mas.s62
lecture 16
MAST, taproot, graftroot

2018-04-09

Tadge Dryja

schedule stuff

for next monday: submit project proposals

office hours tuesday 4-6

today

new types of scripts

- MAST
- taproot
- graftroot

script types

mostly P2PKH or segwit equivalent

OP_DUP OP_HASH160 <pkh>
OP_EQUALVERIFY OP_CHECKSIG

OP_0 <pkh>

(segwit saves 3 bytes)

script types

P2SH or segwit equivalent

P2SH: OP_HASH160 <sh> OP_EQUAL

P2WSH: OP_0 <sh>

(distinguished from P2WPKH by data size (20 vs 32 bytes))

mostly used for multisig

script types

multisig:

```
OP_2 <pkA> <pkB> <pkC> OP_3
OP_CHECKMULTISIG
```

to spend:

```
OP_0 <sigA> <sigC>
```

output vs input size

pay to pubkey:

<pk> OP_CHECKSIG

34 bytes in output script (+10), but saves 33 bytes in signature! Overall 23 bytes smaller!

output vs input size

keep output sizes small as they are in the utxo DB. Need to be randomly read.

Signatures not in DB, only blocks, linear read and latency is OK

output vs input size

similarly, could put full scripts (like multisig) in the output field

space savings overall, but better to keep output size small

big scripts

what if we want really big scripts

2 of 3 multisig, just show all 3 keys, 33 bytes of extra data

2 of 50 multisig...?

big scripts

commit, only reveal part of commitment

...the cause of, and solution to, all a blockchain's problems!

merkle trees!

MAST

merkelized abstract syntax tree

make every opcode a leaf in a tree

perhaps overkill, simpler is "P2SMR"

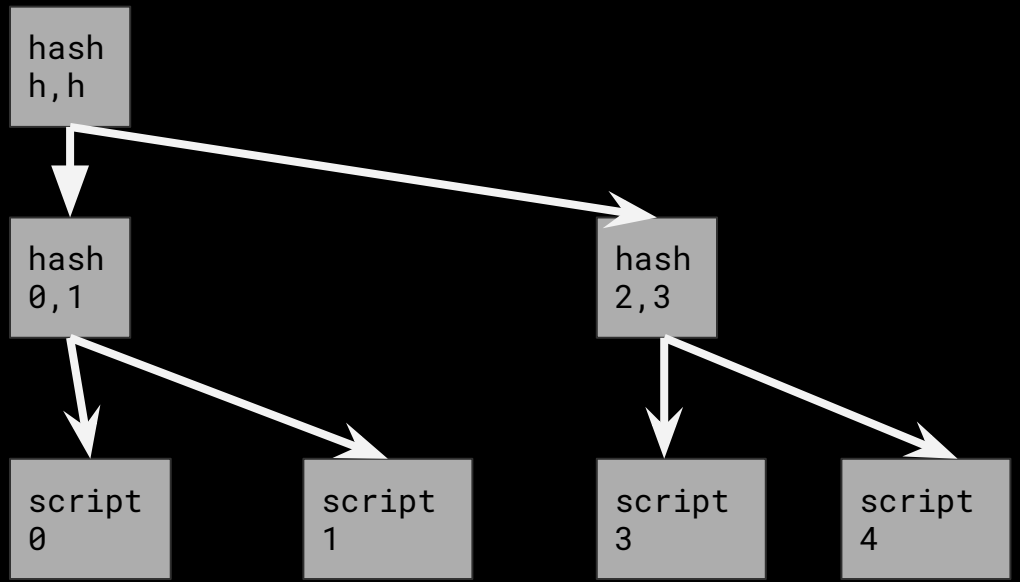
pay to script merkle root

MAST

make a bunch of scripts

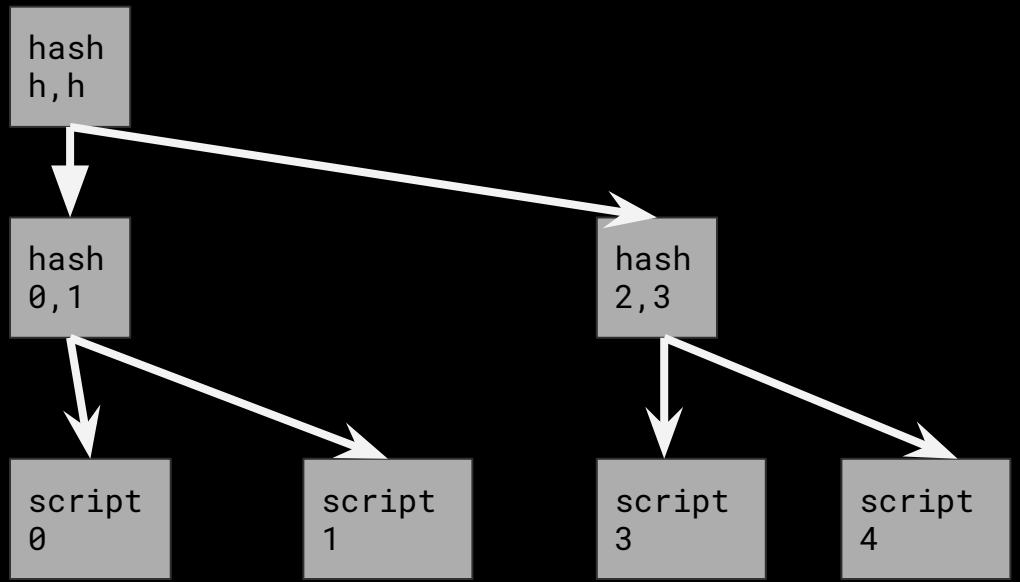
make a merkle tree of them

send to the root



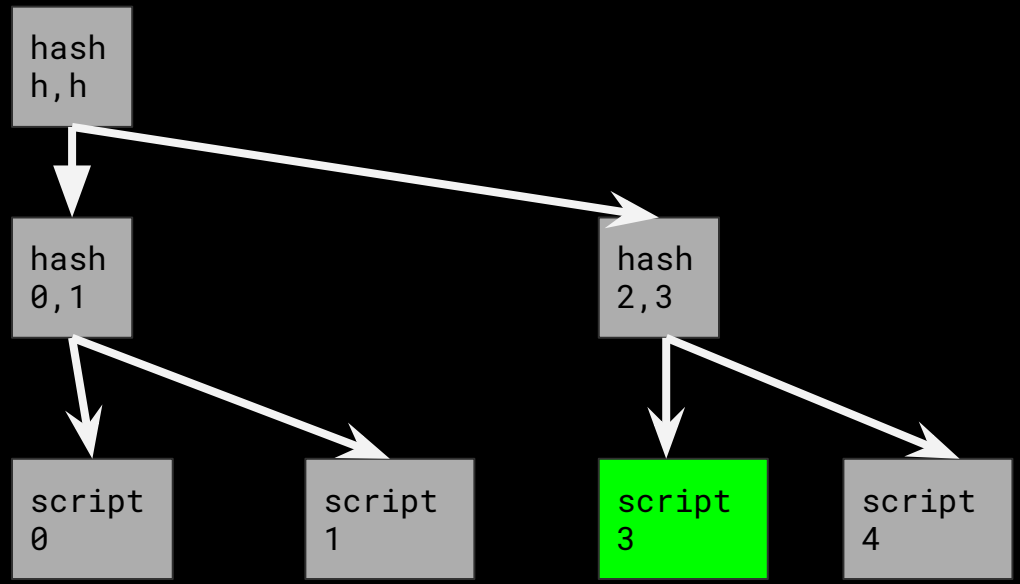
MAST

to spend, reveal which you're spending



MAST

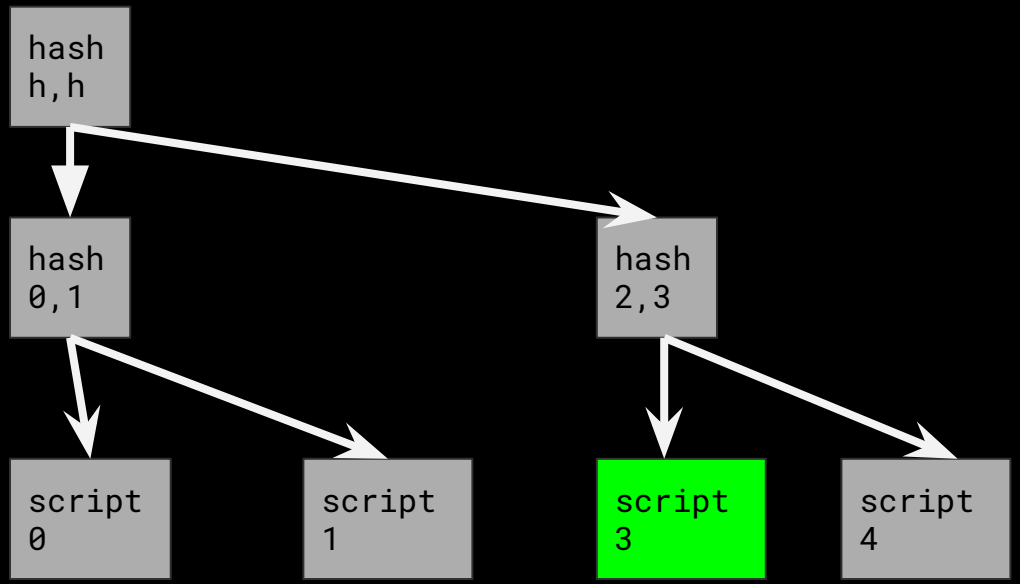
to spend, reveal which you're spending



MAST

to spend, reveal which you're spending

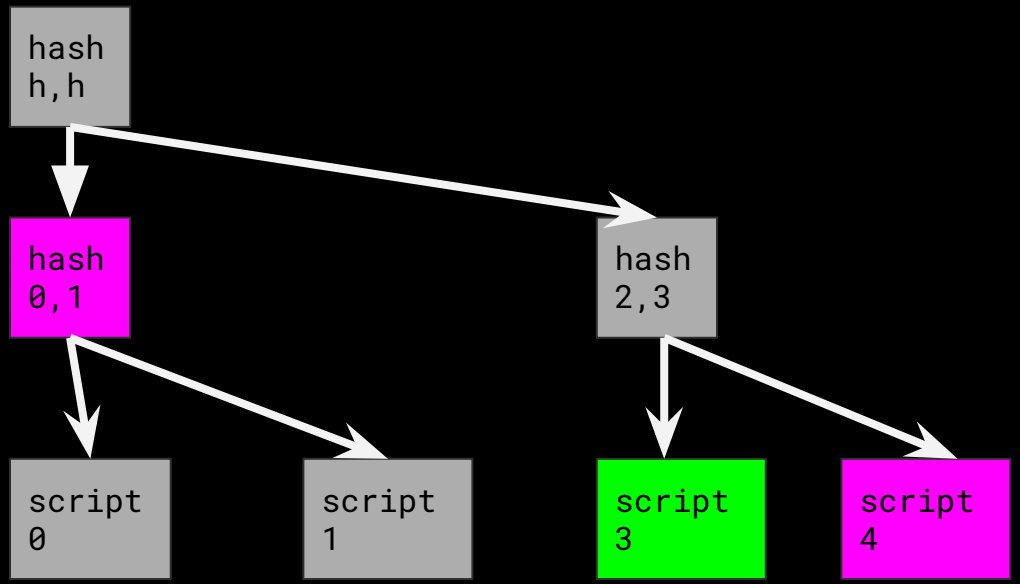
and reveal the path to the root



MAST

to spend, reveal which you're spending

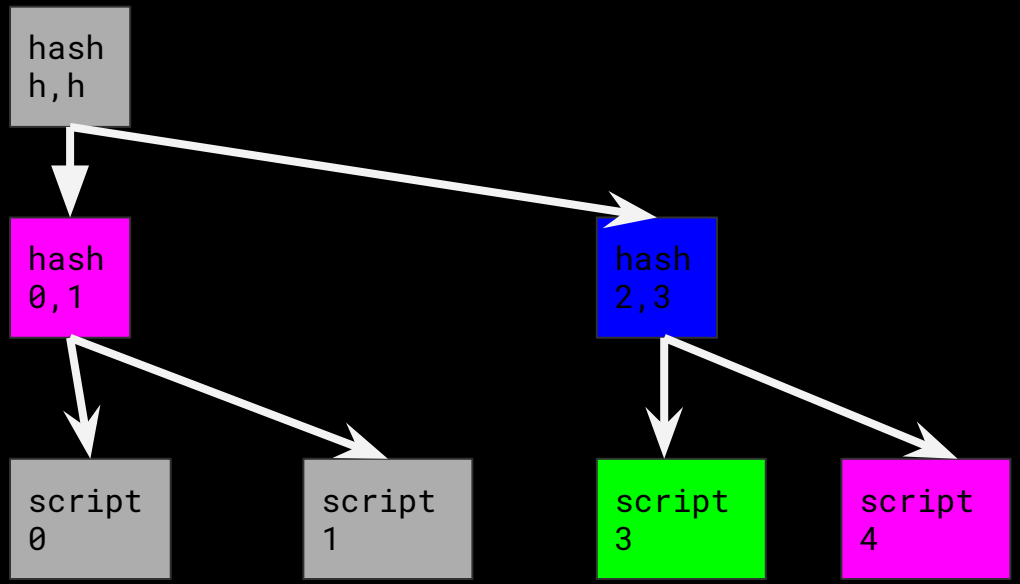
and reveal the path to the root



MAST

to spend, reveal which you're spending

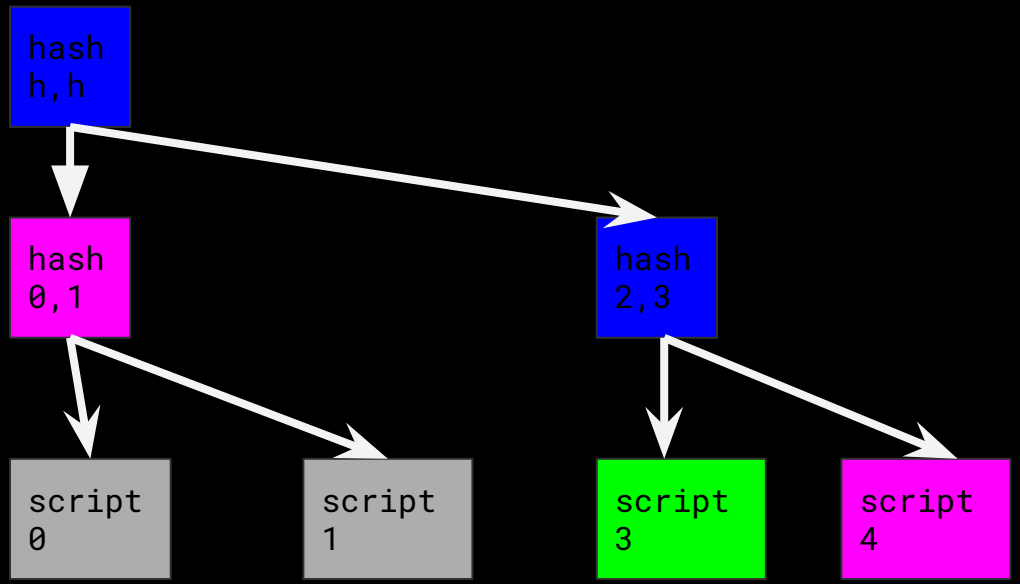
and reveal the path to the root



MAST

to spend, reveal which you're spending

and reveal the path to the root



MAST for big multisig

in the case of 2 of 50, it's

50 choose 2 = 1225 scripts,

tree height 11

proof size 11*32 = 352 bytes

raw is 50*33 = 1650 bytes

MAST for big multisig

25 of 50? 50 choose 25 = ~100T scripts, tree height 47

proof size 22*32 = 1504 bytes

raw is 50*33 = 1650 bytes

not much better. Also have to compute 200 trillion hashes.

MAST deployment

P2SMR, or tail call?

tail call: if there are 2 items left on the stack, treat the top as the MR, and the bottom as the proof & arguments

intermission

1<<7 sec timeout

OP_RETURN

seems unconnected...

people use OP_RETURN to put data in the blockchain.

But why?

OP_RETURN

seems unconnected...

people use OP_RETURN to put data in the blockchain.

But why?

to prove it's there

0 byte OP_RETURN

want to prove knowledge of some data before a blockheight

with 0 bytes overhead...

0 byte OP_RETURN

want to prove knowledge of some data before a blockheight

with 0 bytes overhead...

put it in the signature!

P2CH

pay to contract hash

Poelstra like a year ago?

weird name as it's undetectable

signature is:

$s = k - h(m, R)a$

$sG = R - h(m, R)A$

P2CH

$$s = k - h(m, R)a$$

$$k = j + h(data, jG)G$$

$$s = j+h(data, jG)G - h(m, kG)a$$

to verify, still

$$sG = R - h(m, R)A$$

P2CH

sig: (R, s) pubkey: A message: m

sG = R - h(m, R)A

but signer can prove that R is not kG!

(also, never reveal k, even later)

P2CH

sig: (R, s) pubkey: A message: m

sG = R - h(m, R)a

R = J + h(data, J)G

no way to prove this after the fact

J = h(data, J)G - R ...? J = h(J)

P2CH

put data inside a signature's R point

can even do it with other people's signatures! Just hand them the data, they give you the proof (just J)

OP_RETURN in 0 bytes -- nifty

taproot

ML post by Greg a few months ago

uses P2CH

same equation, but somehow took us a year or two to find this :)

taproot

motivation: P2PKH and P2SH look different. Different is bad.

can use P2SH for everything?

often, scripts OR "everyone signs"

in 2 of 50 multisig... 50 of 50 is also fine

taproot

merge P2PKH and P2SH

make key J, script z. Send to key C

C = J + hash(z, J)G

taproot

$C = J + hash(z, J)G$

treat as p2pkh: sign with

$c = j + hash(z, J)$

treat as p2sh: reveal (z, J), arguments, and run script

taproot

P = sum of everyone's keys

n of n -> 1 sig for schnorr (not ECDSA)

most smart contracts have an "all participants sign" clause

if everyone agrees, don't even show the contract

taproot

weird trick: can make a pubkey and prove there is no known private key

$C = J + hash(z, J)G$

interactive: use someone elses J

non-interactive:

show pre-image of J's x-coordinate

taproot

note that anyone can make a key and script and send to it

only pubkeys needed

which differs from the next cool thing which is...

graftroot

Maxwell, 2 months ago

Allow lots of scripts with O(1) proof size

merkle proofs grow in log(n)

proof that grows O(1)...?

graftroot

Maxwell, 2 months ago

Allow lots of scripts with O(1) proof size

merkle proofs grow in log(n)

proof that grows O(1)...?

signature

graftroot

key or script, but many scripts

send to key C

p2pkh: spend from C

p2sh: show script s, signature from C on message s, script arguments

graftroot

root key must sign every script

need to use private keys to create an address

overhead is 1 signature, to endorse the script being executed

graftroot

overhead is 1 signature, to endorse the script being executed

64 bytes? overhead is 33 bytes; can aggregate the s values (more on that next time)

graftroot

simple! more scripts can be added any time. O(1) scaling. a million scripts in 32 bytes

C can be threshold of many parties

signature can be aggregated within tx

downside: interactive setup

all together

unified output script:

OP_5 <pubkey>

to spend:

all together

to spend:

<sig> P2PKH mode

<J> <script> []<args>

taproot; verify commitment, execute

<C> <sig on script> <script> []<args>

graftroot; verify sig, execute

not implemented

there's code out there, but none of this is in Bitcoin, or any coin

maybe this year? next year?

If interested... start coding it!

(Also... use cases!)

MAST vs graftroot vs both