CPSC 317 – Winter 1 2025 Introduction to Computer Networking

Application Layer Protocols - peer-to-peer

Module 3.5

Norm & Ibtissem

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ADMINISTRATION

- Quiz 1 ongoing
- PA1 due Sunday
- PA2 starting later this week
- iClicker today

READING

- Reading: 2.5

Learning goals – peer-to-peer

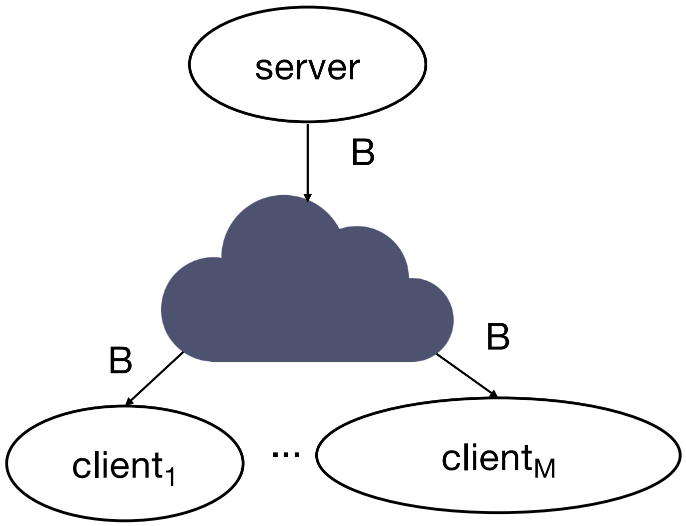
- Describe the architecture of a peer-to-peer application
- Describe the design goals for the bit-torrent protocol
  - Explain the performance benefit of peer-to-peer file sharing over a single server
- Describe the design goals for block-chain protocols
  - Understand the costs

Case study: bit-torrent

- Purpose: file sharing
- Initially designed in 2001
- Protocol v2 in 2017
  - Mostly upgrading the hash function
- Each node functions as both a consumer and provider of data

FILE SHARING Scenario

- Suppose some N machines have a file (N might be just 1)
- Suppose some other M machines want the file (M might be very large)
- If the N machines share the file with the M machines, it might be very slow
  - Limited to the throughput possible by those N machines
  - Imagine if N is 1 and M is 1000



File Sharing Examples In Real World

- Gaming
- Software updates
  - e.g., Android updates to billions of mobile phones

Clicker question

Suppose there is one server with a 1Gbyte file and a 1Gbps network connection. Suppose 1000 clients want a copy of the file. How long will it take the server to deliver the file to the 1000 clients? (Choose the closest answer)

A. 2 days
B. 2 hours
C. 2 minutes
D. 2 seconds

Clicker answer

Suppose there is one server with a 1Gbyte file and a 1Gbps network connection. Suppose 1000 clients want a copy of the file. How long will it take the server to deliver the file to the 1000 clients?

Time taken to send the file to one client = File size/Bandwidth

$= 1*8*\ 2^{30} / 10^{9}$

= 8.589 seconds

Time taken to send the file to 1000 clients = 1000*8.589

= 8589 seconds

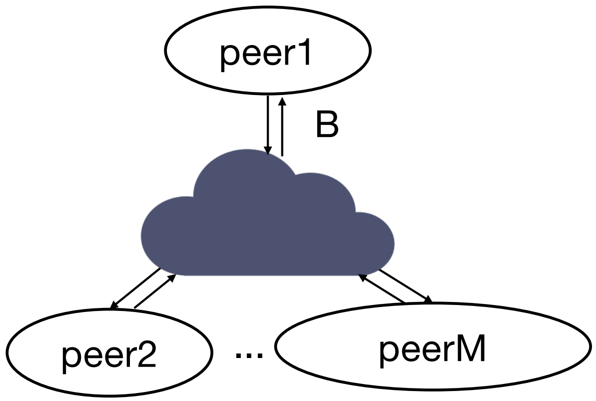
= 143 minutes

= 2.4 hours

Closest answer: B. 2 hours

Bit-Torrent

- All N+M machines participate as both sources and sinks of data
- The N hosts are called "seeds"
- All hosts are called "peers"
- As soon as one of the M peers has a portion of the file it can share it with other peers



Clicker question

Assume that all peers have a 1Gbps network connection. Suppose there is 1 peer (seed) with a 1Gbyte file. Suppose 1000 peers want a copy of the file. How long will it take the seed to deliver the file to the 1000 peers (assuming the seed is clever)? (Choose the closest answer)

A. 2 days
B. 2 hours
C. 2 minutes
D. 2 seconds

Clicker answer

Assume that all peers have a 1Gbps network connection. Suppose there is 1 peer (seed) with a 1Gbyte file. Suppose 1000 peers want a copy of the file. How long will it take the seed to deliver the file to the 1000 peers (assuming the seed is clever)? (Choose the closest answer)

The seed sends a (different) 1/1000 portion of the file to each peer. This takes $2^{30} * 8 / 10^9 = 8.6$ s. Each peer now shares its block with the other 1000 peers, this takes another 8.6 s. Total time: 17.2 s.

Closest answer: D. 2 seconds

What if it is 1,000,000 clients?

- The single server case will take 1000 times longer, or 2,400 hours
  - 100 days
- The peer-to-peer case will take (about) the same amount of time
  - Maybe it takes three rounds rather than 2
  - So 8.6 * 3 = 25.8 seconds

A few details

The file is broken into many pieces

- Fixed size (except for the last one)
- Protected by a cryptographic hash (we'll talk about these in module 8)
  - Allows reliable detection of corruption

A summary (torrent file) gives the necessary start up information:

- How many pieces
- The hash of each piece
- Somewhere to start looking for peers (Seeds, Trackers)

Basic operation

Finding other peers

- Seeds or trackers to start with
- Peer exchange: Each peer tells the other peers it is talking to regarding the peers it knows about
- The group of peers for one particular file is a "swarm"
- Each peer talks to some subset of the "swarm" at any time

Finding pieces

- Each peer shares the identity of the pieces it has with the peers it is talking to
- A peer who doesn't have a piece asks a peer who has to share it

A few policy questions

Which piece does a peer ask for first?

- Rarest first
- Increases the overall “health” of a file

Which of all the peers in a swarm should a peer send data to?

- The ones that are sending the most data to it (preferred peers)
- Tit-for-tat
- Random “opportunistic unchoking”

Implementation

- Bit-torrent is an open protocol with many implementations
- Most use TCP as the transport mechanism
- Some use μTP – a UDP-based reliable transport protocol

Final thoughts

- Popular files can be found and obtained very quickly
- Unpopular files can be hard to find
- Often used to copy copyrighted material
  - The protocol and its implementations aren't illegal in any way
  - Copying material that someone else holds the copyright to is illegal (no matter how it is done)
- But not exclusively
  - Used by Facebook and Twitter to share content between servers

Case study: blockchain

- Purpose: unmodifiable transaction history
- Initially designed in 2008 (based on earlier work) by someone(s) using the pseudonym Satoshi Nakamoto
- Uses cryptography to ensure that records added to the history can never be changed or removed
- Foundation of bitcoin and many other cryptocurrencies

Centralized or de-centralized

- Blockchain can be implemented both ways
- The primary value of the de-centralized approach is that it doesn't require a trusted agent
- The group of peers collaborate to decide which next "link" in the chain is accepted

Mechanism

- All changes are broadcast (using gossip) to every other peer
- Changes are grouped into blocks
- When a block fills up, it is added to the chain
- There is no central repository of the "truth"
  - Every peer holds all of the history
  - This makes it very hard to forget the history since it is replicated very, very heavily

History “forks”

- There can be some disagreement over whether newly added blocks are actually in the chain
  - Concurrent modification
- The group of peers eventually agree on the history
  - Blocks are “scored” somehow, with the group of peers choosing the highest scoring history
- “Proof of work”
  - Each peer must demonstrate how much they like a particular version of the history by doing lots of work to support that version
  - Peers are rewarded for doing this (mining)
- The likelihood of a block being removed from the history gets progressively (exponentially) smaller as it gets older

Blockchain case study: Bitcoin

- There are about 25,000 active computers in the bitcoin peer-to-peer network (2025)
- There were about 10,000 in 2019
- Anyone can join
  - Initial peers found via DNS
- Communication is built on top of TCP
  - Gossip-based
  - Share what you know that your neighbours don’t

Costs – storage

- Bitcoin's block chain is growing rapidly

Year	Size
2014	20GB
2015	30GB
2016	50GB
2017	100GB
2020	>200GB
2025	>600GB

Clicker question

The main cost of a BitCoin transaction is the electrical energy consumed by mining (maintaining the history). How much do you think an individual transaction costs? Choose the closest answer.

A. $0.02
B. $0.20
C. $2.00
D. $20.00
E. $200.00

Clicker answer

The main cost of a BitCoin transaction is the electrical energy consumed by mining (maintaining the history). How much do you think an individual transaction costs? Choose the closest answer.

A. $0.02
B. $0.20
C. $2.00
D. $20.00
E. $200.00

Costs – energy (2025)

- Bitcoin is estimated to consume about 190 terawatt hours of electrical energy per year)
- This number is independent of the number of transactions
- If there are 100,000,000 bitcoin transactions per year, then each transaction costs 1,900 kilowatt-hours
  - Electricity in BC (residential) costs $0.1263 per kwh (flat rate)
  - 1900 * 0.1263 = $239.97 CAD

Costs – energy (2022)

- Bitcoin **was** estimated to consume as much electrical energy (121 terawatt hours per year) as Argentina and more than the Netherlands (109) (22% of Canada's 545)
- Each bitcoin transaction costs 708 kilowatt-hours
  - Electricity in BC (residential) costs $0.126 per kwh
  - 708 * 0.126 = $89.20 CAD

In-class activity

- ICA35

Next Topic:
Transport Layer - Introduction and UDP