The zkEVM Architecture

Part VII: Feijoa (And EIP-4844)

This is Work In Progress

Polygon zkEVM & Universitat Politècnica de Catalunya (UPC)

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Outline

Why Data Availability?

Integrity of execution is not all a rollup needs.

A rollup needs to guarantee one or both of the following:

a) Its full-state is recoverable.
b) Additionally, that one or more concrete transactions were executed correctly.

To achieve the first property we can relay on **availability of state diffs**.

To achieve both, the L2 **transaction data has to be available**.

Data Availability Pre-EIP 4844

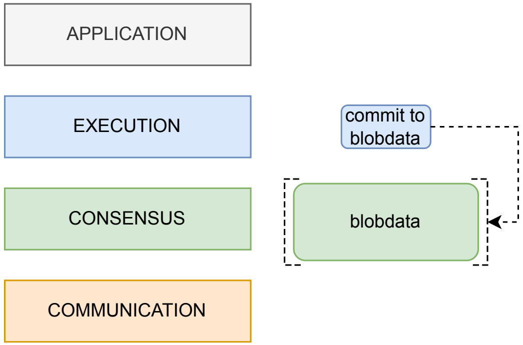
- Data availability options:
  a) Only commitments are available on chain (validium).
  b) State differences are available on chain (state diff rollup).
  c) The complete L2 transactions are available on chain (full rollup).
- Availability is provided in the `calldata` area of L1 transactions.
- Regarding `calldata`:
  - Is accessible by the EVM execution.
  - Is relatively expensive (16 gas per non-zero byte and 4 gas per zero byte).

Ethereum Data Sharding: Danksharding

- Data sharding is the way in which is planned that Ethereum becomes a truly scalable blockchain.
- The aim is to make transactions on Layers 2 as cheap as possible for users and should scale Ethereum to >100,000 transactions per second.
- **Danksharding**[1] is the concrete data sharding scheme used by Ethereum.
- The main ideas behind Danksharding are:
    1. Allow a new type of transaction that is able to carry one or more **blobs**, which stands for ”Binary Large OBject”.
    2. A blob stores binary data, typically large in size and **unstructured** from the point of view of the transporting layer, in this case, blobs have **no meaning for the L1 execution layer** but they are managed by a layer 2.
    3. The idea to make the network scalable is that blobs do not persist forever in the network nodes but they have a limited lifetime (**data pruning**), as a result, blobs should be much **cheaper** than calldata.

[1] The name Danksharding is due to the researcher Dankrad Feist.

Danksharding and Blockchain Layers



- Storage of blob carrying transactions **(blobdata) is only visible at the consensus** client NOT at the execution client.
- The execution layer does not have direct access to blob transactions only to **commitments** to blobs.
- Commitment goes on chain forever (but is small).
- Data stays for a while (weeks) and then disapears.

Commit to BlobData: KZG

Uses the curve BLS12-381 which is pairing friendly.

Commit to BlobData: Versioned Hash

The commitment to each blob is in the format of a versioned hash. It is 32 bytes value where the first byte is the version, currently set to 0x010x01, followed by the last 31 bytes of SHA256 hash of the KZG commitment of the blob, i.e. version_byte + SHA256(KZG(blob))[1:]. The rationale is to keep the possibility of changing the commitment scheme from KZG to something else without breaking the format, just in case KZG commitments are deemed to be not as safe as desired in the future, for instance if quantum computers become practical. The field blob_versioned_hashes denotes a list of commitments to the blobs included in the transaction. Notice that a blob-carrying transaction can carry more than one blob.

Opcode BLOBHASH

It is used as BLOBHASH index Where index is the position of the blob in the blob carrying transaction

Blob Carrying Transaction

In the blob transaction type:

- Data is left outside the transaction itself.
- This is now a responsability of the consensus layer.
- The transaction contains a committment to the blob data but not the data itself.
- Same functionality as EIP-1559 transaction including calldata but not RLP-encoded.
- The transaction is not encoded with RLP, so that it Merklelizes nicely, which is suitable for layers 2.
- The blob Carrying Transaction uses two extra fields: data_fee and data_hashes.

Proposer/Builder

incorporate

Data Availability (DA) sampling

Indep of amount of data but double the data to send.

- We do not use merkle trees for creating the commitment because it breaks the structure of polynomials (we need to use FRI or similars to do this). - We use a commitment that always commits to a polynomial

Blob lifecycle i

- When creating the L2 Tx bundle the rollup operator can do compression and so on.

Changes in the execution-layer

- New transaction type that contains commitments to blobs.
- Opcode that outputs the i’th blob versioned hash in the current transaction.
- Blob verification precompile.
- Point evaluation precompile.

Proof of Equivalence

Easy proof of equivalence between multiple polynomial commitment schemes to the same data

Suppose you have multiple polynomial commitments C1, ... Ck, under k different commitment schemes (eg. Kate, FRI, something bulletproof-based, DARK, etc), and you want to prove that they all commit to the same polynomial P.

We can prove this easily:

Let z=hash(C1....Ck), where we interpret z as an evaluation point at which P can be evaluated.

Blobdata Market

danksharding: merged fee market for all the shards

Danksharding and Proto-Danksharding

- **Proto-Danksharding** (note that the name includes Proto, which comes from Protolambda, another researcher) is an intermediate step along the way to achieve ”full Danksharding”.
- Proto-Danksharding is also known as EIP-4844 (the document in which it is defined).

EIP 4844 Figures

3 gas per byte

1.4 MB

number of blobs per block

goal 10/100 times less gas.

sepolia.blobscan.com

Add figures of video Eth Denver

Outline

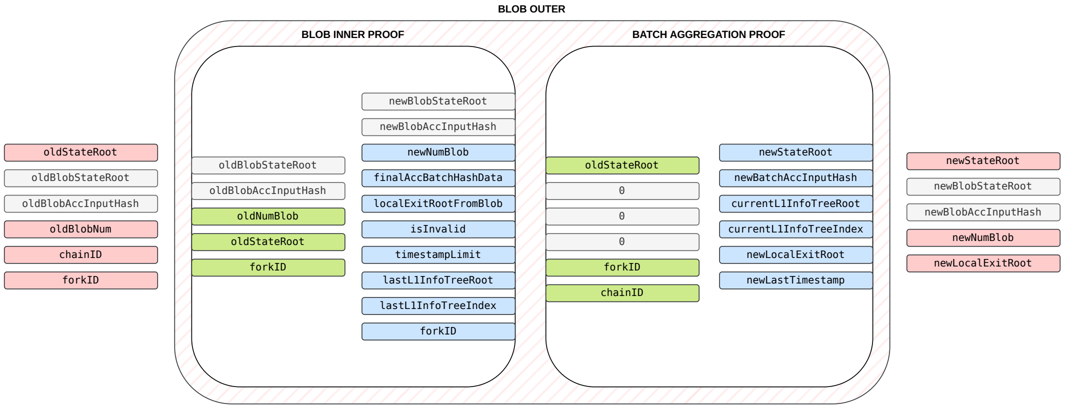
Feijoa i

-

`blobOuter` Circuit

- This circuit is in charge of aggregating a proof $\pi_{\texttt{re2}}$ (or $\pi_{\texttt{re1}}$ in the edge case of "aggregating" a single batch) and a proof $\pi_{\texttt{blobInner}}$ generated using the execution trace generated by the blob-specific ROM which is in charge of validating the blob data.
- Moreover, its responsibility extends to conducting integrity checks on the data received from both sources, ensuring the coherence between the blob data and the batch data, which should be the same, except in some scenarios that will be specified later on.

blobOuter Circuit: Inputs and Outputs



`isValidBlob` Signal

- First of all, the circuit creates a signal named `isValidBlob` that asserts whether the blob processing carried on by the `blobInner` processing is deemed valid. This boolean signal is 1 if and only if this two conditions are satisfied:
    - At least one element within the 8-element array `finalAccBatchData` is non-zero.
    - The input signal `isInvalid` produced by the `blobInner` ROM is 0.
- Whenever the signal `isValidBlob` signal is 0, the batch verifier is automatically disabled as the transmitted blob batches would not align with the provided batch data in the aggregated proof.
- In such instances, the prover can input any signals he/she wish, but we must finally assert a proof of no state change.
- Thus, this signal it is used extensively in the circuit because there are constraints that do not make sense if the blob data processing has resulted invalid.

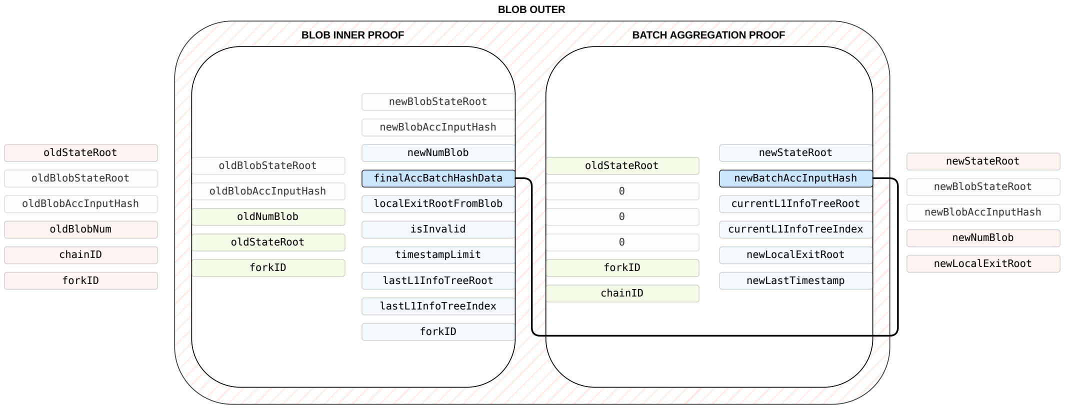
Other Sources of Failure

- However, errors in the input data may arise from scenarios other than the validity of the blob parsing. Specifically, there are two scenarios to consider:
  - When the last timestamp recorded on the batch **newLastTimestamp** is greater than the timestamp limit specified in the blob **timestampLimit** $\to$ **isValidTimestamp**.
  - When the selected information tree index is incorrect $\to$ **isValidL1InfoTreeIndex**
- The three error controlling signals will be accumulated in **isValid** signal, which will only be 1 if and only if each of them is 1. That is

$$\texttt{isValid} = 1 \iff \begin{array}{r} \texttt{isValidBlob} = 1 \text{ and} \\ \texttt{isValidTimestamp} = 1 \text{ and} \\ \texttt{isValidL1InfoTreeIndex} = 1. \end{array}$$

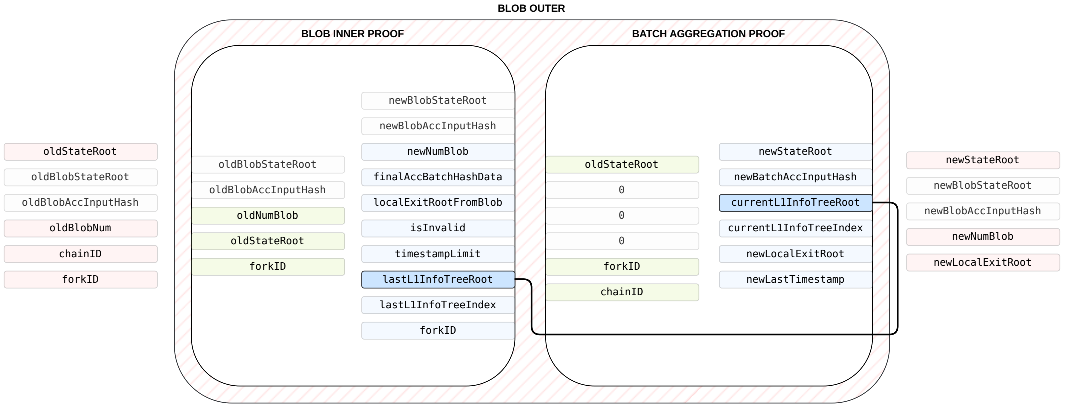
Batch Data Integrity Check

- Component-wise assertion that `finalAccBatchHashData`, computed in `blobInner`, coincides with `newBatchAccInputHash`, computed within the batch aggregation.



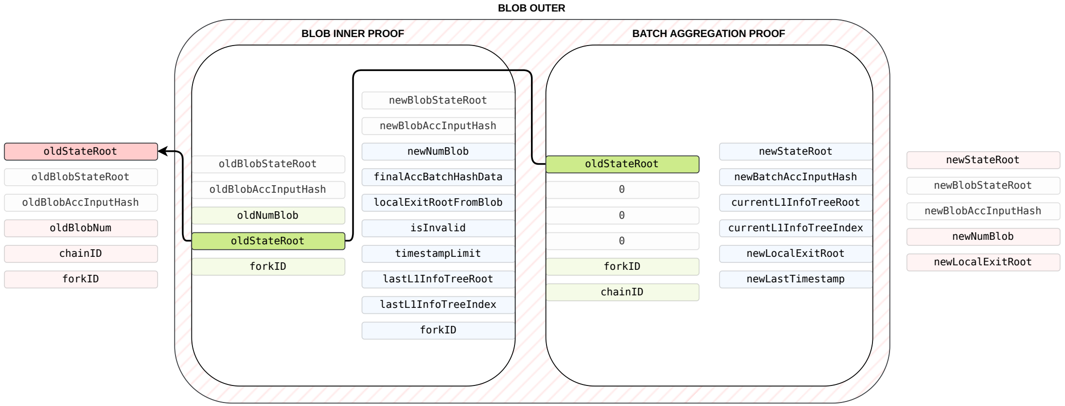
`L1InfoTree` Root Integrity Check

- Component-wise assertion that the root of the L1 Info Tree from the blob data `lastL1InfoTreeRoot` coincides with the one coming with the batch data `currentL1InfoTreeRoot`.



Old State Root Integrity Check and Output Assignment

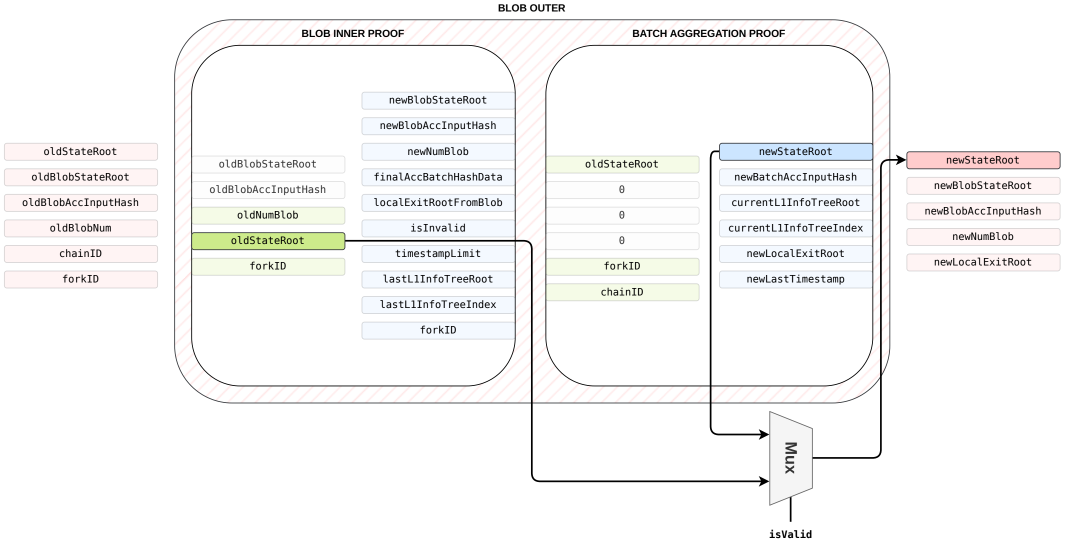
- Component-wise assertion that the old state root obtained from the blob data matches the old state root retrieved from the batch aggregation.
- Furthermore, the output of the old state root from the blob outer circuit is assigned to be one of these roots. This check is performed in all scenarios.



New State Root Integrity Check and Output Assignment

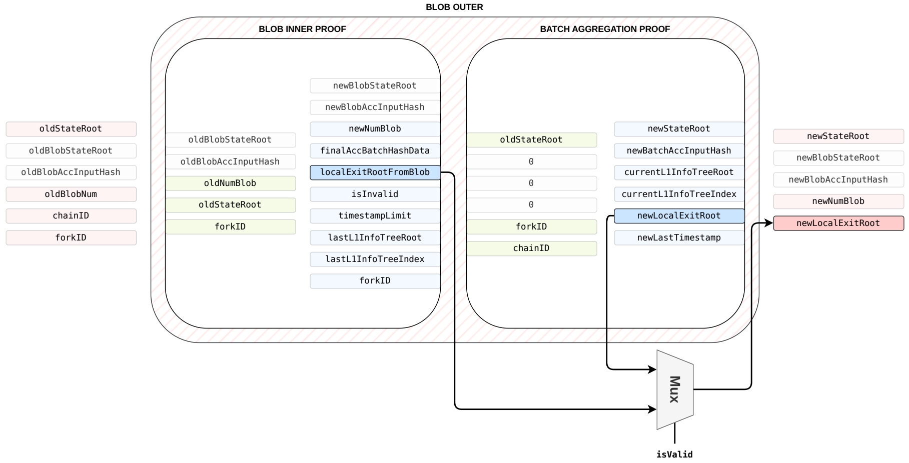
- The circuit's output signal `newStateRoot` is properly determined using a multiplexer.
- When the `isValid` signal is 0 the state root cannot be updated due to some errors.
- In such scenarios, it should be assigned the value of `oldStateRoot` obtained from the `blobInner` circuit.
- It's important to note that we cannot utilize the state root from the batch aggregation because, if the verifier is disabled by the `isValidBlob` signal, the prover has the freedom to provide arbitrary inputs.
- Conversely, when the `isValid` signal is 1, indicating correctness, we can simply assign the `newStateRoot` obtained from the batch aggregation.

New State Root Integrity Check and Output Assignment Circuit



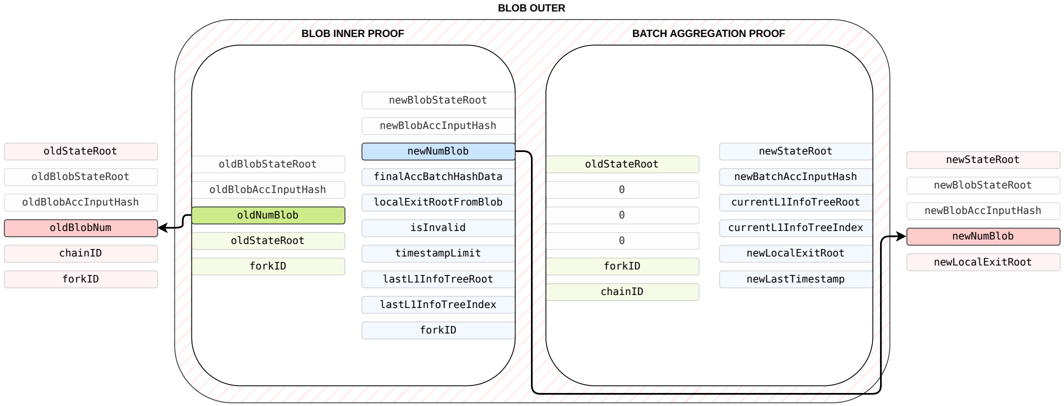
New Local Exit Root Update

- The circuit's output signal `newLocalExitRoot` is properly determined using a multiplexer.



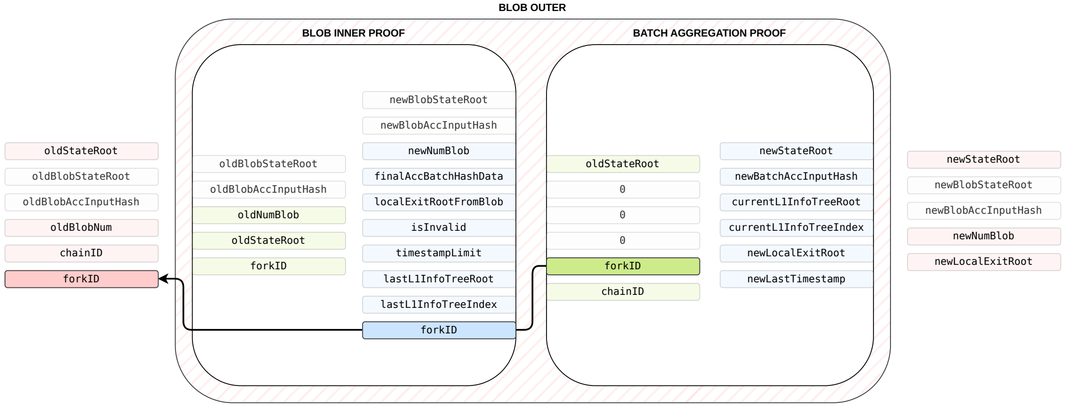
Output Blob Numbers Assignment

- The circuit's output signals `oldBlobNum` and `newBlobNum` are properly assigned from the data coming from the `blobInner` circuit.



ForkID Integrity

- It is checked that the forkID from the blob data coincides with the one coming with the batch aggregation data.



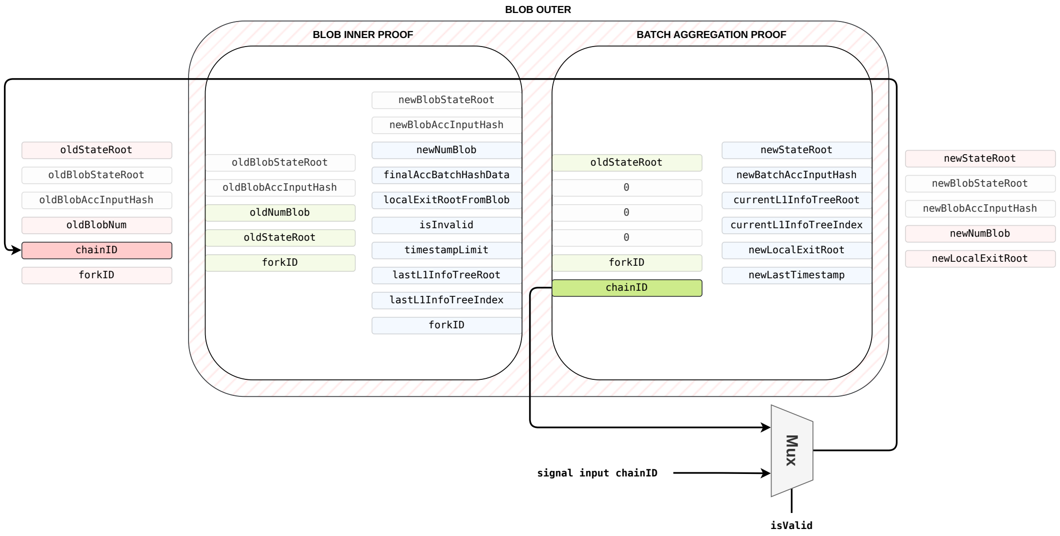
`chainID` Assignment i

- The `chainID` is a the most subtle public parameter to deal with.
- The `chainID` is assigned by the smart contract when the verification procedure is invoked.
- Thus, using an incorrect `chainID` during proving leads to verification failure, highlighting the importance of assigning the correct `chainID` to the output of the `blobOuter` circuit.

`chainID` Assignment ii

- If `isValid` signal is 1, we can retrieve this from the batch aggregation data, however, since `chainID` is not present in the public signals of the previous `blobInner` proof and can only be derived from the publics of the batch aggregation, a problem occurs if `isValid` signal is 0.
- In such scenarios, the prover's input may not be accurate for several reasons, rendering the batch aggregation data unusable and residual.
- To address this situation, the strategy involves passing the `chainID` independently as a private input to the `blobOuter` circuit.
- Since the `chainID` is hardcoded in the verification procedure by the smart contract, the prover cannot tamper with it.

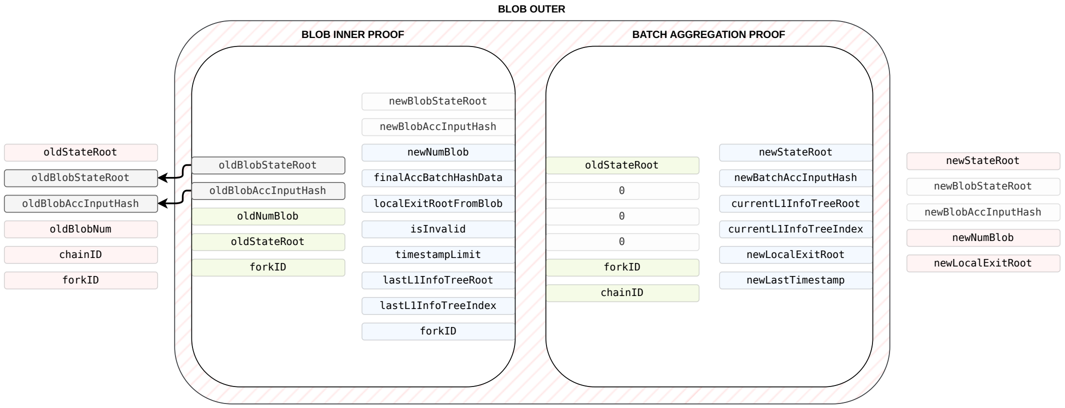
chainID Assignment Circuit



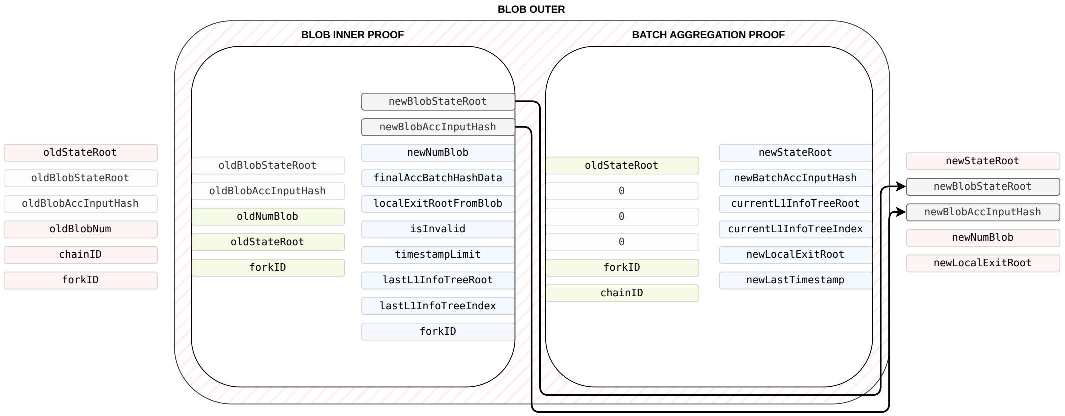
Compression-Related Unused Checks

- In order to avoid making a lot of changes to smart contracts in later forks, which would increase deployment efforts, the team has suggested including all the fields required for data compression in smart contracts within fork-feijoa.
- Thus, these fields must be incorporated into feijoa circuits as publics without currently restricting any specific (that is, correct) value (currently they are set to 0).

Compression-Related *Old*-ish Checks



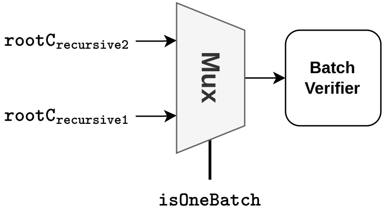
Compression-Related *New*-ish Checks



Considerations About the Constants

- In the whole aggregation process, we should consider whether we are aggregating just one batch or multiple batches because when aggregating only one batch, the `recursive2` circuit is not used.
- We must take this fact into account when incorporating the constants from the previous verifier into the batch's verifier circuit.
- Note that, since there's no aggregation of the `blobOuter` circuit, we can hardcode these constants.

- A multiplexer selects the verifier circuit's constant root based on `isOneBatch`, derived from the negation of `batch_isAggregatedCircuit`, indicating single or multiple batches.



rootC_recursive2
rootC_recursive1
Mux
Batch Verifier
isOneBatch