CS457 – P2P

Fall 2014

Topics

- Types of peer-to-peer networks
  - Directory-based (e.g., original Napster design)
  - Unstructured (e.g., Gnutella, Kazaa, BitTorrent)
  - Structured (e.g., distributed hash tables) (later)
- Challenges in peer-to-peer
  - Legal issues, free riding, fast response to queries, peers coming and going over time, reliability, security, …

Peer-to-Peer Networks: Napster

Shawn Fanning, Northeastern freshman

- Napster history: the rise
  - January 1999: Napster version 1.0
  - May 1999: company founded
  - September 1999: first lawsuits
  - 2000: 80 million users
- Napster history: the fall
  - Mid 2001: out of business due to lawsuits
  - Mid 2001: dozens of P2P alternatives that were harder to touch, though these have gradually been constrained
  - 2003: growth of pay services like iTunes
- Napster history: the resurrection
  - 2003: Napster reconstituted as a pay service
  - 2006: still lots of file sharing going on

Napster Technology: Directory Service

- User installs the software
  - – Download the client program
  - – Register name, password, local directory, etc.
- Client contacts Napster (via TCP)
  - – Provides a list of music files it will share
  - – … and Napster’ s central server updates the directory
- Client searches on a title or performer
  - – Napster identifies online clients with the file
  - – … and provides IP addresses
- Client requests the file from the chosen supplier
  - – Supplier transmits the file to the client
  - – Both client and supplier report status to Napster

Napster Technology: Properties

- Server's directory continually updated
  - Always know what music is currently available
  - Point of vulnerability for legal action
- Peer-to-peer file transfer
  - No load on the server
  - Plausible deniability for legal action (but not enough)
- Proprietary protocol
  - Login, search, upload, download, and status operations
  - No security: clear-text passwords and other vulnerabilities
- Bandwidth issues
  - Suppliers ranked by apparent bandwidth & response time

Napster: Limitations of Central Directory

- Single point of failure
- Performance bottleneck
- Copyright infringement

File transfer is decentralized, but locating content is highly centralized

- So, later P2P systems were more distributed

Peer-to-Peer Networks: Gnutella

- Gnutella history
  - 2000: J. Frankel & T. Pepper released Gnutella
  - Soon after: many other clients (e.g., Morpheus, Limewire, Bearshare)
  - 2001: protocol enhancements, e.g., "ultrapeers"

- Query flooding
  - Join: contact a few nodes to become neighbors
  - Publish: no need!
  - Search: ask neighbors, who ask their neighbors
  - Fetch: get file directly from another node

Gnutella: Query Flooding

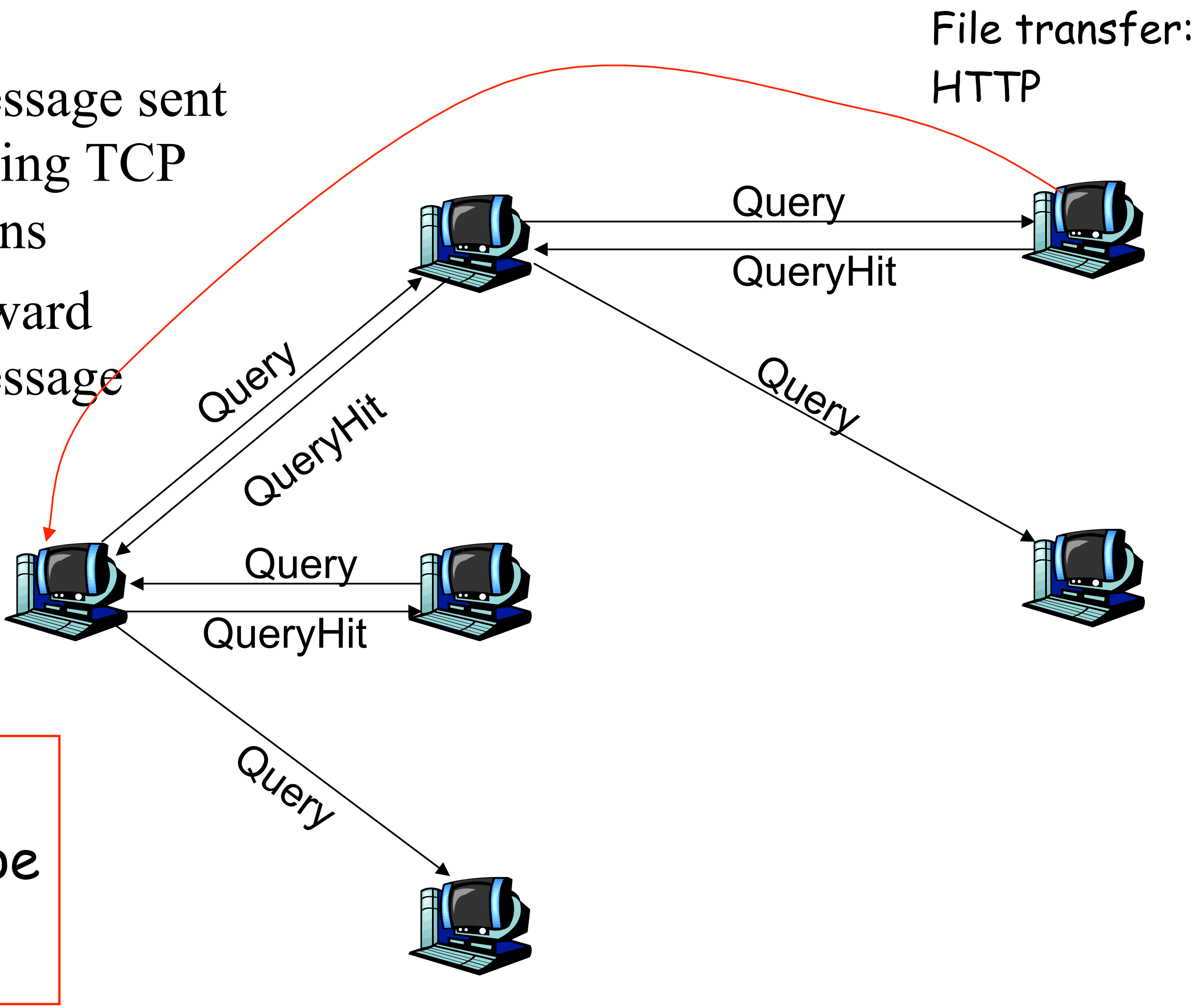
- Fully distributed
  - No central server
- Public domain protocol
- Many Gnutella clients implement the protocol

Overlay network: graph

- Edge between peer X and Y if there's a TCP connection
- All active peers and edges form the overlay network
- Given peer will typically be connected with < 10 overlay neighbors

Gnutella: Protocol

- Query message sent over existing TCP connections
- Peers forward Query message
- QueryHit sent over reverse path



Scalability: limited scope flooding

Gnutella: Peer Joining

- Joining peer X must find some other peer in Gnutella network: use list of candidate peers
- X sequentially attempts to make TCP connection with peers on list until connection setup with Y
- X sends Ping message to Y; Y forwards Ping message.
- Peers receiving Ping message may respond with Pong message
- X receives many Pong messages. It can then setup additional TCP connections

Gnutella: Pros and Cons

- Advantages
  - Fully decentralized
  - Search cost distributed
  - Processing per node permits powerful search semantics
- Disadvantages
  - Search scope may be quite large
  - Search time may be quite long
  - High overhead and nodes come and go often

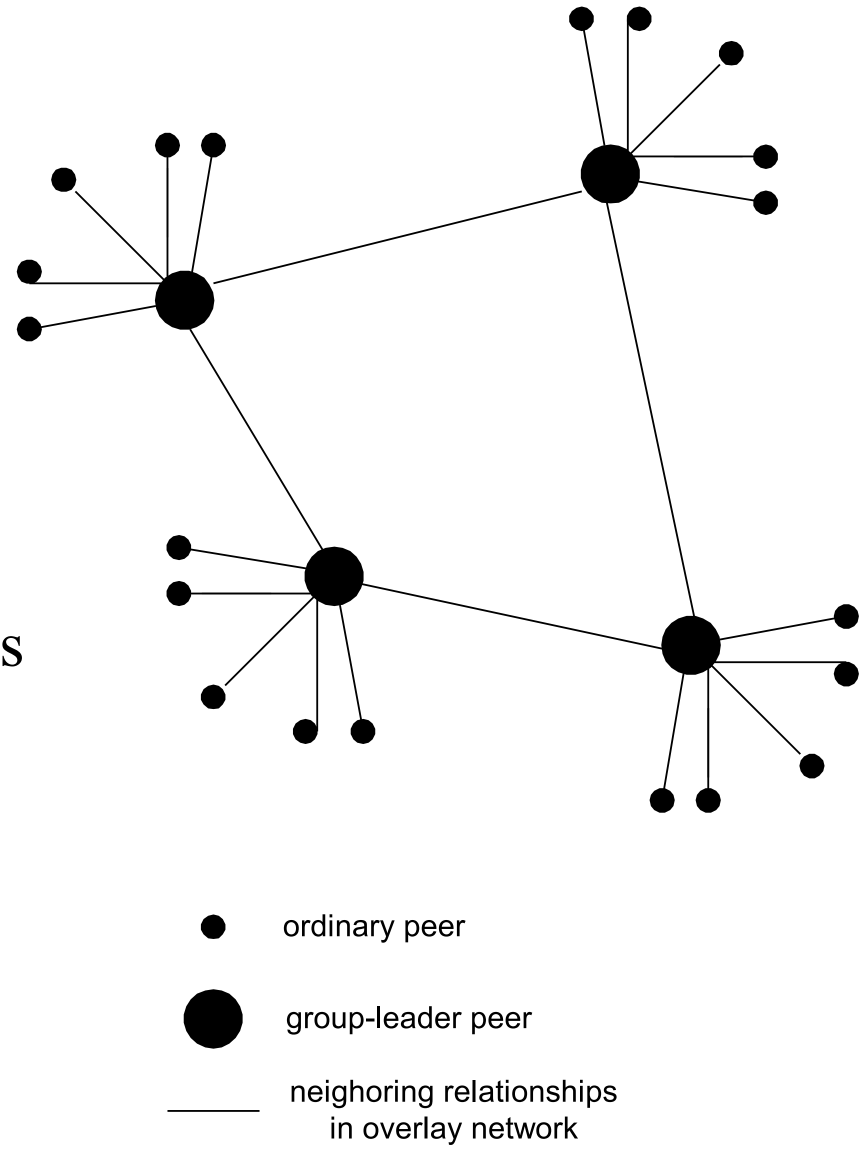
Peer-to-Peer Networks: KaZaA

- KaZaA history
  - 2001: created by Dutch company (Kazaa BV)
  - Single network called FastTrack used by other clients as well
  - Eventually the protocol changed so other clients could no longer talk to it

- Smart query flooding
  - Join: on start, the client contacts a super-node (and may later become one)
  - Publish: client sends list of files to its super-node
  - Search: send query to super-node, and the super-nodes flood queries among themselves
  - Fetch: get file directly from peer(s); can fetch from multiple peers at once

KaZaA: Exploiting Heterogeneity

- Each peer is either a group leader or assigned to a group leader
  - TCP connection between peer and its group leader
  - TCP connections between some pairs of group leaders
- Group leader tracks the content in all its children



KaZaA: Motivation for Super-Nodes

- Query consolidation
  - Many connected nodes may have only a few files
  - Propagating query to a sub-node may take more time than for the super-node to answer itself
- Stability
  - Super-node selection favors nodes with high up-time
  - How long you' ve been up is a good predictor of how long you' ll be around in the future

Peer-to-Peer Networks: BitTorrent

- BitTorrent history and motivation
  - 2002: B. Cohen debuted BitTorrent
  - Key motivation: popular content
    - Popularity exhibits temporal locality (Flash Crowds)
    - E.g., Slashdot effect, CNN Web site on 9/11, release of a new movie or game
  - Focused on efficient *fetching*, not searching
    - Distribute same file to many peers
    - Single publisher, many downloaders
  - Preventing free-loading

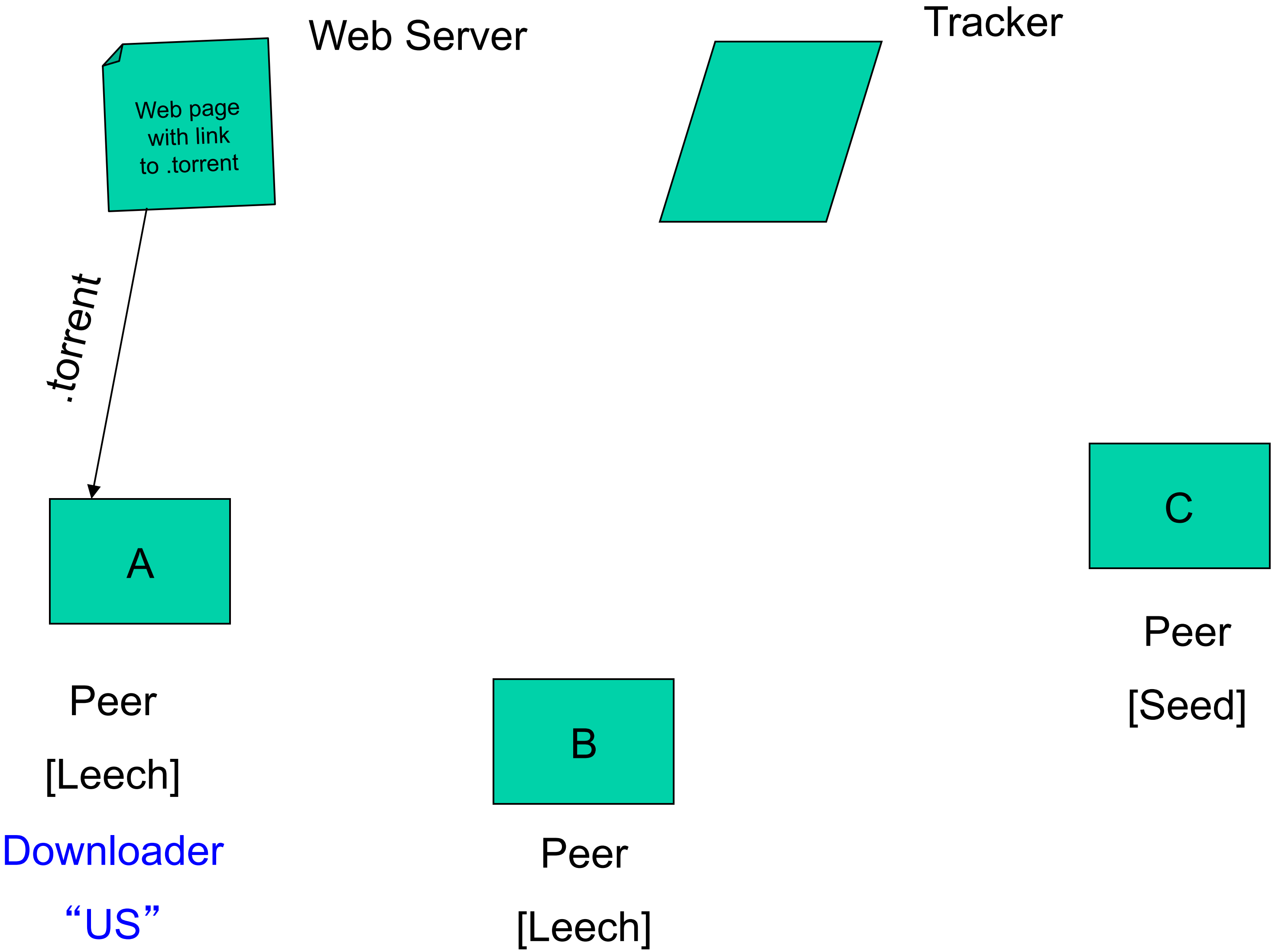
BitTorrent: Simultaneous Downloading

- Divide large file into many pieces
  - Replicate different pieces on different peers
  - A peer with a complete piece can trade with other peers
  - Peer can (hopefully) assemble the entire file
- Allows simultaneous downloading
  - Retrieving different parts of the file from different peers at the same time

BitTorrent Components

- Seed
  - Peer with entire file
  - Fragmented in pieces
- Leacher
  - Peer with an incomplete copy of the file
- Torrent file
  - Passive component
  - Stores summaries of the pieces to allow peers to verify their integrity
- Tracker
  - Allows peers to find each other
  - Returns a list of random peers

BitTorrent: Overall Architecture



Web Server

Web page with link to .torrent

Tracker

.torrent

A

Peer

[Leech]

Downloader

“US”

B

Peer

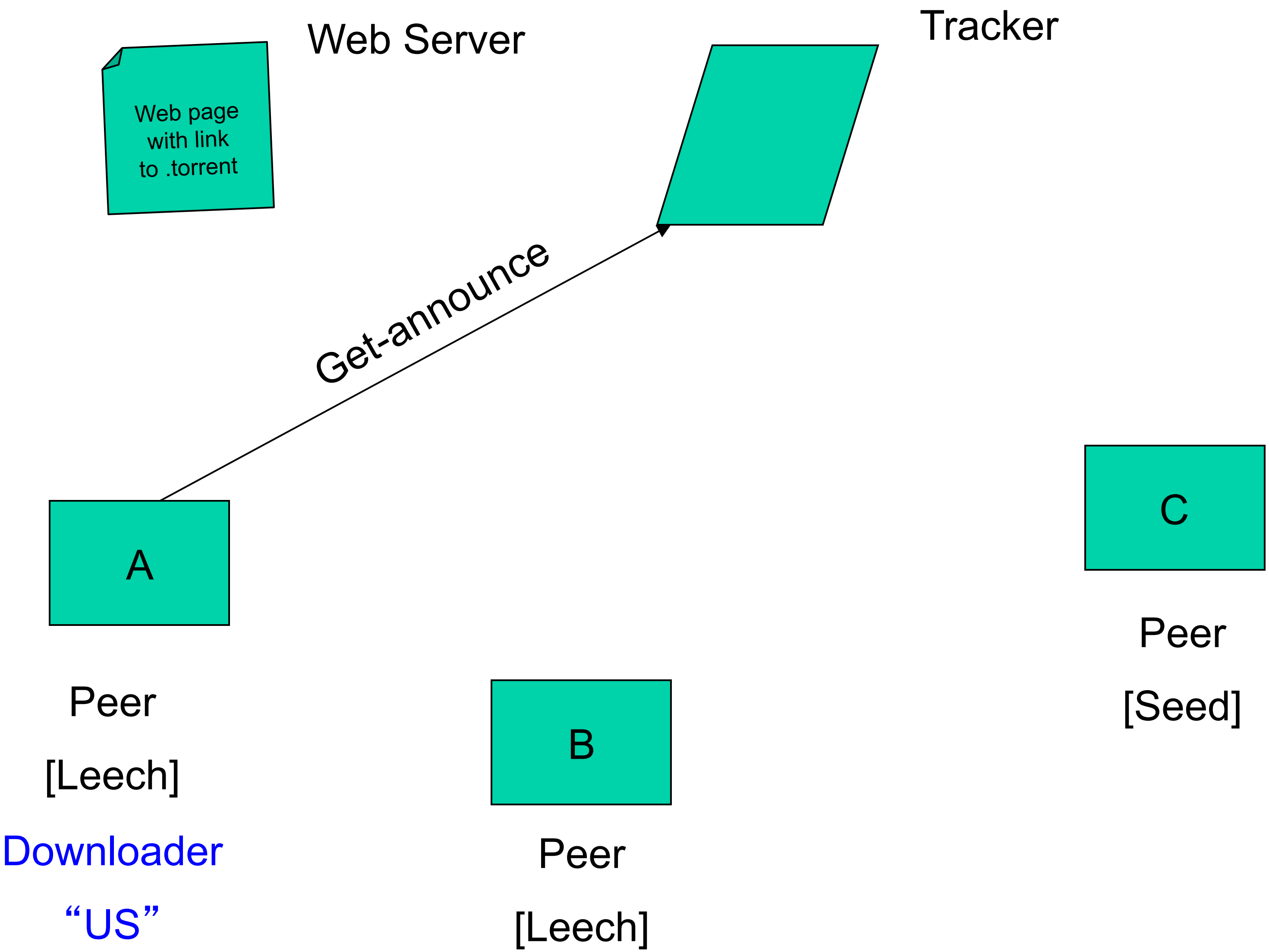
[Leech]

C

Peer

[Seed]

BitTorrent: Overall Architecture



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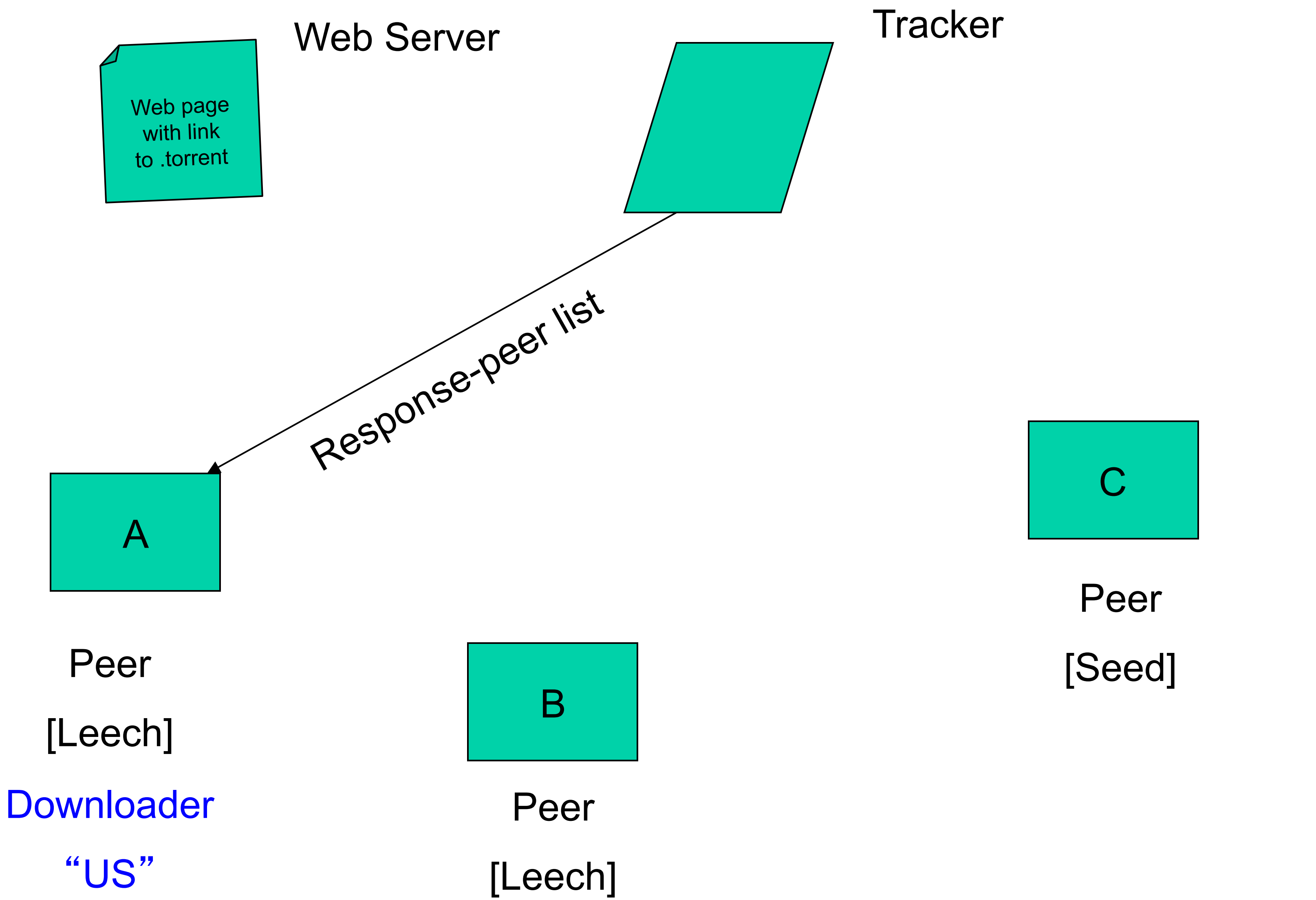

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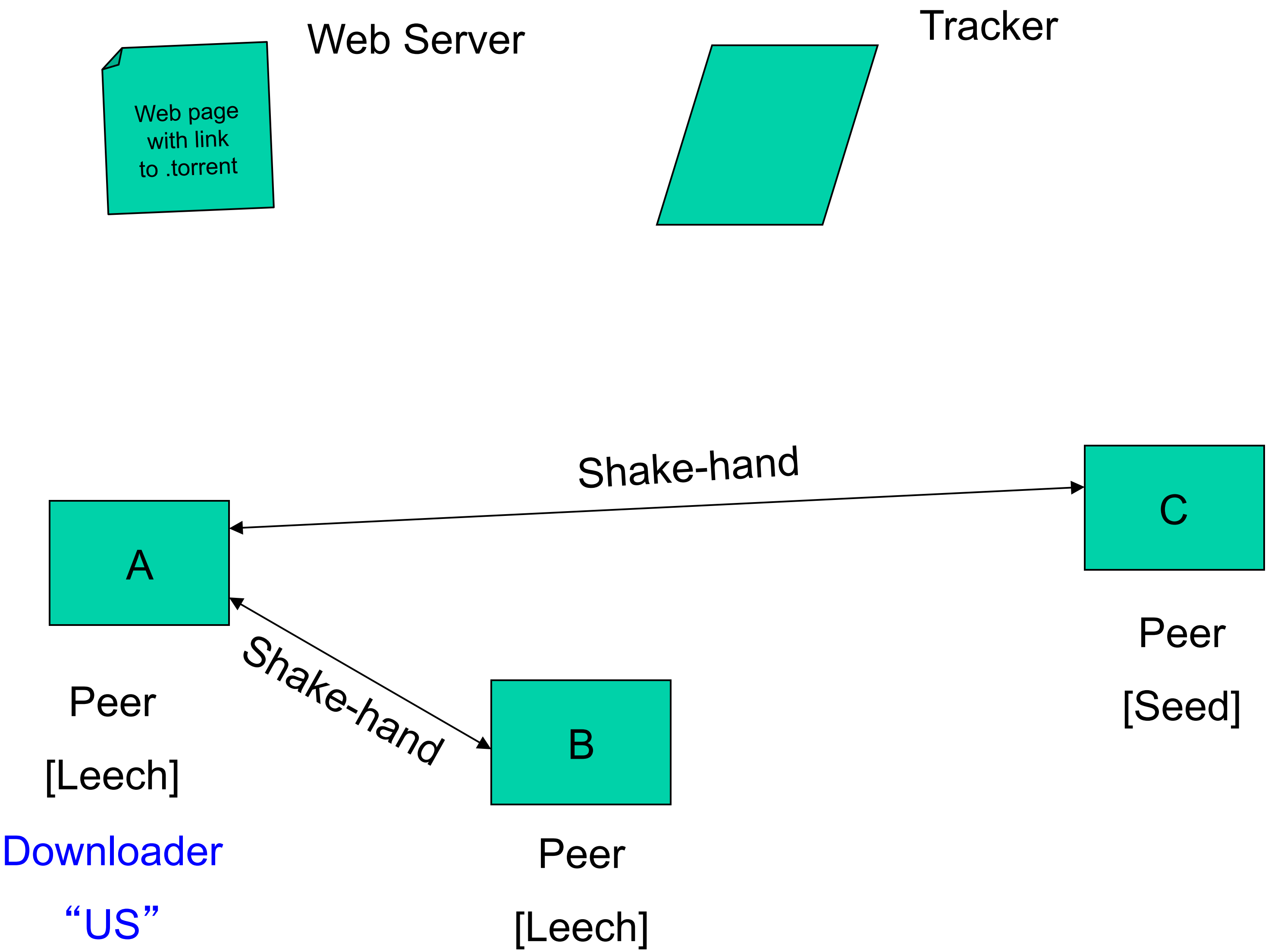

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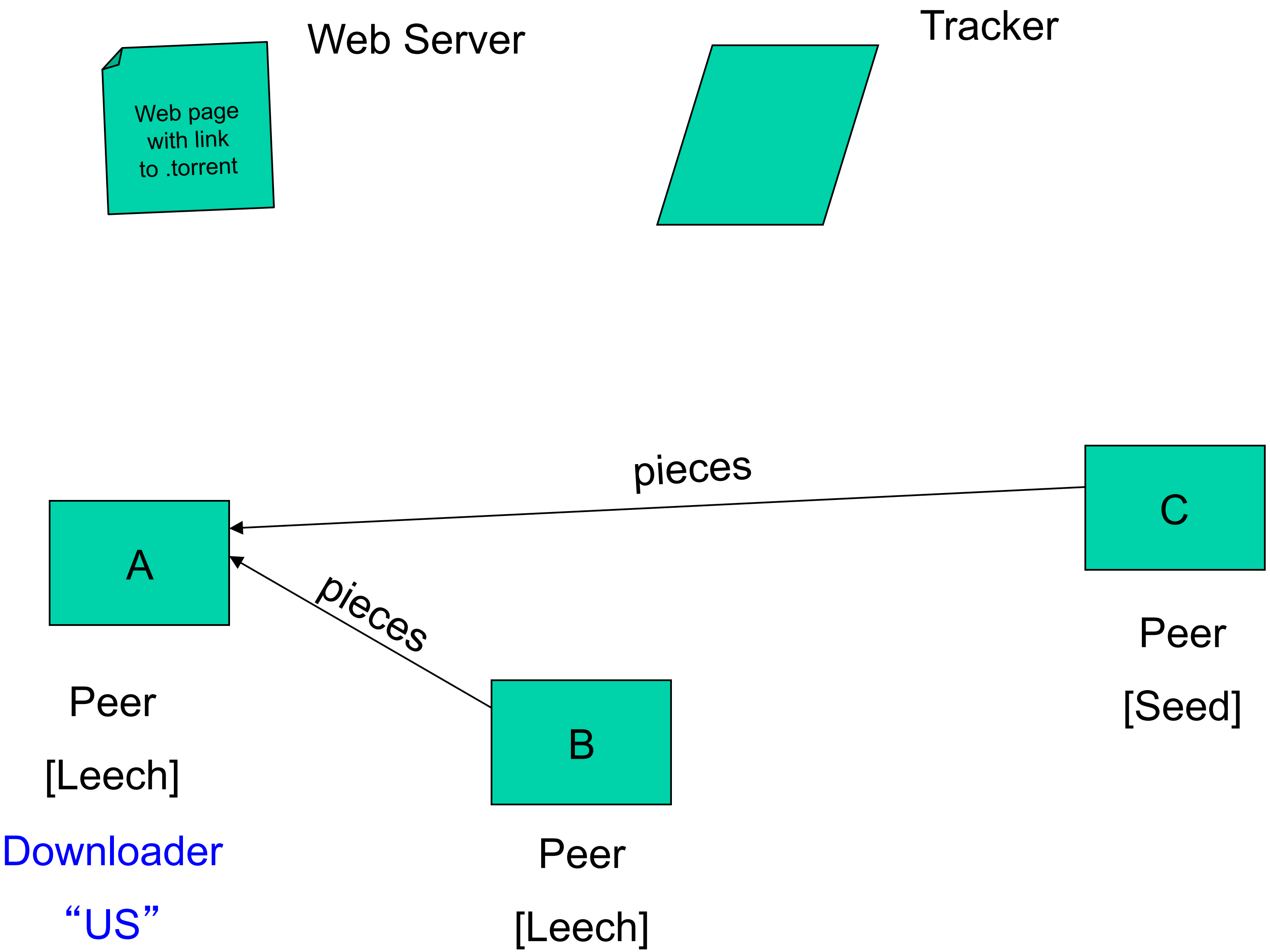


Web page with link to .torrent

Web Server

Tracker

pieces

pieces

A

B

C

Peer

[Leech]

Downloader

“US”

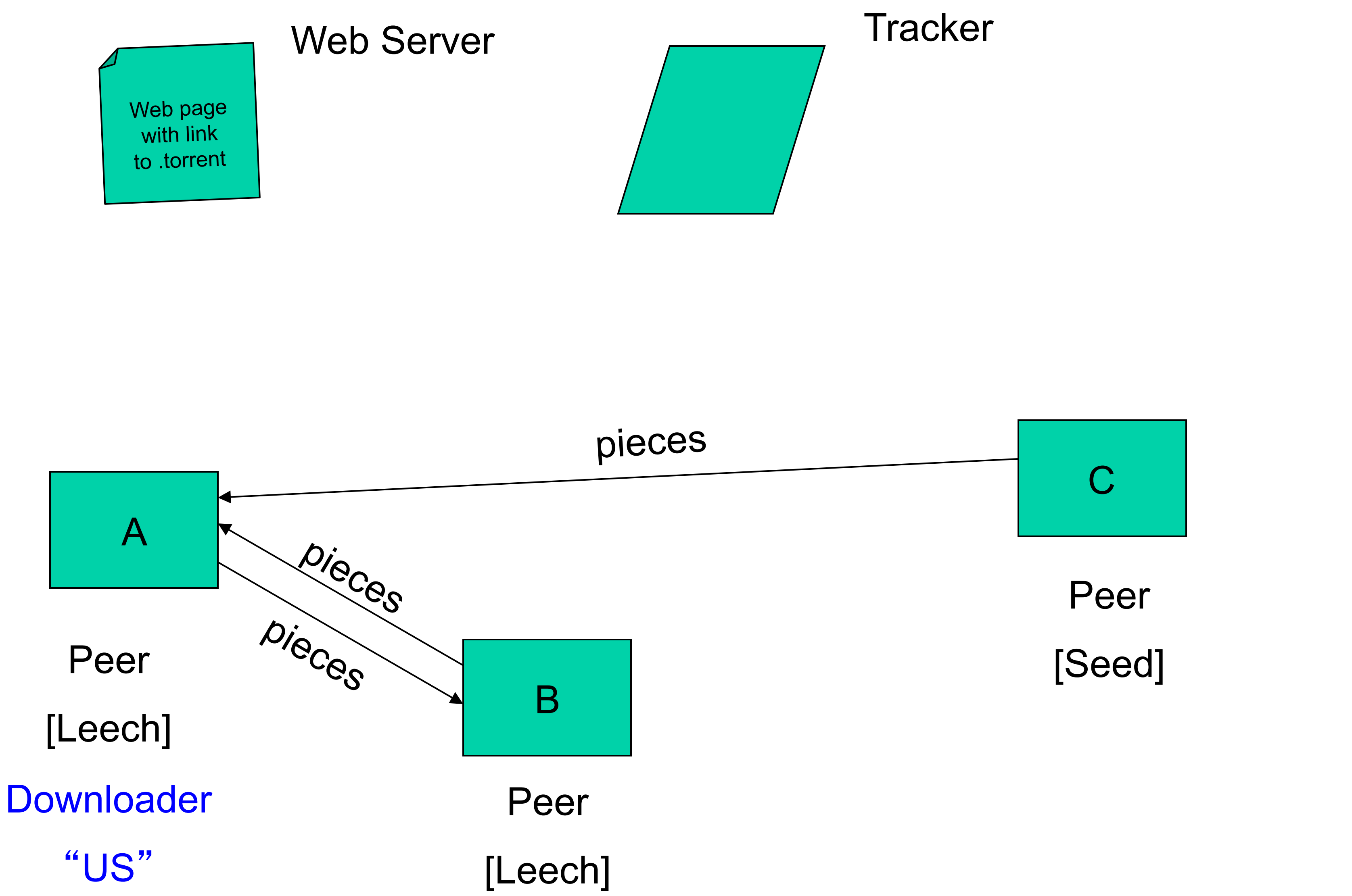
Peer

[Leech]

Peer

[Seed]

BitTorrent: Overall Architecture



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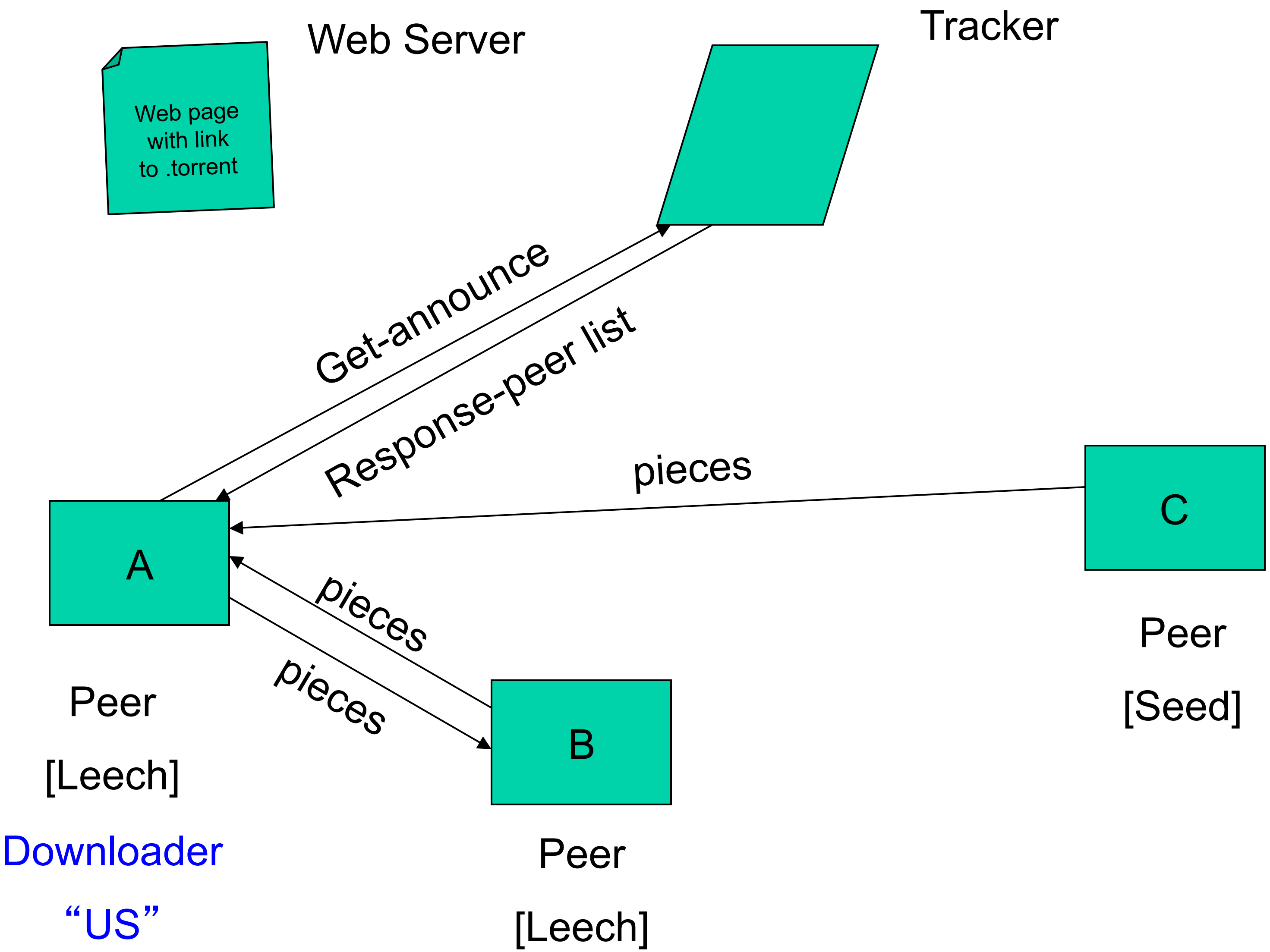

Free-Riding Problem in P2P Networks

- Vast majority of users are free-riders
  - Most share no files and answer no queries
  - Others limit # of connections or upload speed
- A few “peers” essentially act as servers
  - A few individuals contributing to the public good
  - Making them hubs that basically act as a server
- How BitTorrent prevents free riding
  - Allow the fastest peers to download from you
  - Occasionally let some free loaders download

Conclusions

- Peer-to-peer networks
  - Nodes are end hosts
  - Primarily for file sharing, and recently telephony
  - Centralized directory (Napster), query flooding (Gnutella), super-nodes (KaZaA), and distributed downloading and anti-free-loading (BitTorrent)
- Great example of how change can happen so quickly in application-level protocols