

Rift HyperBridge: Enabling Trustless Swaps Between Bitcoin and Ethereum

Clifford Syner, Tristan Barrett, Samee Siddiqui

ABSTRACT

We propose Rift, a protocol that enables trustless cross-chain swaps between Bitcoin and Ethereum by programmatically unlocking escrowed ETH to a Buyer upon verification of a zero-knowledge proof that the Seller was paid a specified amount of BTC.

1. INTRODUCTION

Bitcoin and Ethereum are the two largest blockchains in the world by market cap, yet there is no way to swap between the two assets without trusting highly centralized intermediaries. Bitcoin holders who want to enter Ethereum's vibrant dApp ecosystem, and Ethereum users who want to hold the most widely adopted digital store of value, have no secure way of doing so. As a result, the liquidity between the two largest cryptocurrencies remains highly fragmented.

Trustless cross-chain swaps have been achieved between EVM chains [1], but swaps between Bitcoin and Ethereum are much more complex due to Bitcoin's lack of smart contracts (making it impossible to verify the state of Ethereum, escrow funds on-chain, or verify zero-knowledge proofs), and the prohibitively high gas cost of verifying the state of Bitcoin on Ethereum using a standard light client.

Users who want to swap between Bitcoin and Ethereum today have 4 options:

1. Centralized Exchanges (CEXs)
2. Institutional Market Makers (OTC Desks)
3. Collateralized Bitcoin Stablecoins (BTC Stablecoins)
4. Alternative Layer-1 Blockchains (Alt-L1s)

All of these suffer from the same core problems: they are far less secure than the base chains users hold assets on, and come with other inherent risks:

- 1. Centralized Exchanges** - (e.g. Binance, Coinbase, ChangeNow, etc.) are controlled by single entities and have historically struggled to manage user funds, resulting in multiple bankruptcies and financial losses (e.g. FTX [2], Celsius [3], etc). CEXs are also highly regulated, force KYC, rate-limit swapping, and can freeze customer funds at will.
- 2. Institutional Market Makers** - (e.g., Coinbase Custody, Anchorage Digital, Wintermute, FalconX, Caladan, BitGo, etc.) operate effectively like CEXs for higher trade sizes. They are fully centralized and inherit the same security risks as CEXs as a result.
- 3. Collateralized Bitcoin Stablecoins** - (e.g. wBTC [4], tBTC [5], renBTC, etc.) are a useful primitive but custody Bitcoin in a high-risk N-of-M multisig wallet where if N keys are compromised, all collateral can be stolen [6]. Additionally, since the multisig ownership

is often centralized, they inherit the same censorship and regulatory risks as CEXs. This has already resulted in the collapse of renBTC, which once held >\$1b in collateral [7].

4. **Alt-L1s** - (e.g. THORchain [8], NEAR Chain Abstraction [9], etc.) are more secure than a multisig, but are far less decentralized than Bitcoin and Ethereum [10, 11, 12], and have far less capital staked [13] in the network, leading to much lower security, uptime, and swapping limits for users.

With security via self-custody and decentralization as the core ethos of blockchain technology, and the increasing demand for swaps between Bitcoin and Ethereum [14], the need for a trustless swapping protocol between the two largest cryptocurrencies is more apparent than ever.

2. SOLUTION

Rift implements a set of zero knowledge circuits that verifies a Buyer paid an arbitrary number of Liquidity Providers (LPs) were paid on Bitcoin, and an on-chain order book smart contract on Ethereum [15] that allows Buyers to redeem escrowed ETH deposited by an LP upon verifying a zk-proof [16] that the LP(s) were paid in Bitcoin.

The order book and escrow functionality are combined in a single “Exchange” smart contract, which allows anyone to become an LP by depositing ETH to create a sell order. A sell order specifies an exchange rate (how much BTC should be paid to unlock the ETH being deposited) and the LP’s Bitcoin payout address. Any Buyer can signal their intent to fill an order by paying a fee to reserve an LP, locking that sell order for 8 hours. The Buyer must send the correct amount of BTC to the reserved LP(s) within this time period, or their reservation will expire. Once the Buyer sends the agreed-upon amount of Bitcoin to the reserved LP(s), anyone (including the Buyer) can generate and submit a zk-proof of this payment by providing the proposed Bitcoin transaction and associated block data.

Rift verifies 5 invariants before the Buyer can unlock the LPs ETH:

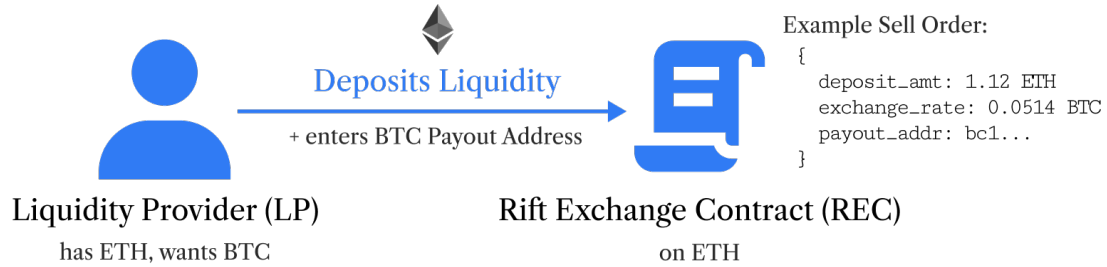
1. The proposed block is a valid and safe Bitcoin block. This is done by verifying Bitcoin’s Proof-of-Work (PoW) [17] consensus mechanism and that the proposed block has 6 confirmation blocks built on top of it in a ZK circuit.
2. The proposed block contains the multi-output transaction from the Buyer to the reserved LP(s). This is done by verifying a Merkle inclusion proof [18] in a ZK circuit.
3. The proposed transaction hash matches the transaction hash in the proposed block. This is done by verifying the hash of the transaction blob in a ZK circuit.
4. The proposed LP reservation hash matches the hashed reservation data in the Exchange contract. This is done by verifying the hash of the reservation data in a ZK circuit.
5. The LPs were paid the correct amount of BTC. This is done by verifying the UTXO outputs of the Buyer’s transaction and that each LP receives the BTC amount associated with the SwapReservation in a ZK circuit.

Once a payment proof is verified, the hash of the block containing the transaction is stored in a smart contract to be used as a circuit input for future payment verifications. By implementing

a Bitcoin ZK light client, we can verify the state of Bitcoin on Ethereum while ensuring the same security guarantee as the Bitcoin network itself (based on computational hashing power). This allows us to execute arbitrary actions on Ethereum based on verified changes in Bitcoin's state, thus enabling trustless swaps between the networks.

3. SWAP FLOW

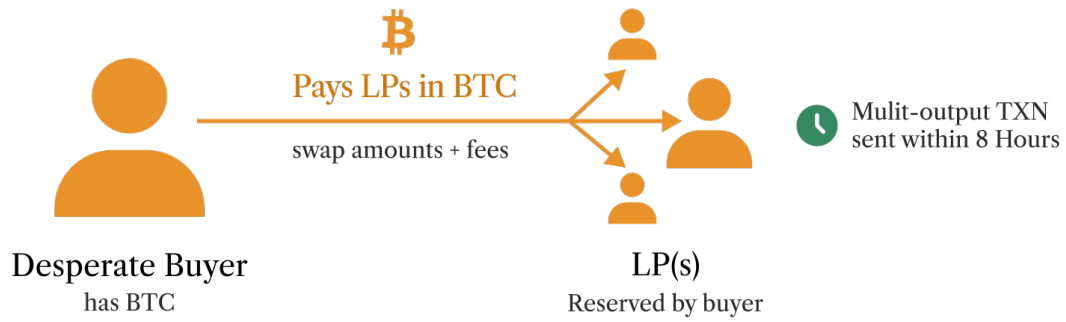
1. Liquidity Providers (LPs) create sell orders by depositing ETH into the Rift Exchange Contract (REC), specifying an exchange rate, and providing a Bitcoin payout address.



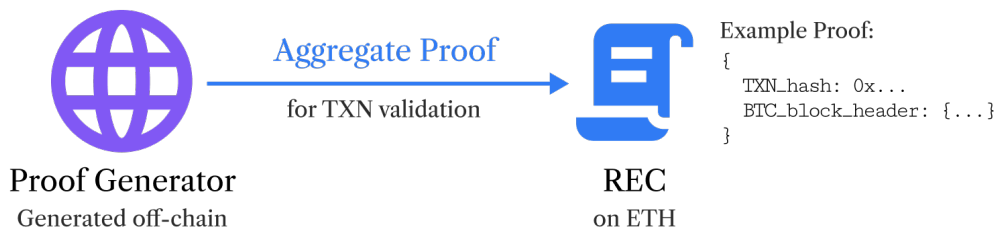
2. A Bitcoin owner (the Buyer) reserves one or more LPs on the REC and pre-pays swap fees in preparation for a swap. This prevents other buyers from attempting to fill the same order and locks the LP liquidity to prevent mid-swap withdrawals.



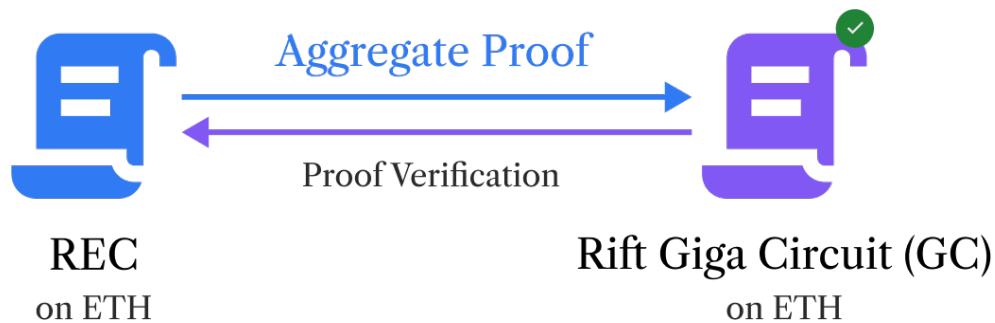
3. Once LP(s) are reserved the Buyer sends the requested amount of BTC to each of the reserved LP(s) in a multi-output transaction with exactly 1 input transaction. The LP reservation data, along with a unique order nonce is inscribed as part of the transaction. If an LP is not paid within 8 hours, that LP becomes unlocked and available for other buyers to reserve.



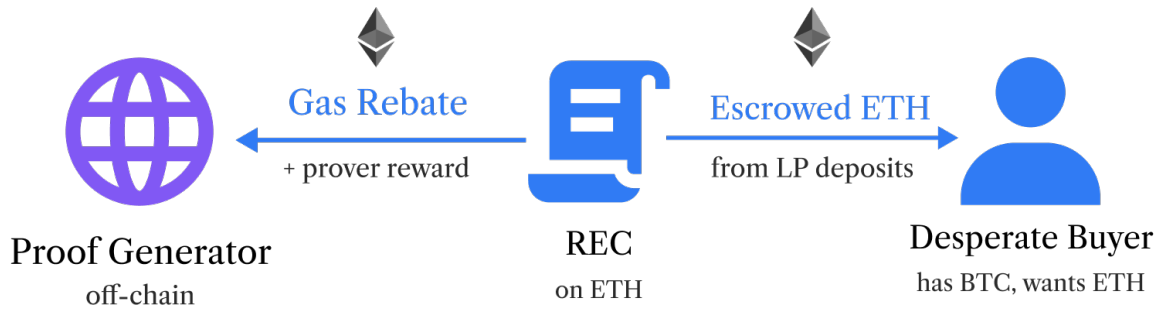
4. Once the Bitcoin transaction is confirmed, and 6 or more confirmation blocks have been built on top of the proposed block, a zk-proof of the payment can be generated off-chain by anyone and submitted to the REC for verification.



5. The proposed proof is then passed to the Exchange Verification Circuit (EVC), which either verifies or rejects it. Upon verification, a reward and gas rebate is paid out to the prover.



6. After proof verification and a 10-minute challenge period, the escrowed ETH can be released (by anyone) to the Buyer's Ethereum payout address. Upon escrow release, a reward and gas rebate is paid out to the releaser and the swap is complete.



4. PROTOCOL

The protocol consists of 2 smart contracts and 5 zk-circuits. The main components and their functionality are outlined below:

Smart Contracts:

1. Rift Exchange Contract (REC)
2. Block Hash Storage Contract (BHSC)

Zero-Knowledge Circuits:

1. Rift Giga Circuit (GC)
2. Block Verification Circuit (BVC)
3. TXN Hash Verification Circuit (TVC)
4. LP Hash Verification Circuit (LPVC)
5. LP Payment Verification Circuit (PVC)

4.1 RIFT EXCHANGE CONTRACT

The REC's purpose is to manage the core exchange logic. The main components of this are the current order book state, escrow functionality, and proof verification. These are implemented in 5 primary functions:

1. `depositLiquidity`
2. `withdrawLiquidity`
3. `reserveLiquidity`
4. `proposeTransactionProof`
5. `releaseLiquidity`

`depositLiquidity` is the entry point for LPs to create sell orders. They deposit ETH, specify an exchange rate, and provide a Bitcoin address for Buyers to pay them. This creates a new `DepositVault`:

```
struct DepositVault {
    uint256 initialBalance - their deposit amount in ETH
    uint256 unreservedBalance - the amount available to reserve from this vault
    uint64 btcExchangeRate - amount of BTC per 1 ETH, in satoshis
    bytes32 btcPayoutLockingScript - locking script representing LPs
    payout address
}
```

LPs can update the exchange rate on their `DepositVault` for any unreserved liquidity. `withdrawLiquidity` allows LPs to cancel their sell order and withdraw the remainder of their liquidity. This is only possible when liquidity is not reserved. `reserveLiquidity` allows Buyers to signal their intent to purchase by locking one or more `DepositVaults`. This prevents two Buyers from paying the same LP, and guarantees their exchange rate and liquidity until the swap is completed.

`DepositVaults` support partial reservations to maximize the efficiency of liquidity for LPs as well as available liquidity for Buyers. A Buyer has 8 hours to pay the LPs until the reservation expires, at which point it becomes available for anyone to reserve. During this reservation window, LPs cannot withdraw their reserved capital. To discourage adversarial locking of liquidity, reservations require paying a percentage of your swap amount as an upfront fee. Upon successful reservation, a `SwapReservation` is created.

```
struct SwapReservation {
    uint32 confirmationBlockHeight - The height of the block that confirmed the
                                   transaction for this swap.
    uint32 reservationTimestamp - The timestamp when the liquidity reservation
                                   was made.
    uint32 unlockTimestamp - The timestamp when the reserved liquidity was
                              unlocked.
    ReservationState state - The current state of the reservation (unlocked,
                              completed, expired, etc.)
    address ethPayoutAddress - The Ethereum address where the escrowed ETH will
                              be sent upon successful swap.
    bytes32 lpReservationHash - A hash representing the specific details of
                              the reserved liquidity provider(s).
    bytes32 nonce - A unique identifier used to prevent replay attacks.
    uint256 totalSwapAmount - The total amount of ETH being swapped in the
                              transaction.
    int256 prepaidFeeAmount - The amount of fees paid upfront when making the
                              reservation.
    uint256[] vaultIndexes - Indices of the vaults from which liquidity is
                              reserved.
    uint256[] amountsToReserve - Amounts of liquidity reserved from each
                              corresponding vault index.
}
```

`proposeTransactionProof` is responsible for verifying the Giga Circuit proof and updating the `Block Hash Storage Contract (BHSC)` with the new block hashes. Proof verification happens by calling the associated verifier contract of the `Giga Circuit`. Anyone with access to Bitcoin block data can generate this proof, including the Buyer. If any of the invariants of the ZK light client return false, it means there was not a valid payment from the Buyer to the LPs, and proof will be rejected. Upon successful verification, the pre-paid prover reward is released.

`releaseLiquidity` releases the escrowed ETH to Buyer's ETH payout address, along with the pre-paid fee to the releaser, after a 10 minute challenge period. This will fail if a longer chain is proposed during the challenge period.

4.2 BLOCK HASH STORAGE CONTRACT

The BHSC's purpose is to store the source of truth about which Bitcoin block hashes are valid, and can be used as inputs for the zk-circuits. Proposed blocks that are verified in the **Block Verification Circuit** (Section 4.4) are stored in the BHSC to be used as inputs to verify further proposed blocks building on top of a verified safe block to form the longest chain. Blocks verified by the BVC are stored using the `addBlock` function, called by the REC to store the verified block height and hash to a mapping in the contract.

```
mapping(uint256 => bytes32) blockchain; // block height => block hash

uint256 public currentHeight;
```

The next time `proposeTransactionProof` from the REC is called, it uses the block hash at the previous safe block height as an input into the GC. If there is a longer valid chain starting from any previous safe block the mapping is updated with the hashes of the longer chain and any shorter chain is overwritten. `addBlock` supports block fast forwarding for up to 24 blocks at a time, so even if there are many Bitcoin blocks between the last swap, the storage contract can be updated with a single verification. In the case of high inactivity and the storage contract falling more than 24 blocks behind Bitcoin, `proposeTransactionProof` can be called with just block data (no transactions) multiple times until the storage contract is up to date. Since the GC requires reading inputs from the BSC to generate a proof, an initial block hash and height must be set by the deployer, but can be easily be verified.

4.3 RIFT GIGA CIRCUIT

The purpose of the GC is to verify the 5 invariants required by our ZK light client specification (outlined in Section 2. Solution). Its associated verifier contract on Ethereum is called by the REC in `proposeTransactionProof` before funds from a `DepositVault` can be released. All the invariant circuits are verified within this single circuit to allow us to verify the entire transaction with a single proof on Ethereum. This greatly reduces the gas cost by setting an upper bound for proof verification, regardless of the complexity of the circuit. The GC requires these inputs to generate a proof:

Public Inputs:

```
// Transaction Hash Verification
transaction_hash - hash of the Buyer's transaction paying the LP(s)

// Payment Verification & LP Hash Verification
order_nonce - order nonce from the SwapReservation for this transaction
expected_payout - total wETH being sent to the Buyer on Ethereum
lp_count - number of LPs being paid in this transaction
lp_reservation_data - list of locking scripts, BTC exchange rates, and the
amount reserved for each LP in a given reservation
lp_reservation_hash - lpReservationHash from the SwapReservation for this
transaction

// Block Verification
confirmation_block_hash - hash of the block 6 blocks ahead of the proposed_block
proposed_block_hash - hash of the block containing the Buyer's transaction
safe_block_hash - hash of the latest block from the BHSC
retarget_block_hash - hash of the latest retarget block from the BHSC
safe_block_height - height of latest block from the BHSC
block_height_delta - difference in proposed block height from last safe block
height
```

Private Inputs:

```
// Transaction Inclusion Verification
proposed_merkle_root - merkle root of the block containing the transaction
proposed_merkle_proof - list of hashes from transaction to root hash of block

// Proofs & Verification Keys of the 4 Remaining Invariants
lp_hash_verification_key - key of the LP hash verification circuit
lp_hash_proof - proof generated by LP hash verification circuit
transaction_hash_verification_key - key of the transaction hash verification
circuit
transaction_hash_proof - proof generated by transaction hash verification circuit
transaction_hash_verification_key_hash_index - index of transaction hash circuit
to use based on transaction data size
intermediate_hash_with_transaction_data - sha256 of the transaction hash + bin
packed data blob of the transaction
payment_verification_key - key of the Payment verification circuit
payment_proof - proof generated by the Payment verification circuit
block_verification_key - key of the block verification circuit
block_proof - proof generated by the block verification circuit
```

These inputs are passed on to the associated circuit verifiers, with the exception of the transaction inclusion proof, which is implemented as a function call. This is a performance optimization, as the Merkle inclusion proof can be implemented in less than ~250k gates, which is the cost to verify a separate circuit. The pseudocode for the inclusion proof itself is as follows:


```

combined_hash = transaction_hash
for..each hash_step in merkle_proof:
    if left:
        combined_hash = hash_step + combined_hash
    if right:
        combined_hash = combined_hash + hash_step
return combined_hash == merkle_root

```

The private input proofs needed to generate a GC proof are the remaining 4 invariants of the zk light client. Their circuit logic is outlined below.

4.4 BLOCK VERIFICATION CIRCUIT

The BVC's purpose is to verify the validity of proposed blocks by implementing Proof-of-Work (PoW) verification as a ZK circuit. The following invariants must be upheld for a valid PoW chain:

1. $\text{sha256}(\text{sha256}(\text{proposed_block_header})) \leq \text{target_block_difficulty}$
2. $\text{sha256}(\text{sha256}(\text{proposed_block_header})) == \text{new_block_hash}$
3. $\text{new_block_height} == \text{prev_block_height} + 1$
4. $\text{new_block.prev_block_hash} == \text{prev_block_hash}$

In order to generate a proof of these invariants, the BVC requires the associated block verification public and private inputs previously mentioned to be passed down from the GC, specifically these private inputs:

```

Private Inputs:
    proposed_block - Block containing the Buyer's transactions
    safe_block - latest Block from BHSC
    retarget_block - latest retarget Block from BHSC
    inner_blocks - list of Blocks between safe_block and proposed_block
    inner_block_hashes - list of hashes of inner_blocks
    confirmation_blocks - list of 6 Blocks after proposed_block
    confirmation_block_hashes - list of hashes of confirmation_blocks

```

The Block struct contains these values:

```

struct Block {
    height: u64
    version: Field
    prev_block_hash: [u8; 32]
    merkle_root: [u8; 32]
    timestamp: Field
    bits: Field
    nonce: Field
}

```

Using these inputs, we can now verify or reject arbitrary blocks by calculating the values needed to

assert the invariants. This can be implemented based on the following pseudocode:

```
new_blocks = [...inner_blocks, proposed_block, ...confirmation_blocks]
new_block_hashes = [...inner_block_hashes, proposed_block_hash,
...confirmation_block_hashes]
prev_block = safe_block
prev_block_hash = safe_block_hash

for i in 0..new_blocks.length:
    new_block = new_blocks[i]
    new_block_hash = new_block_hashes[i]
    proposed_target_difficulty = extract_target_from_block(new_block)
    real_target_difficulty = calculate_target(retarget_block, new_block)
    calculated_new_block_hash = calculate_block_hash(new_block)
    assert(proposed_target_difficulty == real_target_difficulty)

assert(new_block.height == prev_block.height + 1)
assert(new_block.prev_block_hash == prev_block_hash)
assert(calculated_new_block_hash == new_block_hash)
assert(new_block_hash <= proposed_target_difficulty)
```

If true, we can be confident the proposed block containing the Buyer's transaction is valid.

4.5 TRANSACTION HASH VERIFICATION CIRCUIT

The purpose of the THVC is to verify a proposed Buyer transaction hash. This is done by hashing the transaction data within a zk-circuit. The following invariant must be upheld:

1. `sha256(sha256(transaction_data)) == proposed_hash`

This is straightforward, but additional complexity is introduced by the unpredictable size of the transaction data blob. Decoding and hashing the transaction data would mean iterating over a dynamically sized array, which is extremely expensive to do in a circuit. We get around this limitation by generating a separate circuit for every possible transaction size up to 7000 bytes (which allows us to handle up to 175 LPs in a single swap, but could be increased in the future), and generating a proof using the specific circuit that handles the data size of the Buyer's transaction. Once the correct circuit is selected, generating a proof requires these inputs passed down from the GC:

```
Public Inputs:
    transaction_hash
    intermediate_hash_with_transaction_data
```

Using these inputs, we can now verify or reject if a proposed transaction hash matches the presented transaction data.

4.6 LP HASH VERIFICATION CIRCUIT

The purpose of the LPHV is to verify the proposed LP Reservation Hash. This is done by hashing the Reservation Data in a zk-circuit. The following invariant must be upheld:

1. `sha256(lp_reservation_data) == lp_reservation_hash`

Generating a proof requires these inputs to be passed down from the GC:

```
Public Inputs:
  lp_reservation_hash
  lp_reservation_data
  lp_count
```

Using these inputs, we can now verify or reject if a proposed LP Reservation Hash matches the presented Reservation Data.

4.7 LP PAYMENT VERIFICATION CIRCUIT

The purpose of the LPVC is to verify the Buyer paid the LP(s) the correct amount of BTC for their reservation. The following invariants must be upheld for a valid transaction:

1. Each LP is receiving the correct amount of BTC for the amount of ETH that will be unlocked from them
2. Inscribed transaction data must be equal to the reservation order nonce
3. LPs must receive payment to P2WPKH unlock scripts (bc1 addresses) [19]

In order to generate a proof of these invariants, the PVC requires these inputs:

```
Public Inputs:
  transaction_data
  lp_reservation_data
  order_nonce
  expected_payout
  lp_count
```

Using these inputs, we can now verify a Buyer paid each LP the correct amount by iterating over the transaction data to extract the outputs and inscribed `order_nonce`. By asserting the inscribed `order_nonce` is equal to the proposed `order_nonce` from the `SwapReservation`, we ensure that the payment information and list of LPs is correct. We also verify the Buyer is sending from an address with 1 UTXO, as a performance optimization. This can be implemented with the following pseudocode:

```

input_utxos = extract_inputs_from_transaction(transaction_data)
assert(input_utxos == 1)
actual_payout = 0

for i in 0..lp_count
    value = extract_value_from_transaction(transaction_data, i)
    locking_script = extract_locking_script_from_transaction(transaction_data,
i)

    assert(sig_counter == BC1_ADDRESS_LEN)
    assert(value == lp_data[i].amount_reserved)
    assert(locking_script == lp_data[i].locking_script)
    actual_payout += value / lp_data[i].btc_exchange_rate

assert(actual_payout == expected_payout)
inscribed_order_nonce = extract_order_nonce_from_transaction(transaction_data)
assert(inscribed_order_nonce == order_nonce)

```

It's not necessary to verify the input UTXOs as valid, since this block and transaction data has already been verified by the BVC. If this returns true, we can be confident the proposed transaction contains payment of the correct amount to each LP.

5. SECURITY CONSIDERATIONS

Given the objective of creating a maximally secure exchange between Bitcoin and Ethereum, it is critical to discuss all possible attack vectors and how the protocol's design prevents them:

1. **Double claiming ETH for a single BTC payment** - Prevented by the order_nonce inscribed in the Buyer's transaction, which is unique to every SwapReservation. Submitting a zk-proof to claim ETH would fill the order, thus nullifying the order_nonce for future use.
2. **Submitting fraudulent blocks containing a non-existing transaction paying an LP** - Prevented by the BVC, which ensures that proposed blocks must be valid, and part of the longest chain. To successfully create a longer chain, an attacker would need more computational mining power than the Bitcoin network itself, or a stale BHSC far behind the actual Bitcoin network.
3. **Submitting fraudulent blocks to a chain with a stale BHSC** - In the case of a stale chain (with no transactions for an extensive period of time, and thus no updates to the BHSC), an attacker with sufficient computational power could mine fraudulent blocks attempting to claim money from LPs. This is prevented by a challenge period of 10 minutes after block verification where everyone can see the attempted attack occurring, before releaseFunds can be called anyone can submit the legitimate longer chain and invalidate the fraudulent transaction. This would be a relatively cheap operation on a chain with 0 activity (such as a less popular L2). Additionally, this risk is mitigated by economic incentives: a stale chain with no transactions likely has very little liquidity (if any), meaning the cost to perform the attack would likely be higher than the amount of liquidity available.
4. **Submitting fraudulent blocks containing invalid Buyer UTXOs** - Prevented by verifying the validity of the block and the transaction data through the BVC and TVC.

5. **2 Buyers paying the same LP and only 1 claiming the ETH** - Prevented as liquidity can only be reserved by one Buyer at a time.
6. **LP withdraws their funds on Ethereum after they have been paid BTC** - Prevented as LPs are only able to withdraw liquidity if it is unreserved and not part of a completed swap.
7. **LP reservation expires after Buyer has paid, but before they were able to claim ETH** - Prevented by a swap reservation lasting 8 hours, which is much longer than it takes for 6 Bitcoin blocks to be confirmed (the longest time taken for 6 consecutive blocks to confirm is 5.2 hours since 2010 [20]).
8. **Buyer pays LPs, but no third parties are online to generate a proof** - Prevented by anyone being able to generate a transaction proof by running the open-source proving client, including the Buyer.
10. **Maliciously locking liquidity on the protocol, and never completing the transaction** - Mitigated by reservation fee, based on a percentage of the total swap size. Not paying will result in losing this. It is still possible for a motivated and funded actor to reserve without paying, to simulate an “option” contract or simply to DDoS the protocol. This can be further mitigated by a dynamic reservation fee based on the available liquidity in a future improvement.

6. LIMITATIONS AND FUTURE WORK

There are several limitations and subsequent improvements that can be made to the protocol in future iterations:

1. **One way swaps (can only be an LP on Ethereum)** - As of today, there is no way to verify ZK proofs on Bitcoin. As a result, creating trustless unlocking of liquidity via a ZK light client is not possible. We believe this will be possible at some point in the future, at which point the protocol could support two way swaps.
2. **Buyer must pay Ethereum gas fees to make a SwapReservation** - The Buyer must pay fees in ETH to reserve an LP. This can be inconvenient, as a Buyer may not have any ETH. A future upgrade could support an optional gas relay network with operating nodes that receive BTC from a Buyer to pay for their reservation gas fees with ETH. They would be required to stake, and be slashed if they did not perform a reservation.
3. **Upgrade reservation fees into an options market** - Reservations can be seen as an options marketplace, where interested Buyers can pay an upfront fee for the option to fill the order at a specific price. Rather than enforce a static upfront fee, this could become dynamic to reflect the amount of available liquidity and earn higher yield for LPs.
4. **Proof generation network and fee market to incentivize provers** - Proof generation can be seen as a marketplace, where provers prioritize Buyers willing to pay higher fees. Proving rewards could as a result be dynamic, or include a network token. A staking scheme could also be created to increase the provers alignment with the network and increase the probability to earn the next proving job.
5. **Self proving without installing client** - Reduction of circuit size could allow Buyers to generate their own proofs in the browser or on a mobile phone.

6. **Generalization of ZK light client for other DeFi protocols** - The ZK light client can be extended to support reading of arbitrary state on Bitcoin, and as a result new DeFi protocols can be designed around Bitcoin and Ethereum interoperability. Some examples include lending, account abstraction, NFT marketplaces, and collateralized synthetic assets.
7. **Proving multiple transactions with one aggregated proof** - in the current system, transactions get proven and verified individually leading to high transaction costs for Buyers. As the volume of transactions increases and multiple swap transactions occur in a single bitcoin block, provers can aggregate these transaction proofs and submit a single verification on Ethereum, drastically reducing swapping costs.

7. CONCLUSION

In summary, we’ve proposed a protocol that allows for direct, trustless swaps between Bitcoin and Ethereum without relying on security compromising intermediaries. We combined a novel Bitcoin ZK light client implementation with an on chain order book and escrow smart contract to create a cross-chain decentralized exchange. The protocol ensures the same level of security as the Bitcoin and Ethereum networks, and is highly resilient, as it does not rely on staked capital or third parties to submit proofs. Rift can be deployed to any Ethereum Virtual Machine (EVM) chain, allowing liquidity to flow seamlessly between Bitcoin and Ethereum’s ecosystem for the first time.

REFERENCES

- [1] Xie, T., Zhang, J., Cheng, Z., Zhang, F., Zhang, Y., Jia, Y., Boneh, D., & Song, D. (2022). zkBridge: Trustless Cross-chain Bridges Made Practical. Proceedings of the 2022 ACM SIGSAC Conference on Computer and Communications Security, 3003–3017. <https://doi.org/10.1145/3548606.3560652>
- [2] The Collapse of FTX: What Went Wrong With the Crypto Exchange? (n.d.). Investopedia. <https://www.investopedia.com/what-went-wrong-with-ftx-6828447>
- [3] Celsius Network LLC, et al. (n.d.). <https://cases.stretto.com/celsius/>
- [4] wBTC - Wrapped Tokens (2019). <https://wbtc.network/assets/wrapped-tokens-whitepaper.pdf>
- [5] tBTC Bitcoin Bridge | Threshold Docs. (2024, February 14). <https://docs.threshold.network/applications/tbtc-v2>
- [6] Axie Infinity’s Ronin bridge hacked for over \$600M. (2022, March 29). Cointelegraph. <https://cointelegraph.com/news/axie-infinity-s-ronin-bridge-hacked-for-over-600m>
- [7] RenBTC Collapse - RenBridge <https://bridge.renproject.io/>
- [8] THORchain: A Decentralized Liquidity Network (n.d.). GitHub. <https://github.com/thorchain/Resources/blob/master/Whitepaper-May2020.pdf>
- [9] What is Chain Abstraction? | NEAR Documentation. (2024, June 7). <https://docs.near.org/build/chain-abstraction/what-is>
- [10] Validators | Mainnet Beacon Chain (Phase 0) Ethereum 2.0 Explorer. (n.d.). Etherscan Beacon Chain (Phase 0) Ethereum 2.0 Explorer. <https://beaconscan.com/validators>
- [11] Bitcoin (BTC) SHA-256 | Mining Pools. (n.d.). <https://miningpoolstats.stream/bitcoin>
- [12] Bitcoin Hashrate Chart—BTC Hashrate 621.48 EH/s. (n.d.). <https://www.coinwarz.com/mining/bitcoin/hashrate-chart>

- [13] THORChain Network Explorer. (n.d.). <https://thorchain.net/nodes>
- [14] Top Crypto Exchanges Ranked by Trust Score. (n.d.). CoinGecko. <https://www.coingecko.com/en/exchanges>
- [15] Buterin, V. (n.d.). Ethereum: A Next-Generation Smart Contract and Decentralized Application Platform. Ethereum https://ethereum.org/content/whitepaper/whitepaper-pdf/Ethereum_Whitepaper_-_Buterin_2014.pdf
- [16] A Review of zk-SNARKs. (n.d.). Ar5iv. ZK Snarks <https://ar5iv.labs.arxiv.org/html/2202.06877#S1.SS1>
- [17] Nakamoto, S. (n.d.). Bitcoin: A Peer-to-Peer Electronic Cash System. <https://bitcoin.org/bitcoin.pdf>
- [18] Eth2.0-ssz/specs/merkleization/merkle__proofs.md at master · protolambda/eth2.0-ssz. (n.d.). GitHub. https://github.com/protolambda/eth2.0-ssz/blob/master/specs/merkleization/merkle__proofs.md
- [19] P2WPKH | Pay To Witness Public Key Hash. (n.d.). <https://learnmeabitcoin.com/technical/script/p2wpkh/>
- [20] callumr00 / displaying-bitcoin-block-data. (n.d.). Blocks 688991-688986 GitHub. <https://github.com/callumr00/displaying-bitcoin-block-data/blob/main/sample/ExtractData.py>