BLOCKCHAINS

ARCHITECTURE, DESIGN AND USE CASES

SANDIP CHAKRABORTY
COMPUTER SCIENCE AND ENGINEERING,
IIT KHARAGPUR

PRAVEEN JAYACHANDRAN
IBM RESEARCH,
INDIA

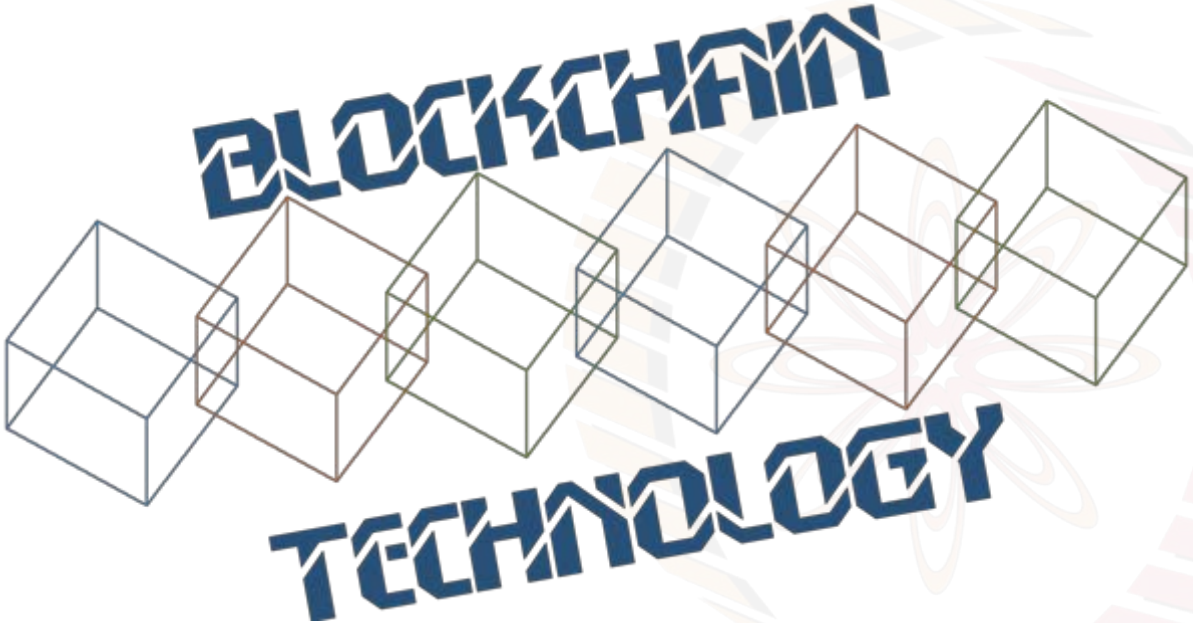


Image courtesy: http://beetfusion.com/

DISTRIBUTED CONSENSUS

Consensus

- A procedure to reach in a common agreement in a distributed or decentralized multi-agent platform
- Important for a message passing system

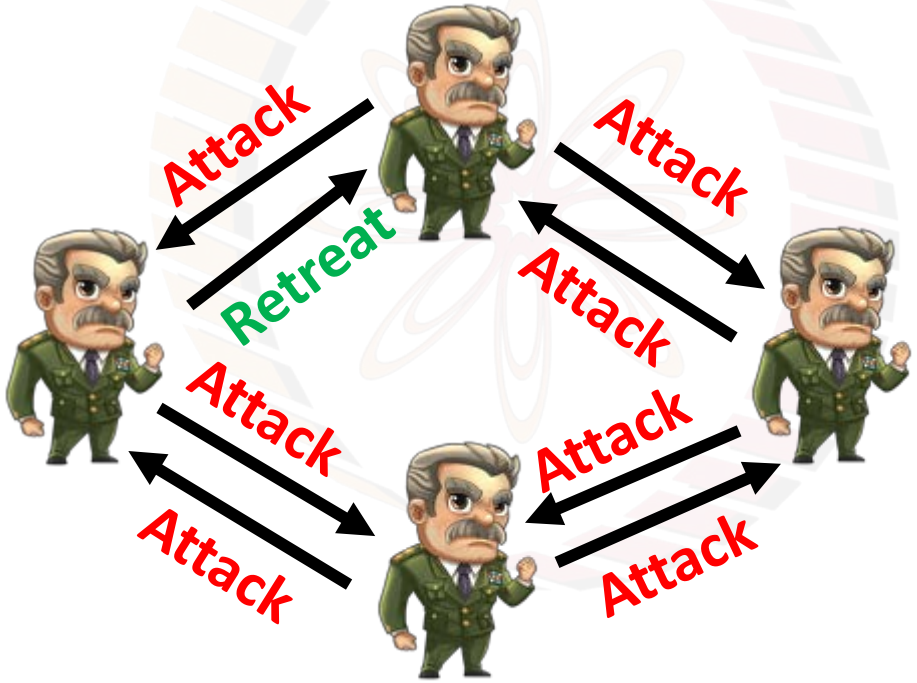
Why Consensus

- Reliability and fault tolerance in a distributed system
  - Ensure correct operations in the presence of faulty individuals

- Example:
  - Commit a transaction in a database
  - State machine replication
  - Clock synchronization

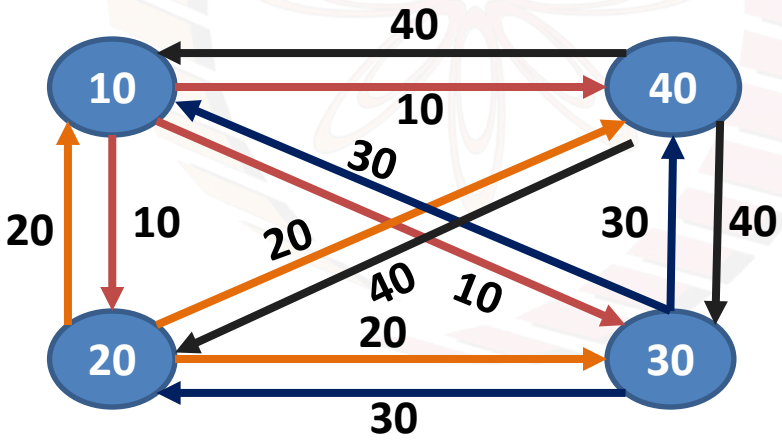
Why Consensus Can be Difficult in Certain Scenarios

- Consider a message passing system, and a general behaves maliciously



Distributed Consensus

- If there is **no failure**, it is easy and trivial to reach in a consensus
  - **Broadcast** the personal choice to all
  - Apply a **choice function**, say the maximum of all the values



Distributed Consensus

- There can be various types of faults in a distributed system.
- **Crash Fault:** A node suddenly crashes or becomes unavailable in the middle of a communication
- **Network or Partitioned Faults:** A network fault occurs (say the link failure) and the network gets partitioned
- **Byzantine Faults:** A node starts behaving maliciously

Distributed Consensus - Properties

- **Termination**: Every correct individual decides some value at the end of the consensus protocol
- **Validity:** If all the individuals proposes the same value, then all correct individuals decide on that value
- **Integrity:** Every correct individual decides at most one value, and the decided value must be proposed by some individuals
- **Agreement:** Every correct individual must agree on the same value

Synchronous vs Asynchronous Systems

- **Synchronous Message Passing System:** The message must be received within a predefined time interval
  - Strong guarantee on message transmission delay

- **Asynchronous Message Passing System:** There is no upper bound on the message transmission delay or the message reception time
  - No timing constraint, message can be delayed for arbitrary period of times

Asynchronous Consensus

- FLP85 (Impossibility Result): In a purely asynchronous distributed system, the consensus problem is impossible (with a deterministic solution) to solve if in the presence of a single crash failure.
  - Results by Fischer, Lynch and Patterson (most influential paper awarded in ACM PODC 2001)
  - Randomized algorithms may exist

Synchronous Consensus

- Various consensus algorithms has been explored by the distributed system community
  - Paxos
  - Raft
  - Byzantine fault tolerance (BFT)

We'll look into these consensus algorithms, but later !!

Correctness of a Distributed Consensus Protocol

- **Safety:** Correct individuals must not agree on an incorrect value
  - Nothing bad happend

- **Liveliness** (or **Liveness**): Every correct value must be accepted eventually
  - Something good eventually happens

Consensus in an Open System

- The tradition distributed consensus protocols are based on
  - Message passing (when individuals are connected over the Internet)
  - Shared memory (when a common memory place is available to read and write the shared variables that everyone can access)

- Message passing requires a **closed** environment – everyone need to know the identity of others

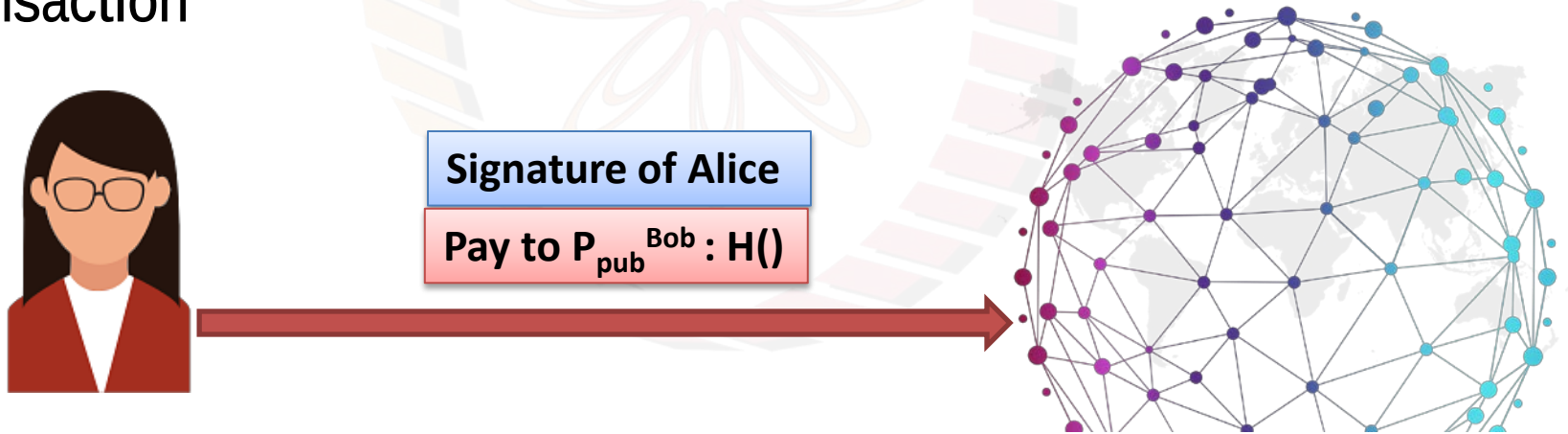
Consensus in an Open System

- Shared memory is not suitable for Internet grade computing
  - Where do you put the shared memory?

- Bitcoin is an open environment
  - Anyone can join in the Bitcoin network anytime
  - How do you ensure consensus in such an open system? – A key challenge

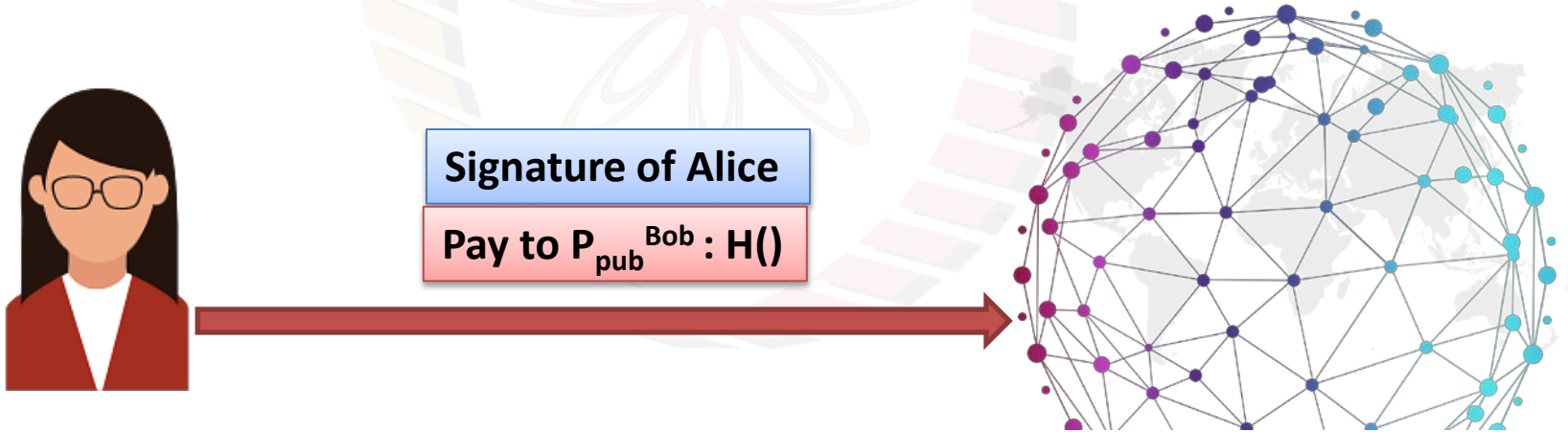
Why Do We Require Consensus in Bitcoin Network

- Bitcoin is a peer-to-peer network
- Alice broadcast a transaction in this peer-to-peer network
- All the nodes in this network need to agree on the correctness of this transaction



Why Do We Require Consensus in Bitcoin Network

- A node does not know all the peers in the network – this is an **open network**
- Some nodes can also initiate **malicious transactions**

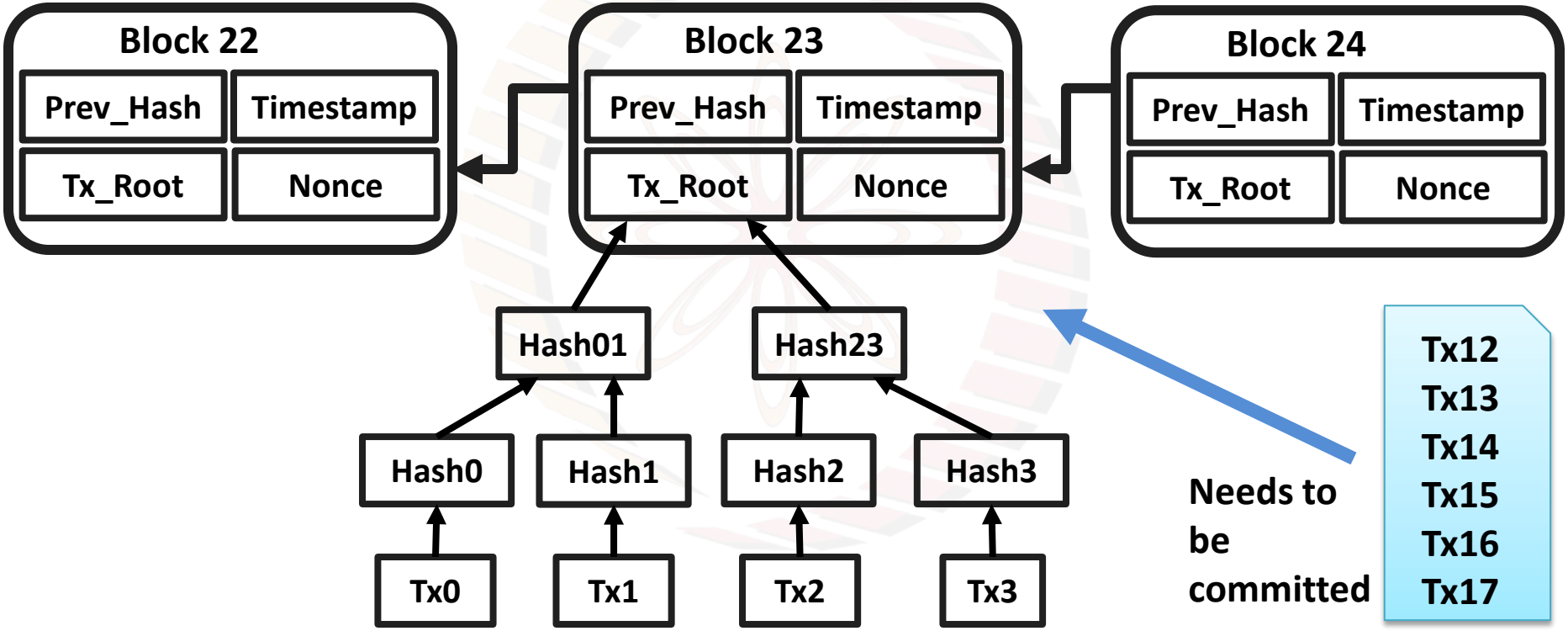


Consensus in a Bitcoin Network

- Every node has **block of transactions** that has already reached into the consensus (**block of committed transactions**)

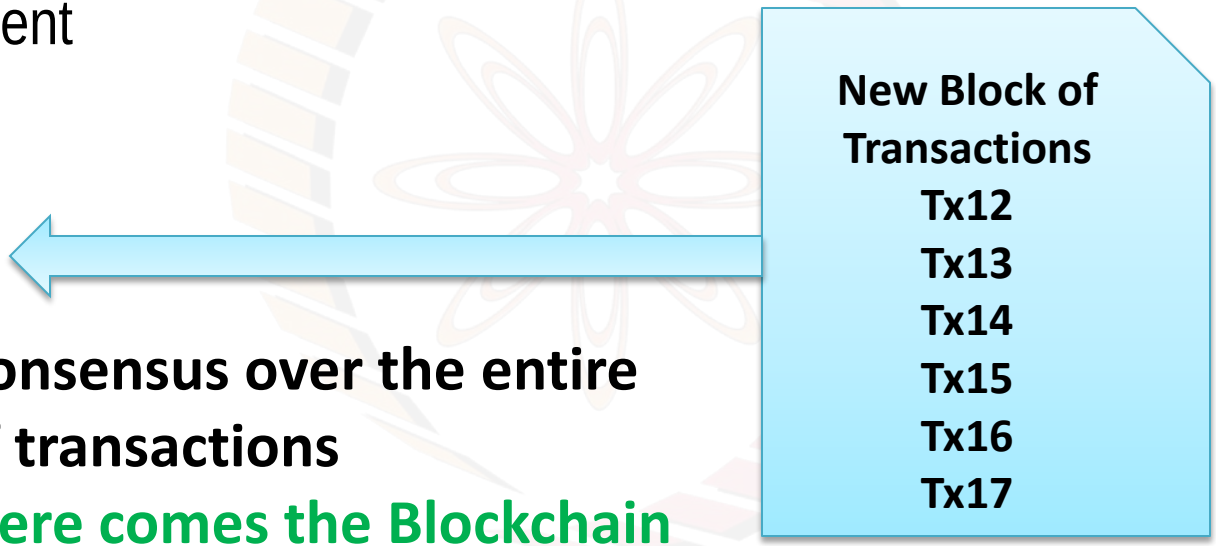
- The nodes also has a list of outstanding transactions that need to be validated against the block of committed transactions

Consensus in a Bitcoin Network



Consensus in Bitcoin

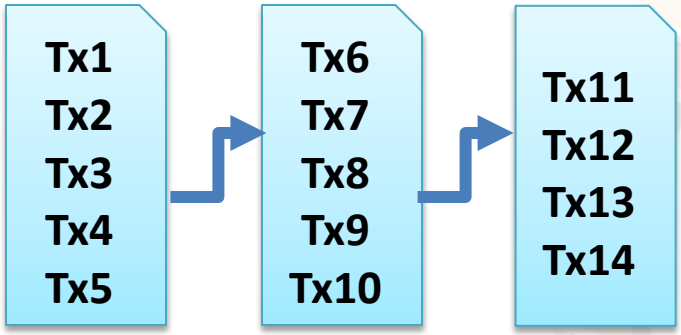
- Per transaction consensus
  - Inefficient
- Block based consensus

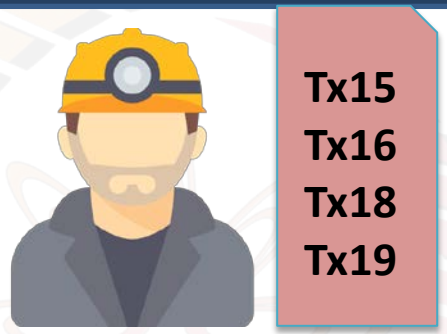


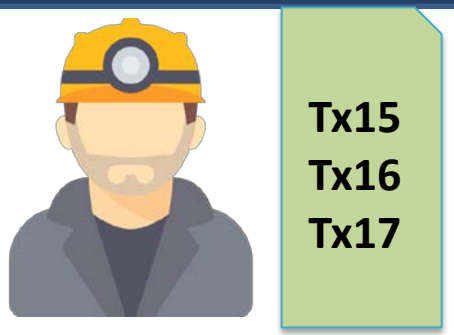
Apply consensus over the entire block of transactions

- **Here comes the Blockchain**

Consensus in Bitcoin

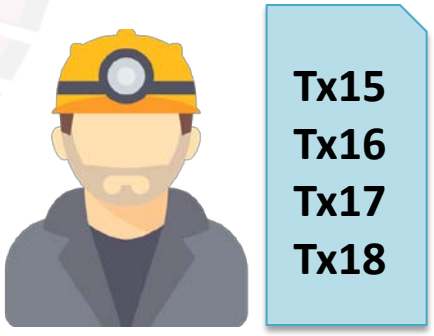






Bitcoin Consensus Objective:

Which block do we add next?



thank you!