Hierarchical Deterministic Wallets

Bitcoinedge initiative

Tel Aviv, Israel
September 2019

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whoami

- Bryan Bishop
- Software development background
- Previously @ LedgerX (4 years!)
- Bitcoin Core contributor
- Biotech projects
- Transcripts - https://diyhpl.us/wiki/transcripts
- Follow me @ https://twitter.com/kanzure

Conflict of interest slide (Just kidding)

C → H → A → I → N → C → O → D → E →

DCO

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What is an HD wallet, briefly?

- Indeterministic wallet: random keys every time
  - Lots of horror stories of lost keys
  - Remember to backup your wallet!
  - Sweep to new change address -> ded.

https://github.com/bitcoin/bips/blob/master/bip-0032.mediawiki

Deterministic wallet: random key, but only once

- Backup the random master seed
- Armory originally implemented deterministic wallets, but it was a giant pool of addresses

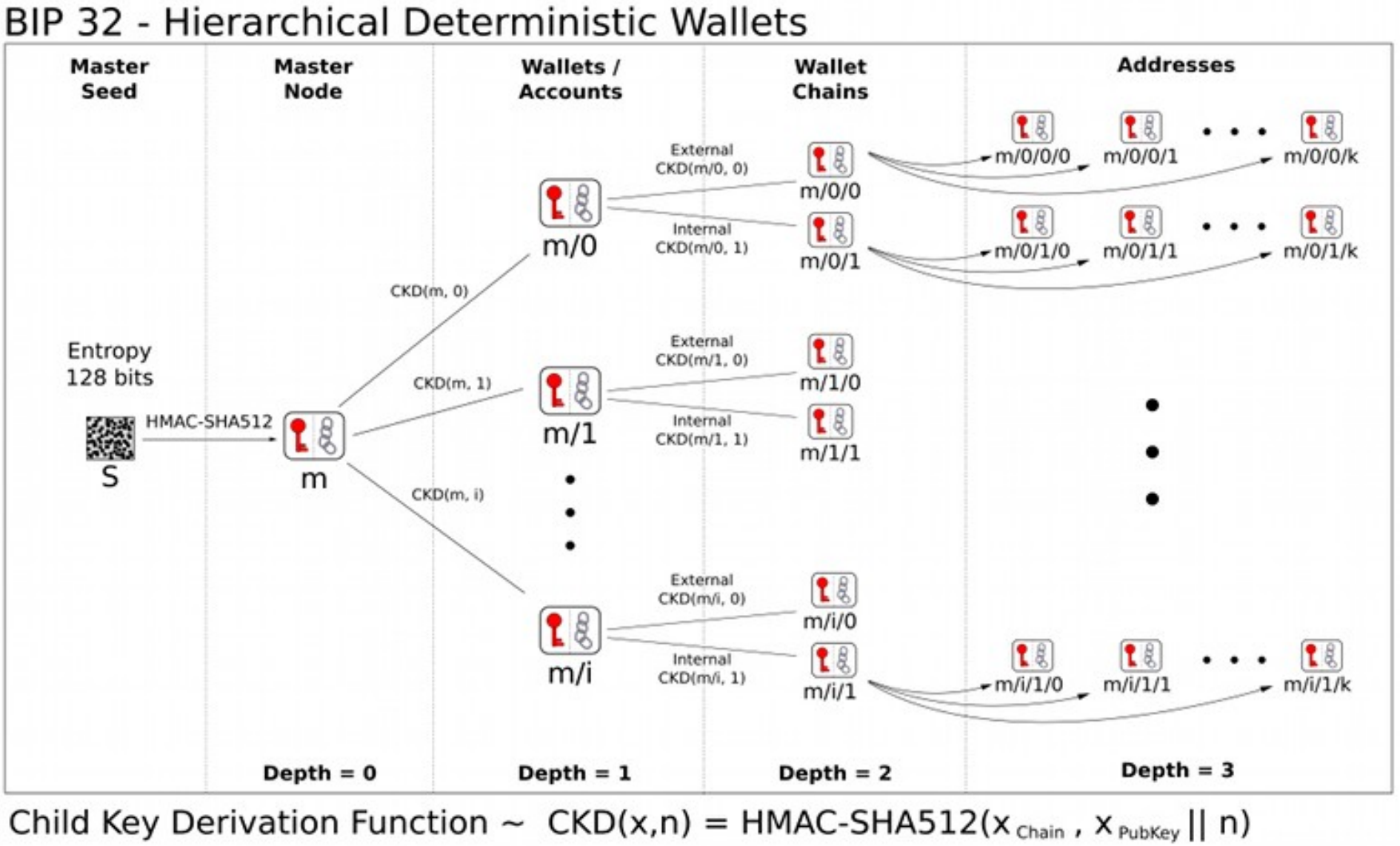
Hierarchical deterministic (HD) wallets

- Backup the master private key (master seed)
- Many deterministic subwallets
- Address reuse bad

Previously on Bitcoin Edge Dev++ (2018)

- James Chiang gave an excellent presentation on bip32:
  - video: https://www.youtube.com/watch?v=OVvue2dXkJo
  - transcript: https://diyhpl.us/wiki/transcripts/scalingbitcoin/tokyo-2018/edgedevplusplus/hierarchical-deterministic-wallets/
- Most of the diagrams in this presentation are from his slides.

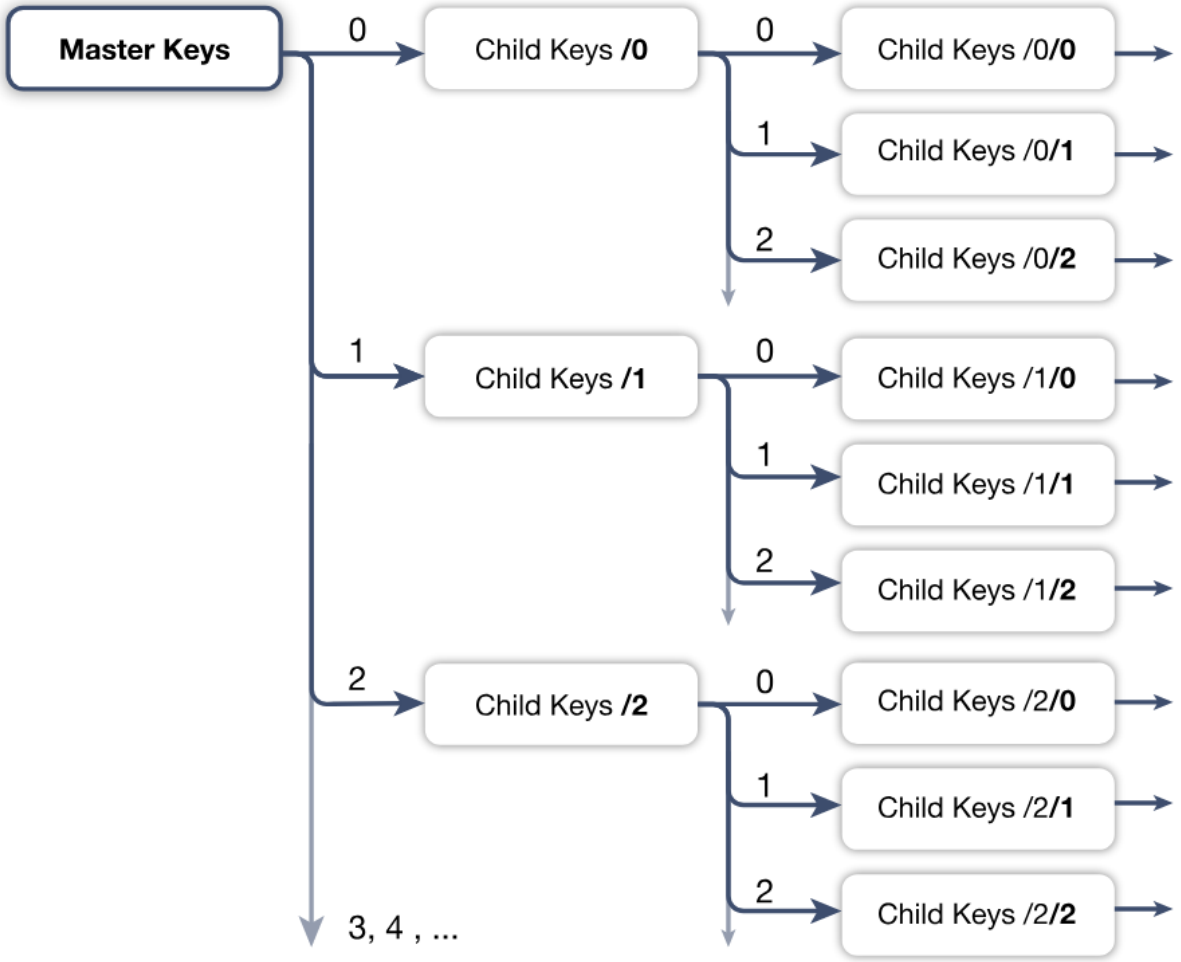
bip32 overview



Child Key Derivation Function ~ $CKD(x,n) = HMAC\text{-}SHA512(x_{Chain}, x_{PubKey} || n)$

bip32 Child Key Derivation Paths (bip32 paths)

Hierarchical Deterministic Wallets (BIP32)



HD wallets (BIP32) can deterministically derive an indefinite number of fresh addresses from a single wallet secret.

HD Tree

- Fresh addresses to improve privacy.
- HD Tree is derived from Master Keys.
- HD Tree can be reconstructed from master Keys (given tree structure).

Master keys

- Derived from HD root secret.

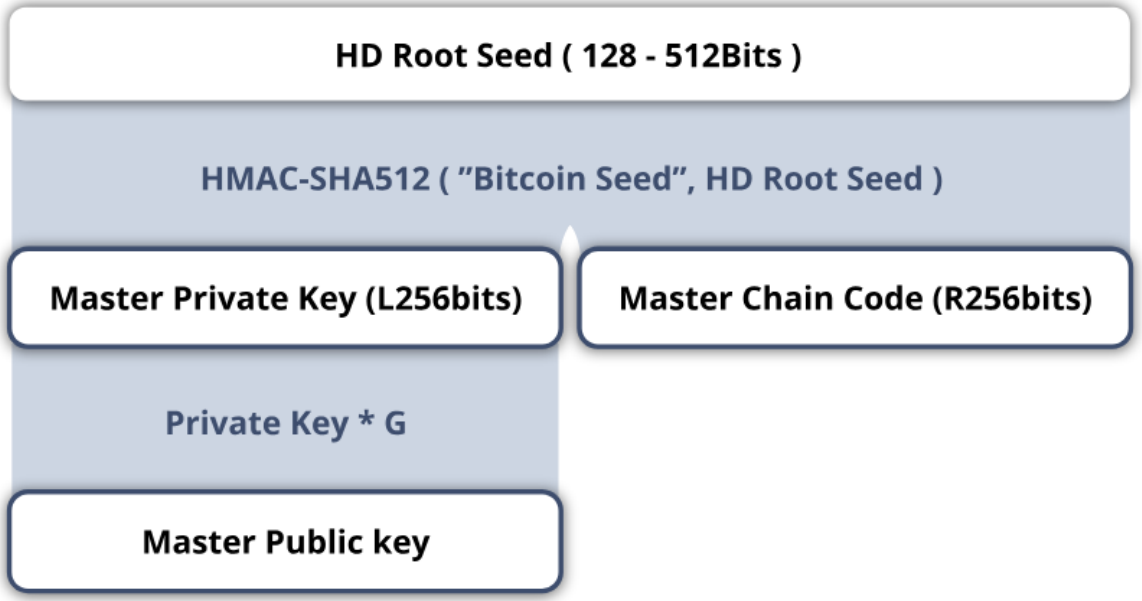
Subtrees

- Allow separation of keys for accounts/usages.
- Selective key sharing.

More bip32 paths

- m/0
- m/1/2/3/1, m/1/2/3/2, m/1/2/3/3, m/1/2/3/4, etc.
- m/1/2'
- m/1/2'/3'
- m/1/2'/3/4'
- m/1'/2/3'/4/5'
- etc...

Master key pair derivation

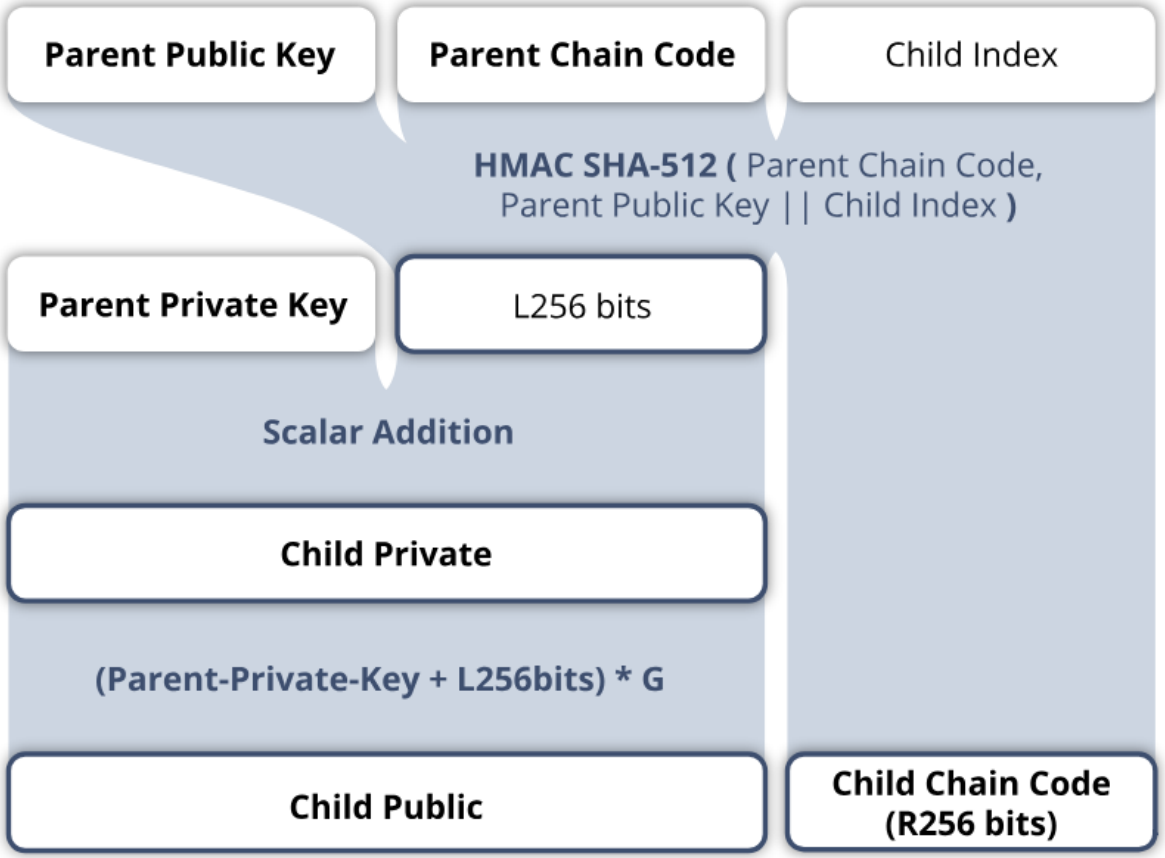


The master key pair is dervied from the HD root secret, and together with the chaincode, provides the basis for deriving subsequent child key generations.

HMAC-SHA512

- 512 bit hash digest is split into left and right 256 bits.
- Right 256 bits are chaincode, used in child key derivation.

Child key pair derivation, part 1



Hierarchical deterministic (child) private keys are derived from parent private keys.

HMAC SHA512

- Key: Parent chaincode
- Data: Parent public Key || Index

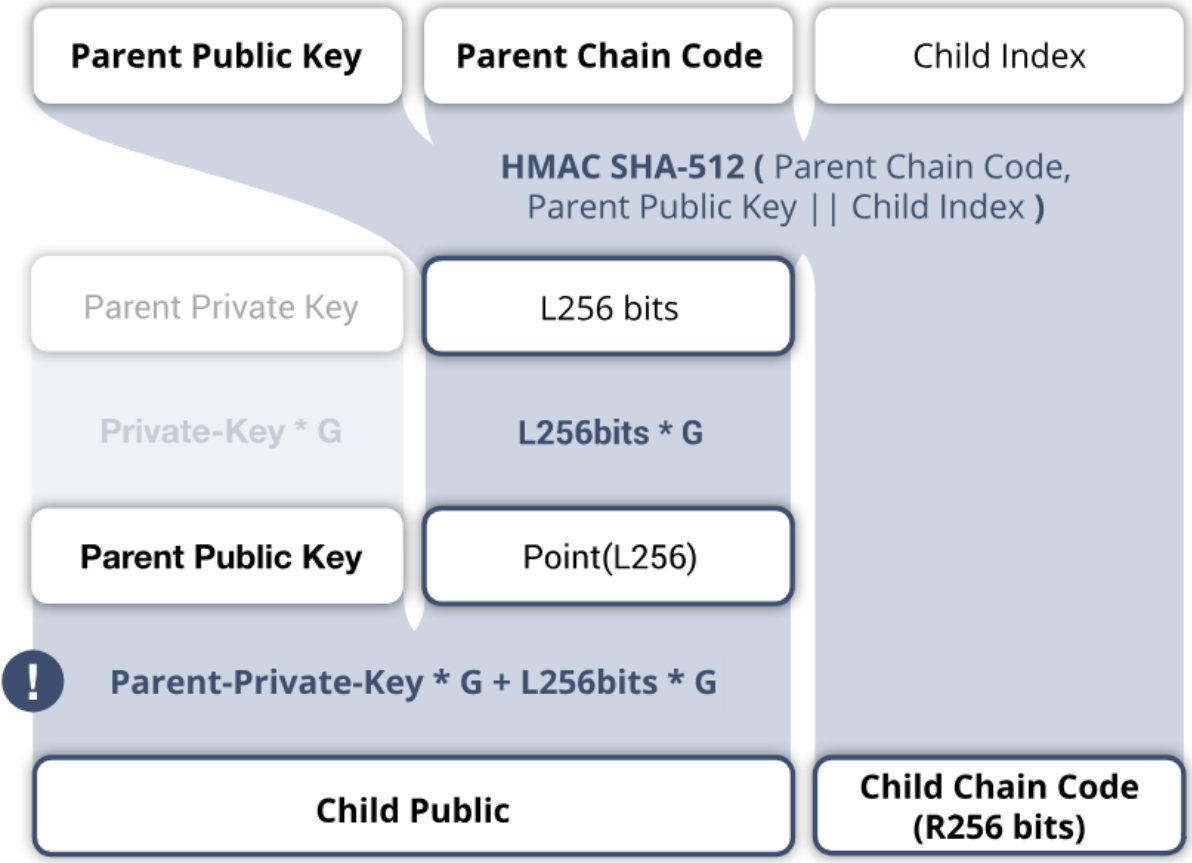
Addition of two 256bit scalars

- Private key + L256
- Result: Child private key

Parent public key to child public key

- HD child public key derivation without parent private key.

Child key pair derivation, part 2



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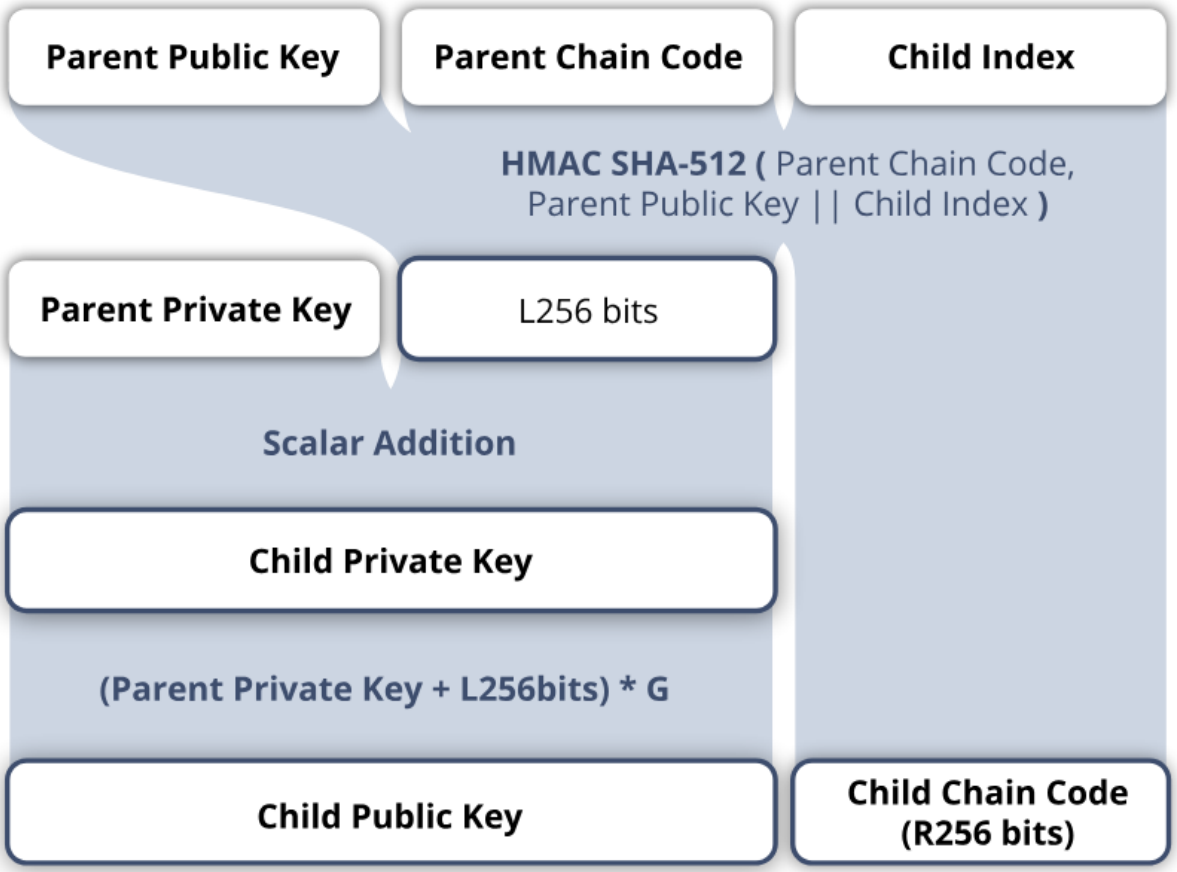
Hardened HD children



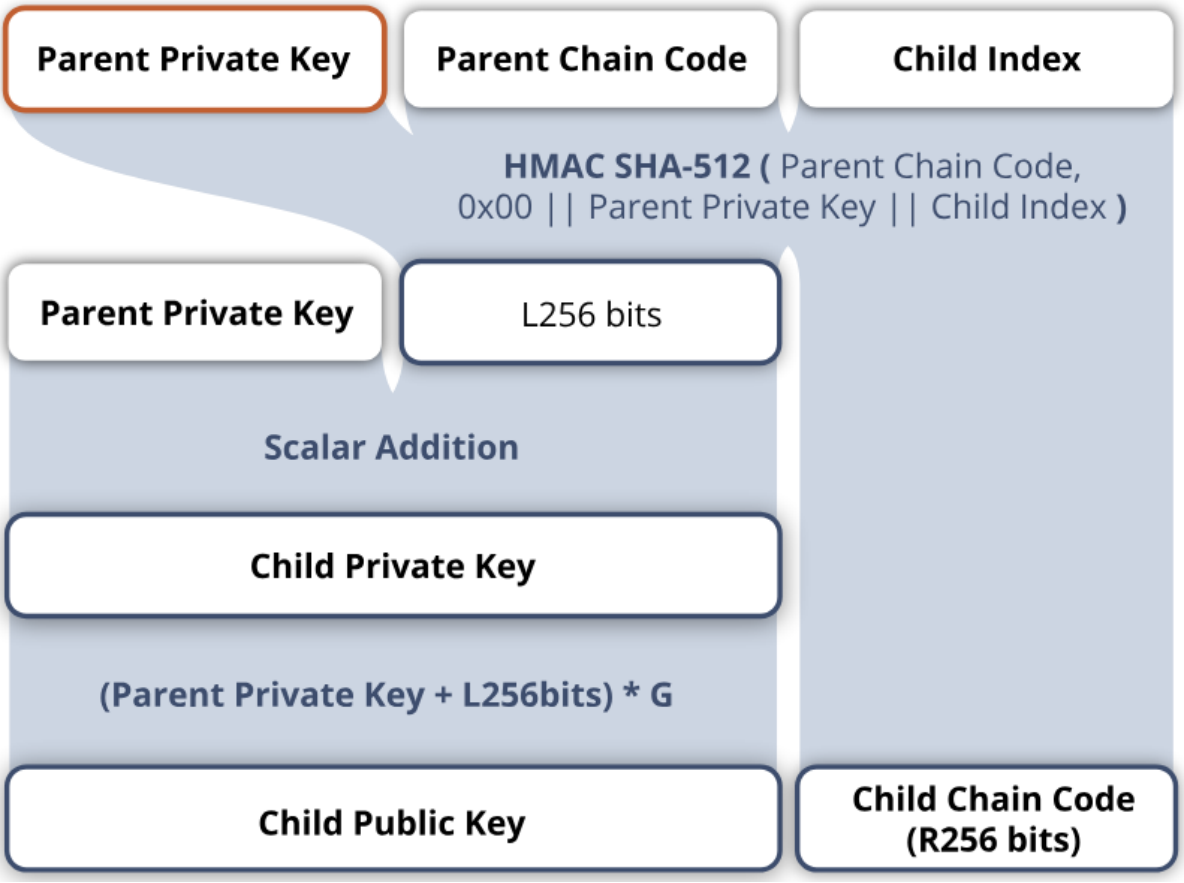
Child private key hardening

- Parent public key replaces private key.
- HMAC512:
  - Key: parent chaincode
  - Data: 0x00 || private key || index
- Hardened Index Notation:
  - i' = i + 2^31

Hardened public keys.

- Cannot derive any children.
- Derived only from hardened parent child key.

Hardened HD children



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Vulnerability: Private key exposure

- This is where hardened keys are useful.
- Note that exposing any child private key and the chaincode results in leaking the private key for the higher levels.
- Hardened keys mitigate this. Hardened keys protect their parent nodes from "downstream" leaks.

Wallets & gap limits

- Gap limit – number of addresses in bip32 tree to check when scanning the blockchain
- When to stop scanning?
- What if a user hands out a receiving address for a specific purpose, and then, since the user is a good user and doesn't reuse addresses, never uses it again? There can be large "gaps".
- Gap limit is usually set to 20 but it's arbitrary.

Quaint "use cases" specified in bip32 spec

- Some of these seem almost historical, has anyone read these in a while? Take a look....
- "Full wallet sharing" between nodes that both need to spend coins (what?)
- Audits: share extended public keys and the auditor can derive child addresses.
- Recurrent business-to-business transactions: Use an incrementing bip32 path off of some bip32 key.
- Receive-only wallet, like for a merchant's online webserver selling some items.

Software libraries

- bx tool (libbitcoin)
- pycoin (python)
- bcwallet (python)
- hdkey (javascript)

- I usually go with "pycoin". Buyer beware for the others; I don't have specific experience with those.

bip44

- "Multi-account hierarchy for deterministic wallets"
- Basically, a standard that recommends a specific hierarchy and labeled purposes for each level in the hierarchy.
- It's basically this:
  - m / purpose' / coin_type' / account' / change / address_index
- https://github.com/bitcoin/bips/blob/master/bip-0044.mediawiki

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