Game Theory

Presented by Hakim Weatherspoon

Game Theory

- Main Question: Can we cheat (and get away with it)?

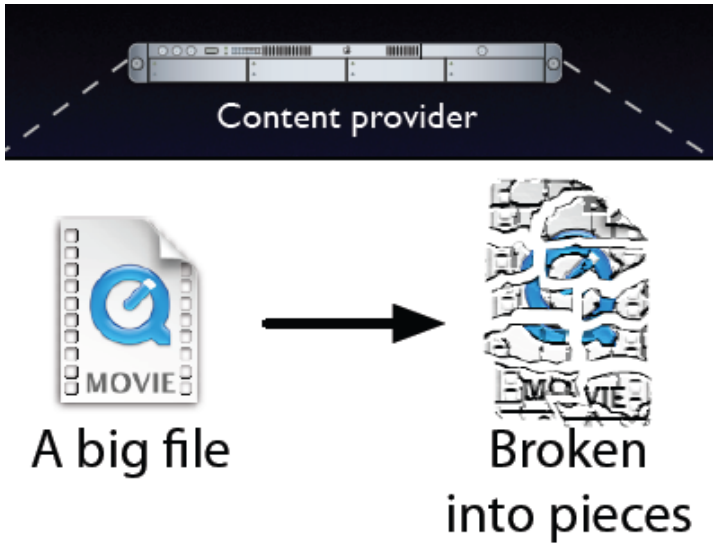
- BitTorrent
  - P2P file distribution tool designed with
    incentives for contribution
  - Users contribute resources to get good performance
- Do Incentives Build Robustness in BitTorrent?
  - Can BitTorrent be gamed?
- BAR Gossip
  - Can content distribution be tamed?

BitTorrent

- Written by Bram Cohen (in Python) in 2001
- “Pull-based” “swarming” approach
  - Each file split into smaller pieces
  - Nodes request desired pieces from neighbors
    - As opposed to parents pushing data that they receive
  - Pieces not downloaded in sequential order
  - Previous multicast schemes aimed to support “streaming”; BitTorrent does not
- Encourages contribution by all nodes

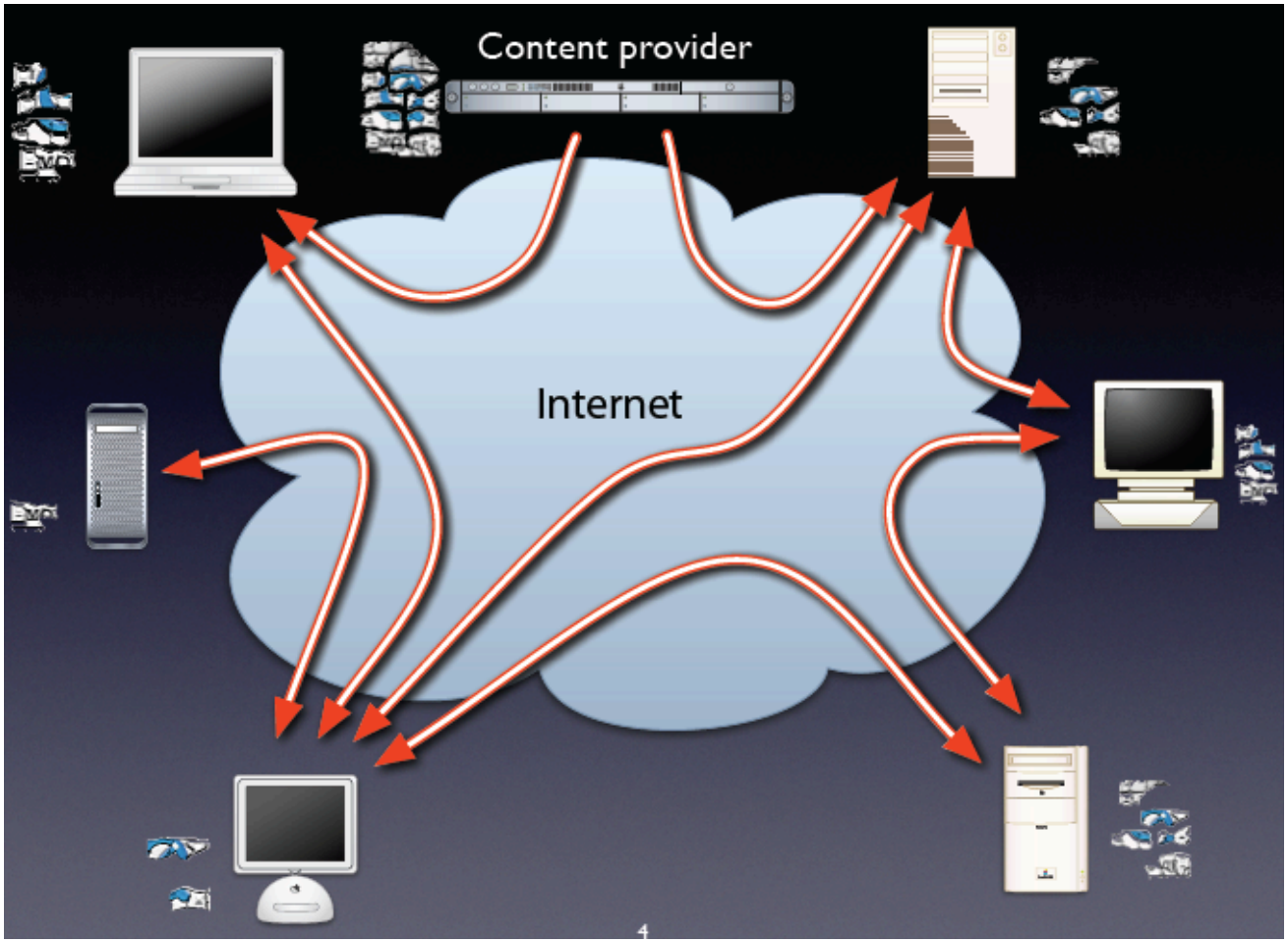
BitTorrent slides from CS 5410, Ken Birman

BitTorrent



Slides from Michael Piatek's NSDI presentation

BitTorrent



BitTorrent Swarm

- Swarm
  - Set of peers all downloading the same file
  - Organized as a random mesh
- Each node knows list of pieces downloaded by neighbors
- Node requests pieces it does not own from neighbors
  - Exact method explained later

How a node enters a swarm for file “popeye.mp4”

- File popeye.mp4.torrent hosted at a (well-known) webserver
- The .torrent has address of tracker for file
- The tracker, which runs on a webserver as well, keeps track of all peers downloading file

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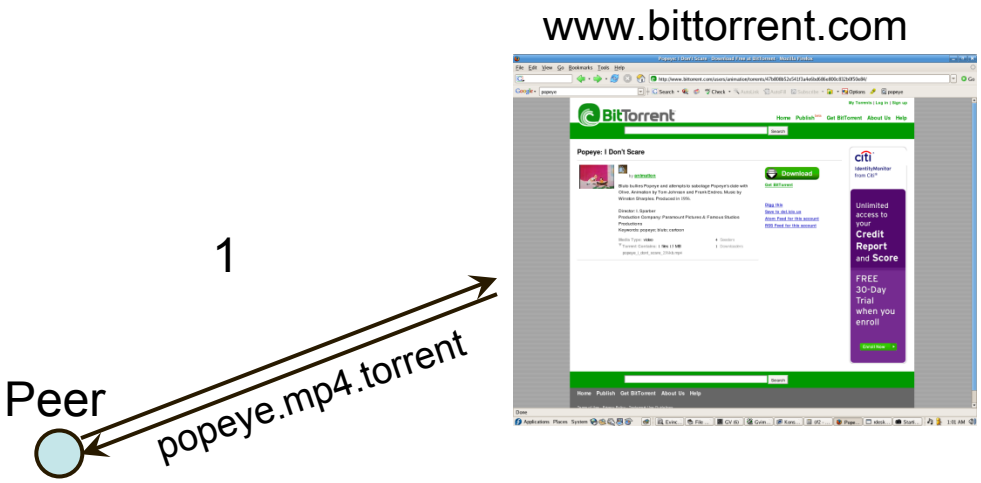

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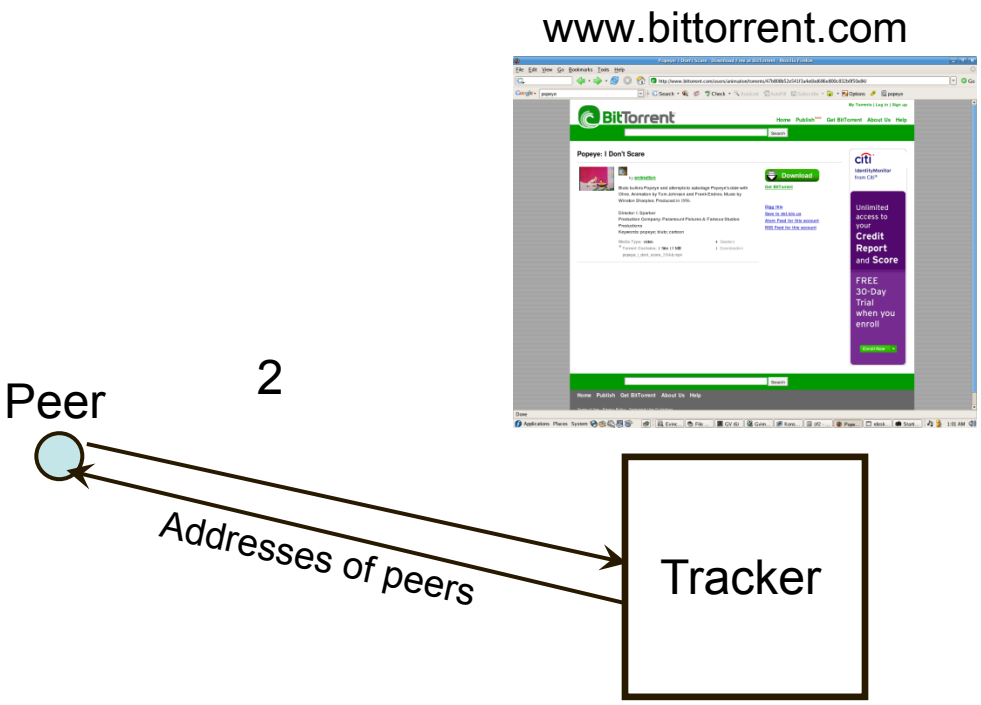

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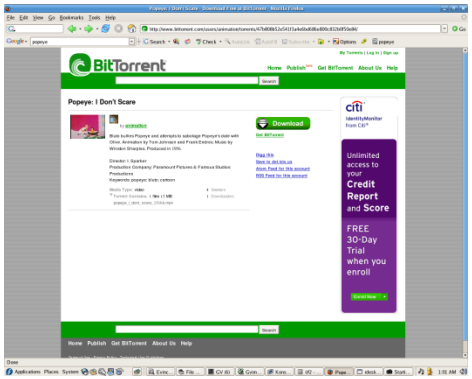
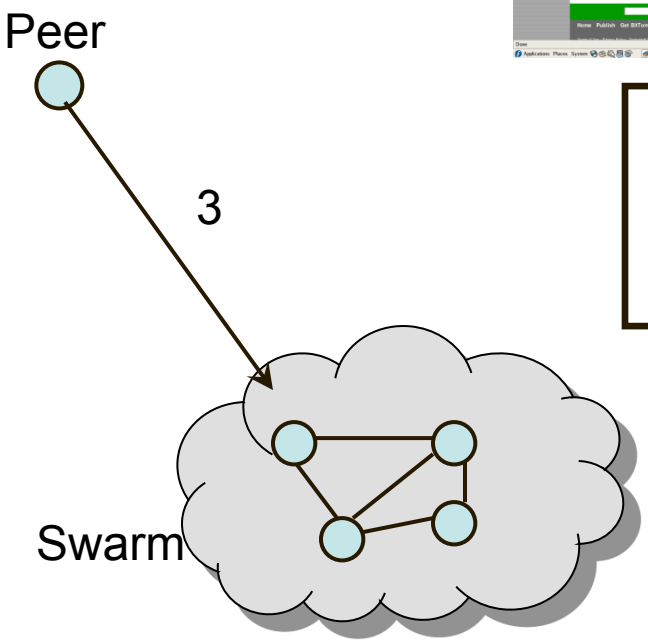
www.bittorrent.com





Tracker

- File popeye.mp4.torrent hosted at a (well-known) webserver
- The .torrent has address of tracker for file
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Contents of .torrent file

- URL of tracker
- Piece length – Usually 256 KB
- SHA-1 hashes of each piece in file
  - For reliability
- “files” – allows download of multiple files

Terminology

- Seed: peer with the entire file
  - Original Seed: The first seed
- Leech: peer that's downloading the file
  - Fairer term might have been "downloader"
- Sub-piece: Further subdivision of a piece
  - The "unit for requests" is a subpiece
  - But a peer uploads only after assembling complete piece

Peer-peer transactions: Choosing pieces to request

- Rarest-first: Look at all pieces at all peers, and request piece that's owned by fewest peers
  - Increases diversity in the pieces downloaded
    - avoids case where a node and each of its peers have exactly the same pieces; increases throughput
  - Increases likelihood all pieces still available even if original seed leaves before any one node has downloaded entire file

Choosing pieces to request

- Random First Piece:
  - When peer starts to download, request random piece.
    - So as to assemble first complete piece quickly
    - Then participate in uploads
  - When first complete piece assembled, switch to rarest-first

Choosing pieces to request

- End-game mode:
  - When requests sent for all sub-pieces, (re)send requests to all peers.
  - To speed up completion of download
  - Cancel request for downloaded sub-pieces

Tit-for-tat as incentive to upload

- Want to encourage all peers to contribute
- Peer *A* said to choke peer *B* if it (*A*) decides *not* to upload to *B*
- Each peer (say *A*) unchoke at most 4 *interested* peers at any time
  - The three with the largest upload rates to *A*
    - Where the tit-for-tat comes in
  - Another randomly chosen (Optimistic Unchoke)
    - To periodically look for better choices
  - 4 is size of active set, but can be more dynamic

Anti-snubbing

- A peer is said to be snubbed if each of its peers chokes it
- To handle this, snubbed peer stops uploading to its peers

➢ Optimistic unchoking done more often

  – Hope is that will discover a new peer that will upload to us

Why BitTorrent took off?

- Better performance through “pull-based” transfer
  - Slow nodes don’t bog down other nodes
- Allows uploading from hosts that have downloaded parts of a file
  - In common with other end-host based multicast schemes

Why BitTorrent took off?

- Practical Reasons (perhaps more important!)
  - Working implementation (Bram Cohen) with simple well-defined interfaces for plugging in new content
  - Many recent competitors got sued / shut down
    - Napster, Kazaa
  - Doesn't do "search" per se. Users use well-known, trusted sources to locate content
    - Avoids the pollution problem, where garbage is passed off as authentic content

Pros and cons of BitTorrent

- Pros
  - Proficient in utilizing partially downloaded files
  - Discourages “freeloading”
    - By rewarding fastest uploaders
  - Encourages diversity through “rarest-first”
    - Extends lifetime of swarm
- Works well for “hot content”

Pros and cons of BitTorrent

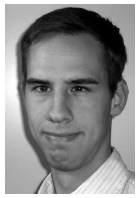
- Cons
  - Assumes all interested peers active at same time; performance deteriorates if swarm “cools off”
  - Even worse: no trackers for obscure content

- Recent studies by team at U. Washington found that many swarms “fail” because there are few changes for repeated interaction with the same peer
  - They suggest fixes, such as “one hop reputation” idea presented at NSDI 2008

Pros and cons of BitTorrent

- Dependence on centralized tracker: pro/con?
  - ☹ Single point of failure: New nodes can't enter swarm if tracker goes down
  - Lack of a search feature
    - ☺ Prevents pollution attacks
    - ☹ Users need to resort to out-of-band search: well known torrent-hosting sites / plain old web-search

Do Incentives Build Robustness in BitTorrent?



- Michael Piatek
  - Grad Student @ UW

- Tomas Isdal
  - Grad Student @ UW

- Tom Anderson
  - Prof @ UW. Author of Nacho's OS

- Arvind Krishnamurthy
  - Prof @ UW

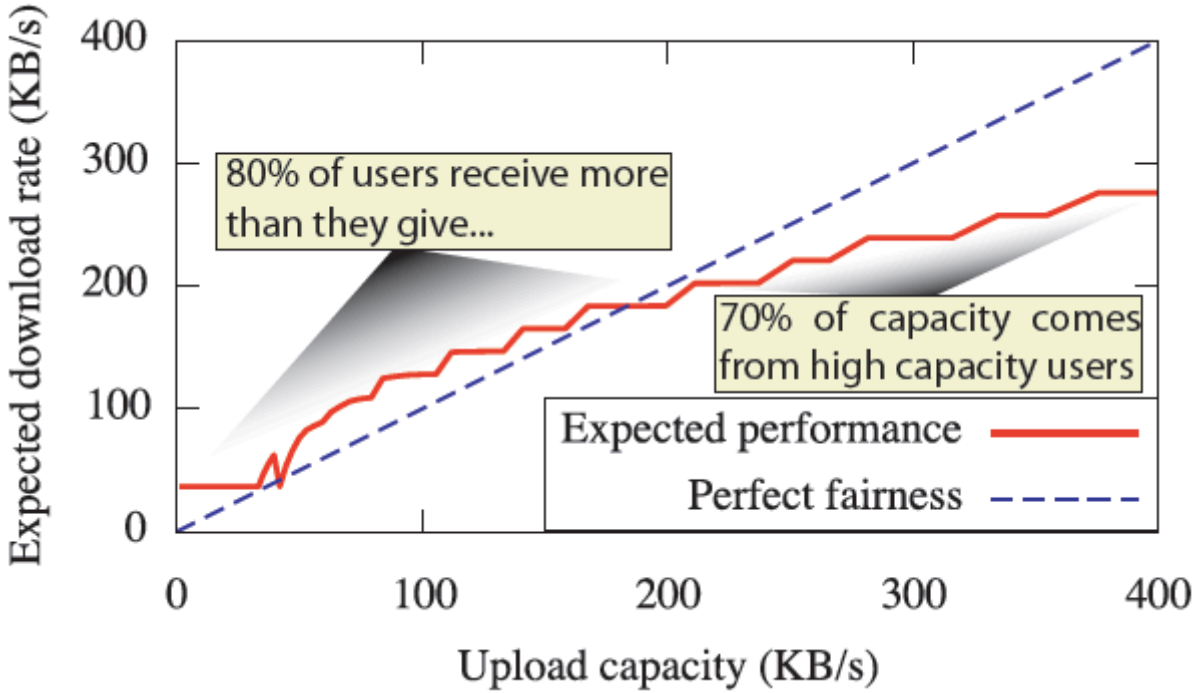
- Arun Venkataramani
  - Prof @ Umass Amerst.

BitTorrent

- BitTorrent is a protocol for bulk data transfer
- The more you give, the more you get
- Tit-for-tat
  - Not really

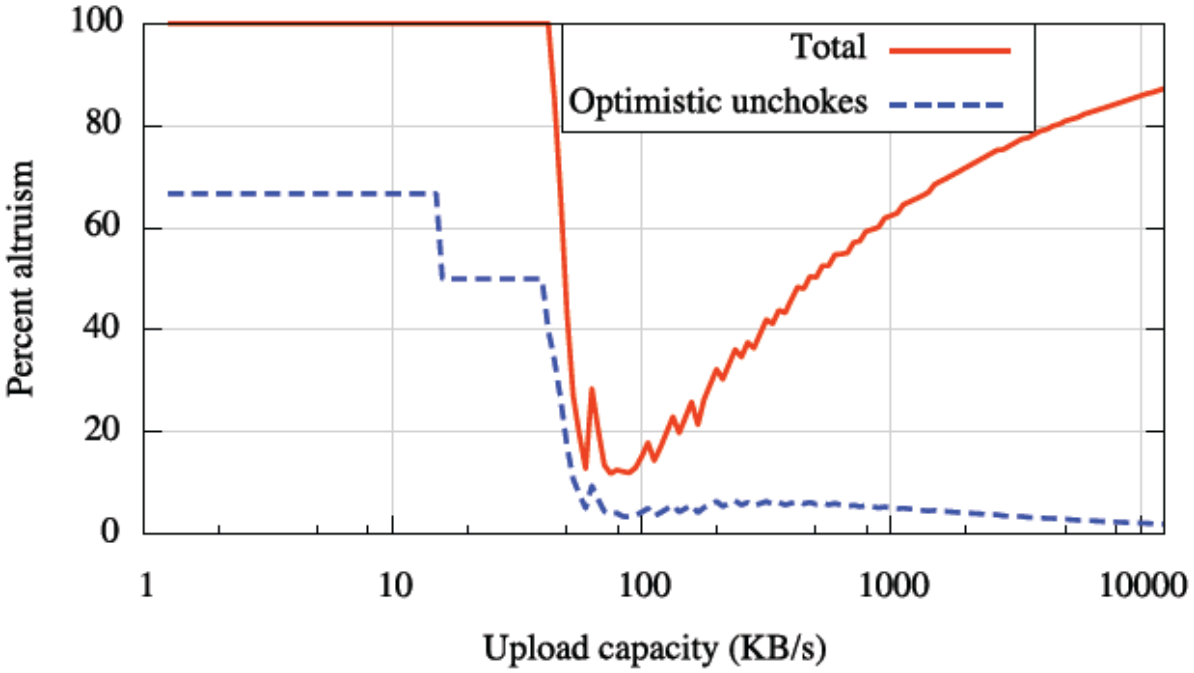
Altruism

- Not really TFT
  - 80% of users get more than they give
  - 70% of capacity comes from high capacity users



Altruism

- Not really TFT
  - 80% of users get more than they give
  - 70% of capacity comes from high capacity users
  - Not really a fair protocol
    - Operates based on altruism of high capacity users



Exploiting Altruism

- Selfish users
  - Rational
  - Want to cheat (as long as they won't get caught!)
  - Can download with many low-speed connections rather than 1 high-speed

Building BitTyrant

- Maximize reciprocation bandwidth per connection
  - Find peers that give the most for the least
- Maximize number of reciprocating peers
  - Get as many peers as possible
  - Until benefit of new peer is outweighed by cost of reduced reciprocation from other peers
- Deviate from equal
  - Decrease uploading on each connection
  - Until peer stops reciprocating

Results

- BitTyrant improves average download performance by 70%
- Regardless of capacity, using BitTyrant is in the selfish interest of every peer individually
- When all peers behave selfishly, average performance degrades for all peers, even those with high capacity

Take-away

- BitTorrent works because people use the default client
  - No cheating
- BitTyrant is now available in the wild
  - This is a test – Do incentives build robustness?
  - Maybe users will continue to donate excess bandwidth
  - Maybe users will be selfish
    - Proven to reduce overall capacity

BAR Gossip

Henry Li, Allen Clement, Edmund Wong, Jeff Napper, Indrajit Roy, *Lorenzo Alvisi*, and *Michael Dahlin*

BAR Model

- **B**yzantine (Arbitrary) Nodes
- **A**ltruistic (Generous) Nodes
- **R**ational (Selfish) Nodes

BAR Gossip Vision

- In presence of:
  - Selfish nodes
  - Byzantine nodes
- We want:
  - Predictable throughput
  - Low latency

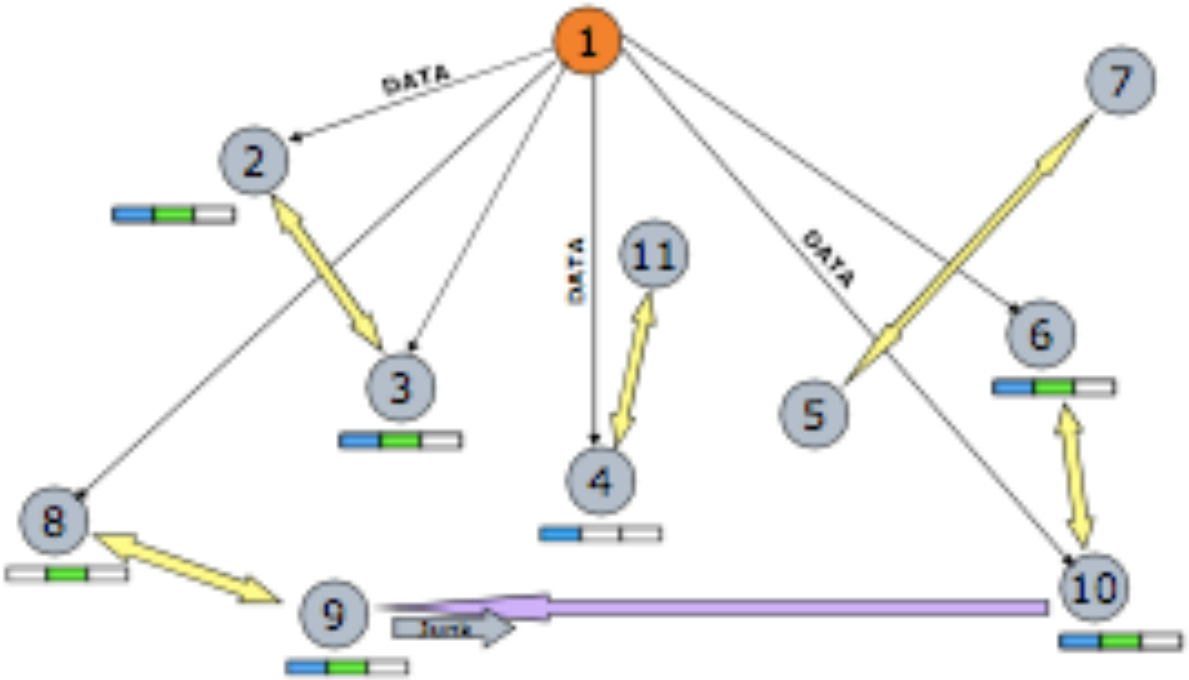
BAR Gossip Differences

- Data exchange in short periods
- No long-term reputation
- Exchanges small blocks of data
- Robust to both *Selfish* and *Byzantine* behavior

BAR Gossip Assumptions

- One data broadcaster
- Static Membership
- Reliable Cryptographic primitives (SHA1,RSA)
- Unique keys and signatures for nodes
- Synchronized Clocks

Overview



Core Idea

- Balanced Exchange
  - When a peer gives some data in exchange of some data. “Trade data for data.“
- Optimistic Push
  - Every peer will willingly help others by giving them data for free. Be a good person and give data for free.
- What about when I don’t have anything to trade off with, am I out of the game then ?

Take-away

- Current gossip protocols are ill-suited for selfish environments.
- Bar Gossip
  - Verifiable pseudo-randomness
  - Signatures
  - Balanced Exchange, achieves 98% reliability.
  - With Optimistic Push, increases to almost 99.9%

Next Time

- Final Presentations
  - ***Room 315*** (from 9am-1pm) *and 5126* (from 1pm-4pm)
  - 9am – 4:00pm, Thursday, December 2nd
  - 15 minute presentations, 5 minute questions
  - Signup for presentation slot
- Final paper
  - Due next Thursday, December 9th
  - Complete paper and comprehensive evaluation

- Thank you!