Lecture #24: Peer-to-Peer Networks and the Network Layer

COMS 4995-001:
The Science of Blockchains
URL: https://timroughgarden.org/s25/

Tim Roughgarden

Goals for Lecture #24

1. The Bitcoin network.
   – using a peer-to-peer network for the dissemination of txs and blocks
2. Ethereum and gossipsub.
   – post-merge ➔ how to organize communication between 1M+ validators?
3. Solana's Turbine.
   – how to disseminate a block as you're assembling it
4. Narwhal.
   – tx dissemination with data availability guarantees

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- network layer functionality implemented in clients
  – typically one dominant client/network (but can have multiple)

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- each node maintains two-way connections with small # of “peers”
  - e.g., connect to 8 random peers when joining the network
    - if nothing else, start from nodes hard-coded into client software
  - communicate only with peers, rely on multi-hop paths for all other nodes

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Terminology: Bitcoin has a “public mempool.”

- i.e., any node can keep track of pending txs (just join P2P network)
  - in particular, all miners will want to do this

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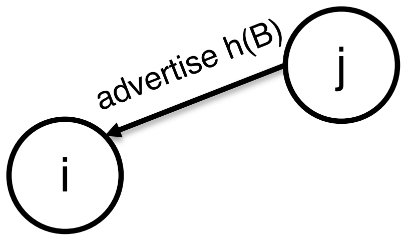

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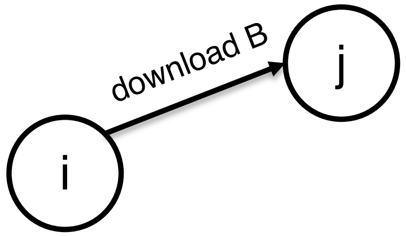

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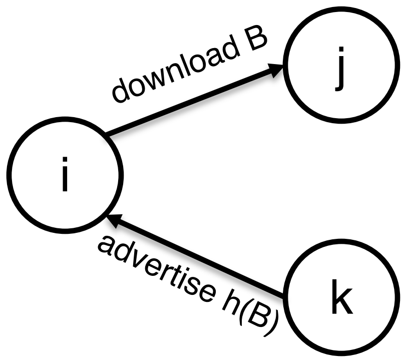

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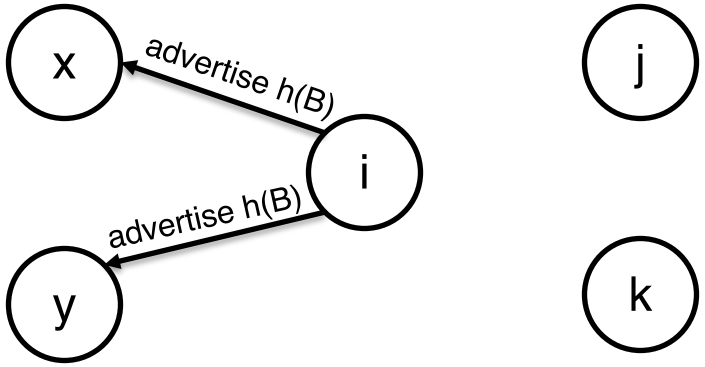

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Hope: tx/block reaches all n nodes in P2P network in ≈ log n hops.

- intuition: each hop should increase # of nodes reached by constant factor
- but no guarantee that P2P network is even connected!

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- each tx/block will be downloaded ≈ n times [good]
- each tx/block will be advertised ≈ m times [less good]
- another issue: propagation delay (in the seconds)
  - multiple hops, unrelated to underlying geography

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- replace “last mile” of flooding with “set reconciliation problem”
  - two peers identify + exchange set difference of what they’ve received

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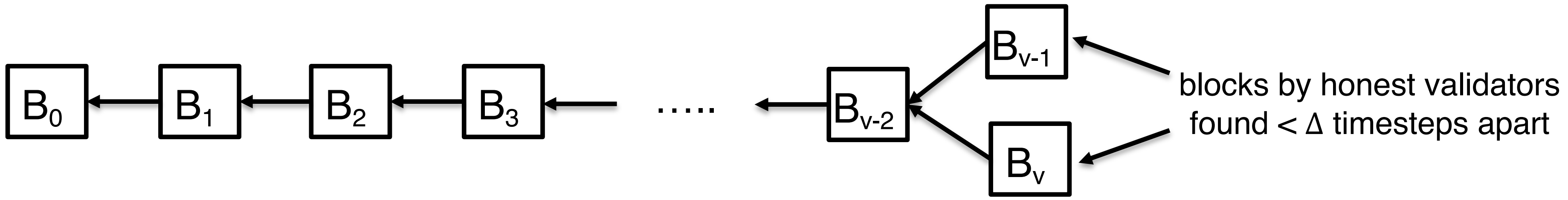
Overlay network: subset of P2P nodes maintain direct (and possibly very fast) connections with each other.

- used by large miners to avoid inadvertent forks:



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- note: not all peer misbehaviors are easily identified
  - e.g., skipping validity checks or advertising

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- source of challenge: Ethereum has > 1 million validators!

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  - currently ≈ 30K validators per slot, ≈ 500 members per committee

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- in gossipsub, use one topic per committee
  - publish attestations to that topic; sig aggregators subscribe to that topic

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  - issues: can be gamed, non-trivial barriers to becoming mesh peer

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- block dissemination done via "Turbine"
  - important component of Solana's performance

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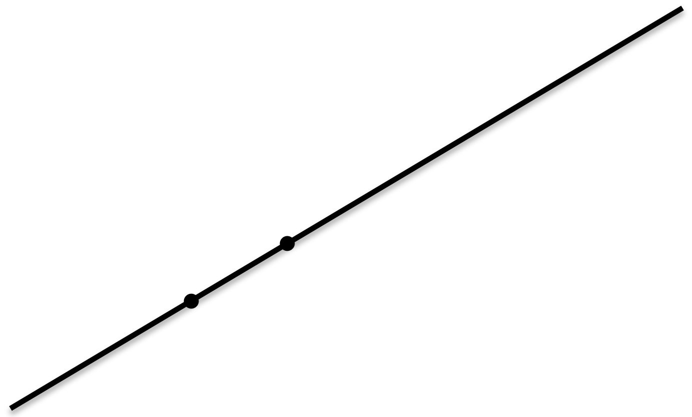

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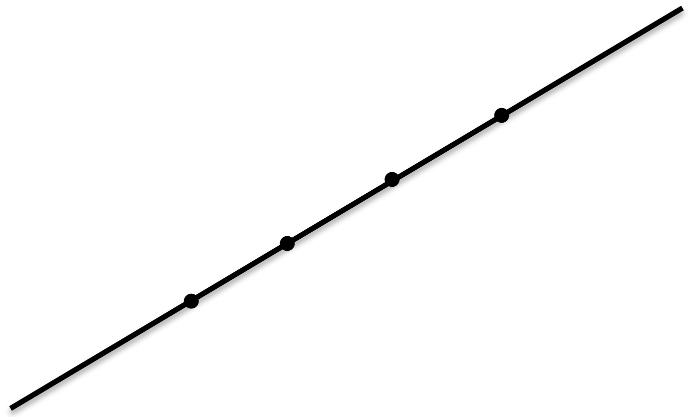

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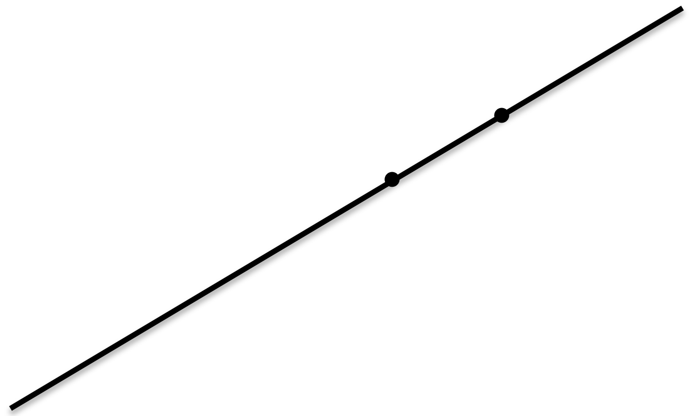
  - – if later remember only (3,14) and (4,19), can still recover line 5x-1



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- validators reconstruct block (or portion of block) from shreds, proceed to executing those txs

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- i sends (round-r) certificate for L_{ir} to all validators

Block proposing: pack block with certificates, not txs.

- < n/3 Byzantine validators ➔ data availability for all certificates
  - validators can download missing txs from other as needed