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# Algorithm for Cross-shard Cross-EE Atomic User-level ETH Transfer in Ethereum

Crosschain Workshop 2021

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# Background

# Ethereum 2

- 64 shards
    - Node space and Users-space are partitioned
- Execution Environments (EEs)
    - Many

# System Events

Peter Robinson, 14 Mar 2020 ethresear.ch

- Similar to events in contracts, which is at application level
- Unforgeability - using Merkle Proof on it

# Netted Balance Approach for EE level Transfers

Vitalik Buterin, 30 Dec 2019 ethresear.ch

- Distribute EE balance on shards
- Globally, for every EE, maintain a matrix
- A row in every shard
- Real balance on a shard
- Add up that column

| | A | B | C |
|---|---|---|---|
| A | 5 | 10 | 0 |
| B | 20 | -5 | 4 |
| C | 1 | 3 | 5 |

| Real | 26 | 8 | 9 |
|---|---|---|---|

# (shard1, EE1) -- X ETH → (shard2, EE2)

- Check realBalance of EE1 on shard1 > X
  - Needs Merkle proofs from all the other 63 shards
- Update locally on the source shard

EE1

| shard1 | shard2 | shard3 |
| --- | --- | --- |
| a1 | a2 | a3 |

| a1-X | a2 | a3 |
| --- | --- | --- |

EE2

| shard1 | shard2 | shard3 |
| --- | --- | --- |
| b1 | b2 | b3 |

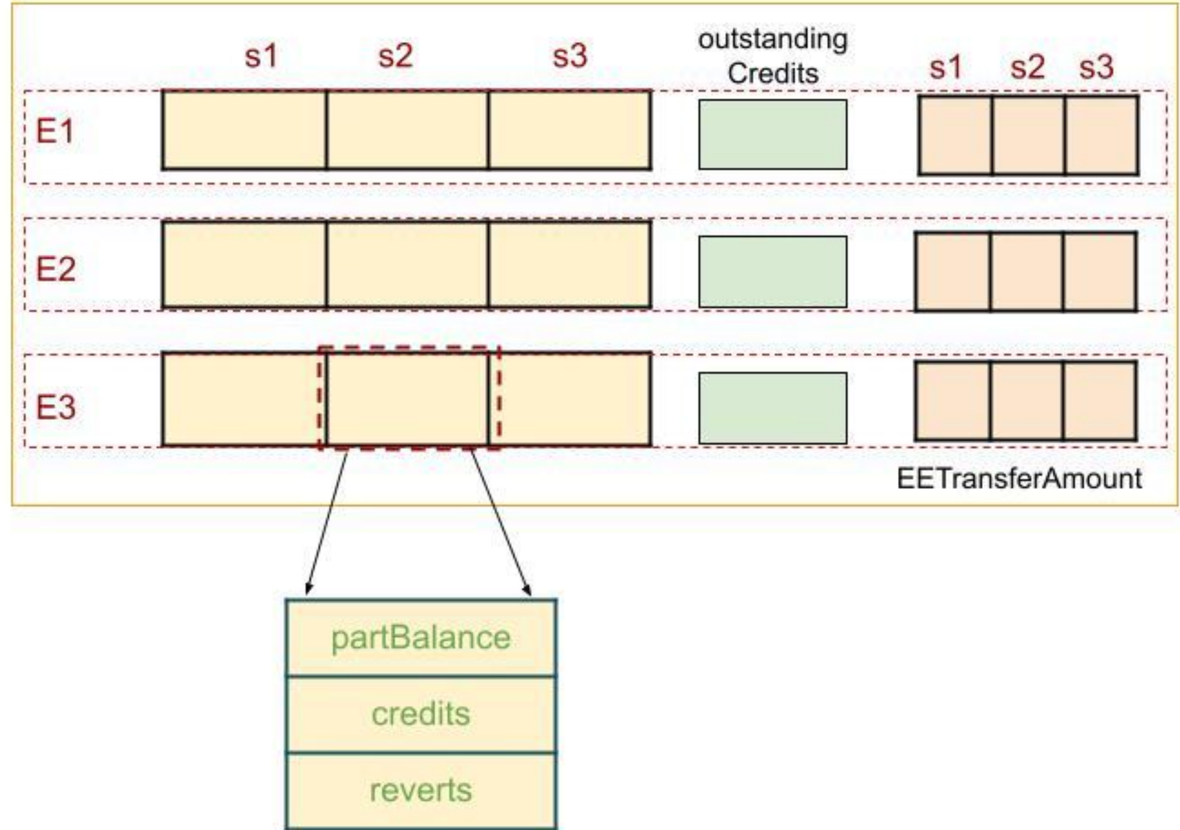
| b1 | b2+X | b3 |
| --- | --- | --- |

# Atomic Asynchronous Cross-shard User-level Transfers

# Core Ideas

- Use the netted shard state to communicate outstanding credits and outstanding reverts
- Make reverts as enshrined EE host functions instead of user transactions avoiding unnecessary gas expense

# Shard State



# Transactions

- Cross-shard debit transfer
  - Signed by the sender. Signature is stored in the fields $v$, $r$ and $s$.
  - $a_i \overset{x_i}{\Longrightarrow} b_i$, cross-shard transfer of $x_i$ ETH from the user $a_i$ on $(s_1, E_1)$ to the user $b_i$ on $(s_2, E_2)$.
  - Submitted on sender shard.
  - Contains a unique transaction identifier.
  - Emits a **ToCredit** System event on success, which includes the block number and an index number
- Cross-shard credit transfer
  - $a_i \xrightarrow{x_i} b_i$, credit transfer of $x_i$ ETH to $b_i$ on $(s_2, E_2)$, which is from $a_i$ on $(s_1, E_1)$.
  - Submitted on recipient shard.
  - Includes the **ToCredit** System Event and the Merkle Proof for it.

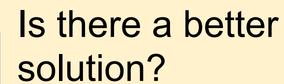
# Block Proposer (BP) Algorithm Sketch

1. Select cross-shard transactions: debit / credit
2. Process each transactions
   a. If debit is success
      i. Emit ToCredit System Event
      ii. Do User-level Debit
      iii. Add credit info to shared state
      iv. Record EE-transfer amount
   b. If credit
      i. Success ⇒ Do User-level Credit
      ii. Fail ⇒ add revert info to shared state, record EE-transfer amount
3. Complete EE-level transfer

# Corner case

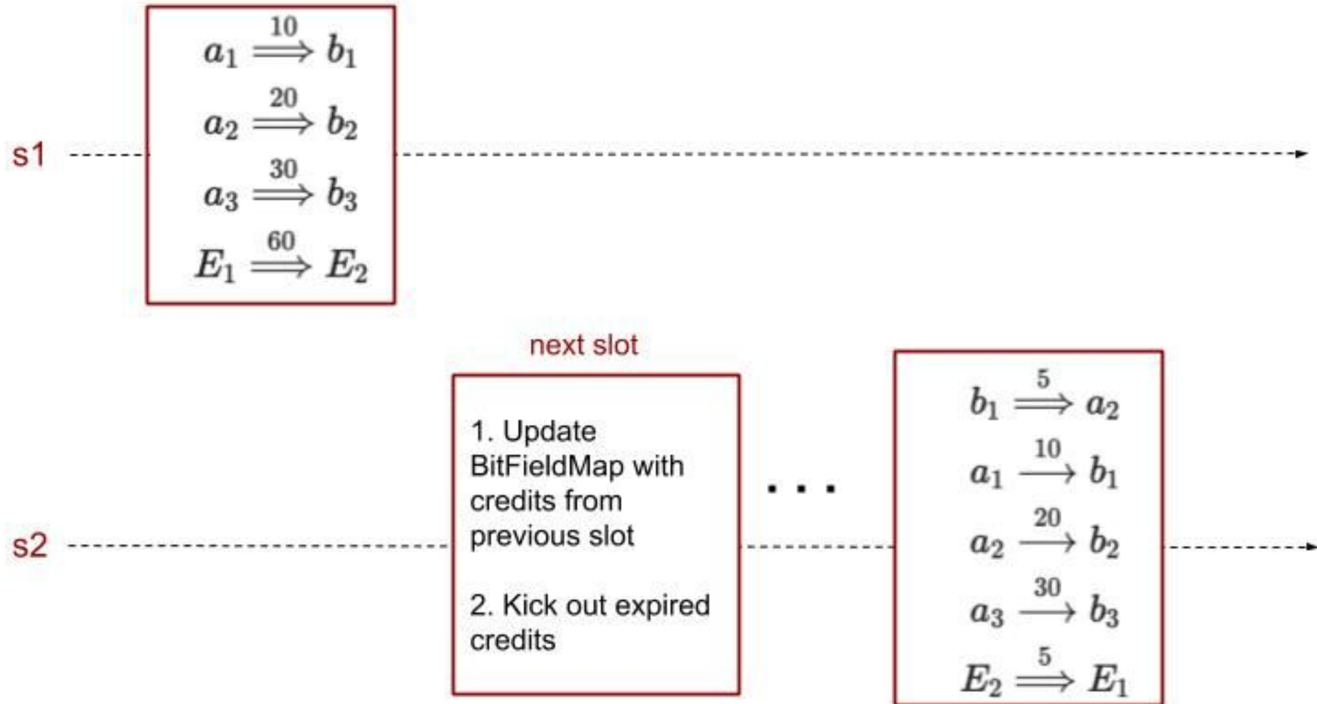
Sender disappears by the time revert happens.

We end up in a state where there is ETH loss at user-level, but not at EE-level.

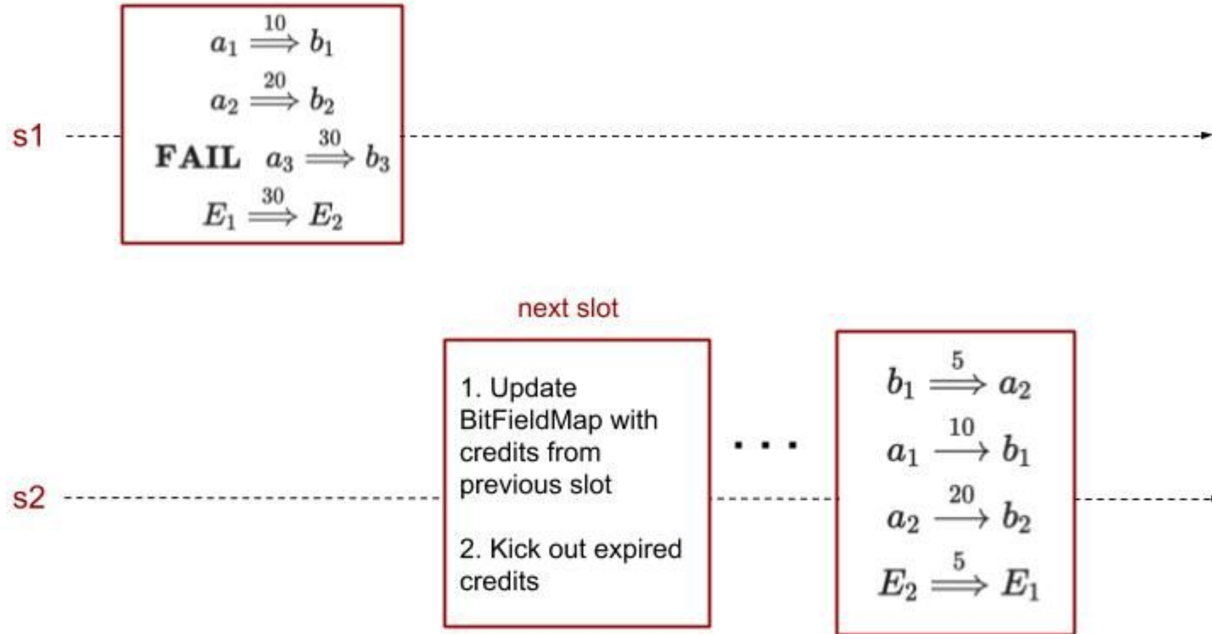


# Example walkthroughs

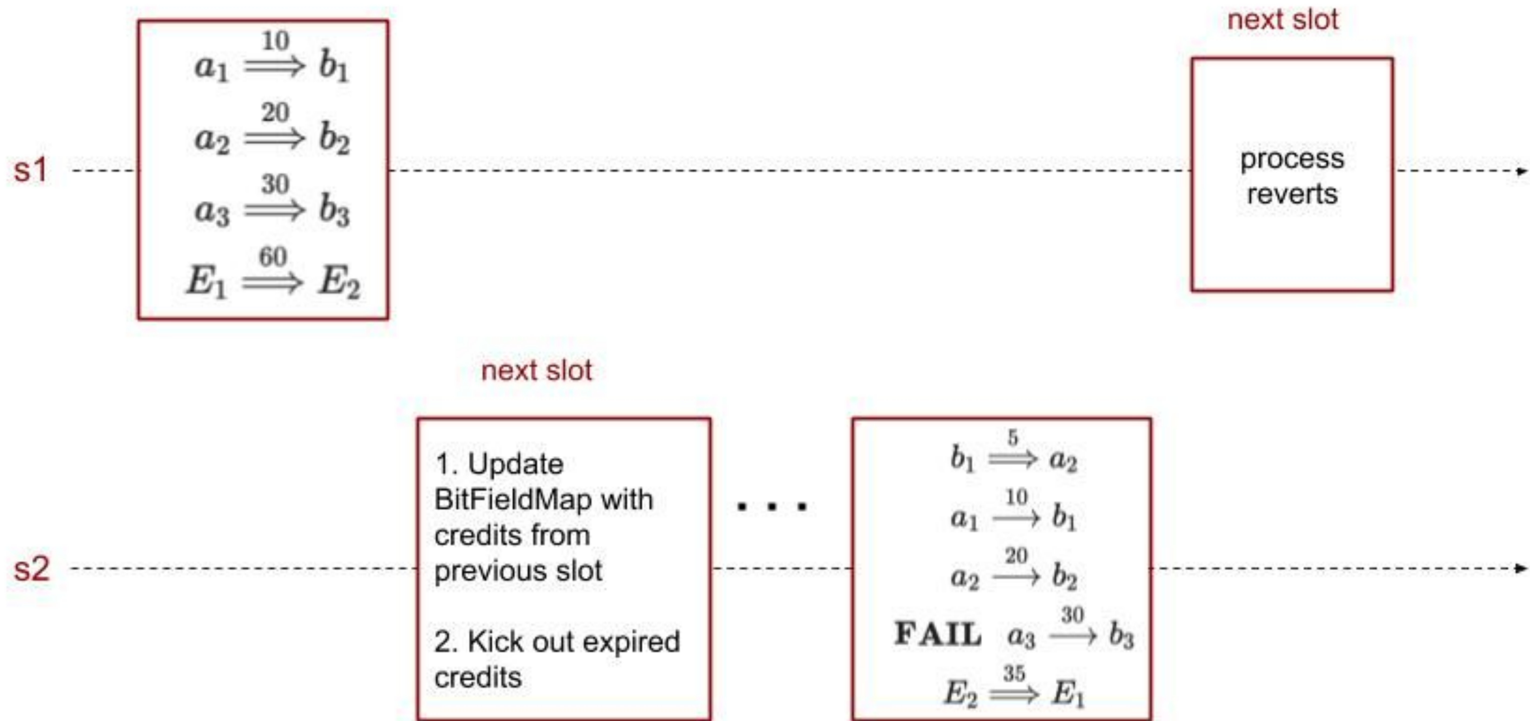
# Optimistic Case



# Debit Fail



# Credit Fail



# Benefits

- Atomic
- No locking and blocking
- No constraint on BP to pick or order specific transactions

# Demerit - Expensive shard state transfers

- In every block, a BP has to get the outstanding credits and reverts from every other shard.
- Inherited from netted balance approach.
- However, in the EE-level netted-balance approach the querying is restricted to the sender EE's that are derived from the user-level transactions included in the block. The problem is aggravated here, because we need to query from all EE's, even for the EE's not touched in this block.

# Threat Analysis of Byzantine BP (BBP)

Block is invalidated by attesters assuming that #Byzantine nodes is within the limit posed by consensus algorithm.

- show no or false
  - part EE-balances or
  - set of impending credits or
  - set of reverts
- not update or wrongly update outstandingCredits with impending credits
- not process or wrongly process impending reverts
- not emit or emit with incorrect data the ToCreditSystem Event
- not include a revert for a failed credit transaction
- not affect appropriate EE-level transfer

# Thank You