Principals and Practice of Cryptocurrencies

Cornell CS 5437, Spring 2016

The Bitcoin-Core Client

Overview

- Specific – we are talking about a single implementation of a specific protocol
  - **The reference client**
- General – similar data structures appear in any similar protocol implementation
- Inaccurate – details change between versions

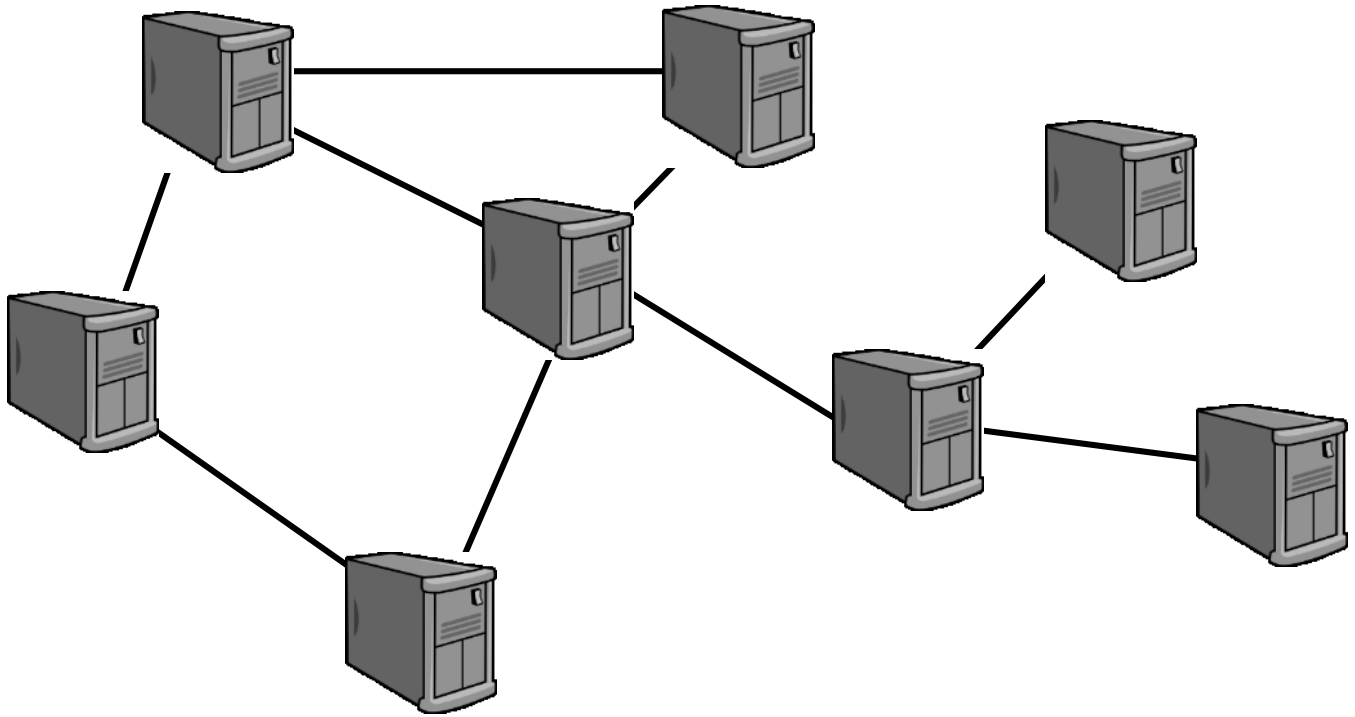
- Mastering Bitcoin, chapters 3 and 6
- https://bitcoin.org/en/developer-reference

Node Roles

- Propagation
  - Transactions
  - Blocks
- Validation
- Mining

Full node

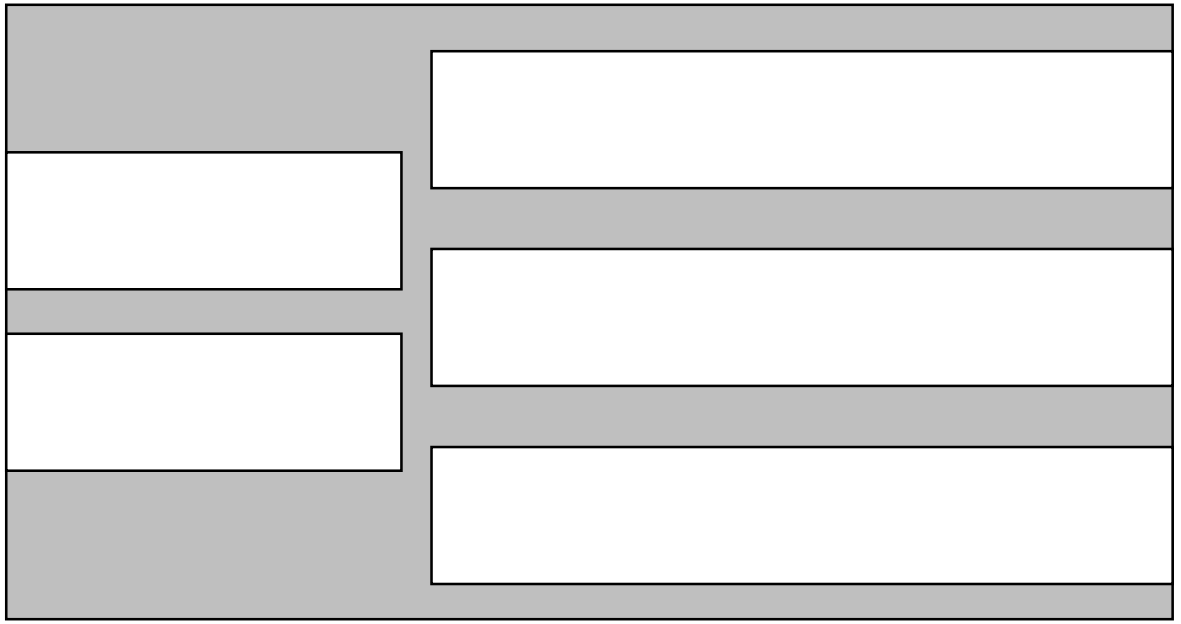
Miner



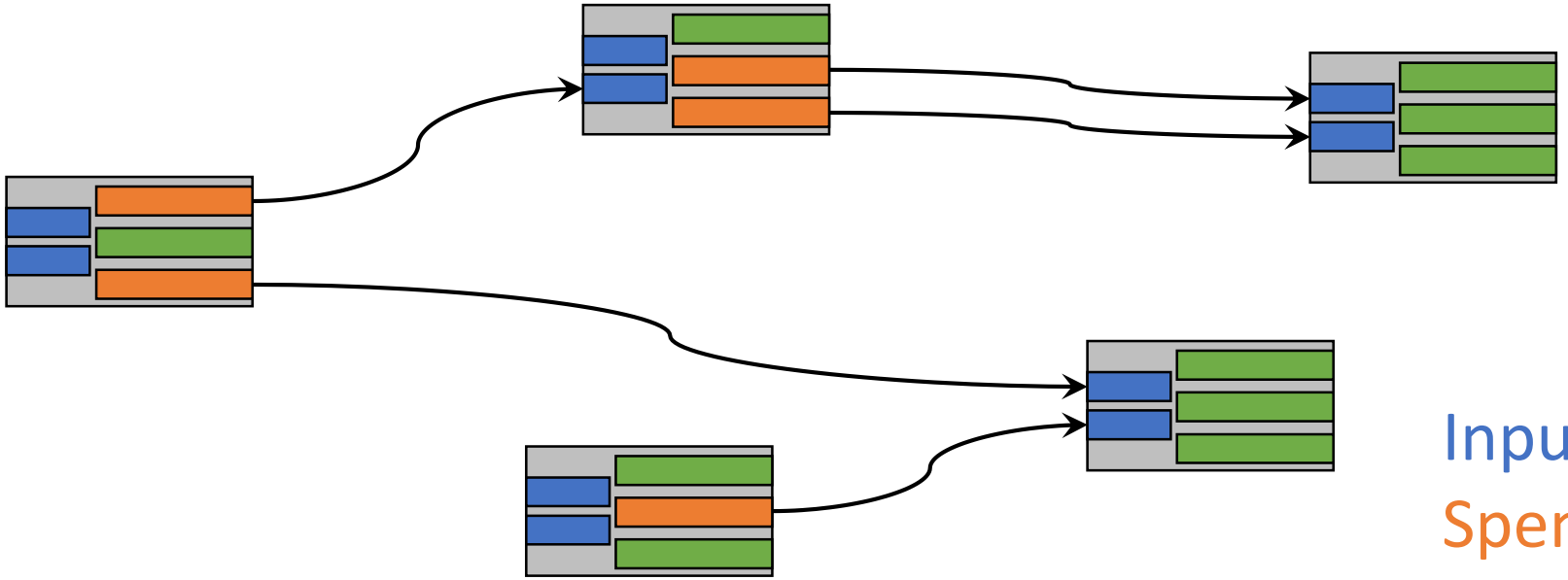
Data structures - Transaction

The transaction data type describes a single transaction, either accepted or not.

- A vector of inputs
- A vector of outputs
- Version
- Lock time



Data structures – UTXO Set



Inputs

Spent outputs

Unspent outputs

Data structures – The mempool

The memory pools contains transactions that were not placed in a block (yet).

- Only with valid inputs (possibly still in mempool)
- Limited size (soon)

Data structures – Block

Size [byte]	Content
4	Magic number: 0xD9B4BEF9
4	Block size [bytes]
80	**Header**
1-9	Transaction count
?	Transactions

`primitives/block.h`

Data structures – Block Header

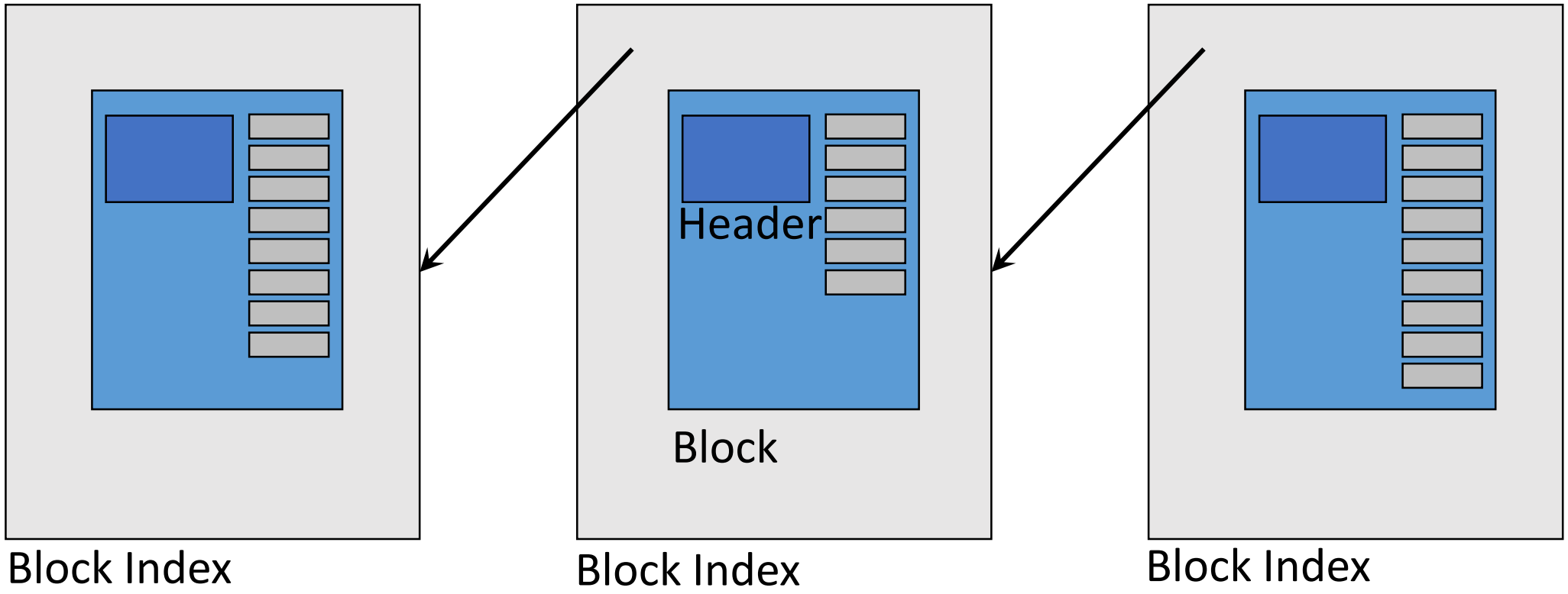
Size [byte]	Content
4	Version
32	Hash ($\mathrm{SHA256}^2$) of previous block header
32	Hash (Merkle root) of blocks' transactions
4	UNIX timestamp
4	Proof-of-Work target
4	Nonce

A block is legal if the hash ($\mathrm{SHA256}^2$) of its header is small enough, as specified by the target field.

`primitives/block.h`

Data Structures – Block Index

Block Index is an internal data structure that connects the blocks to form a Blockchain

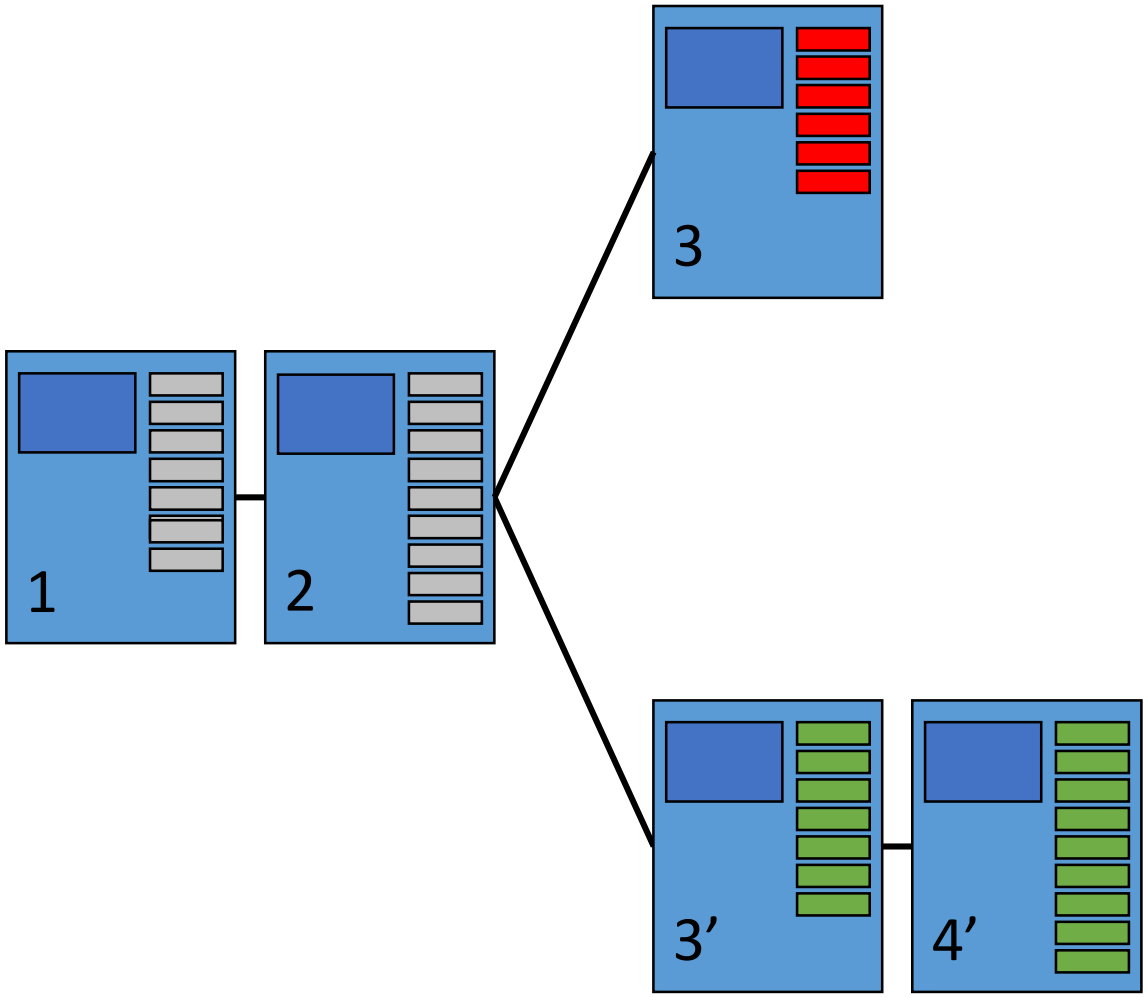


Data Structures – Chain

CChain is a full chain, as a vector for fast access

Often instantiated as **`ActiveChain`** with the active chain
Useful **`Genesis`** and **`Tip`** methods

Chain Reorganization



When a client learns on a better chain, it ***reorganizes*** the Blockchain.

This is done in steps:

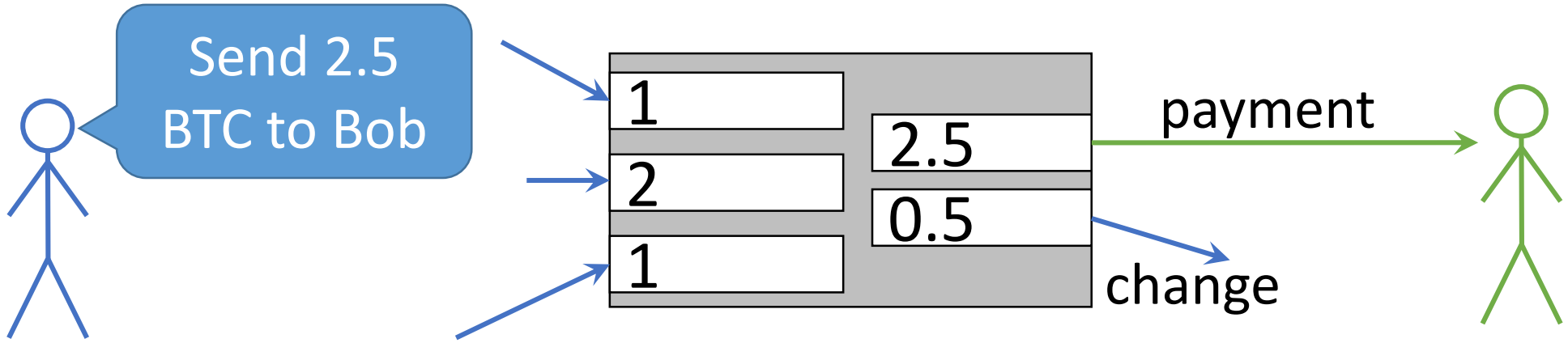
1. Remove block 3
   (new head: 2)
2. Add block 3’
   (new head: 3’)
3. Add block 4’
   (new head: 4’)

`chain.h`

Wallet

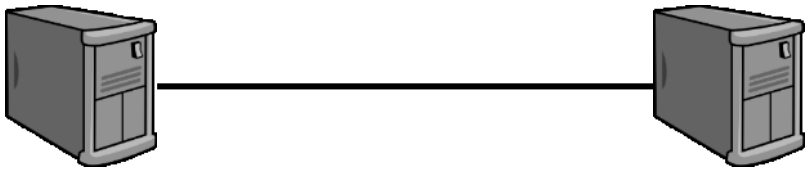
The client serves as a wallet, maintaining the user's funds.

- ***Address***: a public-private key pair
- Aggregated into ***accounts***
- Balance calculated by going through blockchain
- Address generation takes time (crypto operations), so done in advance to fill a ***pool***
- New address for every output
- Transactions accumulate funds and keep change



`wallet/`

Communication



1. Version exchange (version, verack)
   - Node version and basic state
2. Network maintenance
   - Address exchange (addr, getaddr)
   - Link maintenance (ping, pong)
   - Message rejection (reject)
   - Message filtering
   - Alert
3. Data exchange
   - Publish what blocks/transactions a client has (inv)
   - Ask for blocks/transactions/inv (getdata, getblocks, getheaders, mempool)
   - Send data (block, tx, headers)

Modes of Operation

1. **Mainnet**
   Bitcoin's actual network. Not for experiments. Expensive mining, expensive transactions, huge Blockchain.
2. **Testnet**
   For experiments. Large network, but no value to coins.
   Low difficulty, reset.
3. **Regtest**
   For basic testing, free mining.
   No network – connects nowhere.

Modes of Operation

1. **Mainnet**
2. **Testnet**
3. **Regtest**

What's the difference?

- network level
  - TCP port
  - magic number
- Consensus level
  - Genesis block
  - addresses
  - Difficulty
    - Mainnet difficulty updates every 2 weeks
    - Testnet difficulty has an auto-reset
    - Regtest difficulty doesn't update

Interacting with the Client – Bootstrapping

- Data directory
  - Blocks
  - Blockchain data (block index)
  - Wallet
  - Configuration file

- Initialization arguments
- Configuration file

Use multiple local clients with different directories and carefully planned config files to run a regtest network on a single machine

Interacting with the Client – Bootstrapping

- Configuration file

```
testnet=0
addnode=69.164.218.197 # Also look for this node
connect=10.0.0.1:8333 # Only look for this node
maxconnections=125 # incoming + outgoing

server=1 # Accept RPC
rpcuser=myName
rpcpassword=CHOOSE_SMART!
rpcallowip=10.1.1.34
rpcport=8332
```

Interacting with the Client – RPC

- **`sendtoaddress`** (…)
- **`sendfrom`** (…): Send funds from account to address
- **`createrawtransaction`** (tx details)
- **`getaddressesbyaccount`** (account)
- **`getbalance`**: in all accounts
- **`getbestblockhash`**: hash of chain head
- **`getblockcount`**: length of main chain
- **`getblockhash`** (index)
- **`getblock`** (block hash)
- **`getrawmempool`**: Get transaction IDs in mempool
- **`gettransaction`** (tx ID) (index appropriately for all txns)
- **`setgenerate`** (generate, procLimit): procLimit is number of processors to use, or number of blocks to generate in regtest

Full list: https://bitcoin.org/en/developer-reference#rpc-quick-reference

getblock response (not real)


```
{
   "hash" : "000000000fe549a89848c76070d4132872cfb6efe5315d01d7ef77e4900f2d39",
   "confirmations" : 88029,
   "size" : 189,
   "height" : 227252,
   "version" : 2,
   "merkleroot" : "c738fb8e22750b6d3511ed0049a96558b…46f3f77771ec825b22d6a6f4a",
   "tx" : ["c738fb8e22750b6d3511ed0049a96558b0bc57046f3f77771ec825b22d6a6f4a"],
   "time" : 1398824312,
   "nonce" : 1883462912,
   "bits" : “030a2b4a",
   "difficulty" : 120,033,340,651.24,
   "chainwork" : "00000…0000000000000000000000000083ada4a4009841a",
   "previousblockhash" : "00000000c7f4990e6ebf71ad7e21a4713…05b3998d7a814c011df",
   "nextblockhash" : "00000000afe1928529ac766f1237657819a11cfc…f119e868ed5b6188"
}
```

getrawtransaction response (testnet)


```
{
 "hex" : "0100000001268a9ad7bfb21d3c086f0ff28f73a064964aa069ebb69a9e4...",
 "txid" : "ef7c0cbf6ba5af68d2ea239bba709b26ff7b0b669839a63bb01c2cb8e8...",
 "version" : 1,
 "locktime" : 0,
 "vin" : [...]
 "vout" : [...]
 "blockhash" : "00000000103e0091b7d27e5dc744a305108f0c752be249893c749...",
 "confirmations" : 88192,
 "time" : 1398734825,
 "blocktime" : 1398734825
}
```

getrawtransaction response (testnet)

```
"vin" : [{
    "txid" : "d7c7557e5ca87d439e9ab6eb69a04a9664a0738ff20f6f083c1db2...",
    "vout" : 0,
    "scriptSig" : ...
    "sequence" : 4294967295
}]


 "vout" : [{
    "value" : 0.39890000,
    "n" : 0,
    "scriptPubKey" : ...
}]
```

Interacting with the Client – RPC

- Directly: CLI with bitcoin-cli executable

```
> bitcoin-cli getrawtransaction a9d4599e15b53f3eb531608ddb31f48c…
{
  "hex" : "0100000001344630cbff61fbc362f7e1ff2f11a344c29326e4ee9…",
  "txid" : "a9d4599e15b53f3eb531608ddb31…",
  "version" : 1,
  "locktime" : 0,
  …
```

- JSON over HTTP
  - Better with a wrapper