Transactions in Bitcoin

Implementation

What does a transaction look like?

When I receive it on the network

It’s just bytes/hex

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

https://github.com/jimmysong/programmingbitcoin/blob/master/ch05.asciidoc

What does a transaction look like?

When I receive it on the network

To process a transaction I need to:

- Serialize the data
- Deserialize (parse)

What does a transaction contain?

```
01000000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

- Version (4 bytes)
- Inputs (any amount of bytes)
- Outputs (any amount of bytes)
- Locktime (4 bytes)

Transactions

Implementation

```
class Tx:

    '''
    What defines a transaction:
    1. Version
    2. Locktime
    3. Inputs
    4. Outputs
    5. Network (testnet or not)
    '''
    def __init__(self, version, tx_ins, tx_outs, locktime, testnet=False):
        self.version = version
        self.tx_ins = tx_ins
        self.tx_outs = tx_outs
        self.locktime = locktime
        self.testnet = testnet
```

Parsing

Implementing transactions

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

How to transform bytes to TxIn, TxOut, and Tx?

- We need to implement the method *parse*

Version

Parsing

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

- Version (4 bytes)

```python
# When we receive raw transaction (bytes) we want to parse it to figure out what's what
@classmethod
def parse(cls, serialization):
    # get the version:
    version = serialization[0:4]
```

(in reality we will read from a stream; the number is little-endian; 1 = 0100000000)

Version

Parsing

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

```python
# When we receive raw transaction (bytes) we want to parse it to figure out what's what
@classmethod
def parse(cls, s, testnet=False):
    '''Takes a byte stream and parses the transaction at the start
    return a Tx object
    '''
    # s.read(n) will return n bytes
    # version is an integer in 4 bytes, little-endian
    version = little_endian_to_int(s.read(4))
```

Inputs

Parsing

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

The raw data format is:

- Number of inputs = K
- input1, input2, …, inputK

Inputs

Parsing

Inputs/Outputs:

- The first byte is the number of inputs/outputs

So how many can we have?

1 byte = 8 bits = 2^8 = 256 = [0,255] my range

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

Inputs

Parsing

First byte = number of inputs

- Max 255

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

What do I do if I want more inputs?

- **Varint**

Varints

Parsing

Varint = variable integer

- Allows values in the interval $[0,2^{64}-1]$

Rules of varint(n):

1. $n < 253$: 1 byte = n
2. $253 <= n < 2^{16}-1$: 253 (fd) + n (in 2 bytes little-endian)
3. $2^{16} <= n < 2^{32}-1$: 254 (fe) + n (in 4 bytes little-endian)
4. $2^{32} <= n < 2^{64}-1$: 255 (ff) + n (in 8 bytes little-endian)

100 = 0x64
255 = 0xfdff00
70015 = 0xfe7f110100

Varints

Parsing

```
def read_varint(s):
    '''read_varint reads a variable integer from a stream'''
    i = s.read(1)[0]
    if i == 0xfd:
        # 0xfd means the next two bytes are the number
        return little_endian_to_int(s.read(2))
    elif i == 0xfe:
        # 0xfe means the next four bytes are the number
        return little_endian_to_int(s.read(4))
    elif i == 0xff:
        # 0xff means the next eight bytes are the number
        return little_endian_to_int(s.read(8))
    else:
        # anything else is just the integer
        return i
```

Varints

Parsing

```
def encode_varint(i):
    '''encodes an integer as a varint'''
    if i < 0xfd:
        return bytes([i])
    elif i < 0x10000:
        return b'\xfd' + int_to_little_endian(i, 2)
    elif i < 0x100000000:
        return b'\xfe' + int_to_little_endian(i, 4)
    elif i < 0x10000000000000000:
        return b'\xff' + int_to_little_endian(i, 8)
    else:
        raise ValueError('integer too large: {}'.format(i))
```

Inputs

Parsing

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

Elements of an input:

- Previous transaction hash
- Previous input
- Scriptsig
- Sequence

Previous input, sequence little-endian; hash tb.

Inputs

Coding inputs

```
class TxIn:

    def __init__(self, prev_tx, prev_index, script_sig=None, sequence=0xffffffff):
        self.prev_tx = prev_tx
        self.prev_index = prev_index
        if script_sig is None:
            self.script_sig = Script()
        else:
            self.script_sig = script_sig
        self.sequence = sequence
```

Inputs

Coding inputs

```
class TxIn:

    def __init__(self, prev_tx, prev_index, script_sig=None, sequence=0xffffffff):
        self.prev_tx = prev_tx
        self.prev_index = prev_index
        if script_sig is None:
            self.script_sig = Script()
        else:
            self.script_sig = script_sig
        self.sequence = sequence
```

We need to explain Script()

Inputs

Coding inputs

```
class TxIn:

    def __init__(self, prev_tx, prev_index, script_sig=None, sequence=0xffffffff):
        self.prev_tx = prev_tx
        self.prev_index = prev_index
        if script_sig is None:
            self.script_sig = Script()
        else:
            self.script_sig = script_sig
        self.sequence = sequence
```

Need to explain sequence
(for now we will ignore it)

Inputs

Parsing

```
class TxIn:

    .
    .
    .

    @classmethod
    def parse(cls, s):
        '''Takes a byte stream and parses the tx_input at the start
        return a TxIn object
        '''
        # prev_tx is 32 bytes, little endian
        prev_tx = s.read(32)[::-1]
        # prev_index is an integer in 4 bytes, little endian
        prev_index = little_endian_to_int(s.read(4))
        # use Script.parse to get the ScriptSig
        script_sig = Script.parse(s)
        # sequence is an integer in 4 bytes, little-endian
        sequence = little_endian_to_int(s.read(4))
        # return an instance of the class (see __init__ for args)
        return cls(prev_tx, prev_index, script_sig, sequence)
```

Outputs

Parsing

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

The raw data format:

- Number of outputs = K (varint)
- output1, output2, …, outputK

Outputs

Parsing

What does an output contain?

- value (8 bytes) 21,000,000 BTC = 2,100,000,000,000,000 Satoshis > 4 bytes
- ScriptPubKey

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

Outputs

Implementation

```
class TxOut:

    def __init__(self, amount, script_pubkey):
        self.amount = amount
        self.script_pubkey = script_pubkey

    def __repr__(self):
        return '{}:{}'.format(self.amount, self.script_pubkey)

    @classmethod
    def parse(cls, s):
        '''Takes a byte stream and parses the tx_output at the start
        return a TxOut object
        '''
        # amount is an integer in 8 bytes, little endian
        amount = little_endian_to_int(s.read(8))
        # use Script.parse to get the ScriptPubKey
        script_pubkey = Script.parse(s)
        # return an instance of the class (see __init__ for args)
        return cls(amount, script_pubkey)
```

Transactions

Implementation

```
class Tx:

    '''
    What defines a transaction:
    1. Version
    2. Locktime
    3. Inputs
    4. Outputs
    5. Network (testnet or not)
    '''
    def __init__(self, version, tx_ins, tx_outs, locktime, testnet=False):
        self.version = version
        self.tx_ins = tx_ins
        self.tx_outs = tx_outs
        self.locktime = locktime
        self.testnet = testnet
```

Transactions

Implementation

```
class Tx:

    '''
    What defines a transaction:
    1. Version
    2. Locktime
    3. Inputs
    4. Outputs
    5. Network (testnet or not)
    '''
    def __init__(self, version, tx_ins, tx_outs, locktime, testnet=False):
        self.version = version
        self.tx_ins = tx_ins
        self.tx_outs = tx_outs
        self.locktime = locktime
        self.testnet = testnet
```

When can a transaction entre the blockchain = block number?
(ignored if sequence = 0xffffffff
In all the inputs)

Parsing a transaction

```python
class Tx:

    # When we receive raw transaction (bytes) we want to parse it to figure out what's what
    @classmethod
    def parse(cls, s, testnet=False):
        # version is an integer in 4 bytes, little-endian
        version = little_endian_to_int(s.read(4))
        # num_inputs is a varint, use read_varint(s)
        num_inputs = read_varint(s)
        # parse num_inputs number of TxIns
        inputs = []
        for _ in range(num_inputs):
            inputs.append(TxIn.parse(s))
        # num_outputs is a varint, use read_varint(s)
        num_outputs = read_varint(s)
        # parse num_outputs number of TxOuts
        outputs = []
        for _ in range(num_outputs):
            outputs.append(TxOut.parse(s))
        # locktime is an integer in 4 bytes, little-endian
        locktime = little_endian_to_int(s.read(4))
        # return an instance of the class (see __init__ for args)
        return cls(version, inputs, outputs, locktime, testnet=testnet)
```

What can we do up until now?

Parsing

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

How to go from bytes to TxIn, TxOut, y Tx

Serialization

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
06b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02
207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631
e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef0100000000
1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc
762dd5423e332166702cb75f40df79fea1288ac19430600
```

How do we produce these bytes?

- Serialization

Serialization

TxOut

```
class TxOut:

    ...

    def serialize(self):
        '''Returns the byte serialization of the transaction output'''
        # serialize amount, 8 bytes, little endian
        result = int_to_little_endian(self.amount, 8)
        # serialize the script_pubkey
        result += self.script_pubkey.serialize()
        return result
```

Serialization

TxIn

```
class TxIn:
    ...
    def serialize(self):
        '''Returns the byte serialization of the transaction input'''
        # serialize prev_tx, little endian
        result = self.prev_tx[::-1]
        # serialize prev_index, 4 bytes, little endian
        result += int_to_little_endian(self.prev_index, 4)
        # serialize the script_sig
        result += self.script_sig.serialize()
        # serialize sequence, 4 bytes, little endian
        result += int_to_little_endian(self.sequence, 4)
        return result
```

Serialization

Tx

```
class Tx:
    ...
    # When we have a transaction object, to send it to the network we need to serialize it
    def serialize(self):
        '''Returns the byte serialization of the transaction'''
        # serialize version (4 bytes, little endian)
        result = int_to_little_endian(self.version, 4)
        # encode_varint on the number of inputs
        result += encode_varint(len(self.tx_ins))
        # iterate inputs
        for tx_in in self.tx_ins:
            # serialize each input
            result += tx_in.serialize()
        # encode_varint on the number of outputs
        result += encode_varint(len(self.tx_outs))
        # iterate outputs
        for tx_out in self.tx_outs:
            # serialize each output
            result += tx_out.serialize()
        # serialize locktime (4 bytes, little endian)
        result += int_to_little_endian(self.locktime, 4)
        return result
```

The class Tx

An important method

```
class Tx:
    ...
    # Transaction ID; this is our hash pointer in the UTXO set
    # I.e. when you ask for a transaction to a full node, it guards it under this key
    def id(self):
        '''Human-readable hexadecimal of the transaction hash'''
        return self.hash().hex()

    # Well, just the hash
    # Note that the hash is given in "little-endian"
    def hash(self):
        '''Binary hash of the legacy serialization'''
        return hash256(self.serialize())[::-1]
```

Transacition fee

What are we missing?

To work with transactions, we should be able to:

- Determine the value of each input

```
class TxIn:

    def __init__(self, prev_tx, prev_index, script_sig=None, sequence=0xffffffff):
        self.prev_tx = prev_tx
        self.prev_index = prev_index
        if script_sig is None:
            self.script_sig = Script()
        else:
            self.script_sig = script_sig
        self.sequence = sequence
```

Transacition fee

What are we missing?

To work with transactions we need to:

- Know the value of each input
- Input = output of some previous transaction

How do I get this output?

- **From a full node!!!**

Show me the money

Ask something from the UTXO of a full node

```
# The generic format (for mainnet):
#https://blockchain.info/rawtx/b6f6991d03df0e2e04dafffcd6bc418aac66049e2cd74b80f14ac86db1e3f0da?format=hex

#mainnet transaction:
tx_hash = 'b6f6991d03df0e2e04dafffcd6bc418aac66049e2cd74b80f14ac86db1e3f0da'

url = 'https://blockchain.info/rawtx/{}?format=hex'.format(tx_hash)
response = requests.get(url)

raw = bytes.fromhex(response.text)
stream = BytesIO(raw)
tx = Tx.parse(stream)
```

Show me the money

```python
class TxFetcher:

    @classmethod
    def get_url(cls, testnet=False):
        if testnet:
            return 'https://mempool.space/testnet/api/'
        else:
            return 'https://mempool.space/api/'

    @classmethod
    def fetch(cls, tx_id, testnet=False, fresh=False):
        url = '{}/tx/{}/hex'.format(cls.get_url(testnet), tx_id)
        response = requests.get(url)
        try:
            raw = bytes.fromhex(response.text.strip())
        except ValueError:
            raise ValueError('unexpected response: {}'.format(response.text))
        # make sure the tx we got matches to the hash we requested
        if raw[4] == 0:
            # zero imputs = coinbase
            raw = raw[:4] + raw[6:]
            tx = Tx.parse(BytesIO(raw), testnet=testnet)
            tx.locktime = little_endian_to_int(raw[-4:])
        else:
            tx = Tx.parse(BytesIO(raw), testnet=testnet)
        if tx.id() != tx_id:
            raise ValueError('not the same id: {} vs {}'.format(tx.id(), tx_id))
        return tx
```

Transacition fee

What are we missing?

How can we compute the txFee?

- sum = 0
- For each input
- Get the transaction from a full node
- Find the output we need (i.e. That defines this input)
- Add the value of this output to the sum

Subtract the value of outputs (we already have the value)

Transacition fee

Now you

```
'''
# The transaction class
'''
class Tx:

    ...

    # Computes the transaction fee
    # Recall that this will need to connect to a full node to get the input transaction!!!
    def fee(self):
        '''Returns the fee of this transaction in satoshi'''
        ######################
        ####IMPLEMENT THIS####
        ######################
        return 0
```

Transacition fee

Now you

```
class TxIn:

    ...

    def value(self, testnet=False):
        '''Get the outpoint value by looking up the tx hash
        Returns the amount in satoshi
        '''
        ########################
        ####IMPLEMENT THIS####
        ########################
        # You will have to use the TxFetcher class
        return 0
```

Signatures

What do we sign in Bitcoin?

- The entire transaction
- With the empty ScriptSig

Signatures

What do we sign in Bitcoin?

- The entire transaction
- With the ~~empty~~ ScriptSig replaced by ScriptPubKey it spends
- And an authorization code (SIGHASH)

And really really the hash of all that!

Signatures

How do we generate the hash of what we need to sign?

One signature for each input!

1. We remove all the ScriptSig
2. I replace my input with the corresponding ScriptPubKey
3. I concatenate the code specifying what is the authorization for

Signatures

What do we sign?

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d1000000006b483045022100ed81ff192e75a3fd2304004dcadb746fa5e24c5031ccfcf21320b0277457c98f02207a986d955c6e0cb35d446a89d3f56100f4d7f67801c31967743a9c8e10615bed01210349fc4e631e3624a545de3f89f5d8684c7b8138bd94bdd531d2e213bf016b278afeffffff02a135ef01000000001976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc762dd5423e332166702cb75f40df79fea1288ac19430600
```

version
nr_inputs
prev_hash
prev_index
ScriptSig
sequence
…

Signatures – for each input

For each input

Step1:

- Remove all the ScriptSig

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
000feffffff02a135ef0100000001976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac
99c39800000000001976a9141c4bc762dd5423e332166702cb75f40df79fea1288ac19430600
```

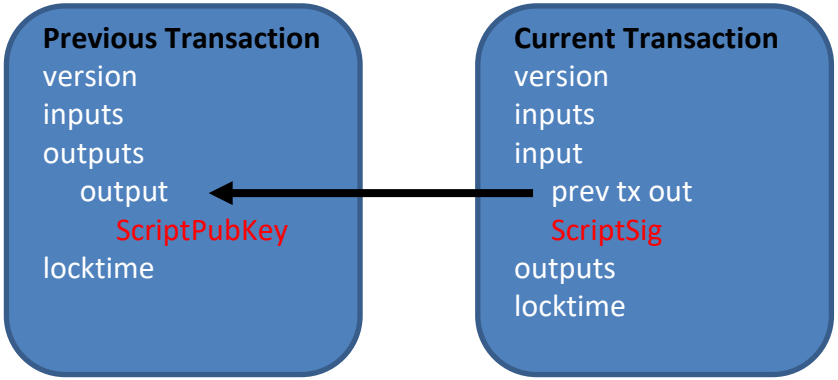
version
nr_inputs
prev_hash
prev_index
ScriptSig
sequence
…

Signatures – for each input

For each input

Step2:

- Replace the ScriptSig of the input we are signing for:

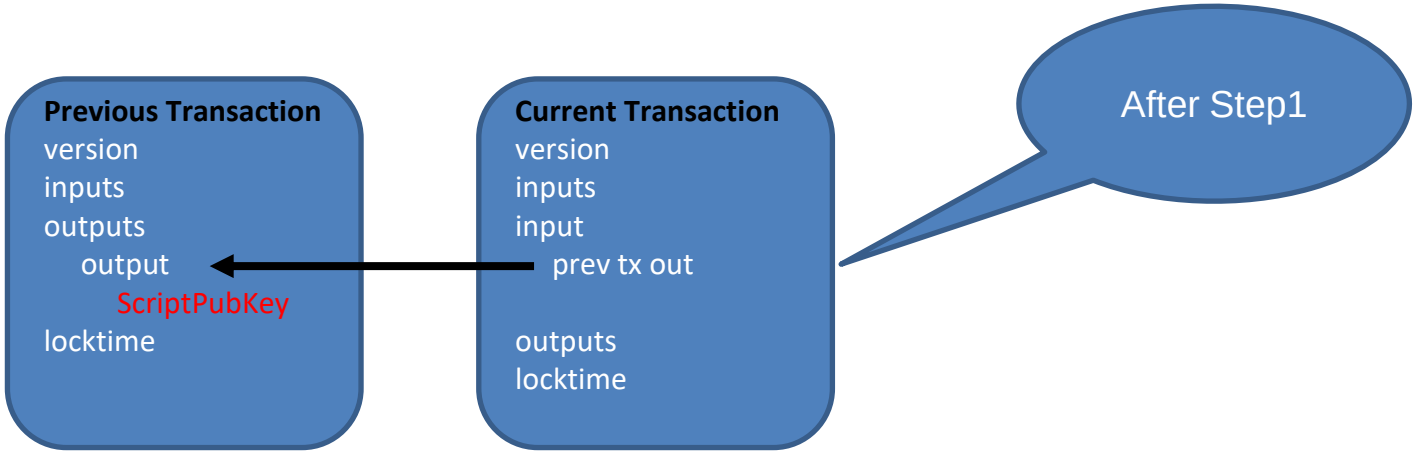


Signatures – for each input

For each input

Step2:

- Replace the ScriptSig of the input we are signing for:

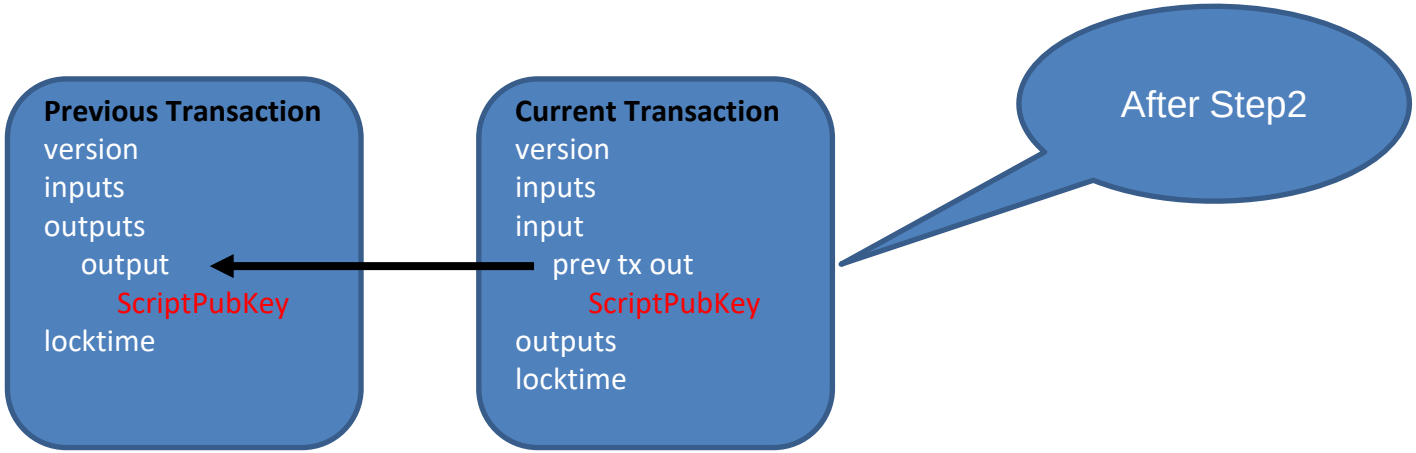


Signatures – for each input

For each input

Step2:

- Replace the ScriptSig of the input we are signing for:



Signatures – for each input

For each input

Step2:

- Replace the ScriptSig of the input we are signing for:

```
01000000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
000feffffff02a135ef0100000000 1976a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac
99c39800000000001976a9141c4bc762dd5423e332166702cb75f40df79fea1288ac19430600
```

version
nr_inputs
prev_hash
prev_index
ScriptSig
sequence
…

Signatures – for each input

For each input

Step2:

- Replace the ScriptSig of the input we are signing for:

```
01000000 01 813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d1 00000000
01 1976a914a802fc56c704ce87c42d7c92eb75e7896bdc41ae88ac feffffff 02 a135ef0100000000 19:
76a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac 99c3980000000000 1976a9141c4bc76
2dd5423e332166702cb75f40df79fea1288ac 19430600
```

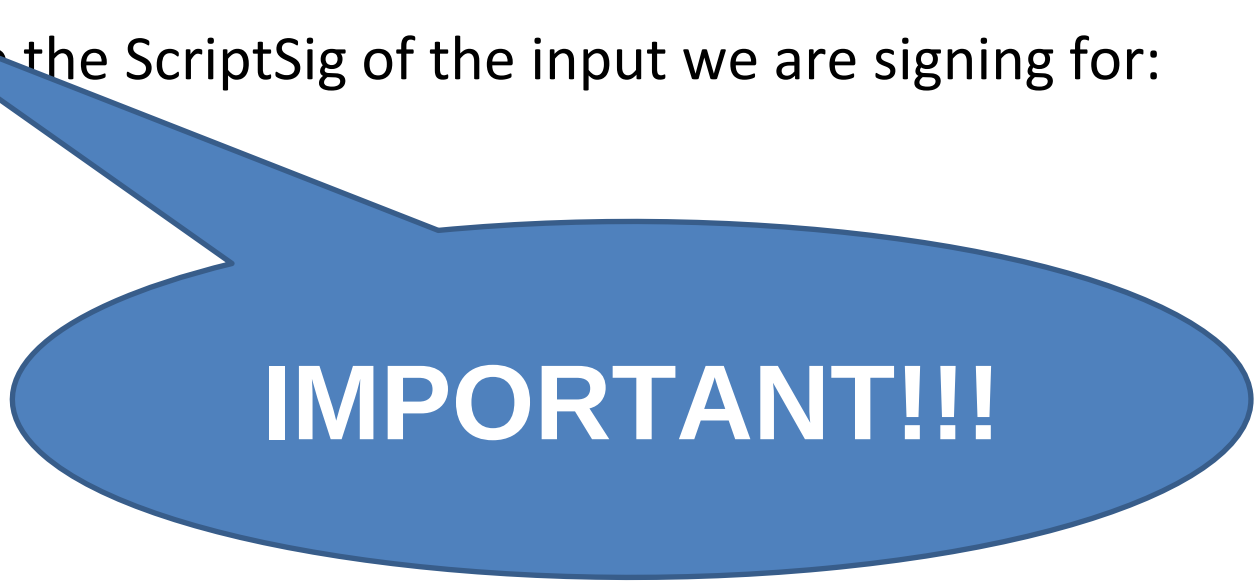
version
nr_inputs
prev_hash
prev_index
ScriptSig
sequence
…

Signatures – for each input

For each input

Step2:

- Replace the ScriptSig of the input we are signing for:



Signatures – for each input

For each input

Step2:

- Replace the ScriptSig of the input we are signing for
- **If this is a P2SH!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!**
- ScriptSig is replaced by <redeem script>
- And **not** by the ScriptPubKey!!!

Signatures – for each input

For each input

Step3:

- Authorization code (4 bytes) concatenated at the end

SIGHASH_ALL -- input can go with other inputs/outputs of the tx
SIGHASH_SINGLE – can go with a specific output
SIGHASH_NONE – can go with any output

SIGHASH_ALL = 1 in 4 bytes little-endian

Signatures – for each input

For each input

Step3:

- SIGHASH is concatenated at the end

```
01000000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
01976a914a802fc56c704ce87c42d7c92eb75e7896bdc41ae88acfeffffff02a135ef010000000019
76a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc76
2dd5423e332166702cb75f40df79fea1288ac1943060001000000
```

version
nr_inputs
prev_hash
prev_index
ScriptSig
sequence
…
SIGHASH_ALL

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
    signed for index input_index'''
    # start the serialization with version
    # use int_to_little_endian in 4 bytes
    s = int_to_little_endian(self.version, 4)
    # add how many inputs there are using encode_varint
    s += encode_varint(len(self.tx_ins))
    # loop through each input using enumerate, so we have the input index
    for i, tx_in in enumerate(self.tx_ins):
        # if the input index is the one we're signing
        if i == input_index:
            # if the RedeemScript was passed in, that's the ScriptSig
            if redeem_script:
                script_sig = redeem_script
            # otherwise the previous tx's ScriptPubkey is the ScriptSig
            else:
                script_sig = tx_in.script_pubkey(self.testnet)
        # Otherwise, the ScriptSig is empty
        else:
            script_sig = None
        # add the serialization of the input with the ScriptSig we want
```

Version

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
    signed for index input_index'''
    # start the serialization with version
    # use int_to_little_endian in 4 bytes
    s = int_to_little_endian(self.version, 4)
    # add how many inputs there are using encode_varint
    s += encode_varint(len(self.tx_ins))
    # loop through each input using enumerate, so we have the input index
    for i, tx_in in enumerate(self.tx_ins):
        # if the input index is the one we're signing
        if i == input_index:
            # if the RedeemScript was passed in, that's the ScriptSig
            if redeem_script:
                script_sig = redeem_script
            # otherwise the previous tx's ScriptPubkey is the ScriptSig
            else:
                script_sig = tx_in.script_pubkey(self.testnet)
        # Otherwise, the ScriptSig is empty
        else:
            script_sig = None
        # add the serialization of the input with the ScriptSig we want
```

Nr Inputs

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
    signed for index input_index'''
    # start the serialization with version
    # use int_to_little_endian in 4 bytes
    s = int_to_little_endian(self.version, 4)
    # add how many inputs there are using encode_varint
    s += encode_varint(len(self.tx_ins))
    # loop through each input using enumerate, so we have the input index
    for i, tx_in in enumerate(self.tx_ins):
        # if the input index is the one we're signing
        if i == input_index:
            # if the RedeemScript was passed in, that's the ScriptSig
            if redeem_script:
                script_sig = redeem_script
            # otherwise the previous tx's ScriptPubkey is the ScriptSig
            else:
                script_sig = tx_in.script_pubkey(self.testnet)
        # Otherwise, the ScriptSig is empty
        else:
            script_sig = None
        # add the serialization of the input with the ScriptSig we want
```

Iterate over the inputs

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
    signed for index input_index'''
    # start the serialization with version
    # use int_to_little_endian in 4 bytes
    s = int_to_little_endian(self.version, 4)
    # add how many inputs there are using encode_varint
    s += encode_varint(len(self.tx_ins))
    # loop through each input using enumerate, so we have the input ind
    for i, tx_in in enumerate(self.tx_ins):
        # if the input index is the one we're signing
        if i == input_index:
            # if the RedeemScript was passed in, that's the ScriptSig
            if redeem_script:
                script_sig = redeem_script
            # otherwise the previous tx's ScriptPubkey is the ScriptSig
            else:
                script_sig = tx_in.script_pubkey(self.testnet)
        # Otherwise, the ScriptSig is empty
        else:
            script_sig = None
        # add the serialization of the input with the ScriptSig we want
```

If this is the input I am signing for

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
    signed for index input_index'''
    # start the serialization with version
    # use int_to_little_endian in 4 bytes
    s = int_to_little_endian(self.version, 4)
    # add how many inputs there are using encode_varint
    s += encode_varint(len(self.tx_ins))
    # loop through each input using enumerate, so we have the input ind
    for i, tx_in in enumerate(self.tx_ins):
        # if the input index is the one we're signing
        if i == input_index:
            # if the RedeemScript was passed in                the ScriptSig
            if redeem_script:
                script_sig = redeem_script
            # otherwise the previous tx's ScriptPubkey is the ScriptSig
            else:
                script_sig = tx_in.script_pubkey(self.testnet)
        # Otherwise, the ScriptSig is empty
        else:
            script_sig = None
        # add the serialization of the input with the ScriptSig we want
```

P2SH

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
    signed for index input_index'''
    # start the serialization with version
    # use int_to_little_endian in 4 bytes
    s = int_to_little_endian(self.version, 4)
    # add how many inputs there are using encode_varint
    s += encode_varint(len(self.tx_ins))
    # loop through each input using enumerate, so we have the in
    for i, tx_in in enumerate(self.tx_ins):
        # if the input index is the one we're signing
        if i == input_index:
            # if the RedeemScript was passed in, that's the
            if redeem_script:
                script_sig = redeem_script
            # otherwise the previous tx's Scri          is the ScriptSig
            else:
                script_sig = tx_in.script_pubkey(self.testnet)
        # Otherwise, the ScriptSig is empty
        else:
            script_sig = None
        # add the serialization of the input with the ScriptSig we want
```

Else use ScriptPubKey of the (previous) output we are spending

What do we sign?

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_i
    '''Returns the integer
    signed for index input_
    # start the serializat
    # use int_to_little_en
    s = int_to_little_endi
    # add how many inputs
    s += encode_varint(len
    # loop through each in
    for i, tx_in in enumer
        # if the input ind
        if i == input_inde
            # if the Redee
            if redeem_scri
                script_sig
            # otherwise th
            else:
                script_sig = tx_in.script_pubkey(self.testnet)
        # Otherwise, the ScriptSig is empty
        else:
            script_sig = None
        # add the serialization of the input with the ScriptSig we want
```

```
class TxIn:

    ...

    def fetch_tx(self, testnet=False):
        return TxFetcher.fetch(self.prev_tx.hex(), testnet=testnet)

    def script_pubkey(self, testnet=False):
        '''Get the ScriptPubKey by looking up the tx hash
        Returns a Script object
        '''
        # use self.fetch_tx to get the transaction
        tx = self.fetch_tx(testnet=testnet)
        # get the output at self.prev_index
        # return the script_pubkey property
        return tx.tx_outs[self.prev_index].script_pubkey
```

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
    signed for index input_index'''
    # start the serialization with version
    # use int_to_little_endian in 4 bytes
    s = int_to_little_endian(self.version, 4)
    # add how many inputs there are using encode_varint
    s += encode_varint(len(self.tx_ins))
    # loop through each input using enumerate, so we have the in
    for i, tx_in in enumerate(self.tx_ins):
        # if the input index is the one we're signing
        if i == input_index:
            # if the RedeemScript was passed in, that's the
            if redeem_script:
                script_sig = redeem_script
            # otherwise the previous tx's ScriptPubke          criptSig
            else:
                script_sig = tx_in.script_pu          self.testnet)
        # Otherwise, the ScriptSig is em
        else:
            script_sig = None
        # add the serialization of the input with the ScriptSig we want
```

If it is not ***my*** input, leave SriptSig empty

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
        # add the serialization of the input with the ScriptSig we want
        s += TxIn(
            prev_tx=tx_in.prev_tx,
            prev_index=tx_in.prev_index,
            script_sig=script_sig,
            sequence=tx_in.sequence,
        ).serialize()
    # add how many outputs there are using encode_varint
    s += encode_varint(len(self.tx_outs))
    # add the serialization of each output
    for tx_out in self.tx_outs:
        s += tx_out.serialize()
    # add the locktime using int_to_little_endian in 4 bytes
    s += int_to_little_endian(self.locktime, 4)
    # add SIGHASH_ALL using int_to_little_endian in 4 bytes
    s += int_to_little_endian(SIGHASH_ALL, 4)
    # hash256 the serialization
    h256 = hash256(s)
    # convert the result to an integer using int.from_bytes(x, 'big')
    return int.from_bytes(h256, 'big')
```

Serialize the input

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
        # add the serialization of the input with the ScriptSig we want
        s += TxIn(
            prev_tx=tx_in.prev_tx,
            prev_index=tx_in.prev_index,
            script_sig=script_sig,
            sequence=tx_in.sequence,
        ).serialize()
    # add how many outputs there are using encode_varint
    s += encode_varint(len(self.tx_outs))
    # add the serialization of each output
    for tx_out in self.tx_outs:
        s += tx_out.serialize()
    # add the locktime using int_to_little_endian in 4 bytes
    s += int_to_little_endian(self.locktime, 4)
    # add SIGHASH_ALL using int_to_little_endian in 4 bytes
    s += int_to_little_endian(SIGHASH_ALL, 4)
    # hash256 the serialization
    h256 = hash256(s)
    # convert the result to an integer using int.from_bytes(x, 'big')
    return int.from_bytes(h256, 'big')
```

Nr outputs

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
        # add the serialization of the input with the ScriptSig we want
        s += TxIn(
            prev_tx=tx_in.prev_tx,
            prev_index=tx_in.prev_index,
            script_sig=script_sig,
            sequence=tx_in.sequence,
        ).serialize()
    # add how many outputs there are using encode_varint
    s += encode_varint(len(self.tx_outs))
    # add the serialization of each output
    for tx_out in self.tx_outs:
        s += tx_out.serialize()
    # add the locktime using int_to_little_endian in 4 bytes
    s += int_to_little_endian(self.locktime, 4)
    # add SIGHASH_ALL using int_to_little_endian in 4 bytes
    s += int_to_little_endian(SIGHASH_ALL, 4)
    # hash256 the serialization
    h256 = hash256(s)
    # convert the result to an integer using int.from_bytes(x, 'big')
    return int.from_bytes(h256, 'big')
```

Serialize each output

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
        # add the serialization of the input with the ScriptSig we want
        s += TxIn(
            prev_tx=tx_in.prev_tx,
            prev_index=tx_in.prev_index,
            script_sig=script_sig,
            sequence=tx_in.sequence,
        ).serialize()
    # add how many outputs there are using encode_varint
    s += encode_varint(len(self.tx_outs))
    # add the serialization of each output
    for tx_out in self.tx_outs:
        s += tx_out.serialize()
    # add the locktime using int_to_little_endian in
    s += int_to_little_endian(self.locktime, 4)
    # add SIGHASH_ALL using int_to_little_endian in 4 bytes
    s += int_to_little_endian(SIGHASH_ALL, 4)
    # hash256 the serialization
    h256 = hash256(s)
    # convert the result to an integer using int.from_bytes(x, 'big')
    return int.from_bytes(h256, 'big')
```

Locktime

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
        # add the serialization of the input with the ScriptSig we want
        s += TxIn(
            prev_tx=tx_in.prev_tx,
            prev_index=tx_in.prev_index,
            script_sig=script_sig,
            sequence=tx_in.sequence,
        ).serialize()
    # add how many outputs there are using encode_varint
    s += encode_varint(len(self.tx_outs))
    # add the serialization of each output
    for tx_out in self.tx_outs:
        s += tx_out.serialize()
    # add the locktime using int_to_little_endian in 4 by
    s += int_to_little_endian(self.locktime, 4)
    # add SIGHASH_ALL using int_to_little_endian i  bytes
    s += int_to_little_endian(SIGHASH_ALL, 4)
    # hash256 the serialization
    h256 = hash256(s)
    # convert the result to an integer using int.from_bytes(x, 'big')
    return int.from_bytes(h256, 'big')
```

SIGHASH (4 bytes)

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
        # add the serialization of the input with the ScriptSig we want
        s += TxIn(
            prev_tx=tx_in.prev_tx,
            prev_index=tx_in.prev_index,
            script_sig=script_sig,
            sequence=tx_in.sequence,
        ).serialize()
    # add how many outputs there are using encode_varint
    s += encode_varint(len(self.tx_outs))
    # add the serialization of each output
    for tx_out in self.tx_outs:
        s += tx_out.serialize()
    # add the locktime using int_to_little_endian
    s += int_to_little_endian(self.locktime,
    # add SIGHASH_ALL using int_to_little_endian in 4 bytes
    s += int_to_little_endian(SIGHASH_ALL, 4)
    # hash256 the serialization
    h256 = hash256(s)
    # convert the result to an integer using int.from_bytes(x, 'big')
    return int.from_bytes(h256, 'big')
```

Double SHA256

What do we sign?

For each input

```
# Here we compute the serialization of what will be signed in a transaction
def sig_hash(self, input_index, redeem_script=None):
    '''Returns the integer representation of the hash that needs to get
        # add the serialization of the input with the ScriptSig we want
        s += TxIn(
            prev_tx=tx_in.prev_tx,
            prev_index=tx_in.prev_index,
            script_sig=script_sig,
            sequence=tx_in.sequence,
        ).serialize()
    # add how many outputs there are using encode_varint
    s += encode_varint(len(self.tx_outs))
    # add the serialization of each output
    for tx_out in self.tx_outs:
        s += tx_out.serialize()
    # add the locktime using int_to_little_endian in 4 bytes
    s += int_to_little_endian(self.locktime, 4)
    # add SIGHASH_ALL using int_to_little_endian in 4 
    s += int_to_little_endian(SIGHASH_ALL, 4)
    # hash256 the serialization
    h256 = hash256(s)
    # convert the result to an integer usi g int.from_bytes(x, 'big')
    return int.from_bytes(h256, 'big')
```

What I will sign with ECC

How do we sign?

For each input

We have the bytes:

```
0100000001813f79011acb80925dfe69b3def355fe914bd1d96a3f5f71bf8303c6a989c7d10000000
01976a914a802fc56c704ce87c42d7c92eb75e7896bdc41ae88acfeffffff02a135ef010000000019
76a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada88ac99c39800000000001976a9141c4bc76
2dd5423e332166702cb75f40df79fea1288ac19430600 01000000
```

```python
# Firmo para input 0
z = transaction.sig_hash(0)
private_key = PrivateKey(secret = 12345)
signature = private_key.sign(z).der()
signature = signature + SIGHASH_ALL.to_bytes(1,'big')
```

How do we sign?

For each input

We have the bytes:

```
010000000 1813f79011acb80925dfe69b3def35                    0000000
01976a914a802fc56c704ce87c42d7c92eb75e78                    00000019
76a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada              1976a9141c4bc76
2dd5423e332166702cb75f40df79fea1288ac 1943060001000000
```

1 byte!!!
Big-endian!!!

```python
# Firmo para input 0
z = transaction.sig_hash(0)
private_key = PrivateKey(secret = 12345)
signature = private_key.sign(z).der()
signature = signature + SIGHASH_ALL.to_bytes(1,'big')
```

How do we sign?

For each input

WTF Satoshi?!?

We have the bytes:

```
0100000001813f79011acb80925dfe69b3def35                                    0000000
01976a914a802fc56c704ce87c42d7c92eb75e78                                   00000019
76a914bc3b654dca7e56b04dca18f2566cdaf02e8d9ada                             1976a9141c4bc76
2dd5423e332166702cb75f40df79fea1288ac1943060001000000
```

1 byte!!!
Big-endian!!!

```
# Firmo para input 0
z = transaction.sig_hash(0)
private_key = PrivateKey(secret = 12345)
signature = private_key.sign(z).der()
signature = signature + SIGHASH_ALL.to_bytes(1,'big')
```

All about signing

Check out:

- https://en.bitcoin.it/wiki/OP_CHECKSIG
- https://bitcoin.stackexchange.com/questions/3374/how-to-redeem-a-basic-tx

What are we missing?

To be able to crate transactios we need to

- Create/serialize scripts of Script!!!

To validate transactions we need to

- Run the scripts of Script!!!

Next we will implement this!

References

- Jimmy Song, Programming Bitcoin, chapters 5,6,7