Reducing Round Complexity of Byzantine Broadcast

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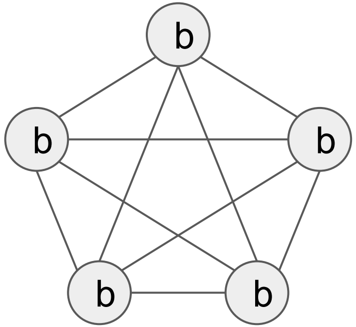
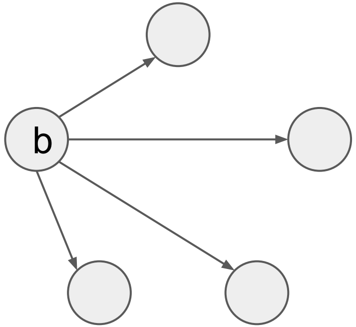
Byzantine Agreement and Broadcast

- **n** users, up to **f** are corrupted
- Honest users must agree

Byzantine Agreement

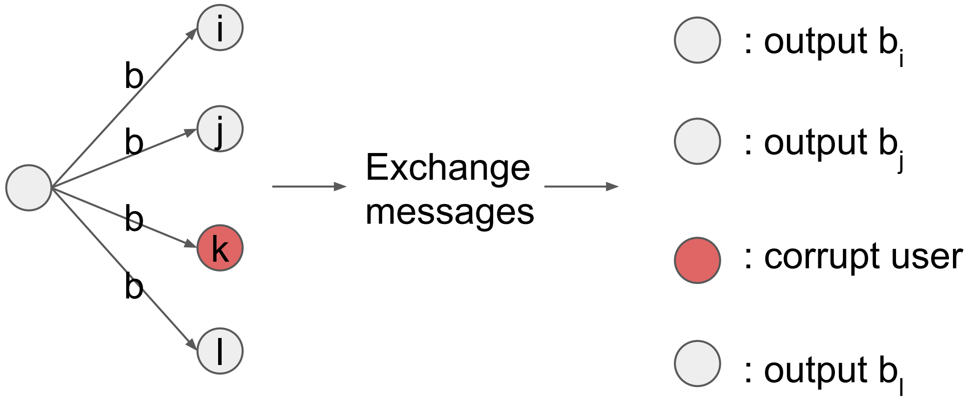


Byzantine Broadcast



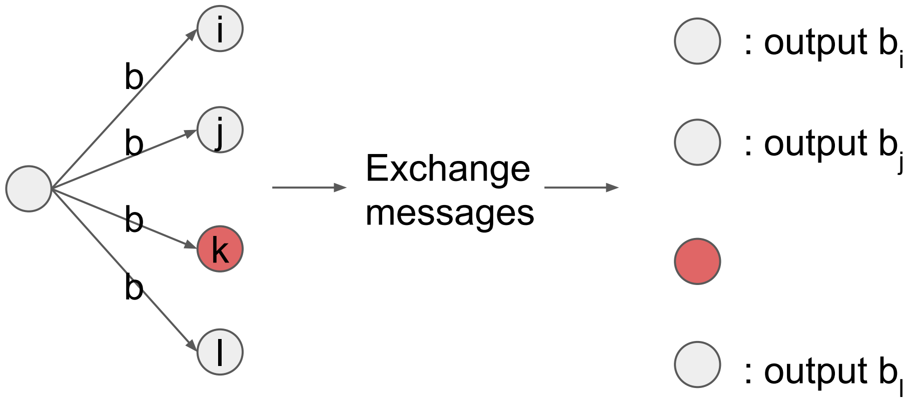
Properties of Byzantine Broadcast

At the end of the protocol, each user i **outputs** b_i



Consistency: all honest users agree

Properties of Byzantine Broadcast



Validity: if the leader is honest, all honest users output the leader's bit

Liveness: all honest users will eventually terminate

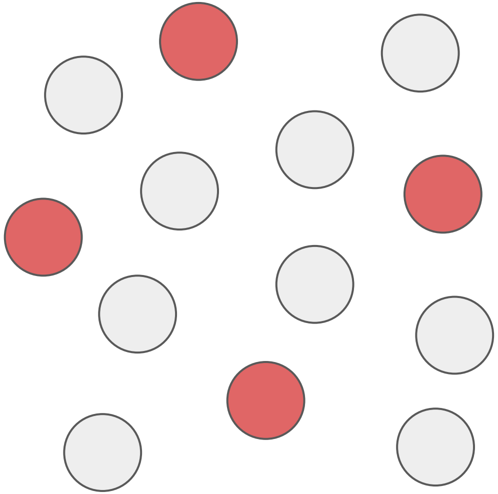
Assumptions

Synchronous: messages sent in round r are received before round r+1

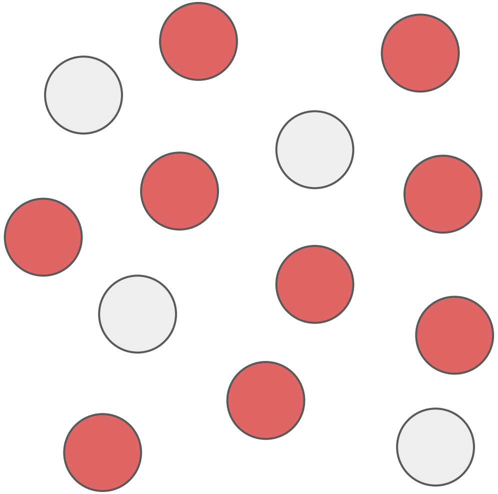
Digital signatures: each message is accompanied by a user’s signature

Honest or Dishonest Majority

Honest Majority (f < n/2)



Dishonest Majority (f > n/2)



Static or Adaptive Adversary

Static adversary: corrupts up to f users at the beginning of the protocol

Adaptive adversary: corrupts users in the middle of the protocol

- If a user is corrupted in round r, the adversary can inject, modify, or remove messages sent in round r
- Users that are corrupted stay corrupted

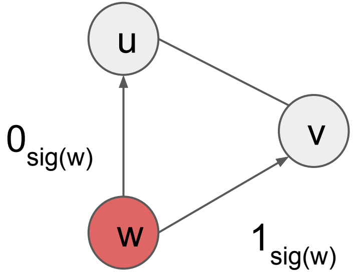
Expected Round Complexity Results

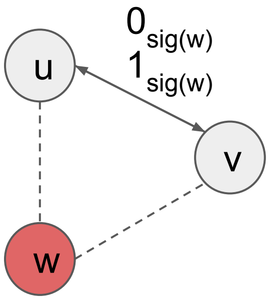
	Best Previous Result	**Our Result**
Honest Majority Static Adversary	10	8
Honest Majority Adaptive Adversary	16	10
Dishonest Majority	3d per epoch	3d-2 per epoch

- Communication complexity is $\tilde{O}(n^4)$; previous honest majority result is $O(n^2)$

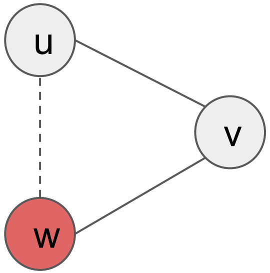
Attacks by Corrupt Users

1. w sends equivocating messages → u and v detect equivocation from w





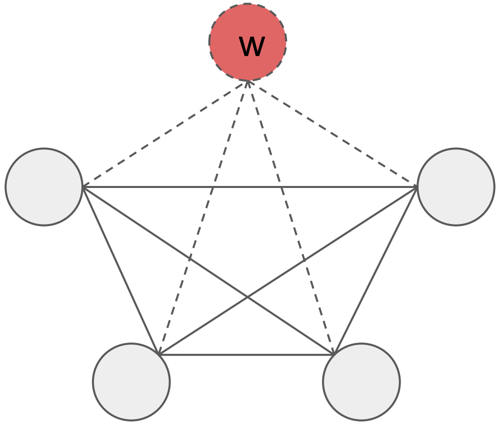
2. w does not send message to u → v knows at least one of u or w is corrupt



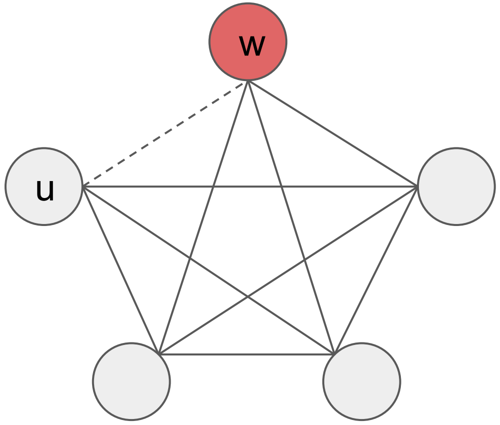
Previous work: Trust Graph

- n nodes, edge between nodes = trust
- Maximum diameter of $d = \lceil n/h \rceil + \lfloor n/h \rfloor - 1$

w sends equivocating messages:

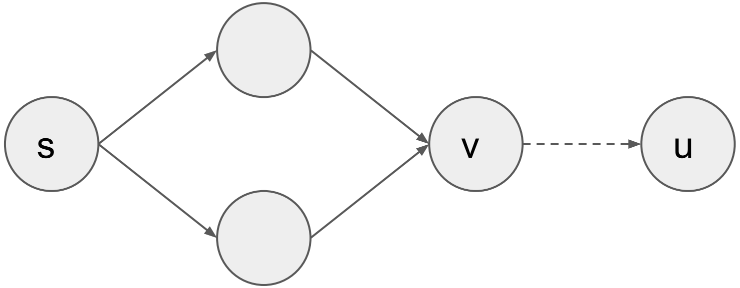


w does not send to u:



Previous work: TrustCast Protocol

- s wants to send a message to all users
- For every round $1 \leq r \leq d$:
    - If a user does not receive s' message, remove edges with all neighbors that are distance less than r from s



If u does not receive s' message in round 3, remove edge with v

Byzantine Broadcast Protocol

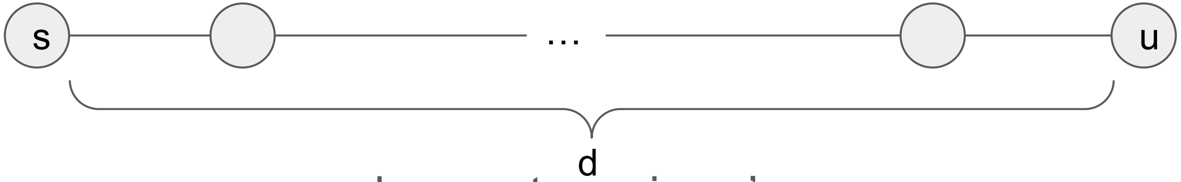
For each epoch:

- **Propose**: the leader TrustCasts its input bit to other users
- **Vote**: users TrustCast the leader’s proposal to other users
- **Commit**: if a user receives votes on the leader’s proposal from everyone in their trust graph, output the proposed bit and TrustCast a commit message to other users

Terminate: if a user receives commit messages from everyone in their trust graph, terminate

Reducing Round Complexity of TrustCast Protocol

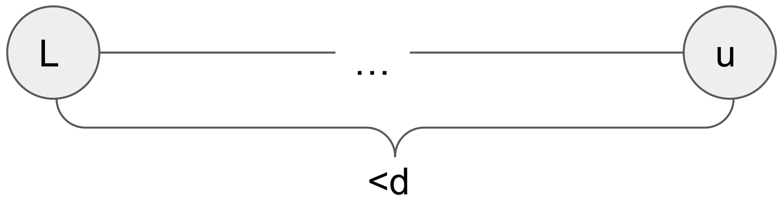
- **d rounds of TrustCast**: every user u either (1) received s' message or (2) s is removed from u's trust graph
- **d-1 rounds of TrustCast**: either (1), (2), or s is distance d from u in u's trust graph



u does not receive s' message

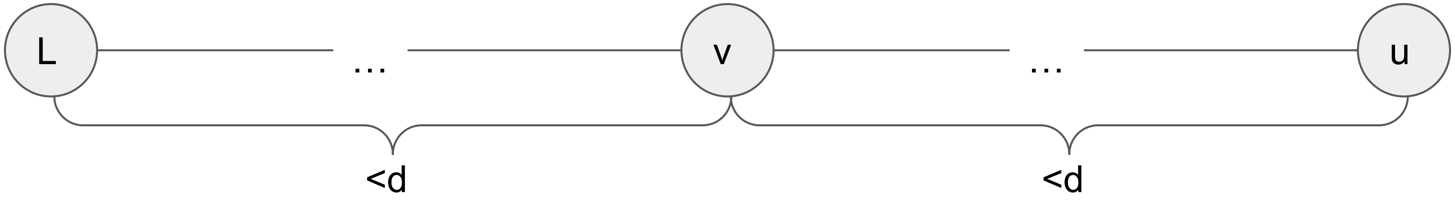
Reduced Round Complexity: Propose

- For Propose and Vote phases: use modified TrustCast protocol
- **Propose**: at least one honest user u receives proposal



Reduced Round Complexity: Vote

Vote: every honest user u receives a vote on the leader's proposal from at least one other honest user v



- If all honest users are distance d from u or distance d from L, then there needs to be more than n users

Dishonest Majority Round Complexity

- **Propose:** d-1 rounds
- **Vote:** d-1 rounds
- **Commit:** d rounds

3d-2 rounds per epoch

Honest Majority: Trust Array

- **Trust array**: u.A[v,w] = 1 (trust) or 0 (not trust)

1. w sends equivocating messages

    all users u set u.A[v,w] = 0 for all v

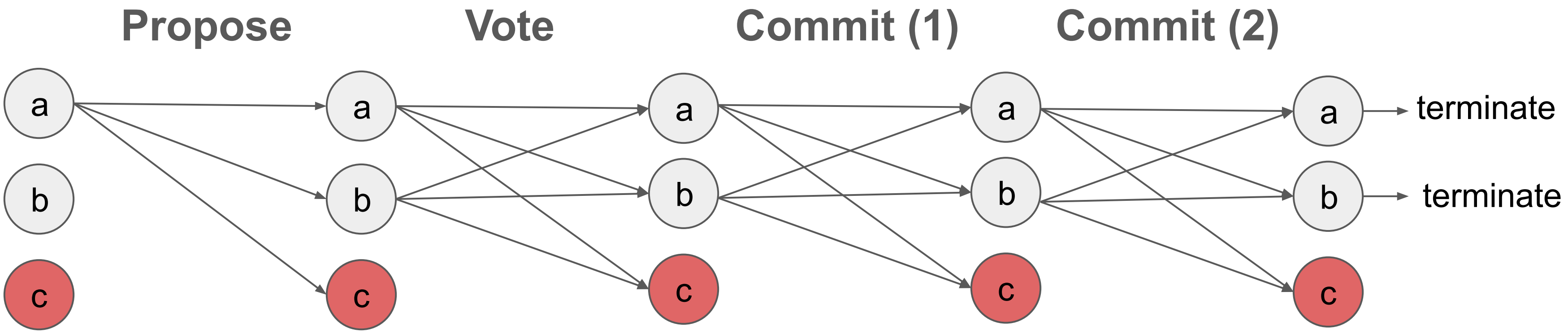
2. w does not send message to v

    all users u set u.A[v,w] = 0

Honest Majority Protocol

- $d = \lceil n/h \rceil + \lfloor n/h \rfloor - 1 = 2$
- Propose, Vote: d-1=1 round
- Commit: d=2 rounds
- **To send messages**: broadcast to all users
- **To commit**: u receives votes from all users v such that u.A[u,v] * u.A[v,L] = 1
- **To terminate**: u receives f+1 commit messages

Honest Majority Protocol



Honest Majority, Adaptive Adversary

Adaptive adversary repeatedly corrupts the leader

- Delay leader election

Adaptive adversary forges equivocating proposals after leader election

- **Propose round 1**: every user broadcasts a proposal
- **Propose round 2**: relay all proposals

Honest Majority Round Complexity

- If leader is honest, all users terminate in that epoch
- Expected 2 epochs

Static Adversary	4 rounds per epoch	Expected 8 rounds total
Adaptive Adversary	5 rounds per epoch	Expected 10 rounds total

Acknowledgments

- Mentor: Jun Wan
- MIT PRIMES program

Thank you!