Mimblewimble and Scriptless Scripts

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- Mimblewimble is an anonymously-originated design for a blockchain-based ledger that is very different from Bitcoin.
- Unlike Bitcoin transactions, transaction verification can be done with only "kernels", which are multisignature keys of the transactors. The inputs and outputs are auxiliary and can be deleted.
- To allow this deletion, Mimblewimble outputs (and inputs) are inherently scriptless.
- However, smart contracting in Mimblewimble is still possible using "scriptless scripts". These are more efficient and private than ordinary Bitcoin or Ethereum scripts, and can potentially be used with those blockchains.

An Anonymous History of Blockchain Tech

- November 2008: Satoshi Nakamoto announces Bitcoin; first client released January 2009
- December 2012: Nicolas van Saberhagen announces Bytecoin, using ring signatures to enhance transaction privacy
- September 2013: Horaus Yuan Mouton announces "OWAS", a pre-Mimblewimble technology whitepaper that uses pairing-based cryptography
- August 2014: sundance describes "Byzantine Cycle Mode", a method to improve Greg Maxwell's CoinJoin by better hiding transaction amounts.

An Anonymous History of Blockchain Tech

- August 2016: Tom Elvis Jedusor posts a .onion link to a text file on IRC and disappears. It describes "Mimblewimble", an enhanced variant of Maxwell's Confidential Transactions, on IRC and disappears
- October 2016: "Ignotus Peverell" appears on IRC and announces a project on Github to implement MimbleWimble.
- November 2016-Present: yet more Harry Potter characters have appeared and continue to develop the project

More History of Mimblewimble

- After Ignotus Peverell appeared, we discussed practicalities and found that aggregate signatures would give space savings on top of the Voldemort scheme
- January 2017: Ethan Heilman (of TumbleBit fame), Ruben Somsen and myself discover that we could add a weak form of scripting to MimbleWimble to get Lightning, atomic swaps, Tumblebit, etc.
- However, adding scripting to Mimblewimble would hurt its otherwise perfect fungibility
- These ideas evolve into "scriptless scripts", a way to move the script verification into the signatures themselves, simplifying and hiding them

More History of Mimblewimble

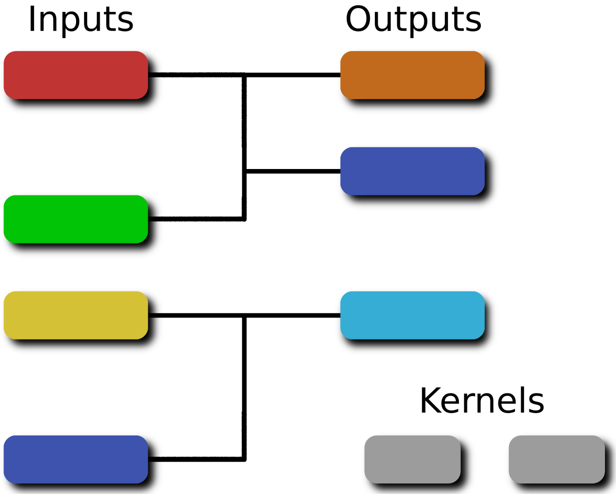
- January 2017: Tim Ruffing and Pedro Moreno-Sanchez announce ValueShuffle, a method to securely combine Confidential Transactions
- April 2017: Blockstream announces Confidential Assets, I publish a design I'd been sitting on for a multi-asset Mimblewimble
- May 2017: Luna Lovegood appears on the Mimblewimble list to discuss ValueShuffle on Mimblewimble. In fact, Tim had already been planning to work on this.

Mimblewimble Transactions

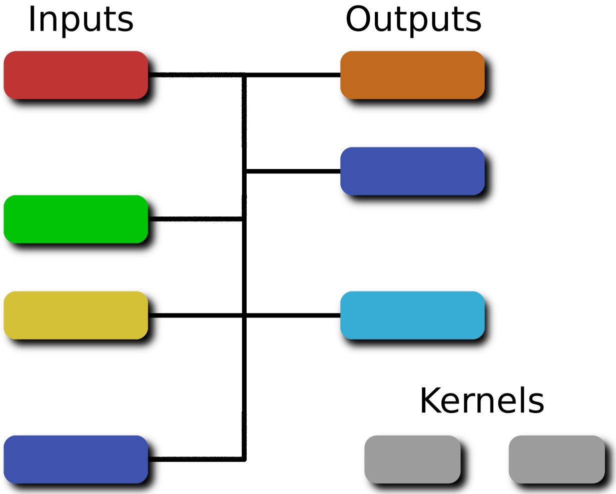
A Mimblewimble transaction is the following data:

- Inputs (references to old outputs).
- Outputs: confidential transaction outputs (group elements, which blind and commit to amounts), plus rangeproofs.
- Kernel: algebraically, difference between outputs and inputs (group element); morally a multisignature key for all transacting parties.
- Kernel signature: proves the kernel is really a multisignature key, and is not hiding any coins

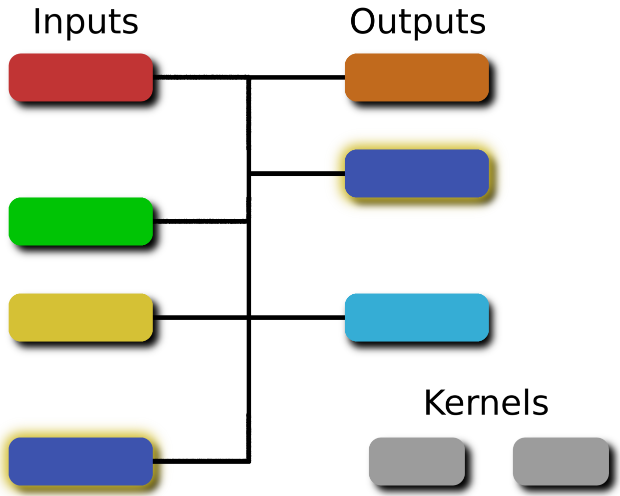
Mimblewimble Transactions



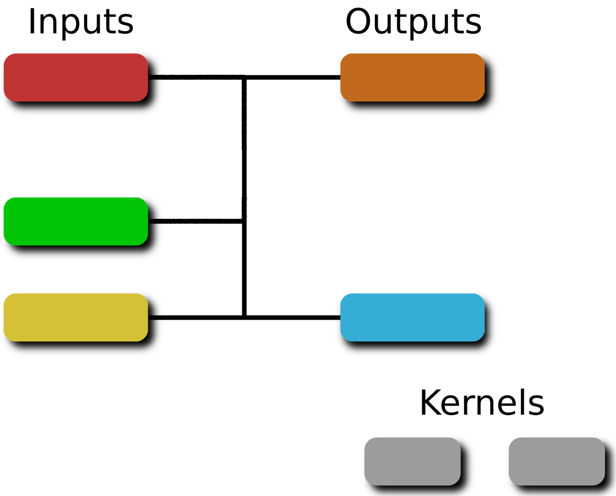
Mimblewimble Transactions



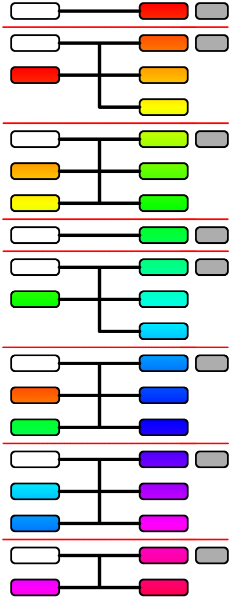
Mimblewimble Transactions



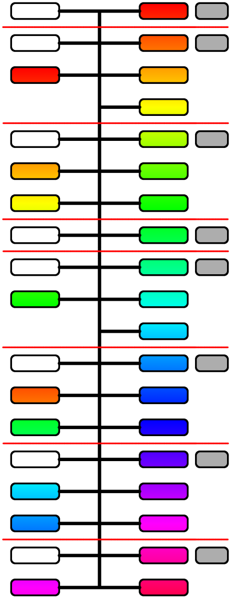
Mimblewimble Transactions



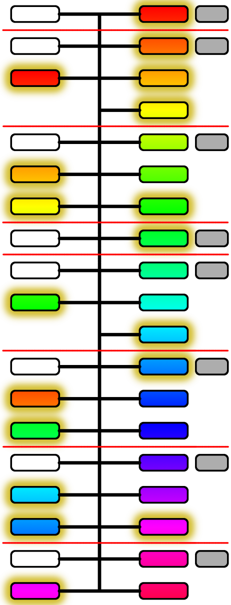
Mimblewimble Transactions



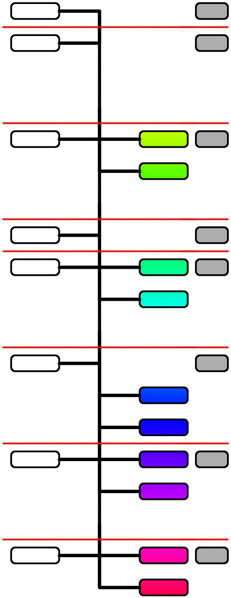
Mimblewimble Transactions



Mimblewimble Transactions



Mimblewimble Transactions



Mimblewimble Scaling: Real Numbers

- In Bitcoin there are 150 million transactions with about 350 million outputs, 45 million of which are unspent.
- This takes about 100Gb of space on disk today; with CT this would be over 1Tb!
- MimbleWimble gives us CT and requires storing: 15Gb of transaction kernels, headers etc.; 2Gb of unspent outputs, and 100Gb of UTXO rangeproofs.
- In pre-segwit Bitcoin, none of this is separable "witness data" which can be dropped in exchange for trust. In MW the rangeproofs are, leaving less than 20Gb of normative blockchain space.

“Scriptless Scripts”

- Scriptless scripts: magicking digital signatures so that they can only be created by faithful execution of a smart contract.
- Limited in power, but not nearly as much as you might expect.
- Mimblewimble is a blockchain design that supports only scriptless scripts, and derives its privacy and scaling properties from this.

Why use Scriptless Scripts?

- Bitcoin (and Ethereum, etc.) uses a scripting language to describe smart contracts and enforce their execution.
- These scripts must be downloaded, parsed, validated by all full nodes on the network. Can't be compressed or aggregated.
- The details of the script are visible forever, compromising privacy and fungibility.
- With scriptless scripts, the only visible things are public keys (i.e. uniformly random curvepoints) and digital signatures.

Schnorr Signatures Support Scriptless Scripts

- Schnorr signatures: signer has a keypair (x, P).
- A signature is the public half of an "ephemeral keypair" (k, R) along with a linear equation in x and k. Equation depends on the hash of a message.
- Signature can be verified because the key-derivation map $x \mapsto P$ is also linear.
- ECDSA signatures (used in Bitcoin) have the same basic shape but aren't linear in x and k, so they are less useful.

Simplest (Sorta) Scriptless Script

- `OP_RETURN` outputs are used in Bitcoin to encode data for purpose of timestamping.
- Alternate: replace a public key P with $P + \mathtt{Hash}(P \| m)G$.
- Replacing the signer's public key is called "pay to contract" and is used by Elements and Liquid to move coins onto a sidechain.
- Replacing the ephemeral key is called "sign to contract". Used to attach a timestamp to an unrelated transaction with zero network overhead.

Schnorr multi-Signatures are Scriptless Scripts

- By adding Schnorr signature keys, a new key is obtained which can only be signed with with the cooperation of all parties.
- Can be generalized to m-of-n by all parties giving m-of-n linear secret shares to all others so they can cooperatively replace missing parties.
- (Don't try this at home: some extra precautions are needed to prevent adversarial choice of keys.)

ZKCPs in Scriptless Script

- Zero-Knowledge Contingent payments (Greg Maxwell): sending coins conditioned on the recipient providing the solution to some hard problem.
- Recipient provides a hash H and a zk-proof that the preimage is the encryption key to a valid solution. Sender puts coins in a script that allows claimage by revealing the preimage.
- Use the signature hash e in place of H and now you have a scriptless script ZKCP: a single digital signature which cannot be created without the signer solving some arbitrary (but predetermined) problem for you.
- Alternate: Banasik, Dziembowski and Malinowski (2016/451)

Simultaneous Scriptless Scripts

- Executing separate transactions in an atomic fashion is traditionally done with preimages: if two transactions require the preimage to the same hash, once one is executed, the preimage is exposed so that the other one can be too.
- Atomic Swaps (Tier Nolan) and Lightning channels (Poon/Dryja) use this construction.
- "Use the message-hash as the hash" doesn't work here to scriptless-scriptify this because message hashes can't be fixed before a signature is created. Worse, this would link the two transactions, violating the spirit of scriptless scripts.

Adaptor Signatures

- Instead use another ephemeral keypair (t, T) and treat T as the "hash" of t.
- When doing a multi-signature replace the old ephemeral key R with $R + T$, and now the signature s must be replaced by $s + t$ to be valid.
- Now the original s is an "adaptor signature". Anyone with this can compute a valid signature from t or vice-versa. They can verify that it is an adaptor signature for T, no trust needed.
- One can compute an adaptor signature without knowing t, but they will then be unable to produce a real signature.

Atomic (Cross-chain) Swaps

- Parties Alice and Bob send coins on their respective chains to 2-of-2 outputs. Bob thinks of a keypair (t, T) and gives T to Alice.
- Before Alice signs to give Bob his coins, she demands adaptor signatures with T from him for *both* his signatures: the one taking his coins and the one giving her coins.
- Now when Bob signs to take his coins, Alice learns t from one adaptor signature, which she can combine with the other adaptor signature to take *her* coins.

Basic Lightning

- Suppose Alice is paying David through Bob and Carol. She produces an onion-routed path

  $$\text{Alice} \to \text{Bob} \to \text{Carol} \to \text{David}$$

  and asks for public keys B, C and D from each participant.

- She sends coins to a 2-of-2 between her and Bob. She asks Bob for an adaptor signature with $B + C + D$ before signing to send him the coins.

- Similarly Bob sends coins to Carol, first demanding an adaptor signature with $C + D$ from her. Carol sends to David, demanding an adaptor signature with D.

Features of Adaptor Signatures

- Adaptor signatures work across blockchains, even if they use different EC groups, though this requires a bit more work.
- After a signature hits the chain, anyone can make up a (t, T) and compute a corresponding "adaptor signature" for it, so the scheme is deniable. It also does not link the signatures in any way.
- Adaptor signatures are re-blindable, as we saw in the Lightning example. This is also deniable and unlinkable.

Sorceror's Scriptless Script

- Mimblewimble is the ultimate scriptless script.
- Every input and output has a key, and a transaction signature uses a multisignature of all these keys.
- Transaction validity is now contained in a scriptless script; further, the signature has be used with other scriptless script constructions (atomic swaps, ZKCP, etc.) to add additional validity requirements with zero overhead or even visibility to the network.

Open Problems

- Quantum-resistant Mimblewimble
- Efficient / Aggregatable rangeproofs
- Preserving scriptless scripts in multisig
- ECDSA support
- Locktimes and other extrospection
- Formalizing/understanding limits of scriptless scripts

Thank You

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