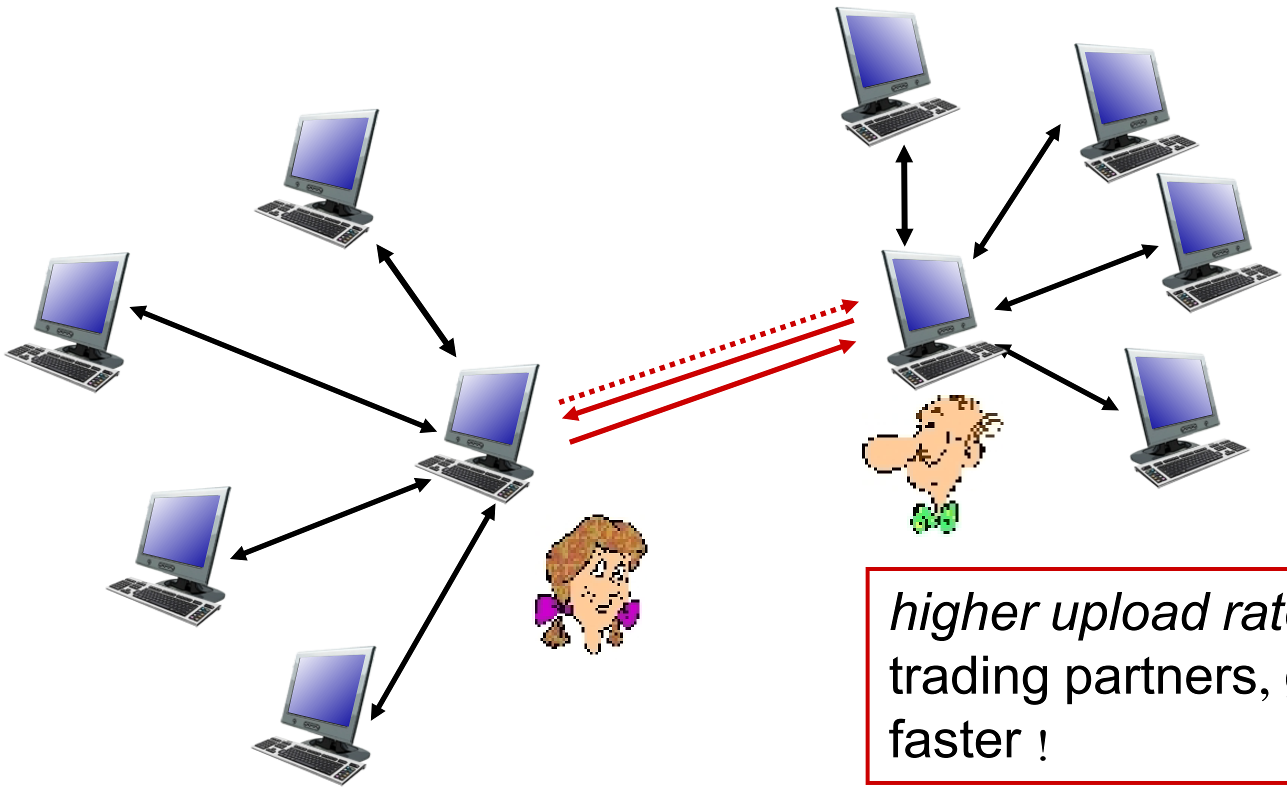
- Alice sends chunks to those four peers currently sending her chunks *at highest rate*
  - other peers are choked by Alice (do not receive chunks from her)
  - re-evaluate top 4 every10 secs
- every 30 secs: randomly select another peer, starts sending chunks
  - "optimistically unchoke" this peer
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

Distributed Hash Table (DHT)

- Hash table
- DHT paradigm
- Circular DHT and overlay networks
- Peer churn

Simple Database

Simple database with (key, value) pairs:

- key: human name; value: social security #

Key	Value
John Washington	132-54-3570
Diana Louise Jones	761-55-3791
Xiaoming Liu	385-41-0902
Rakesh Gopal	441-89-1956
Linda Cohen	217-66-5609
…….	………
Lisa Kobayashi	177-23-0199

- key: movie title; value: IP address

Hash Table

- More convenient to store and search on numerical representation of key
- key = hash(original key)

Original Key	Key	Value
John Washington	8962458	132-54-3570
Diana Louise Jones	7800356	761-55-3791
Xiaoming Liu	1567109	385-41-0902
Rakesh Gopal	2360012	441-89-1956
Linda Cohen	5430938	217-66-5609
…….		………
Lisa Kobayashi	9290124	177-23-0199

Distributed Hash Table (DHT)

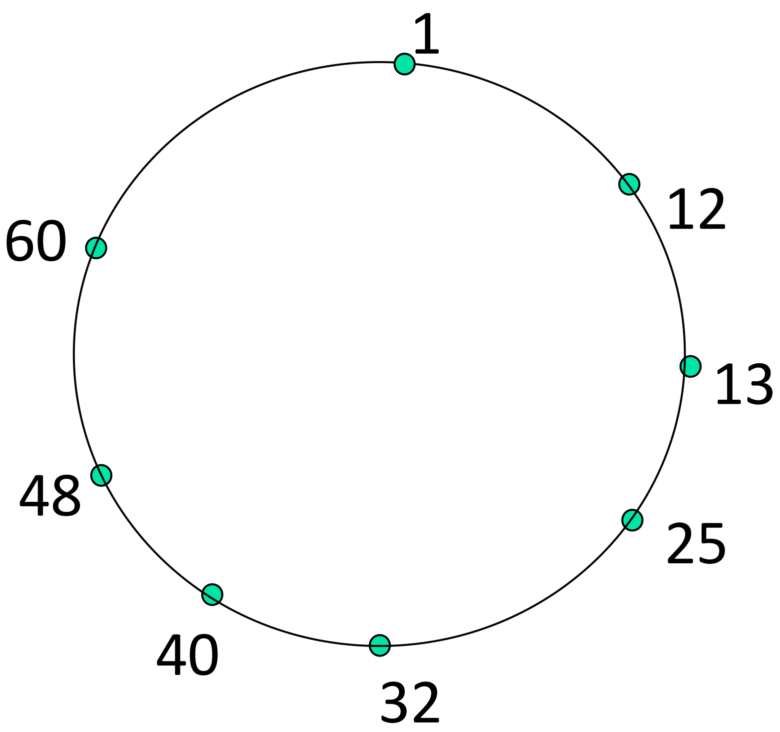
- Distribute (key, value) pairs over millions of peers
  - pairs are evenly distributed over peers
- Any peer can query database with a key
  - database returns value for the key
  - To resolve query, small number of messages exchanged among peers
- Each peer only knows about a small number of other peers
- Robust to peers coming and going (churn)

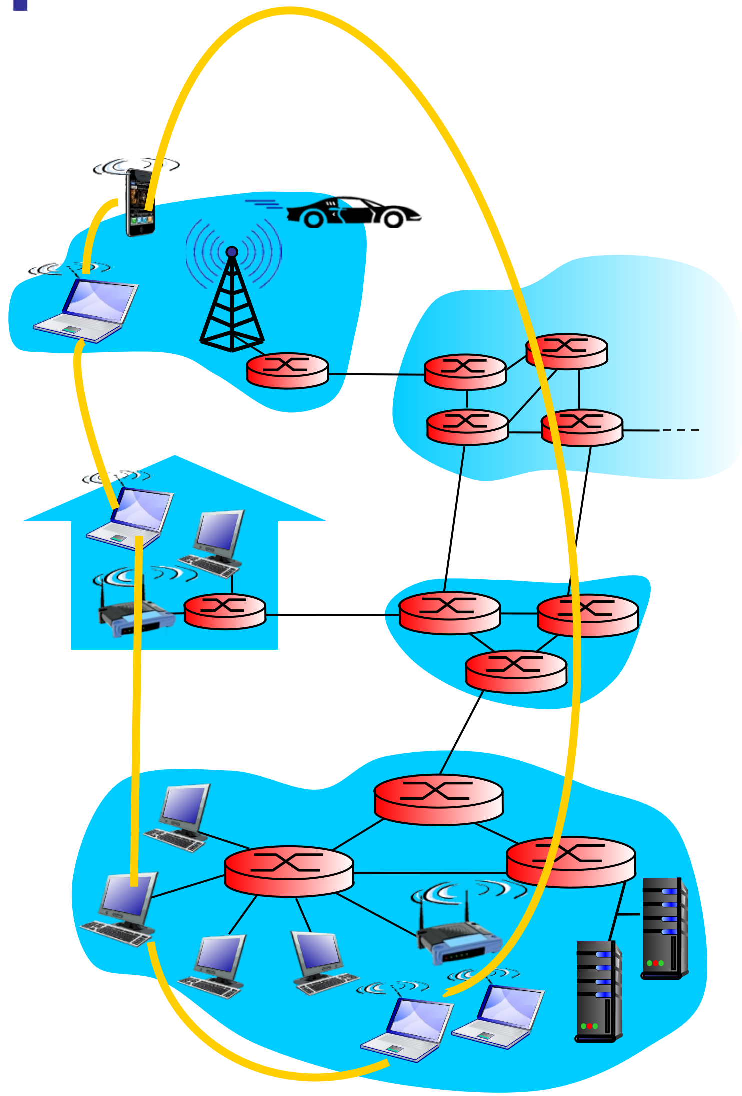
Assign key-value pairs to peers

- rule: assign key-value pair to the peer that has the *closest* ID.
- convention: closest is the *immediate successor* of the key.
- e.g., ID space {0,1,2,3,…,63}
- suppose 8 peers: 1,12,13,25,32,40,48,60
  - If key = 51, then assigned to peer 60
  - If key = 60, then assigned to peer 60
  - If key = 61, then assigned to peer 1

Circular DHT

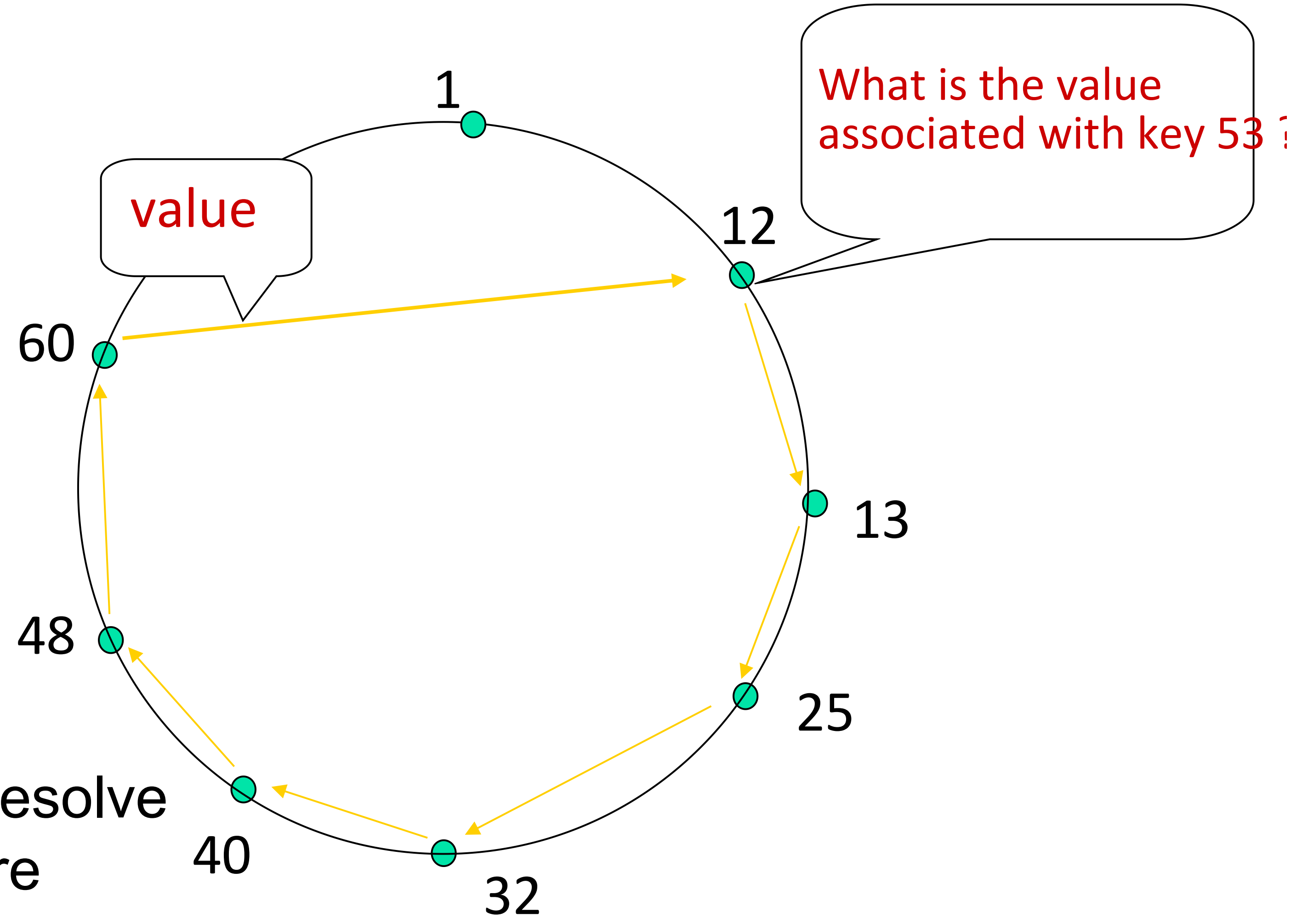
- each peer *only* aware of immediate successor and predecessor.





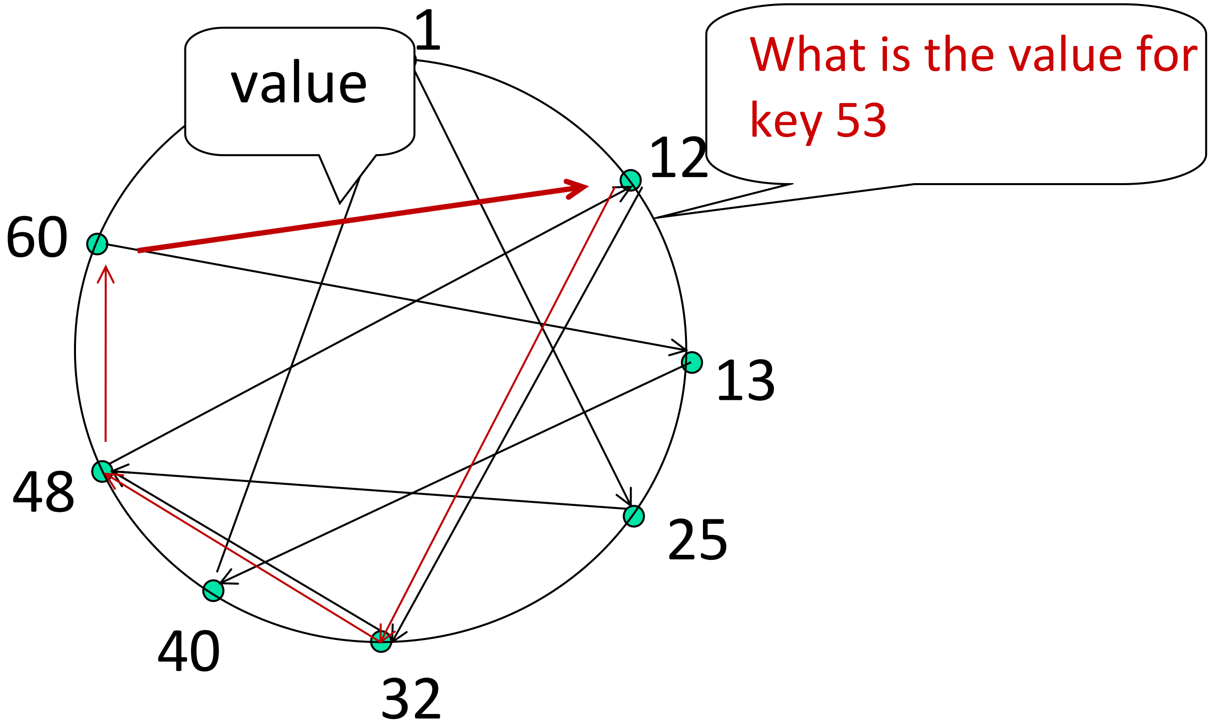
"overlay network"

Resolving a query



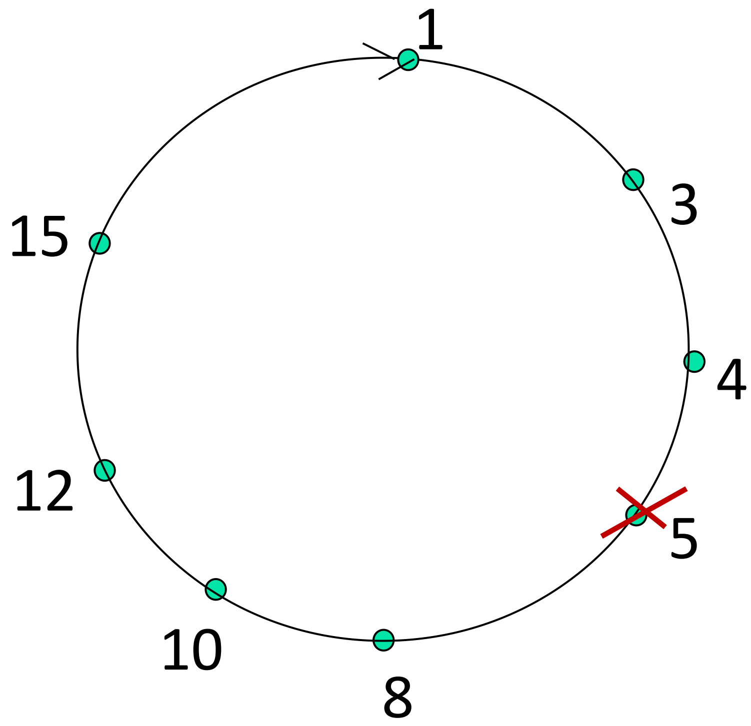
$O(N)$ messages on avgerage to resolve query, when there are N peers

Circular DHT with shortcuts



- each peer keeps track of IP addresses of predecessor, successor, short cuts.
- reduced from 6 to 3 messages.
- possible to design shortcuts with *O(log N)* neighbors, *O(log N)* messages in query

Peer churn

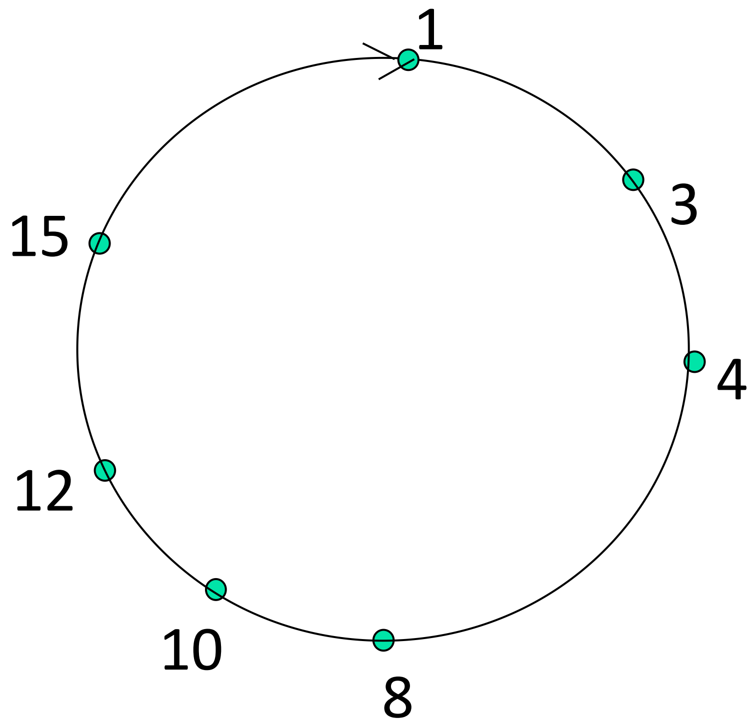


example: peer 5 abruptly leaves

handling peer churn:

- peers may come and go (churn)
- each peer knows address of its two successors
- each peer periodically pings its two successors to check aliveness
- if immediate successor leaves, choose next successor as new immediate successor

Peer churn



handling peer churn:

- peers may come and go (churn)
- each peer knows address of its two successors
- each peer periodically pings its two successors to check aliveness
- if immediate successor leaves, choose next successor as new immediate successor

example: peer 5 abruptly leaves

- peer 4 detects peer 5's departure; makes 8 its immediate successor
- 4 asks 8 who its immediate successor is; makes 8's immediate successor its second successor.

Major problems

User issues

- Security
- Viruses

Community/Network issues

- Polluted files
- Flash crowds
- Freeloading

Thought questions

- Is success due to massive number of servers or simply because content is free?
- Copyright infringement issues: direct vs indirect.