BLOCKCHAINS

ARCHITECTURE, DESIGN AND USE CASES

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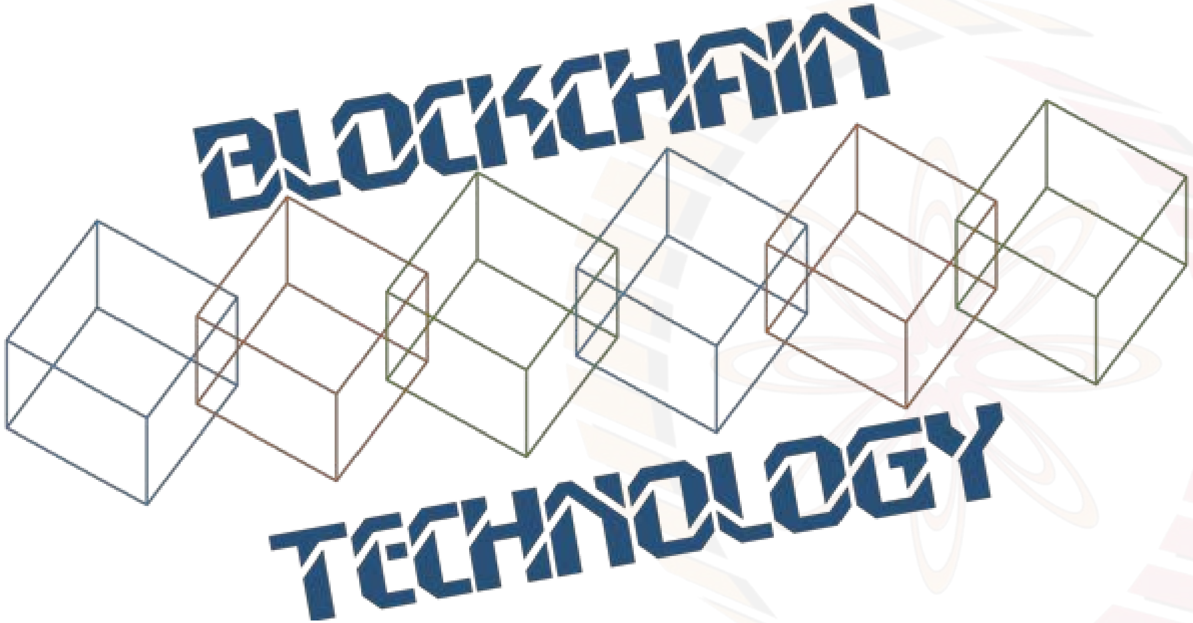
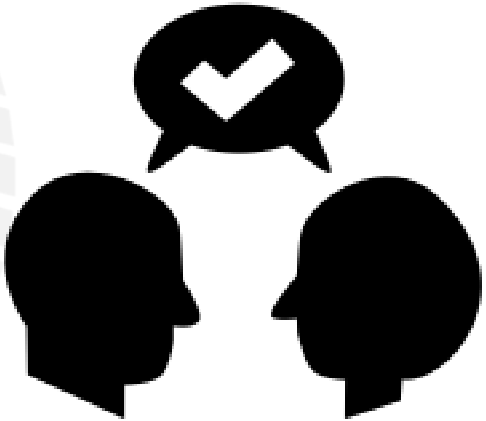
INDIA

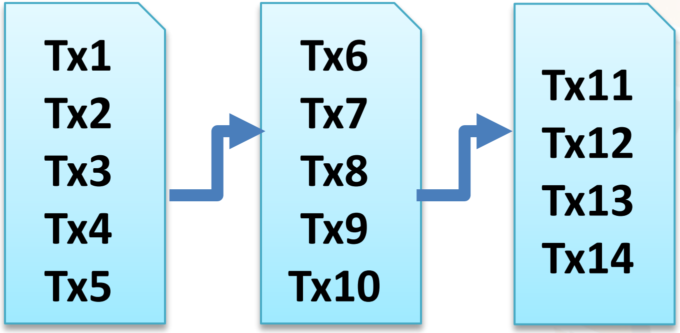
Image courtesy: http://beetfusion.com/





CONSENSUS IN BITCOIN

Consensus in Bitcoin



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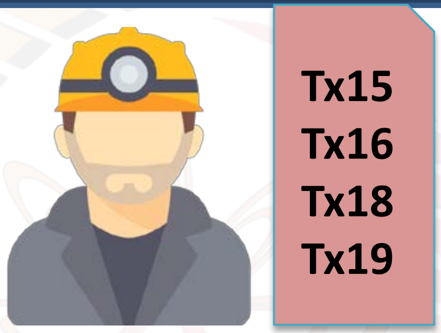

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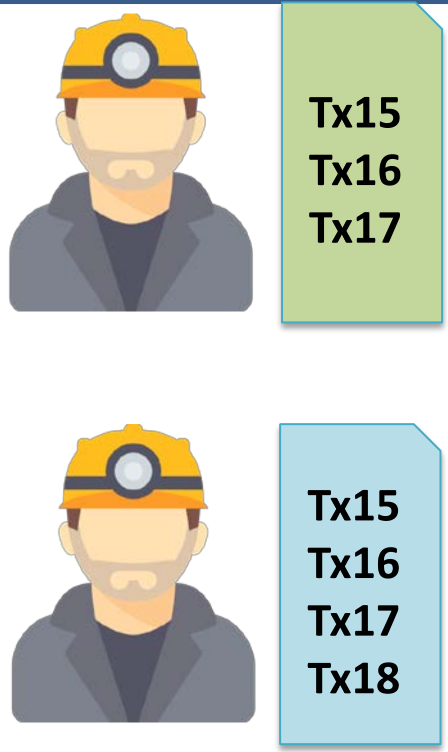

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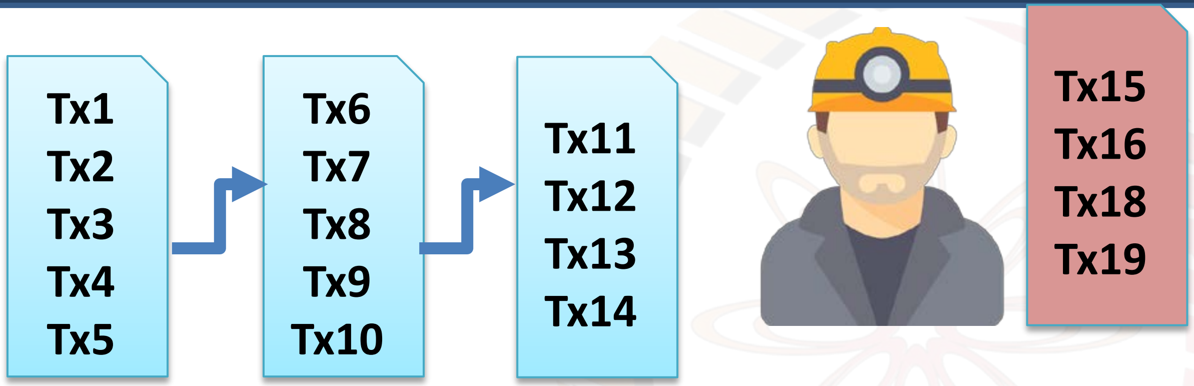
Bitcoin Consensus Objective:

Which block do we add next?

Consensus in Bitcoin



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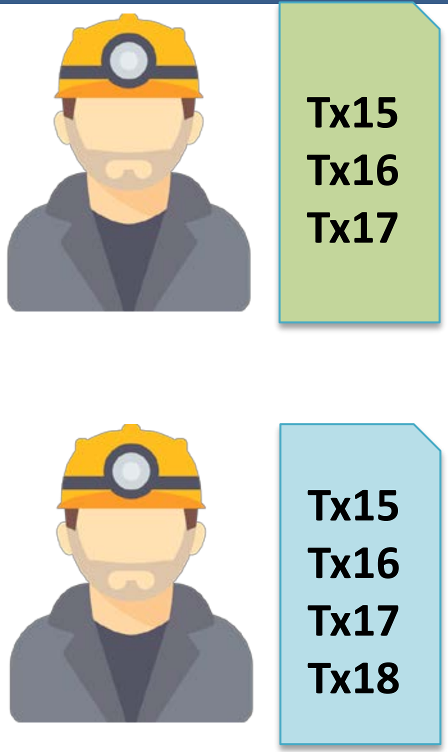

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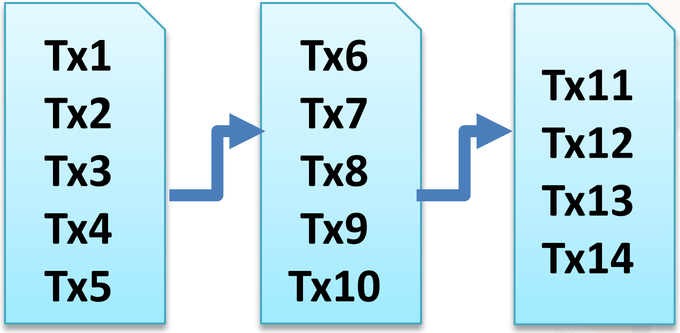
Bitcoin Consensus Objective:

Which block do we add next?

Challenge:

The miners do not know each other

Consensus in Bitcoin



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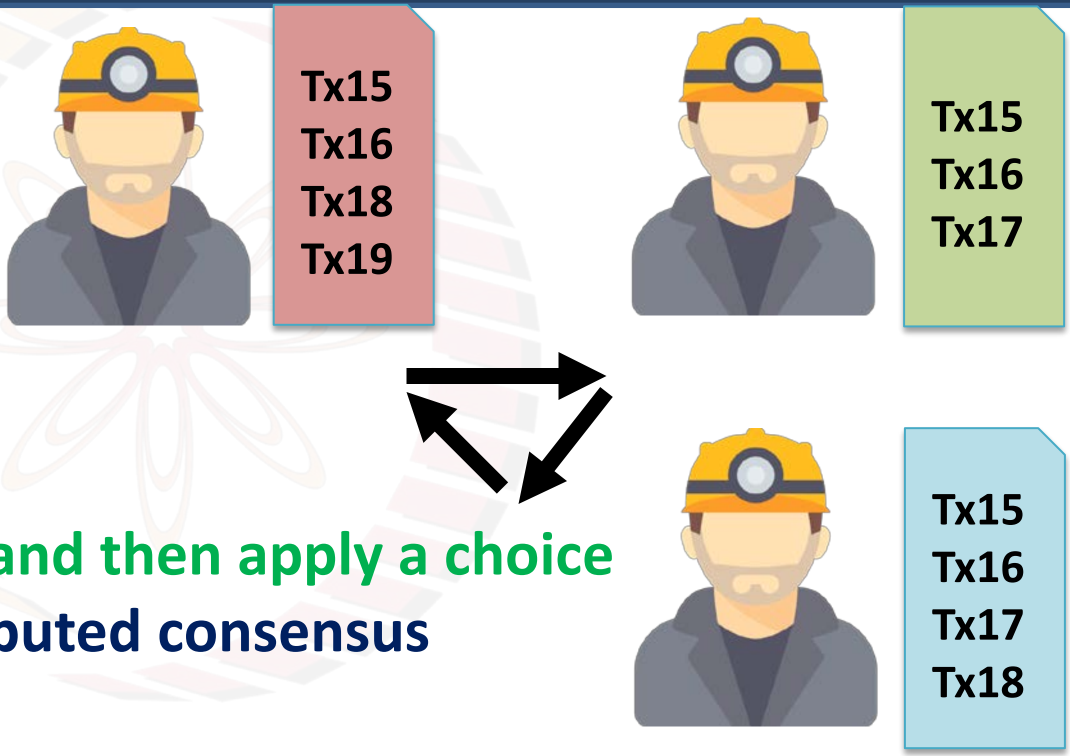

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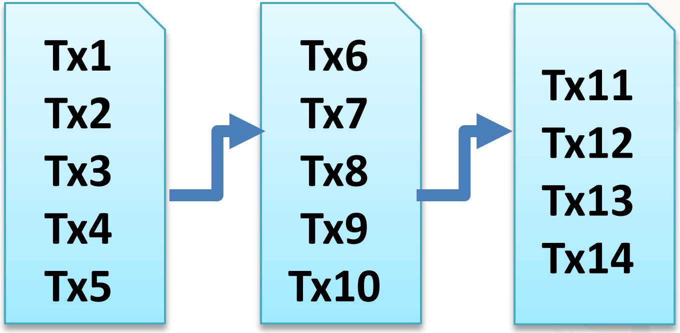
Possible Solution:

Broadcast the information and then apply a choice function – traditional distributed consensus algorithms

Consensus in Bitcoin



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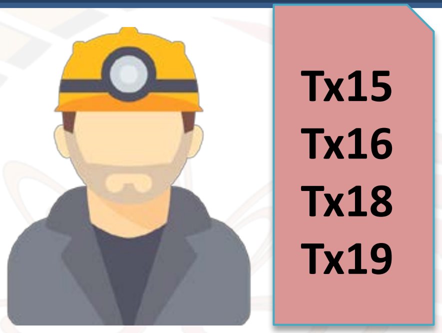

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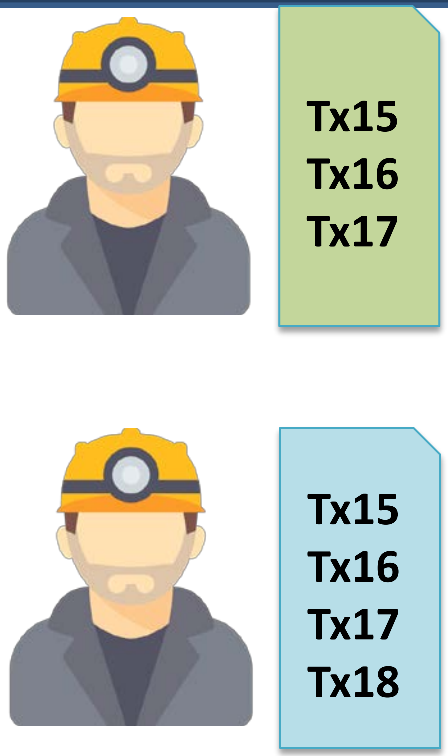

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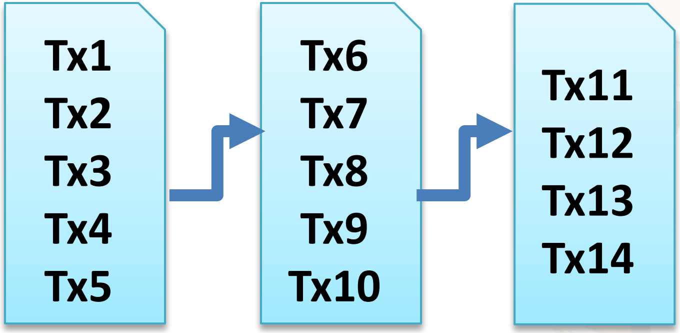
May not be Feasible:

You do not have a global clock! How much time will you wait to hear the transactions

Remember the impossibility result

Consensus in Bitcoin



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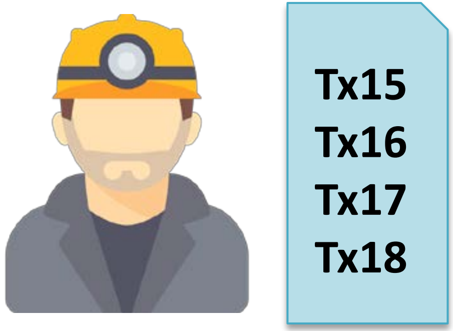

Tx15
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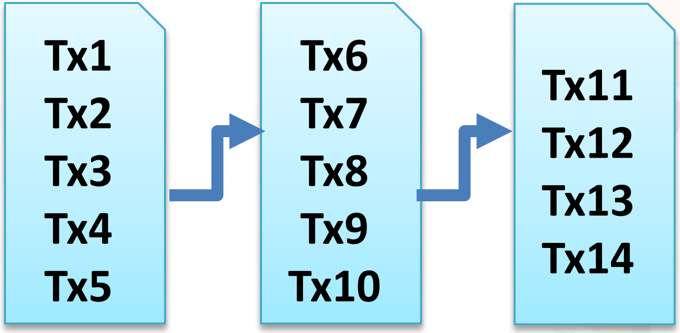
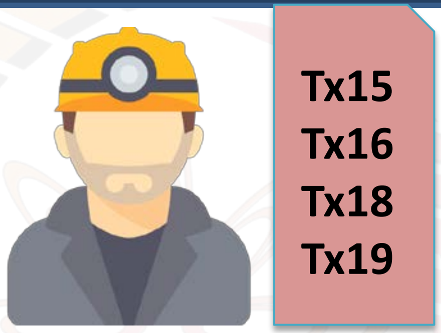
Tx18

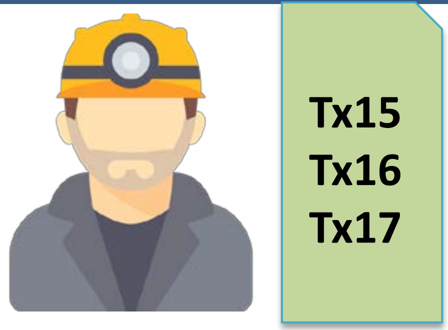
Observation - 1:

- Any valid block (a block with all valid transactions) can be accepted, even if it is proposed by only one miner

Consensus in Bitcoin

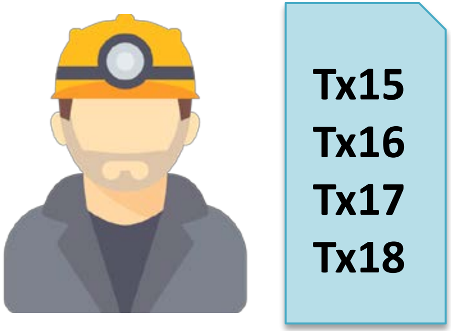




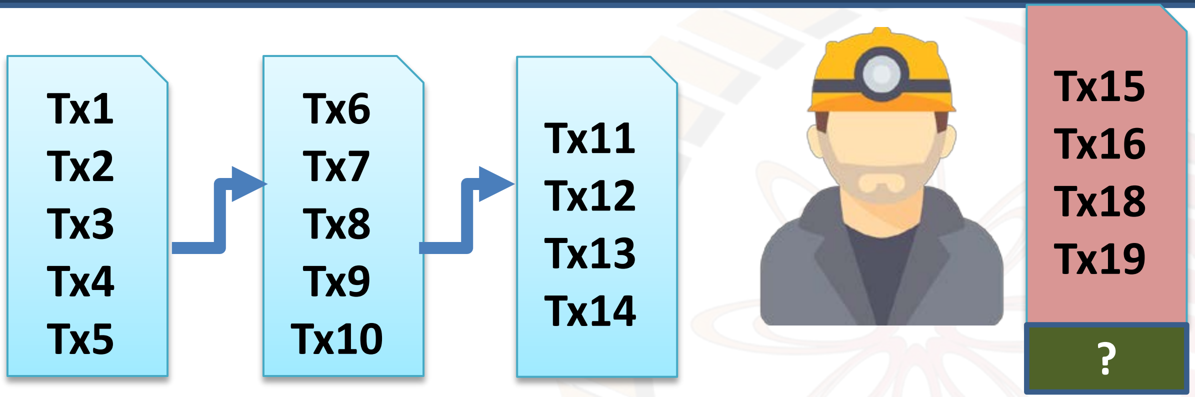


Observation - 2:

- The protocol can work in rounds
  - Broadcast the accepted block to the peers
  - Collect the next set of transactions



Consensus in Bitcoin



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Tx11 Tx12 Tx13 Tx14

Tx15 Tx16 Tx18 Tx19

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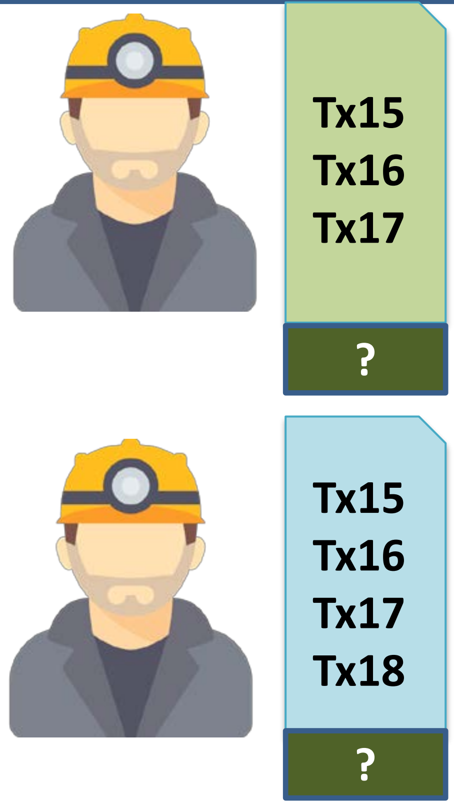

Tx15 Tx16 Tx17

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Tx15 Tx16 Tx17 Tx18

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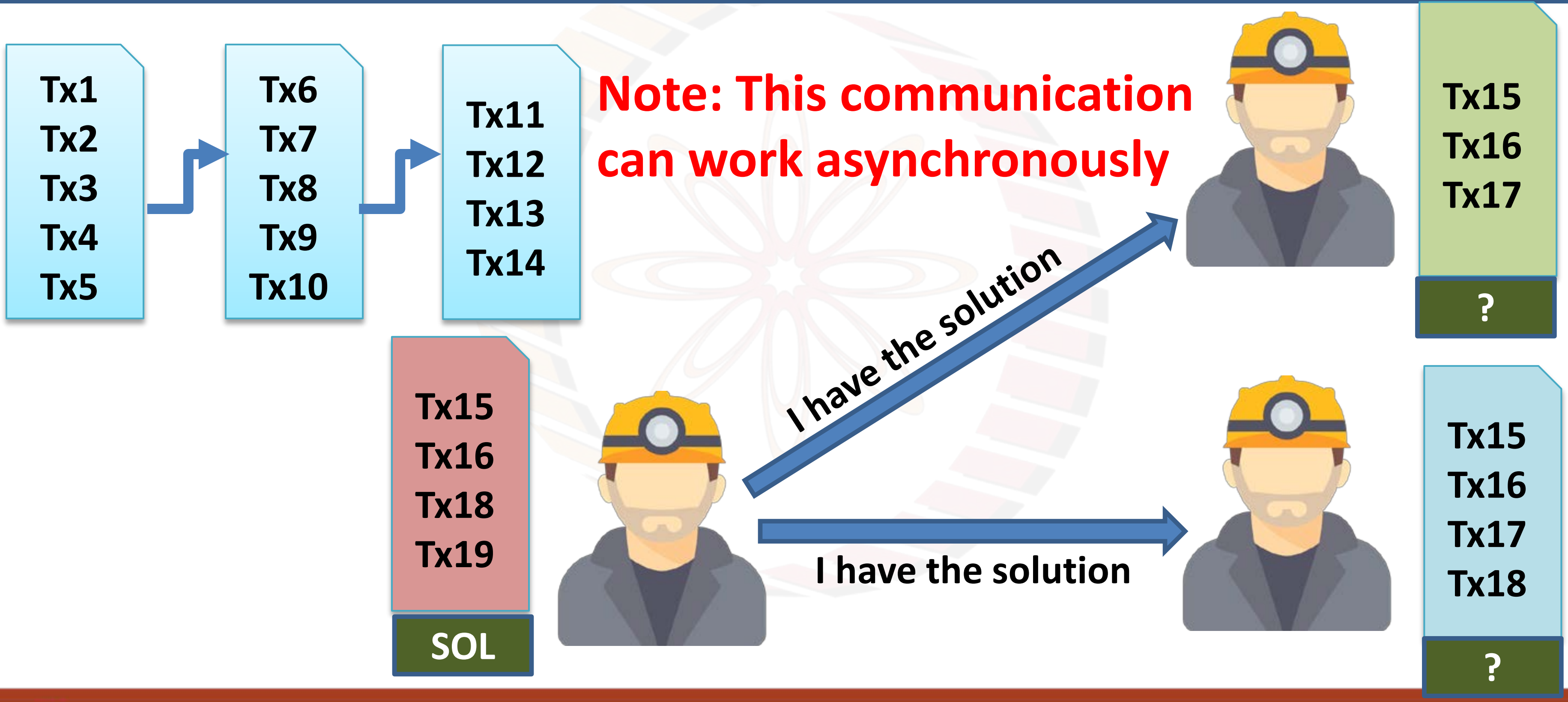
Solution:

- Every miner independently tries to solve a challenge
- The block is accepted for the miner who can **prove first** that the challenge has been solved

Consensus in Bitcoin



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Note: This communication can work asynchronously

Tx15
Tx16
Tx18
Tx19

SOL

I have the solution

I have the solution

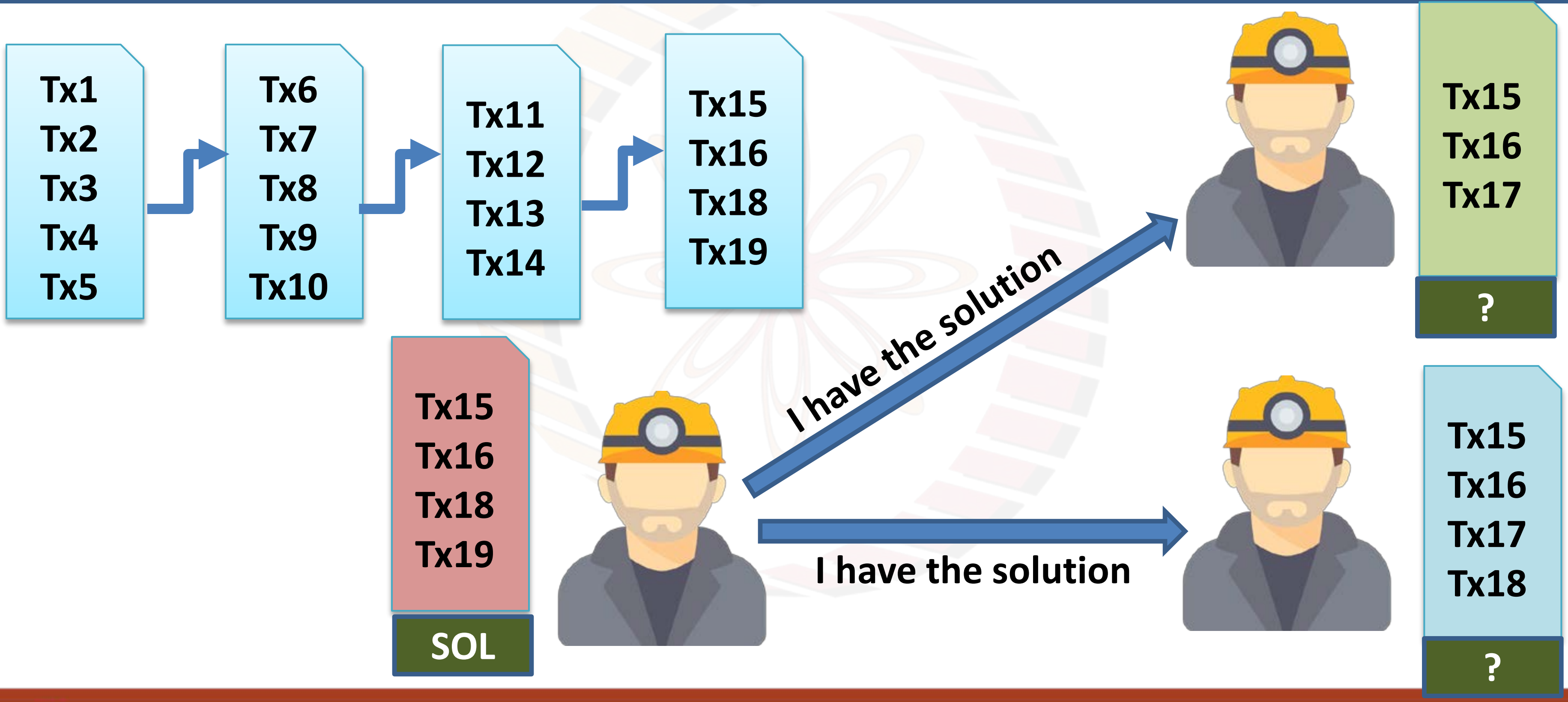
Tx15
Tx16
Tx17

?

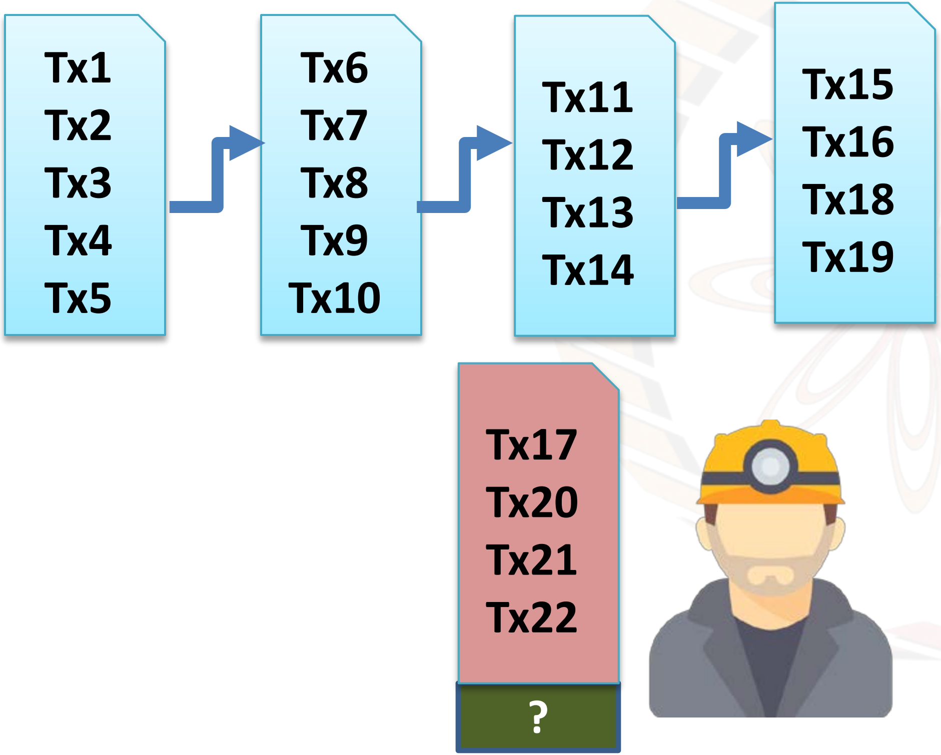
Tx15
Tx16
Tx17
Tx18

?

Consensus in Bitcoin

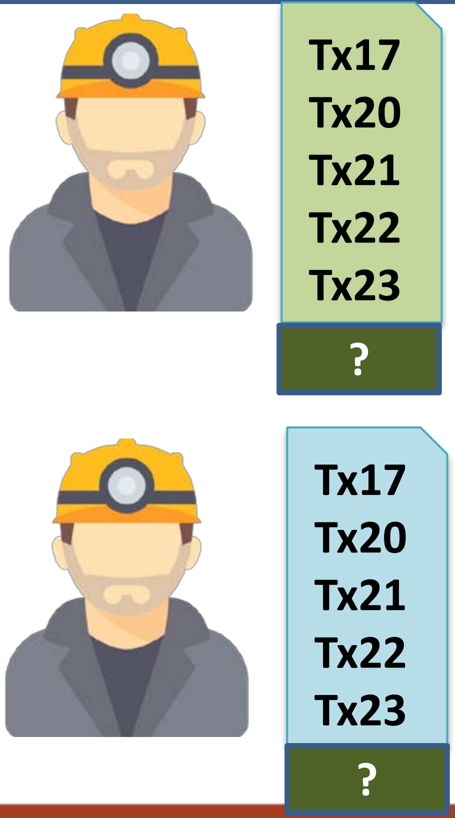


Consensus in Bitcoin



Note: Everyone can see that Tx18 and Tx19 have been committed, but Tx17 has not been committed.

Include that in the next round



Proof of Work (Pow)

- An economic measure to deter service abuses by requiring some work from the service requester (usually processing time by a computer)

- The idea came from Dwork and Naor (1992), to combat junk emails
  - You have to do some work to send a valid email
  - The attacker would be discouraged to send junk emails

Dwork, Cynthia; Naor, Moni (1993). "Pricing via Processing, Or, Combatting Junk Mail, Advances in Cryptology". ***CRYPTO'92: Lecture Notes in Computer Science No. 740*****. Springer: 139–147.**

Proof of Work (PoW) Features

- Asymmetry
  - The work must be moderately hard, but feasible for the service requester
  - The work must be easy check for the service provider

- Service requesters will get discouraged to forge the work, but service providers can easily check the validity of the work

Cryptographic Hash as the PoW

- Use the **puzzle friendliness** property of cryptographic hash function as the work
  - Given X and Y, find out k, such that $Y = Hash(X||k)$
  - It is difficult (but not infeasible) to find such k
  - However, once you have a k, you can easily verify the challenge

- Used in **Hashcash**, a proof of work that can be added with an email as a "*good-will*" token

Adam Back, "Hashcash - A Denial of Service Counter-Measure", technical report, August 2002

Hashcash PoW

- A textual encoding of a hashcash stamp is included in an email header
  - Proof that the sender has expended a modest amount of CPU time calculating the stamp before sending the email
  - It is unlikely that the sender is a spammer

- The receiver can verify the hashcash stamp very easily

- Any change in the header requires a change in the hashcash
  - Brute force is the only way to find a hashcash

Hashcash PoW

- The hashcash is included in the email header, looks like this

```
X-Hashcash:
1:20:180401:sandipc@cse.iitkgp.ac.in::0000000267674
b591257b87:6078
```

- Version: number of zero bits in the hashed code: date: resource: optional extension: string of random characters: counter

Hashcash PoW – Sender Side

- Construct the header

```
1:20:180401:sandipc@cse.iitkgp.ac.in::<hash>:<counter>
```

- The sender initializes the counter value to a random number

- Compute 160 bit SHA-1 hash of the header.
  - If the first 20 bit of the hash are all zeros, then it is accepted
  - Else try with a different counter

Hashcash PoW – Recipient Side

- Recipient checks
  - The date – should be within two days
  - Email address
  - The random string – should not be used repeatedly within a certain duration (prevent replay)

- Compute the 160 bit SHA-1 hash of the entire received string

```
1:20:180401:sandipc@cse.iitkgp.ac.in::0000000267674b591257b87:6078
```

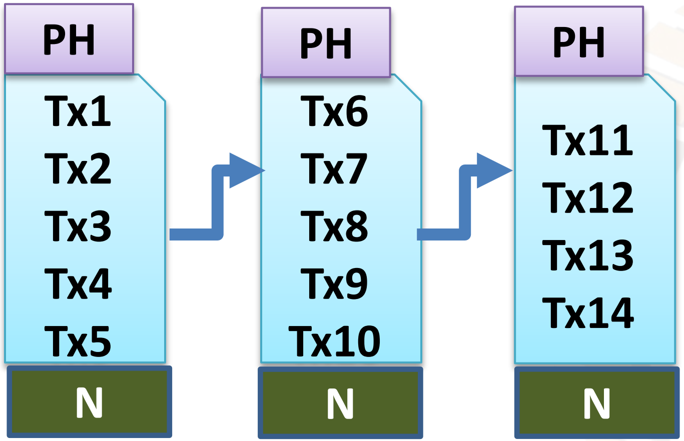
  - If the first 20 bits are not zero then it is invalid

Hashcash PoW

- On average, the sender will have to try 2^{20} hash values to find a valid header (takes about a few seconds in a general purpose computer)
  - There are 2^{160} possible hash values
  - 20 zero bits at the beginning – 2^{140} possible hash values that satisfy this criteria
  - Chance of randomly selecting a header with 20 zero bits at the prefix is 1 in 2^{20}

- The recipient requires around 2 microsecond to validate

Bitcoin Proof of Work System

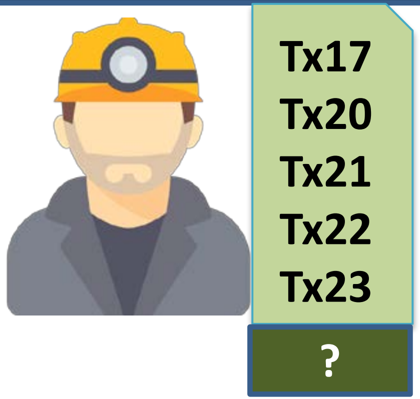


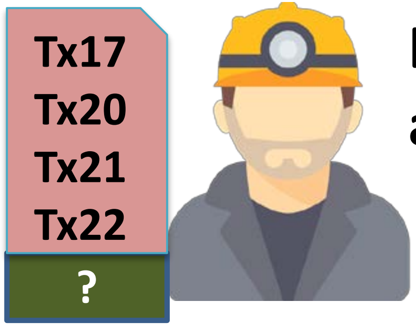
BH: Block Hash

PH: Previous Block Hash

MR: Merkle Root

N: Nonce

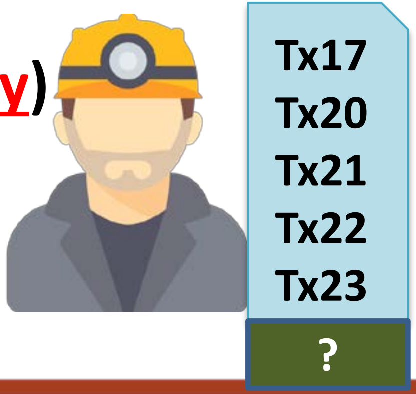




BH should have certain zeros (<u>difficulty</u>) at the beginning

BH = Hash(PH:MR:N)

N = ?



Bitcoin Proof of Work (PoW) System

- Most implementations of Bitcoin PoW use double SHA256 hash function
- The miners collect the transactions for 10 minutes (default setup) and starts mining the PoW
- The probability of getting a PoW is low – it is difficult to say which miner will be able to generate the block
  - No miner will be able to control the bitcoin network single handedly

Explore ...

- http://www.hashcash.org/
  - Download the source and try with different numbers of zero bit targets
  - Increase the number of targeted zero bits at the hash prefix, say from 20 to 2020, at a step of 100, and observe the time to compute the hashcash
  - Use **`sha1sum`** (in Linux) to compute the SHA-1 checksum of the obtained hashcash values from the above experiment. How much time do you require to validate a hashcash?

thank you!