

CSE 3550/5000: Blockchain Technology

Lecture 4 Bitcoin - Part II

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Outline

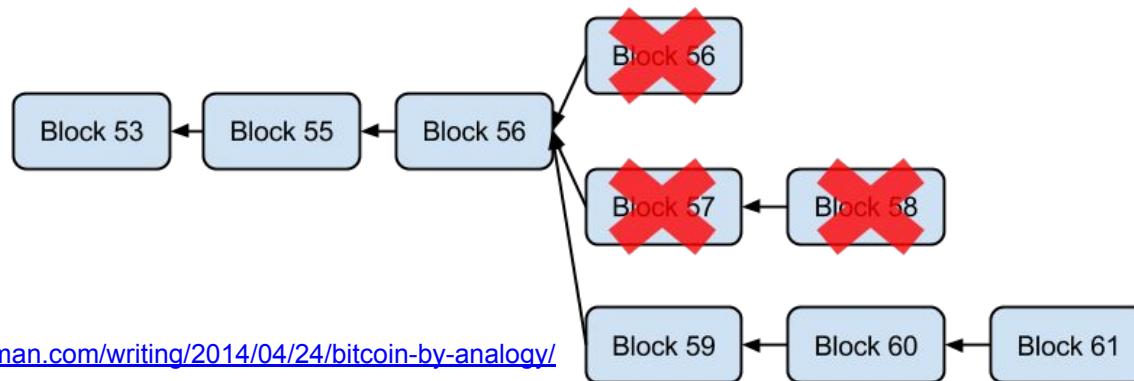
- More about Bitcoin:
 - Consensus.
 - Blockchain forking.
 - Properties like transparency, public verifiability, immutability, etc.
 - Bitcoin scripting language and transaction processing.

Consensus

- Miners hold, hopefully, consistent copies of the blockchain.
 - Only differ in the most recent unconfirmed blocks.
 - A block is confirmed when it is buried under at least 6 blocks.
- A miner votes for a block implicitly:
 - Accept it by including it in the chain and start mining on top of it.
 - Reject it by ignoring the new block and continue mining based on the older blockchain or another newly announced block.
- Remember: Bitcoin network is not perfect!
 - propagation delays, not all nodes hear all announced transactions, nodes may crash at any point of time, etc.
- Result: the blockchain may have multiple branches, i.e., forks.

Blockchain Forking

- Miners work on different branches.
- Resolved by adopting the longest branch since it means more work effort and larger history record.
 - That is, when a miner hears about another branch that longer than the current one it has, it will switch to the new branch.
- Older history is consistent; all honest miners will agree on a common prefix of the blockchain. They may differ in recent (unconfirmed) history.

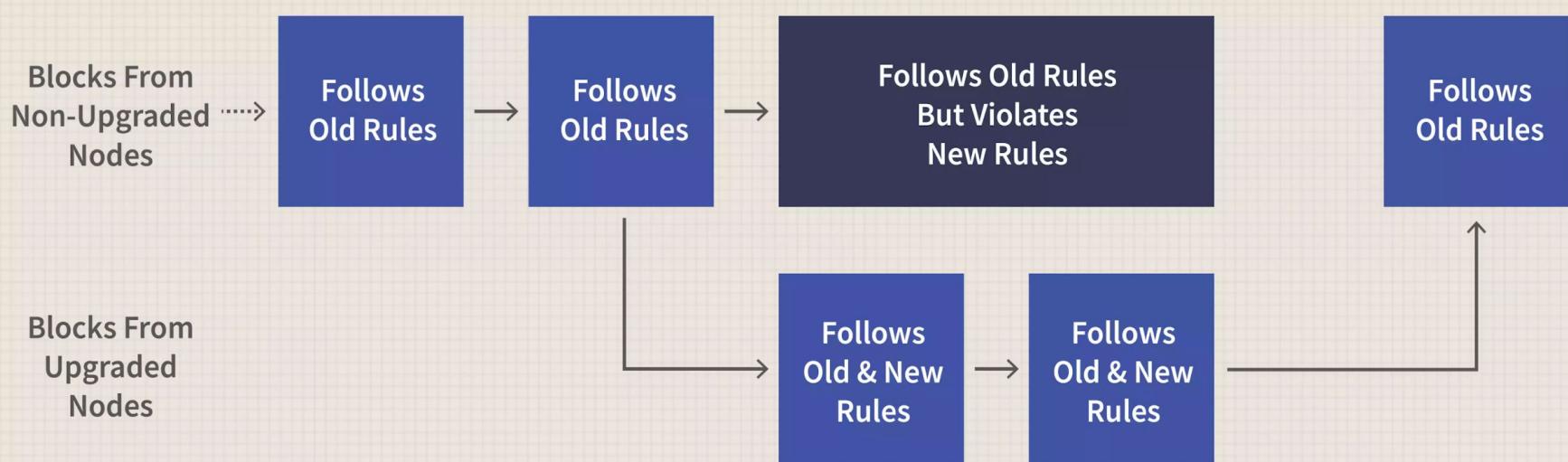


Source: <http://www.ybrikman.com/writing/2014/04/24/bitcoin-by-analogy/>

Forking Types - Soft Fork

- Temporary fork in the blockchain due to updating the consensus protocol to include additional rules on validating the blocks.
 - Generally, soft forks are related to adopting stricter rules to validate blocks/transactions.
- Why is it called soft?
 - Blocks considered valid by an old version of the protocol are not all valid by the new version.
 - But blocks considered valid by the new version are all valid based on the old version.
- If the majority of the nodes switch to the new version of the protocol, the old nodes will switch eventually since many of their mined blocks will be dropped.
 - Remember we assume honest majority.

Soft Fork - Pictorially



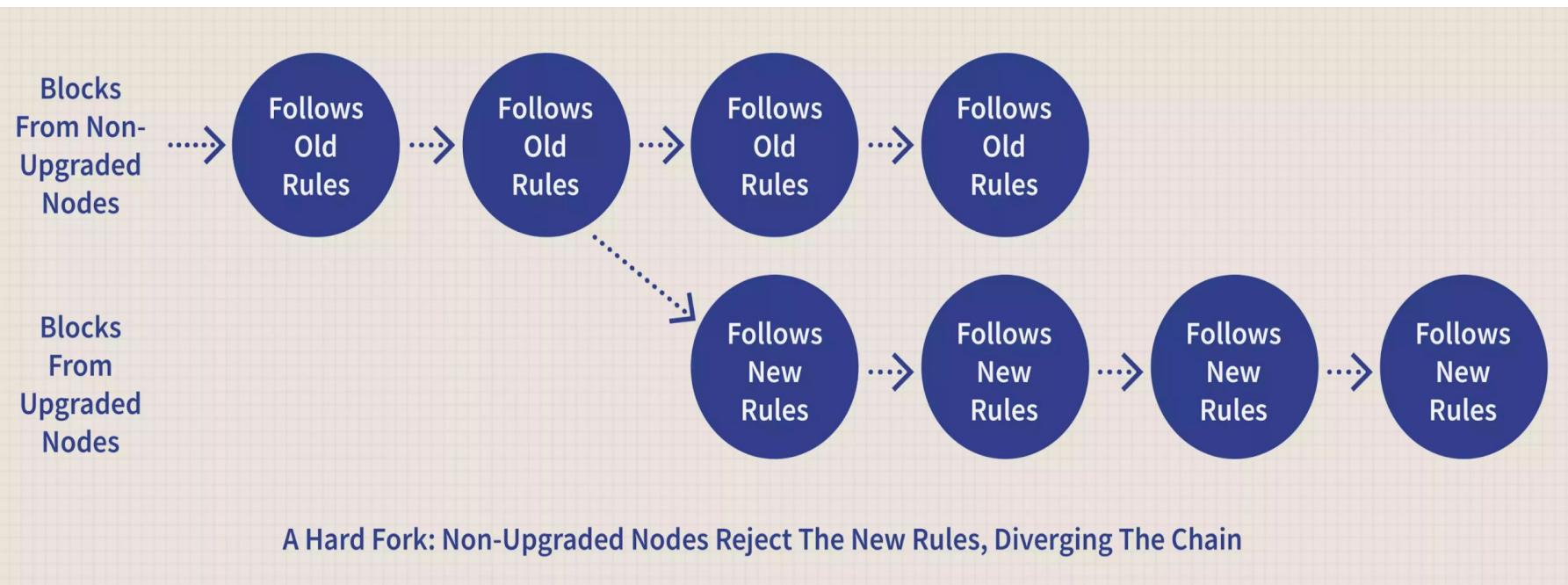
A Soft Fork: blocks violating new rules are made stale by the upgraded mining majority

From <https://www.investopedia.com/terms/s/soft-fork.asp>

Forking Types - Hard Fork

- Permanent fork in the blockchain due to core changes in the consensus protocol.
- Why is it called hard?
 - All blocks that are valid according to the new version are considered invalid by the old protocol version.
 - Thus, the two branches will not have any blocks/transactions in common.
 - Results in two different blockchains.
- So, a miner can be on one branch (or basically a blockchain) but not on both.
- Historically, Bitcoin experienced several hard forks, e.g., Bitcoin Cash, Bitcoin Gold, Bitcoin Satoshi Version (SV).

Hard Fork - Pictorially



From <https://www.investopedia.com/terms/h/hard-fork.asp>

Forking Types - Velvet Fork

- A conditional soft fork.
 - More strict validity rules for transactions and blocks that are applied when certain conditions are met.
 - If such conditions are not met, then the new rules are ignored.
- Usually used for improving protocol design but without producing two different blockchains or forcing miners to upgrade their versions of the network protocol.
 - Called backward-compatible since again blocks/transactions under the new version are also valid under the old version.

Blockchain (Bitcoin) Attractive Properties

Apart from decentralization and the open-access work model that we already covered

Take notes ;)

Transparency

- What does that mean?
- How does Bitcoin achieve it?

Public Verifiability

- What does that mean?
- How does Bitcoin achieve it?
- Can public verifiability and transparency achieve a sense of accountability in distributed systems?

Immutability

- What does that mean?
- How does Bitcoin achieve it?

Sybil-attack Resistance

- What are Sybil attacks?
- Why do they matter in Bitcoin?
- How is Bitcoin resistant to Sybil attacks?

Asynchronous Broadcast Channel

- What does that mean?
- How does Bitcoin achieve it?

Bitcoin Scripting Language

Validating Transactions

- Involves validating/checking:
 - The format of a transaction (including that total value of output does not exceed total input value),
 - and that the inputs can be spent to the outputs.
- The latter is done in a programmable way using Bitcoin scripting language.
 - This allows for greater flexibility and introduces the notion of ***programmable money***.

Bitcoin Scripting Language

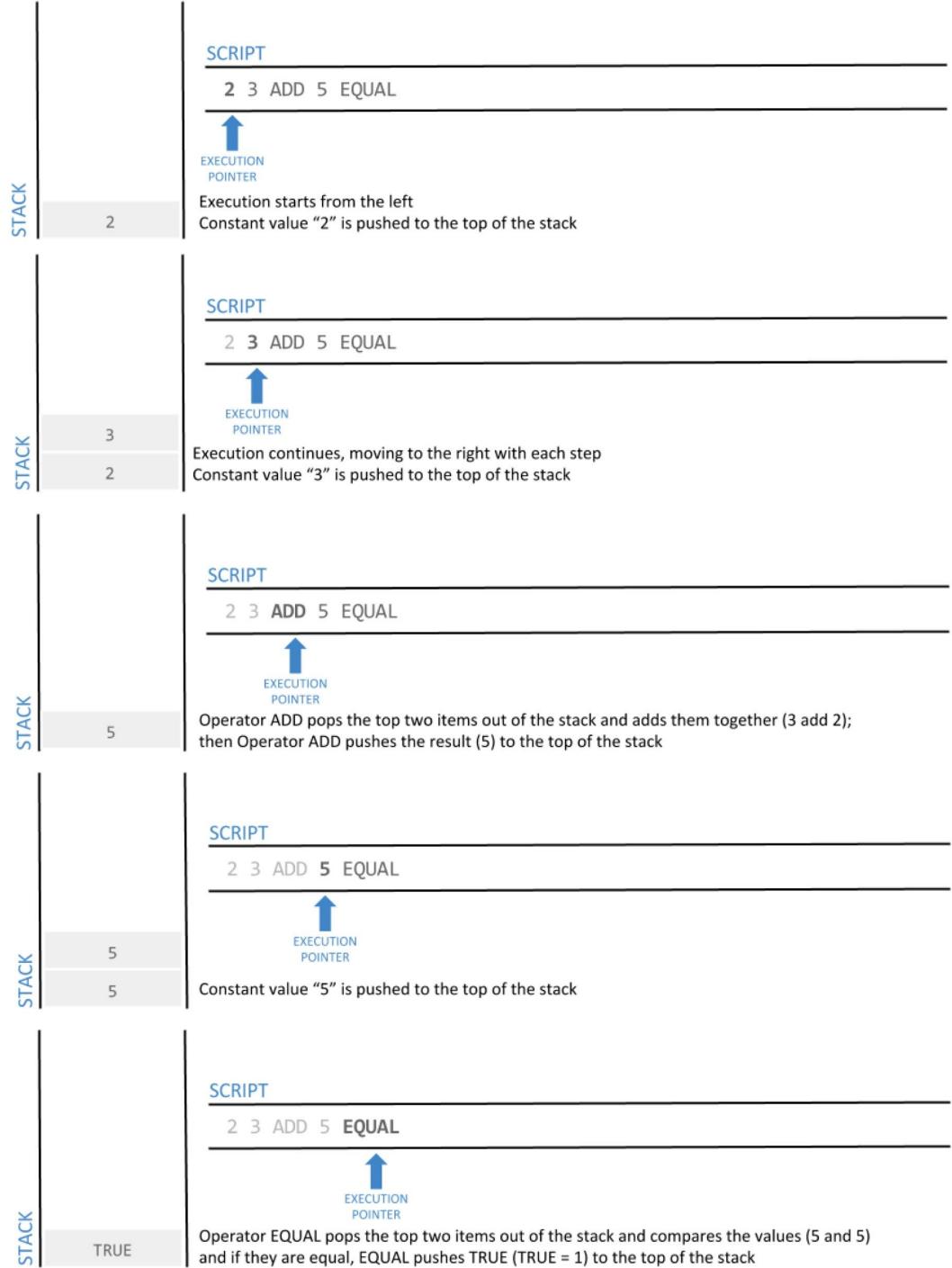
- Non Turing-complete, does not support loops.
 - Limited complexity and it has a predictable execution time.
 - Stack based.
 - Kept simple for security reasons.
 - More complex scripting languages, or better saying Turing-complete, provide greater flexibility for the programmer to build complicated functionalities.
 - It is hard to get it right!! Writing fully secure scripts or programs is not easy.
 - Attackers are financially motivated to dig into these programs and find security bugs.
- .

Script Construction

- Two parts: unlocking and locking scripts.
 - Locking: specify conditions that when met a given input (aka coins) can be spent.
 - Unlocking: a proof that the conditions have been met (i.e., provide inputs for the locking script to unlock it).
- Thus, a transaction has an unlocking script for each of its inputs that is processed alongside a locking script for the output of the referenced input transaction.
 - Recall that an input for a (new) transaction is an unspent output from a previous transaction.
 - The concatenated unlocking and locking scripts have to evaluate to **TRUE** in order to allow spending the coins.

Stack-based Scripting

- A clarifying example from “Mastering Bitcoin” book, Chapter 6.
- Locking and Unlocking scripts will be written similarly.



Script Construction - P2PKH

- Most popular transaction type in Bitcoin is pay to public key hash.
 - It means sending coins to some public key.

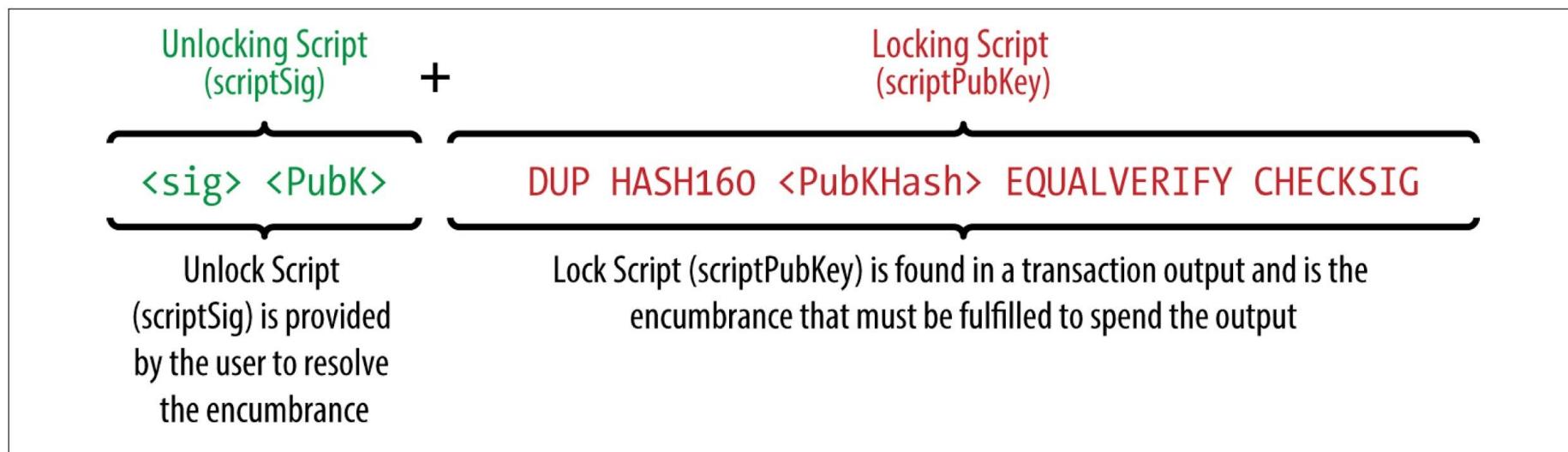


Figure from “Mastering Bitcoin” book, Chapter 6.

P2PKH Script Evaluation I

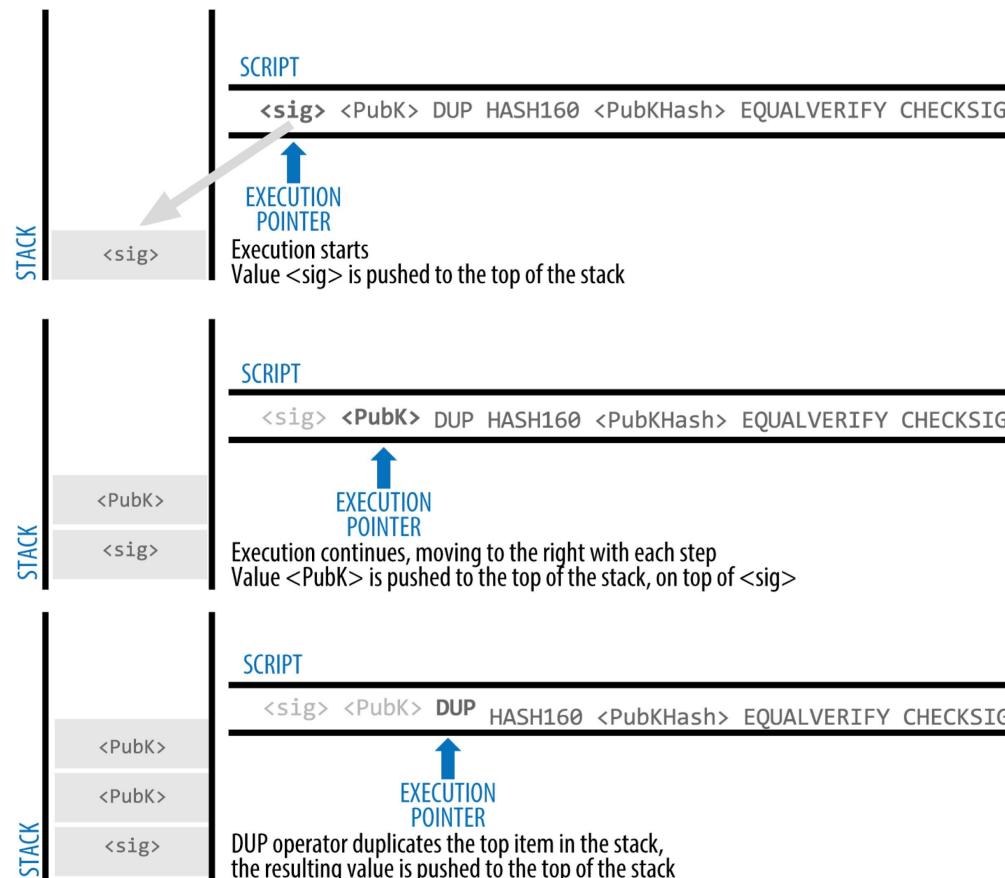
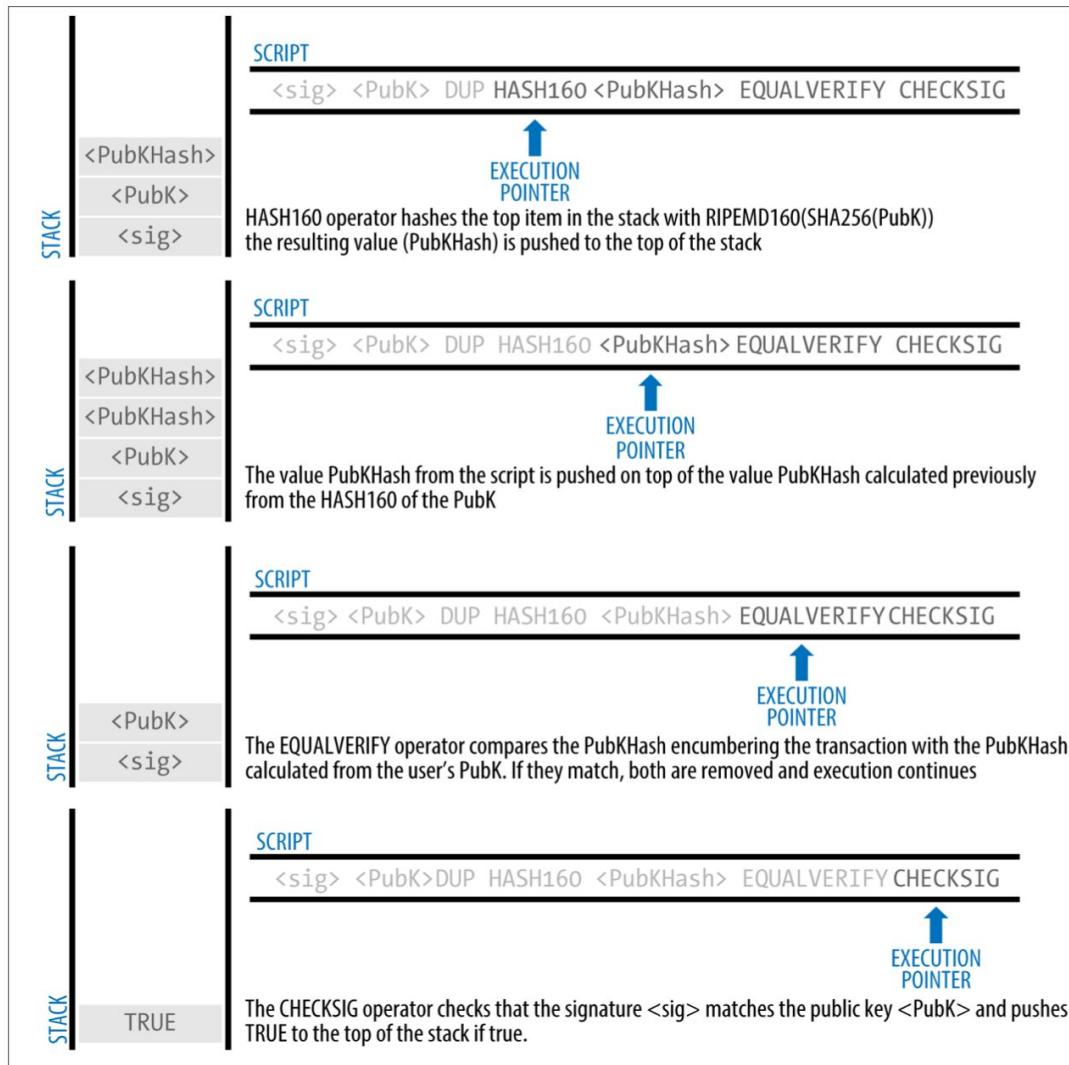


Figure from “Mastering Bitcoin” book, Chapter 5.

P2PKH Script Evaluation II



Bitcoin Standard Transactions

- Pay to public key hash (P2PKH).
 - Vast majority of Bitcoin transactions are of this type.
 - X pays Y a Z value of Bitcoins.
- Pay to public key.
 - Same as above but instead of using addresses (hashed public keys), use the public key itself.
 - Hashed public keys are more efficient as they are shorter.
- Data output.
 - Use OP_RETURN to store up to 40 byte data on the blockchain (e.g., document timestamping).
- Pay to script hash.
- Pay to multi-signature.
 - More about the above two in the next slides.

Pay to Multi-signature (P2MS)

- One of the very useful and widely implemented scripts in P2SH.
- The script requires signatures from multiple users to unlock the currency instead of one signature from one user.
- Can be built also in a threshold based way, like 2 out of 3 signatures are enough to spend the currency.
 - Up to 3 signatories are allowed, however, if P2SH (will be studied shortly) is used instead, then up to 15 signatories are allowed.
- Mostly used to create escrows.

P2MS - An Example

- Locking, unlocking, and concatenated scripts for a 2 out of 3 multisig transaction (from “Mastering Bitcoin”, Chapter 5).

```
2 <Public Key A> <Public Key B> <Public Key C> 3 CHECKMULTISIG
```

```
<Signature B> <Signature C>
```

```
<Signature B> <Signature C> 2 <Public Key A> <Public Key B> <Public Key C> 3 CHECKMULTISIG
```

Note: Due to a bug in the implementation of the CHECKMULTISIG opcode, an extra dummy input is needed in front of the unlocking script. Usually the value 0 or OP_0 is placed there. We will ignore that during the course.

Pay to Script Hash (P2SH) |

- Provides ways to implement advanced operations in Bitcoin beyond the standard currency transfer transactions.
- The address is the hash of some script, thus, these addresses start with 3 to differentiate them from normal addresses.
- To spend the currency locked under the script hash address you must present an unlocking script that makes this locking script evaluate to TRUE.
 - If the result is indeed true the currency is transferred to the destination address you specify.
- The scripts that you can code are limited by the primitives/opcodes supported in Bitcoin Scripting language (check <https://en.bitcoin.it/wiki/Script>).

Pay to Script Hash (P2SH) - Example

Redeem Script	2 PubKey1 PubKey2 PubKey3 PubKey4 PubKey5 5 CHECKMULTISIG
Locking Script	HASH160 <20-byte hash of redeem script> EQUAL
Unlocking Script	0 Sig1 Sig2 <redeem script>

- To spend it, one presents:

<Sig1> <Sig2> <2 PK1 PK2 PK3 PK4 PK5 5 OP_CHECKMULTISIG>

- The transaction is executed in two stages: First the script hash is
<2 PK1 PK2 PK3 PK4 PK5 5 OP_CHECKMULTISIG> OP_HASH160 <redeem scriptHash>
OP_EQUAL
- Then, second, the script is checked to evaluate to TRUE (I am ignoring the 0
' '
<Sig1> <Sig2> 2 PK1 PK2 PK3 PK4 PK5 5 OP_CHECKMULTISIG

Pay to Script Hash (P2SH) - Note

- Note that verifying the redeem script hash will remove the redeem script itself from the stack.
 - To allow evaluating the script on the input in the second phase, the miner will create a copy of the script to be used for later.
 - In particular, it will create a copy of the stack state, and if script hash verification outputs 1, the stack is reloaded with the older state containing the redeem script.

