Rewards under decoupled consensus



Rewards under decoupled consensus



- A proposal for rewards and penalties under Goldilocks.
- We start with incentives in today’s protocol, then turn to the new design.
- The aim is to reward useful participation while keeping the power of proposer and attester balanced.

Minority discouragement attacks on current consensus

- We want to address griefing.
  - Reduce competitors’ rewards more than your own to outcompete them.
    If some leave, equilibrium staking rewards may rise.

Minority discouragement attacks on current consensus

- We want to address griefing.
  - Reduce competitors' rewards more than your own to outcompete them.
    If some leave, equilibrium staking rewards may rise.
- Griefing factor: $G = \frac{\text{other validator's loss}}{\text{your loss}}$

Minority discouragement attacks on current consensus

- We want to address griefing.
  - Reduce competitors' rewards more than your own to outcompete them.
    If some leave, equilibrium staking rewards may rise.

- Griefing factor: $$G = \frac{\text{other validator's loss}}{\text{your loss}}$$

- Griefing ratio: $$g = \frac{\text{other validator's loss per ETH}}{\text{your loss per ETH}}$$

  - Relates losses to stake shares and helps assess the effect on equilibrium.
  - With 0.1% of stake each, you and your competitor both lose income.
    If $G = 10$, what does g tell us?

Minority discouragement attacks on current consensus

Red = attacker, green = victim

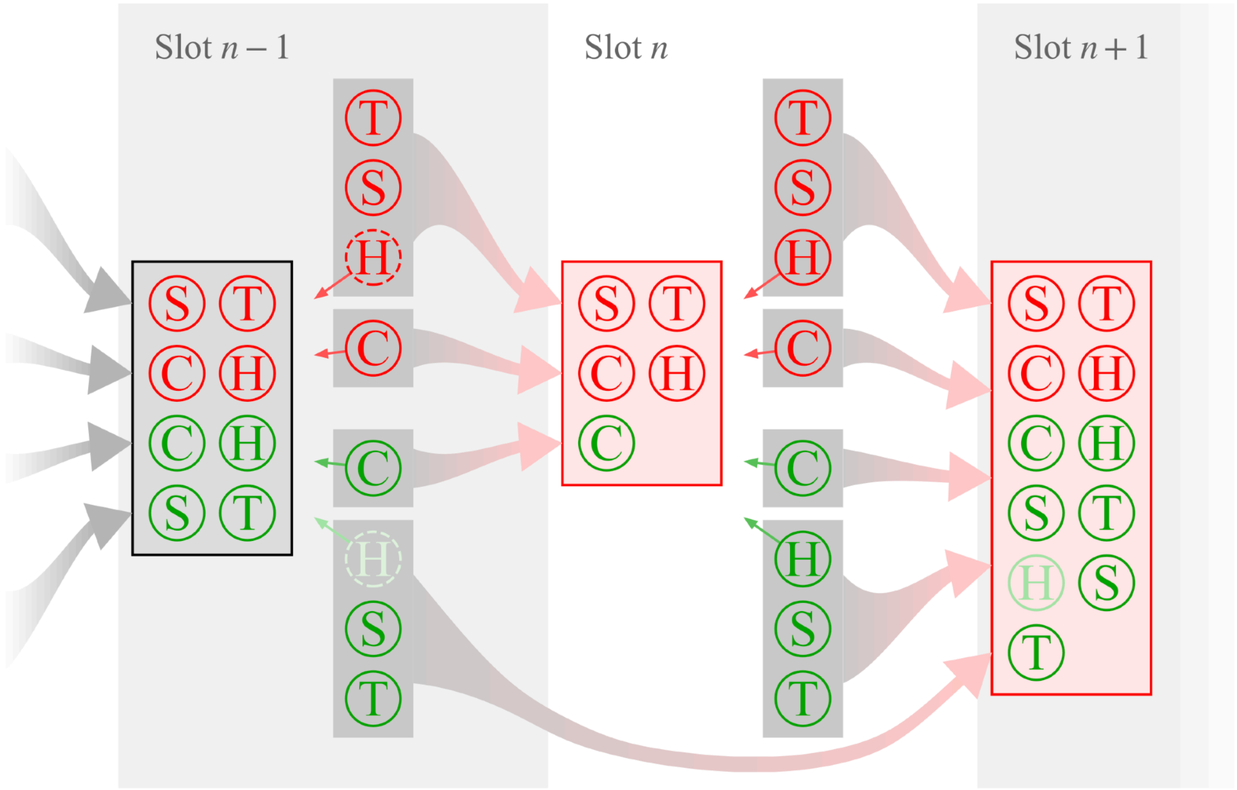
H = head, S = source, T = target, C = sync committee.

Omit attestation, then include in your own block

Dropped

Withheld

Reorg



$$G = \frac{\text{Attester head reward}}{\text{Proposer head share}} = \frac{14}{14 \div 7} = 7$$

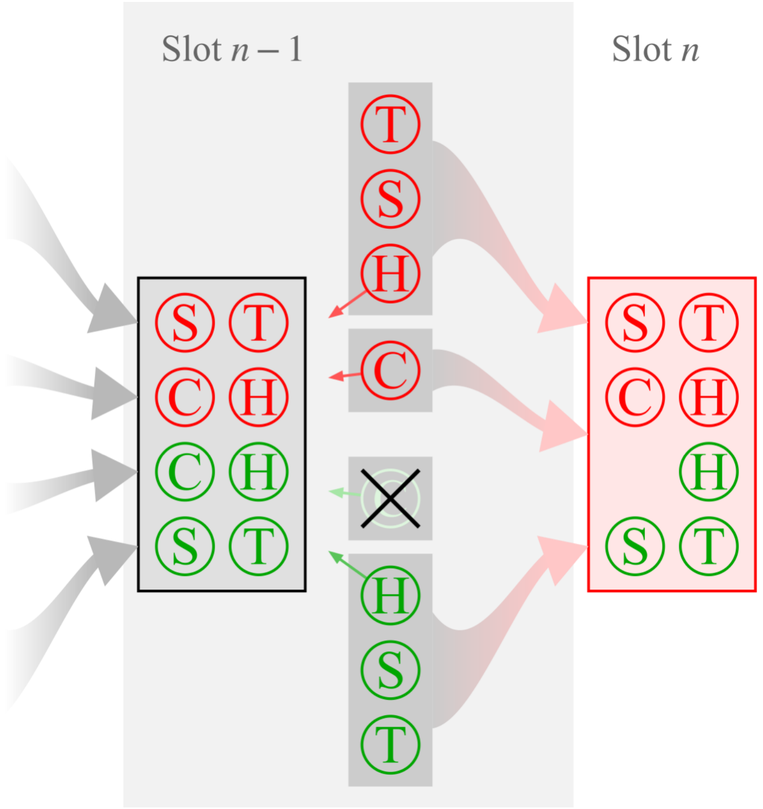
The proposer recovers its source and target shares, so only its head share is lost.

Omit a sync committee vote

Dropped

Withheld

Reorg



$$G = \frac{\text{Attester sync reward + sync penalty}}{\text{Proposer sync share}} = \frac{2 + 2}{2 \div 7} = 14$$

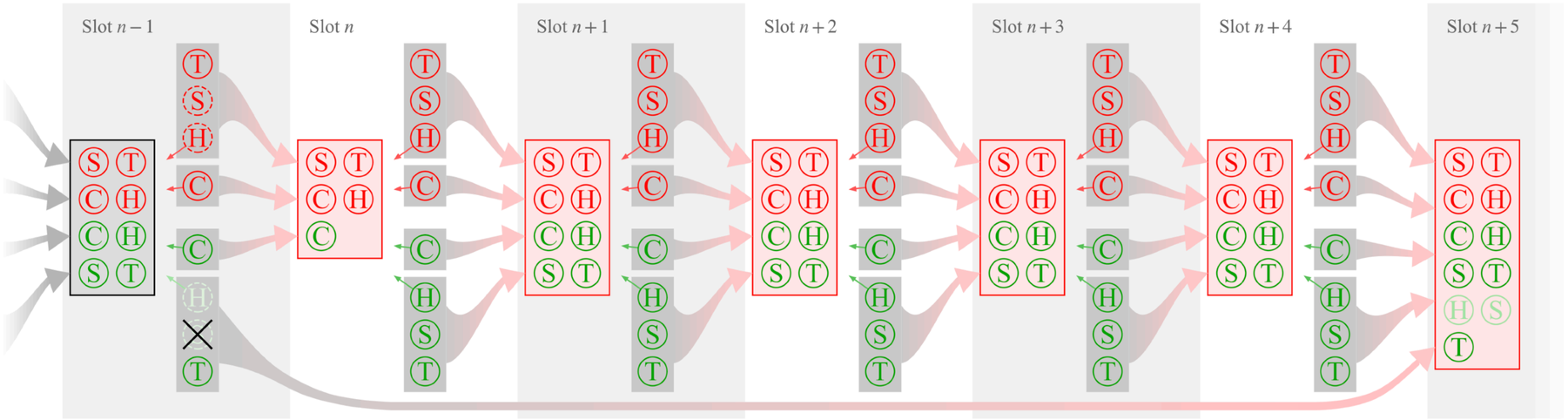
The attester loses its sync reward and pays an equal penalty.

Omit until the source reward expires

Dropped

Withheld

Reorg



$$G = \frac{\text{Attester head + source reward + source penalty}}{\text{Proposer head + source shares}} = \frac{14 + 14 + 14}{(14 + 14) \div 7} = 10.5$$

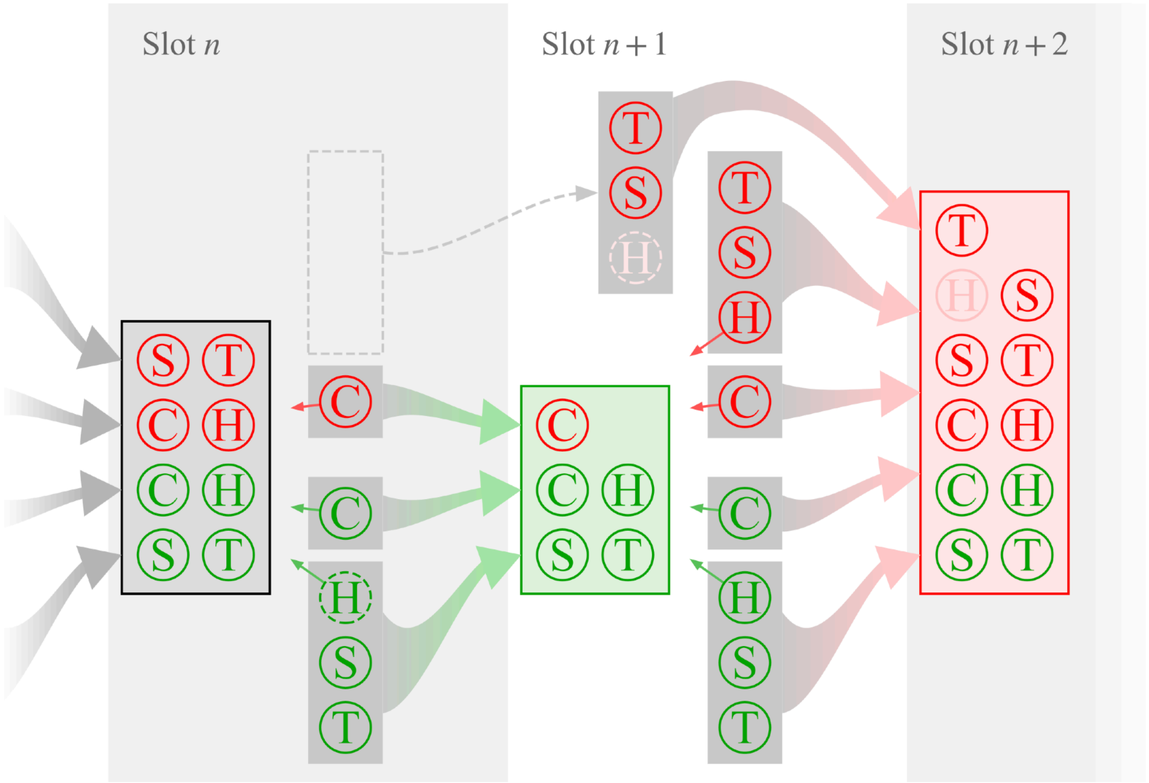
After six consecutive proposals, only the target inclusion share can be recovered.

Withhold for your own next proposal

Dropped

Withheld

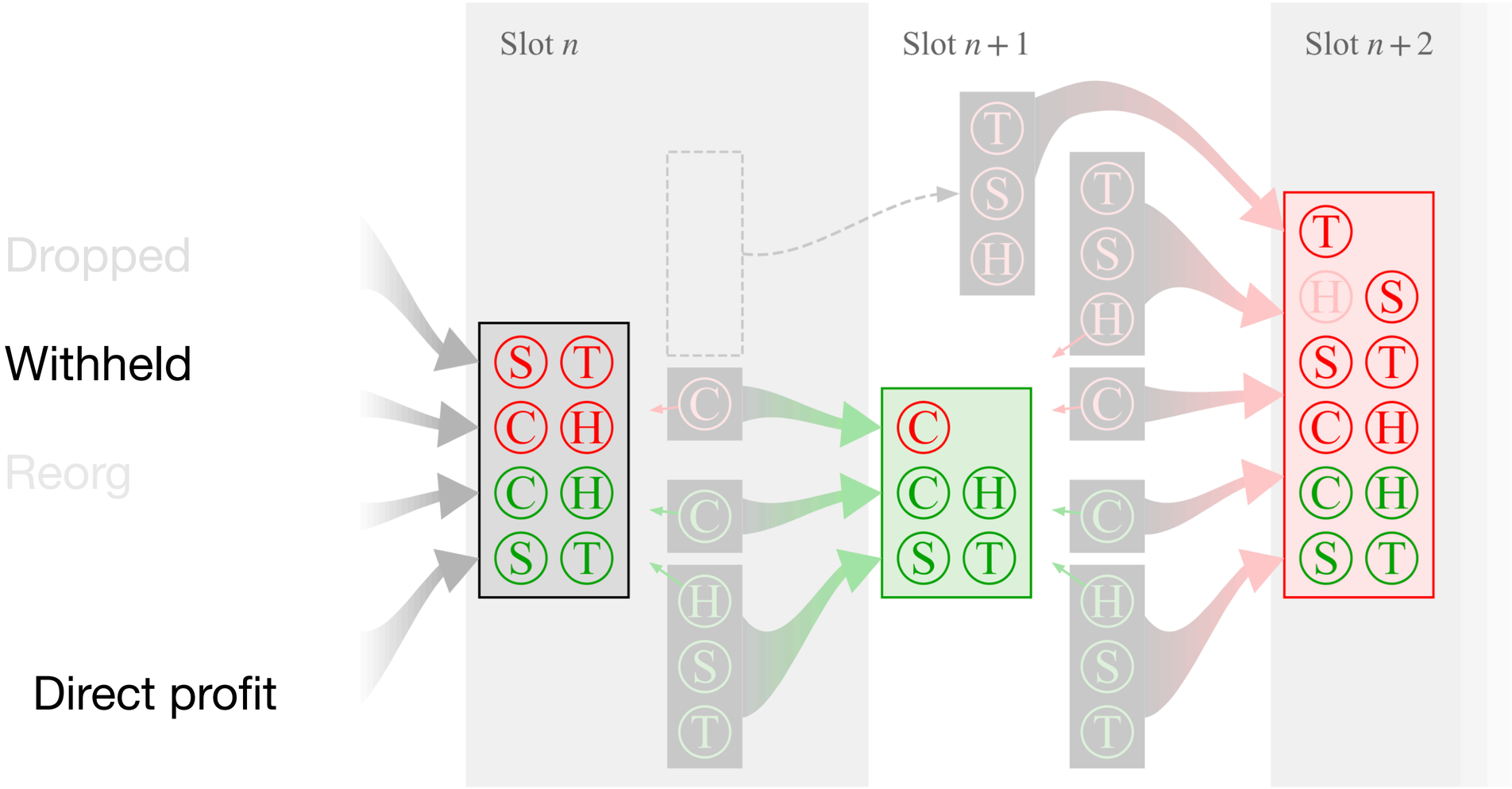
Reorg



$$G = \frac{\text{Proposer head + source + target shares}}{\text{Attester head reward} - \text{recovered proposer shares}} = \frac{14 + 14 + 26}{7 \times 14 - (14 + 26)} \approx 0.93$$

The attacker recovers the source and target proposer shares in its own next proposal.

Withholding during the inactivity leak



Attester rewards stop while inclusion rewards continue, making withholding profitable.

What did we learn?

- Preserve power balance between proposer and attesters!

What did we learn?

- Preserve power balance between proposer and attesters!
  - If we drop rewards for attesters (e.g., inactivity leak), we must drop rewards for proposers as well: otherwise we tilt the power balance.

What did we learn?

- Preserve power balance between proposer and attesters!
  - If we drop rewards for attesters (e.g., inactivity leak), we must drop rewards for proposers as well: otherwise we tilt the power balance.

- Coupling votes in an attestation makes selective attacks difficult.

What did we learn?

- Preserve power balance between proposer and attesters!
  - If we drop rewards for attesters (e.g., inactivity leak), we must drop rewards for proposers as well: otherwise we tilt the power balance.
- Coupling votes in an attestation makes selective attacks difficult.
- Attestation inclusion even after the first slot reduces the proposer's ability to grief: *reward decay is viable.*

What did we learn?

- Preserve power balance between proposer and attesters!
  - If we drop rewards for attesters (e.g., inactivity leak), we must drop rewards for proposers as well: otherwise we tilt the power balance.
- Coupling votes in an attestation makes selective attacks difficult.
- Attestation inclusion even after the first slot reduces the proposer's ability to grief: *reward decay is viable.*
- Adding penalties without rebalancing can make censorship more damaging.

Goldilocks: votes, slots and rounds

- The available chain (AC) uses a committee vote each slot (thus isolated).
  - Provides stabilization, replacing the separate stabilization gadget (SG) vote.

Goldilocks: votes, slots and rounds

- The available chain (AC) uses a committee vote each slot (thus isolated).
  - Provides stabilization, replacing the separate stabilization gadget (SG) vote.
- The finality attestation combines height and finalization votes (thus coupled, but both long-lived).

Goldilocks: votes, slots and rounds

- The available chain (AC) uses a committee vote each slot (thus isolated).
  - Provides stabilization, replacing the separate stabilization gadget (SG) vote.
- The finality attestation combines height and finalization votes (thus coupled, but both long-lived).
- The full validator set participates once per round (8 voting slots).

Goldilocks: votes, slots and rounds

- The available chain (AC) uses a committee vote each slot (thus isolated).
  - Provides stabilization, replacing the separate stabilization gadget (SG) vote.
- The finality attestation combines height and finalization votes (thus coupled, but both long-lived).
- The full validator set participates once per round (8 voting slots).
- Each validator must have an assigned slot (enforced).

Goldilocks: votes, slots and rounds

- The available chain (AC) uses a committee vote each slot (thus isolated).
  - Provides stabilization, replacing the separate stabilization gadget (SG) vote.
- The finality attestation combines height and finalization votes (thus coupled, but both long-lived).
- The full validator set participates once per round (8 voting slots).
- Each validator must have an assigned slot (enforced).
- During a stall, an earlier vote may already satisfy the duty.

Reward weights and decay

Vote	Attester	Proposer	Initial decay	Later decay	Proposer decay
AC head	6	4	1	—	—
Height	24	3	1/8	1/24	1/2
Finalization	24	3	1/8	1/24	1/2

- The weights sum to 64 (mimicing current spec), including 10 for proposers.
- Initial and later decay apply to attesters. Decay is the fraction lost each extra slot.

Reward weights and decay

Vote	Attester	Proposer	Initial decay	Later decay	Proposer decay
AC head	6	4	1	—	—
Height	24	3	1/8	1/24	1/2
Finalization	24	3	1/8	1/24	1/2

- The weights sum to 64 (mimicing current spec), including 10 for proposers.
- Initial and later decay apply to attesters. Decay is the fraction lost each extra slot.
- No penalties. Keeps the spec lean and protects solo stakers.

When does the reward start declining?

- Full rewards require inclusion in the slot after the assigned voting slot, allowing time for propagation and aggregation.

When does the reward start declining?

- Full rewards require inclusion in the slot after the assigned voting slot, allowing time for propagation and aggregation.
- Every subsequent slot counts as delay, including empty slots. Resending does not restore the full reward.

When does the reward start declining?

- Full rewards require inclusion in the slot after the assigned voting slot, allowing time for propagation and aggregation.
- Every subsequent slot counts as delay, including empty slots. Resending does not restore the full reward.
- The network should not forward votes before their assigned slot, and early inclusion should not earn rewards.

When does the reward start declining?

- Full rewards require inclusion in the slot after the assigned voting slot, allowing time for propagation and aggregation.
- Every subsequent slot counts as delay, including empty slots. Resending does not restore the full reward.
- The network should not forward votes before their assigned slot, and early inclusion should not earn rewards.
- The first assigned inclusion slot must be identifiable. This remains an assumption, since the vote contains no round number.

Proposer in several slots and omits attestations

Extra slots	**Attester**	**Proposer**	$G = \dfrac{\text{Attester reward lost}}{\text{Proposer share lost}}$
0	48	6	—

Proposer in several slots and omits attestations

Extra slots	Attester	Proposer	$G = \frac{\text{Attester reward lost}}{\text{Proposer share lost}}$
0	48	6	—
1	42	3	$G = \frac{48 - 42}{6 - 3} = 2.00$

Proposer in several slots and omits attestations

Extra slots	**Attester**	**Proposer**	$G = \dfrac{\text{Attester reward lost}}{\text{Proposer share lost}}$
0	48	6	—
1	42	3	$G = \dfrac{48 - 42}{6 - 3} = 2.00$
2	40.25	1.5	$G = \dfrac{48 - 40.25}{6 - 1.5} \approx 1.72$

Proposer in several slots and omits attestations

Extra slots	Attester	Proposer	$G = \frac{\text{Attester reward lost}}{\text{Proposer share lost}}$
0	48	6	—
1	42	3	$G = \frac{48 - 42}{6 - 3} = 2.00$
2	40.25	1.5	$G = \frac{48 - 40.25}{6 - 1.5} \approx 1.72$
3	38.57	0.75	$G = \frac{48 - 38.57}{6 - 0.75} \approx 1.80$

Proposer in several slots and omits attestations

Extra slots	Attester	Proposer	$G = \frac{\text{Attester reward lost}}{\text{Proposer share lost}}$
0	48	6	—
1	42	3	$G = \frac{48 - 42}{6 - 3} = 2.00$
2	40.25	1.5	$G = \frac{48 - 40.25}{6 - 1.5} \approx 1.72$
3	38.57	0.75	$G = \frac{48 - 38.57}{6 - 0.75} \approx 1.80$

- Initial decay discourages withholding. Gentler later decay limits repeated omission.

Proposer in several slots and omits attestations

Extra slots	Attester	Proposer	$G = \frac{\text{Attester reward lost}}{\text{Proposer share lost}}$
0	48	6	—
1	42	3	$G = \frac{48 - 42}{6 - 3} = 2.00$
2	40.25	1.5	$G = \frac{48 - 40.25}{6 - 1.5} \approx 1.72$
3	38.57	0.75	$G = \frac{48 - 38.57}{6 - 0.75} \approx 1.80$

- Initial decay discourages withholding. Gentler later decay limits repeated omission.
- Proposer rewards fall faster, reducing what a later proposal recovers.

Attester withholding

- Attester instead withholds, then proposes.

Attester withholding

- Attester instead withholds, then proposes.

$$G = \frac{\text{Initial proposer share}}{\text{Attester reward lost} - \text{recovered proposer share}}$$

Attester withholding

- Attester instead withholds, then proposes.

$$G = \frac{\text{Initial proposer share}}{\text{Attester reward lost} - \text{recovered proposer share}} = \frac{6}{(48 - 42) - 3} = 2$$

Griefing factors under the proposal

Vote	O-I	O-P	O-O-P	O-O-O-P	W-I	W-P
AC	1.50	1.50	1.50	1.50	0.67	0.67

- In the table, O means omit and W means withhold. P is a later own proposal and I an independent proposal.

Griefing factors under the proposal

Vote	O-I	O-P	O-O-P	O-O-O-P	W-I	W-P
AC	1.50	1.50	1.50	1.50	0.67	0.67
Finality	1.00	2.00	1.72	1.80	1.00	2.00

- In the table, O means omit and W means withhold. P is a later own proposal and I an independent proposal.

What earns an AC reward?

- An AC vote is useful for one slot, so rewards require inclusion in the next slot.



What earns an AC reward?

- An AC vote is useful for one slot, so rewards require inclusion in the next slot.
- The baseline attester reward depends on the correct head. The proposer earns rewards for valid votes regardless of which block they support.

What earns an AC reward?

- An AC vote is useful for one slot, so rewards require inclusion in the next slot.
- The baseline attester reward depends on the correct head. The proposer earns rewards for valid votes regardless of which block they support.
- Honest views can differ, and the head condition may encourage waiting.

What earns an AC reward?

- An AC vote is useful for one slot, so rewards require inclusion in the next slot.
- The baseline attester reward depends on the correct head. The proposer earns rewards for valid votes regardless of which block they support.
- Honest views can differ, and the head condition may encourage waiting.
- A smaller participation payment could soften this, while also paying unhelpful votes.

What earns an AC reward?

- An AC vote is useful for one slot, so rewards require inclusion in the next slot.
- The baseline attester reward depends on the correct head. The proposer earns rewards for valid votes regardless of which block they support.
- Honest views can differ, and the head condition may encourage waiting.
- A smaller participation payment could soften this, while also paying unhelpful votes.
- Omitting both AC reward shares is a more drastic alternative. AC participation also enables finality progress.

What earns an AC reward?

- An AC vote is useful for one slot, so rewards require inclusion in the next slot.
- The baseline attester reward depends on the correct head. The proposer earns rewards for valid votes regardless of which block they support.
- Honest views can differ, and the head condition may encourage waiting.
- A smaller participation payment could soften this, while also paying unhelpful votes.
- Omitting both AC reward shares is a more drastic alternative. AC participation also enables finality progress.
- Does the lock functionality benefit from any additional incentives?

Reward eligibility must survive the quorum

- Votes beyond the first two-thirds should still earn rewards.

Reward eligibility must survive the quorum

- Votes beyond the first two-thirds should still earn rewards.
- Completing a height or finalization must not abruptly end that eligibility.

Reward eligibility must survive the quorum

- Votes beyond the first two-thirds should still earn rewards.
- Completing a height or finalization must not abruptly end that eligibility.
- Retain reward history and accept older votes for rewards even when their completed components no longer affect consensus.

Reward eligibility must survive the quorum

- Votes beyond the first two-thirds should still earn rewards.
- Completing a height or finalization must not abruptly end that eligibility.
- Retain reward history and accept older votes for rewards even when their completed components no longer affect consensus.
- If omission destroys all rewards, the attester loses 48 and the proposer loses 6.

$$G = \frac{\text{Attester height + finalization rewards}}{\text{Proposer height + finalization shares}} = \frac{24 + 24}{3 + 3} = 8$$

Rewards while a height is stalled

- Recorded useful votes could keep earning each round while the same duty remains pending, without another message.

Rewards while a height is stalled

- Recorded useful votes could keep earning each round while the same duty remains pending, without another message.
- The proposer following the assigned slot then receives its share each round too(?)

Rewards while a height is stalled

- Recorded useful votes could keep earning each round while the same duty remains pending, without another message.
- The proposer following the assigned slot then receives its share each round too(?)
- Late inclusion could earn outstanding rewards, with decay from each round’s first inclusion slot and each component paid once per round.

Participation scaling of reward

- Can start from existing functionality.

Participation scaling of reward

- Can start from existing functionality.
- But apply to both attester and proposer (invariance).

Participation scaling of reward

- Can start from existing functionality.
- But apply to both attester and proposer (invariance).
- For finality, measure each component through the end of the following round and pay both rewards then.

Participation scaling of reward

- Can start from existing functionality.
- But apply to both attester and proposer (invariance).
- For finality, measure each component through the end of the following round and pay both rewards then.
- Still later payments use that factor, without revising earlier payments.

Participation scaling of reward

- Can start from existing functionality.
- But apply to both attester and proposer (invariance).
- For finality, measure each component through the end of the following round and pay both rewards then.
- Still later payments use that factor, without revising earlier payments.
- The AC factor counts valid votes regardless of which block they support..?

Participation scaling of reward

- Can start from existing functionality.
- But apply to both attester and proposer (invariance).
- For finality, measure each component through the end of the following round and pay both rewards then.
- Still later payments use that factor, without revising earlier payments.
- The AC factor counts valid votes regardless of which block they support..?
- Remove participation scaling?

  + Simplicity, ETH value as participation scaling

  - Removing a direct incentive to get along

Inactivity leak

- The leak restores finality when inactive stake prevents a quorum.

Inactivity leak

- The leak restores finality when inactive stake prevents a quorum.
- Keep the familiar inactivity leak for simplicity, with only the necessary changes?

Inactivity leak

- The leak restores finality when inactive stake prevents a quorum.
- Keep the familiar inactivity leak for simplicity, with only the necessary changes?
  - Continue both reward shares, with the same scaling and decay, so publishing promptly remains worthwhile.

Inactivity leak

- The leak restores finality when inactive stake prevents a quorum.
- Keep the familiar inactivity leak for simplicity, with only the necessary changes?
  - Continue both reward shares, with the same scaling and decay, so publishing promptly remains worthwhile.
- Count the height and finalization votes a validator could and should send. An earlier vote may still count during a stall.

Inactivity leak

- The leak restores finality when inactive stake prevents a quorum.
- Keep the familiar inactivity leak for simplicity, with only the necessary changes?
  - Continue both reward shares, with the same scaling and decay, so publishing promptly remains worthwhile.
- Count the height and finalization votes a validator could and should send. An earlier vote may still count during a stall.
- Move accounting to rounds and adjust the grace period, scores and penalty rate to preserve the leak’s pace.

Inactivity leak

- The leak restores finality when inactive stake prevents a quorum.
- Keep the familiar inactivity leak for simplicity, with only the necessary changes?
  - Continue both reward shares, with the same scaling and decay, so publishing promptly remains worthwhile.
- Count the height and finalization votes a validator could and should send. An earlier vote may still count during a stall.
- Move accounting to rounds and adjust the grace period, scores and penalty rate to preserve the leak’s pace.
- Proposers do not pay for offline attesters. Censorship can still impose large losses on someone with a high inactivity score.

Open questions

- Could part of the leak become an inactivity purge?

Open questions

- Could part of the leak become an inactivity purge?
  - Remove inactive voting weight without destroying principal.

Open questions

- Could part of the leak become an inactivity purge?
  - Remove inactive voting weight without destroying principal.
  - Retain slashability and delay re-entry. Lost staking income still affects incentives.

Open questions

- Could part of the leak become an inactivity purge?
  - Remove inactive voting weight without destroying principal.
  - Retain slashability and delay re-entry. Lost staking income still affects incentives.

- How should timeouts be rewarded?

Open questions

- Could part of the leak become an inactivity purge?
  - Remove inactive voting weight without destroying principal.
  - Retain slashability and delay re-entry. Lost staking income still affects incentives.

- How should timeouts be rewarded?
  - Can help recovery. Consider a small height reward, or none.

Open questions

- Could part of the leak become an inactivity purge?
  - Remove inactive voting weight without destroying principal.
  - Retain slashability and delay re-entry. Lost staking income still affects incentives.

- How should timeouts be rewarded?
  - Can help recovery. Consider a small height reward, or none.
  - Small timeout reward -> applies to both attester and proposer

Open questions

- Could part of the leak become an inactivity purge?
  - Remove inactive voting weight without destroying principal.
  - Retain slashability and delay re-entry. Lost staking income still affects incentives.

- How should timeouts be rewarded?
  - Can help recovery. Consider a small height reward, or none.
  - Small timeout reward -> applies to both attester and proposer

- Should attestation rewards eventually expire?

Open questions

- Could part of the leak become an inactivity purge?
  - Remove inactive voting weight without destroying principal.
  - Retain slashability and delay re-entry. Lost staking income still affects incentives.

- How should timeouts be rewarded?
  - Can help recovery. Consider a small height reward, or none.
  - Small timeout reward -> applies to both attester and proposer

- Should attestation rewards eventually expire?
  - A cutoff limits record keeping but can increase the loss from censorship.

Open questions

- Could part of the leak become an inactivity purge?
  - Remove inactive voting weight without destroying principal.
  - Retain slashability and delay re-entry. Lost staking income still affects incentives.

- How should timeouts be rewarded?
  - Can help recovery. Consider a small height reward, or none.
  - Small timeout reward -> applies to both attester and proposer

- Should attestation rewards eventually expire?
  - A cutoff limits record keeping but can increase the loss from censorship.
  - Votes may remain useful for consensus after their reward expires.