Hyperledger Indy Public Blockchain

Hyperledger Bootcamp Russia

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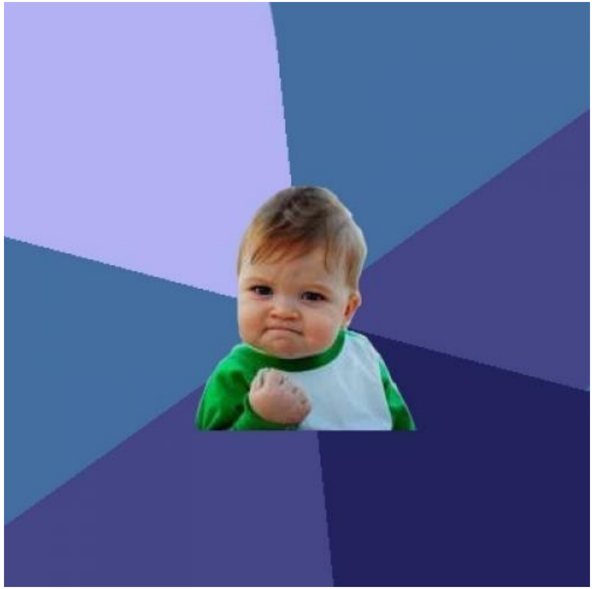
HYPERLEDGER INDY

- Indy has its own implementation of Distributed Ledger not dependent on any other blockchain platform
- Indy has its own implementation of a PBFT-like consensus protocol



HYPERLEDGER INDY

- Indy is one **active** Hyperledger projects
- Indy deployment (Sovrin) is in production for more than 2 years

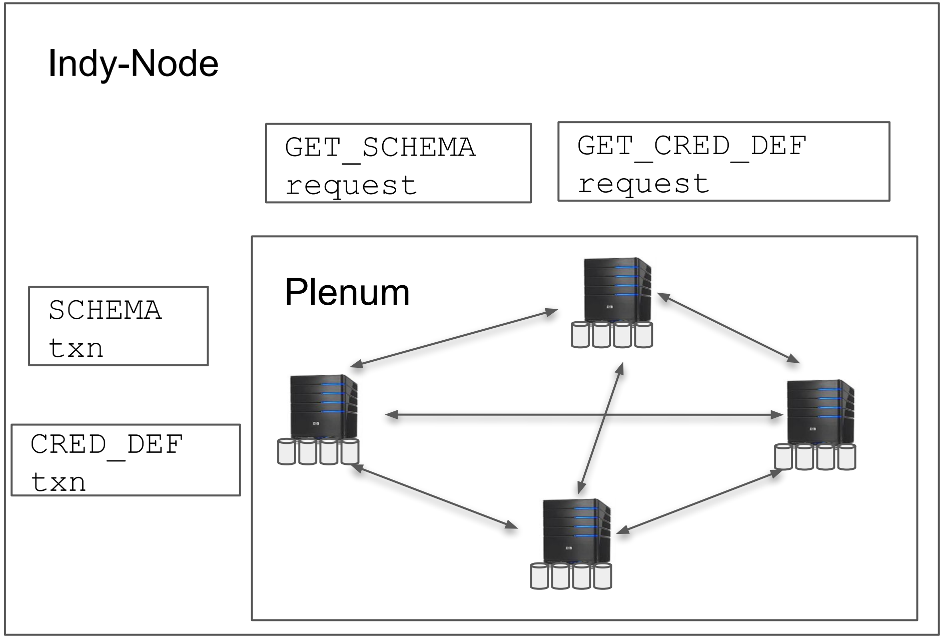
Sovrin Networks:
- Builder Net
- Staging Net
- Main Net

Agenda

1. Indy-Plenum and Indy-Node
2. Architecture Overview
3. Ledger
4. Consensus Protocol
    - RBFT
    - Moving to Aardvark
    - Plenum protocol specific
5. Summary and Key Features

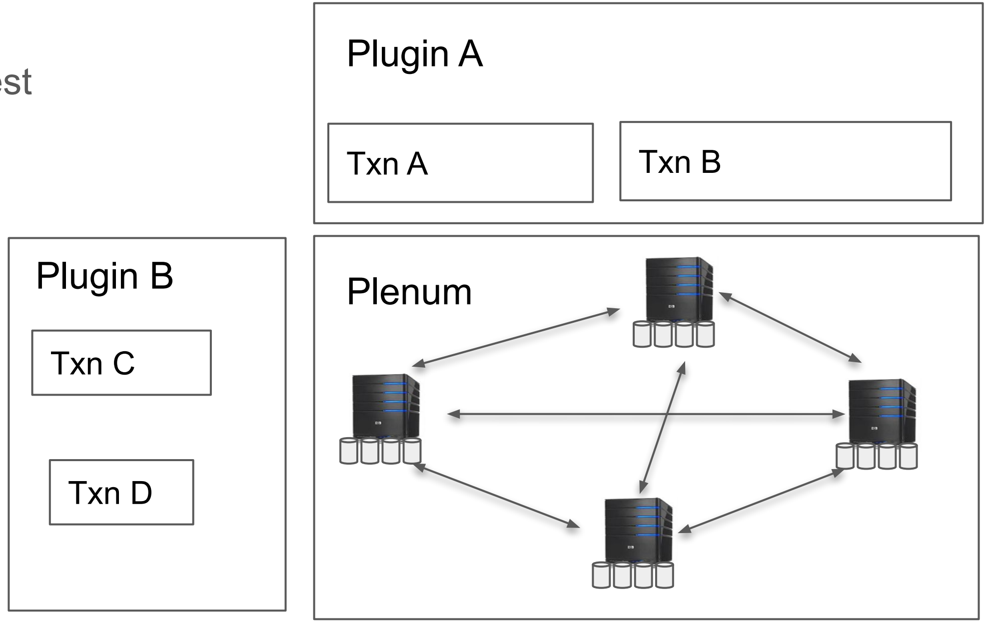
Indy-Plenum and Indy-Node

- Indy-Plenum:
  - https://github.com/hyperledger/indy-plenum
  - Consensus Protocol
  - Ledger
- Indy-Node:
  - https://github.com/hyperledger/indy-node
  - Depends on indy-plenum
  - Identity-specific transactions



Indy-Plenum and Indy-Node

- Indy is a Ledger purpose-build for Identity
- Can be used as a general-purpose Ledger
  - Extend Plenum
  - Custom transactions (pluggable request handlers)
  - Plugins



Indy-Plenum and Indy-Node

- Written in Python
- Depends on
  - ZMQ
  - Indy-crypto (Ursa)
  - Libsodium
- Message-driven and modular architecture
  - Recent refactorings improved this
- Extensive test coverage
  - TDD
  - Unit tests
  - Integration tests
  - Property-based and simulation tests
  - System tests
  - Load tests (usually 25 Nodes)

Architecture Overview: Indy Blockchain Type

BITCOIN is decentralized money.

ETHEREUM is decentralized applications.

INDY is decentralized identity.

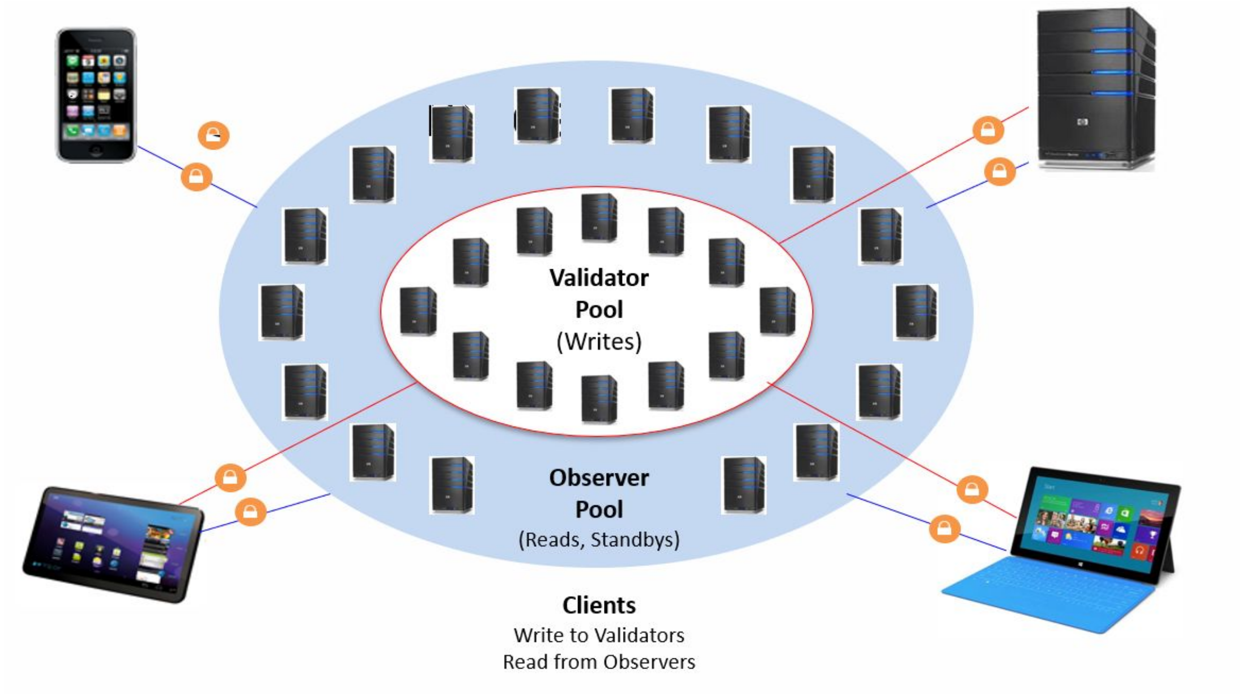
Validation

Access	Permissionless	Permissioned
Public	Bitcoin Etherium	Indy/Sovrin
Private	Enterprise Ethereum Alliance	Hyperledger Fabric Hyperledger Sawtooth R3 Corda

Architecture Overview: What data is on Blockchain

- No private data is written to the Blockchain
- Only Public data (such as Issuer’s Public Key) is there

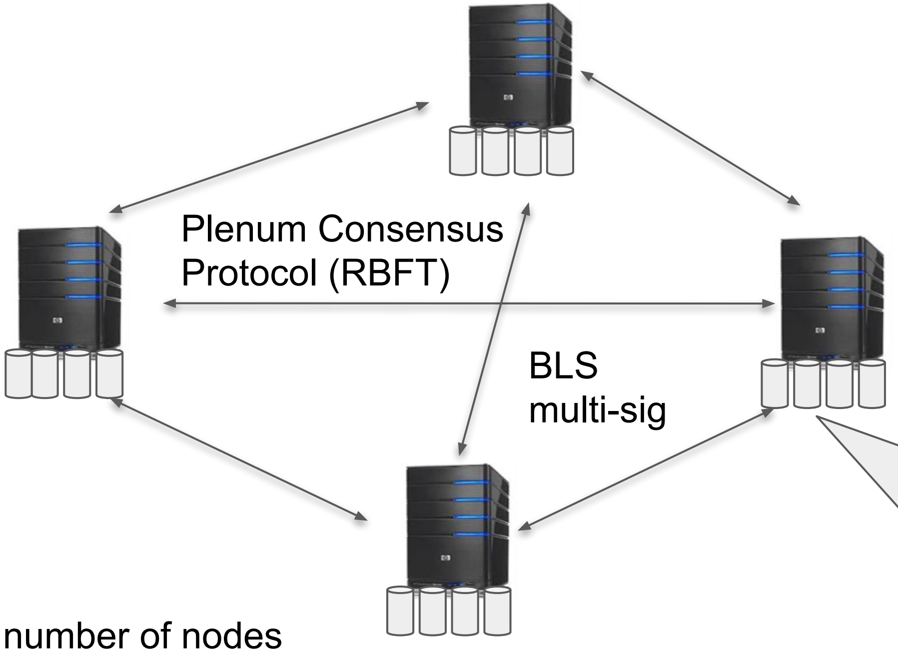
Architecture Overview: Validator and Observer Nodes



- Validator
  - Handles Writes and Reads
  - These are the nodes that come to consensus
- Observer*
  - Handles Reads
  - Keep their “state” in sync with the Validators

*Partially implemented

Architecture Overview: Validator Nodes



ZMQ as secure transport

- TCP-based
- CurveCP, libsodium
- Authenticated encryption, no digital signatures
  - Authentication: Poly1305 MAC
  - Symmetric key crypto: XSalsa20
  - Public Key crypto: Curve25519

- Each Node replicates all ledgers
- Each Ledger has a Merkle Tree
- Most of the Ledgers have State based on Patricia Merkle Trie

N=3F+1

- N - number of nodes
- F - max number of malicious nodes

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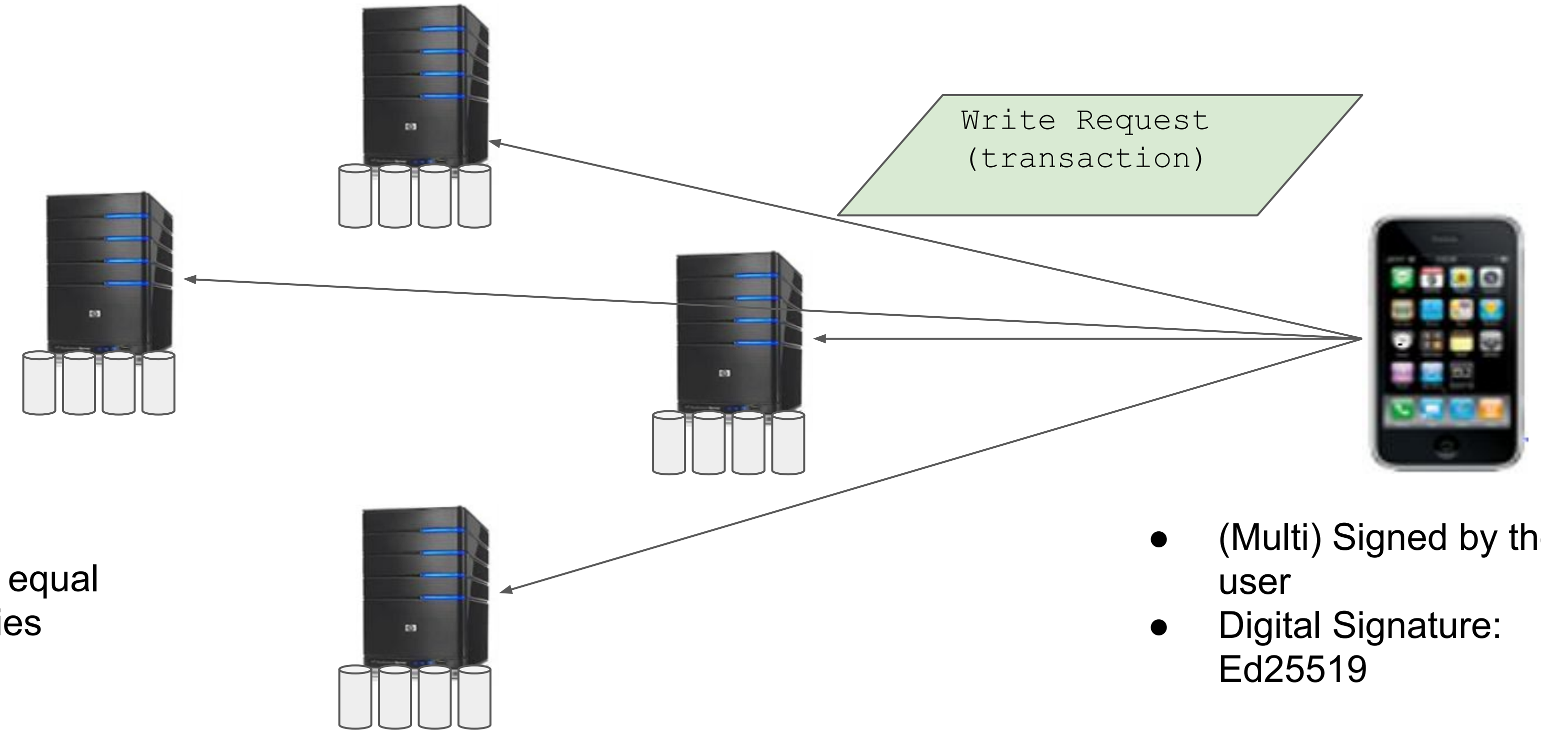
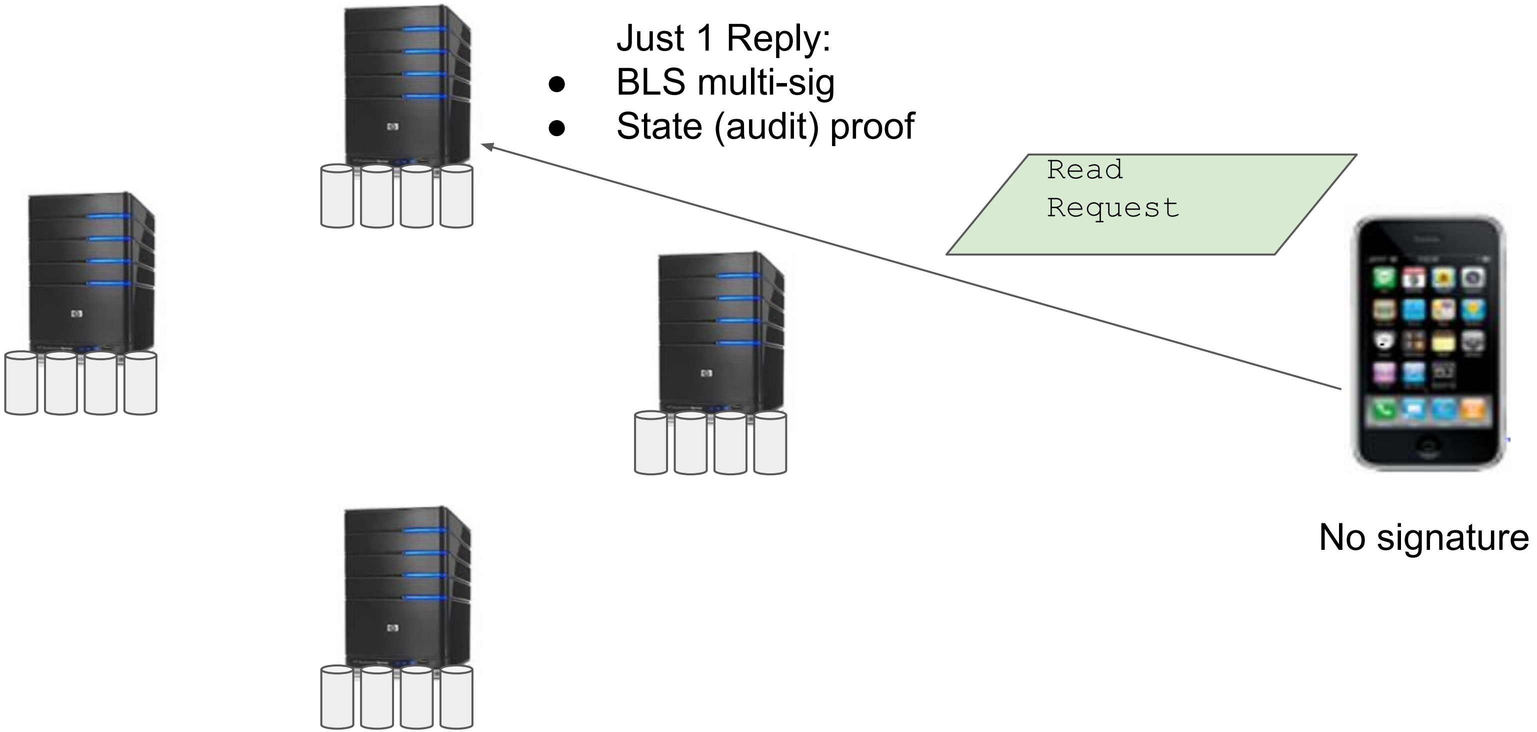
Architecture Overview: Write Requests



F+1 equal replies

- (Multi) Signed by the user
- Digital Signature: Ed25519

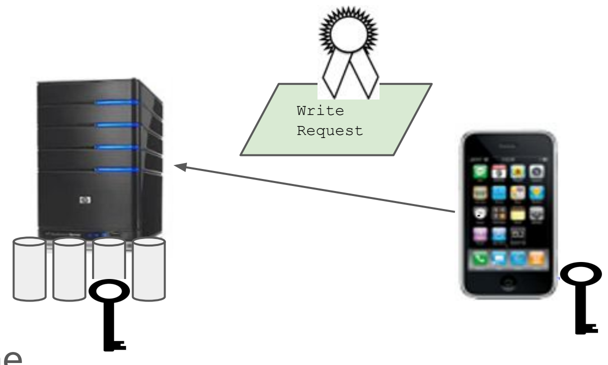
Architecture Overview: Read Requests



Architecture Overview: Authentication

Authentication is based on the information present in the Ledger

- Write Requests:
  - Must be signed (Ed25519 digital signature)
  - Signature is verified against a Public Key stored on the Ledger (DID txn)
  - Every transaction author must have a DID transaction on the Domain Ledger
- Read Requests:
  - Anyone can read, no authentication is required



Architecture Overview: Authorization

Authorization is based on the information present in the Ledger

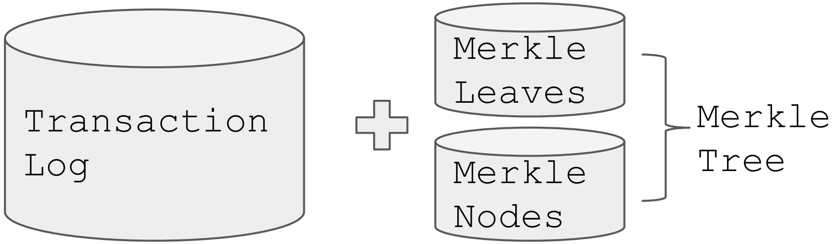
- Write Requests:
  - There is a role associated with every DID
  - There are configurable auth rules (stored in Config Ledger) which can define authorization policy for every action
  - The rules may define how many signatures of the given role are required
  - The rules can be composed by OR/AND expressions
- Read Requests:
  - Anyone can read, no authorization is required

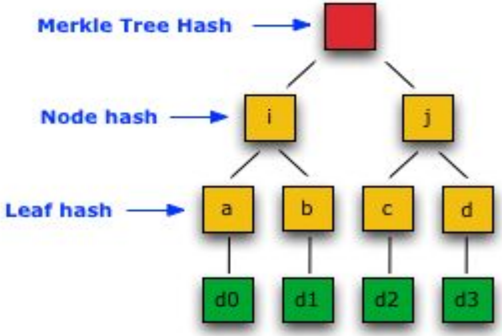
```
Add a new SCHEMA:

(1 TRUSTEE) OR
(2 STEWARDS)
```

Ledger: Transaction Log and Merkle Tree

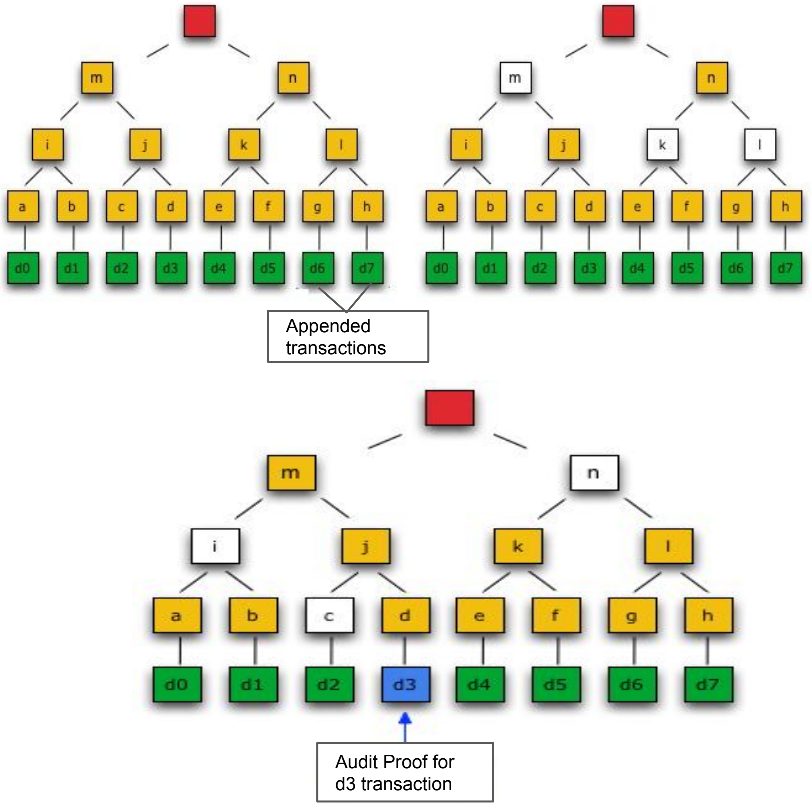
- Ledger:
  - Ordered log of transactions
  - Merkle Tree for the whole ledger
  - No real blocks
- RocksDB as key-value storage
- MessagePack for serialization
- Ledger catch-up procedure
  - On Start-up
  - On lagging behind





Ledger: Merkle Tree

1. Merkle Tree Root Hash
   - Ledger Catchup
   - Transaction Validation
2. Consistency Proof
   - Ledger Catchup
3. Inclusion (audit) Proof
   - Reply to written transaction
   - GET_TXN reply



Ledger: Ledger Types

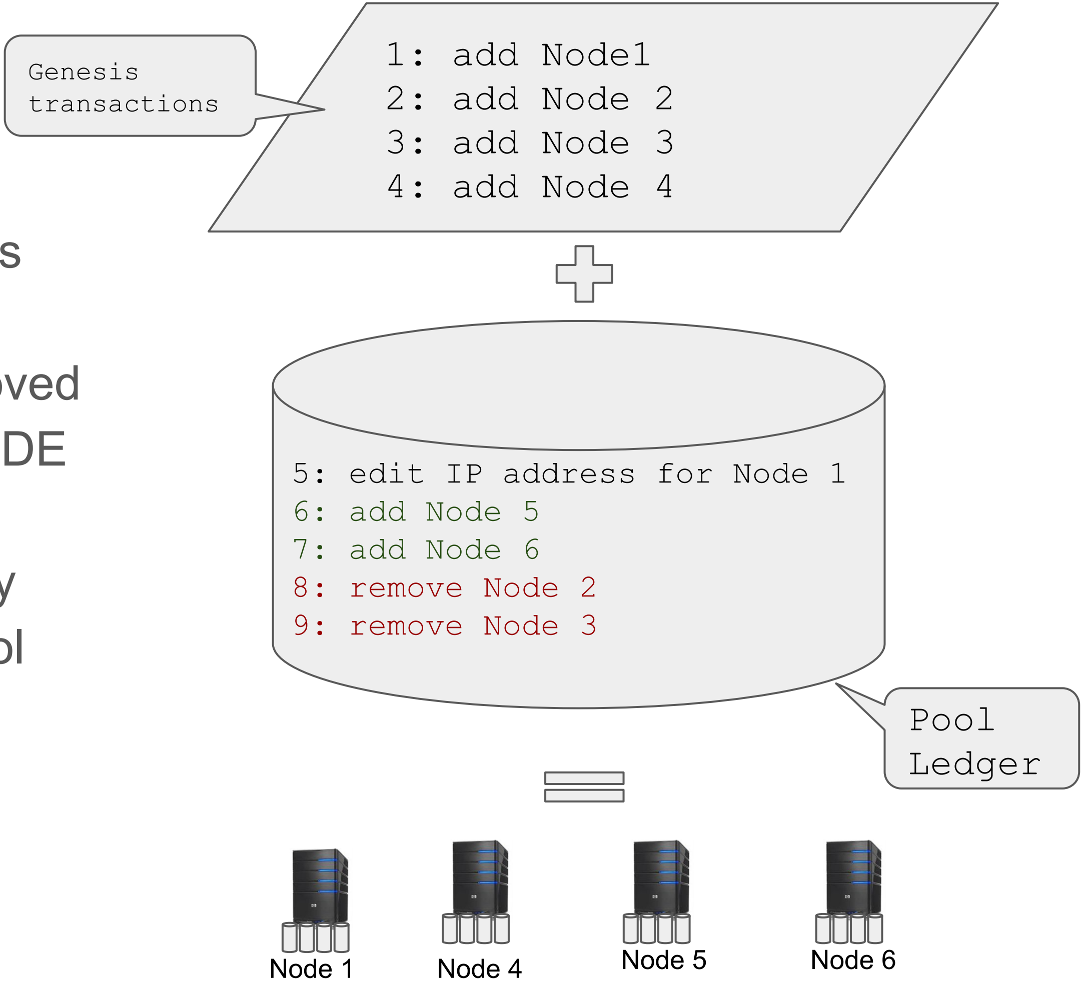
Indy has multiple Ledgers (each with a separate transaction log and a merkle tree):

- Audit Ledger
  - Order across ledgers
- Pool Ledger
  - Transaction for every Node in the pool
  - Adding, editing, removing nodes
- Config Ledger
  - Pool config parameters
  - Used in transaction validation
- Domain Ledger
  - Identity-specific transactions
  - Application-specific transactions

- Plugins can add new ledgers

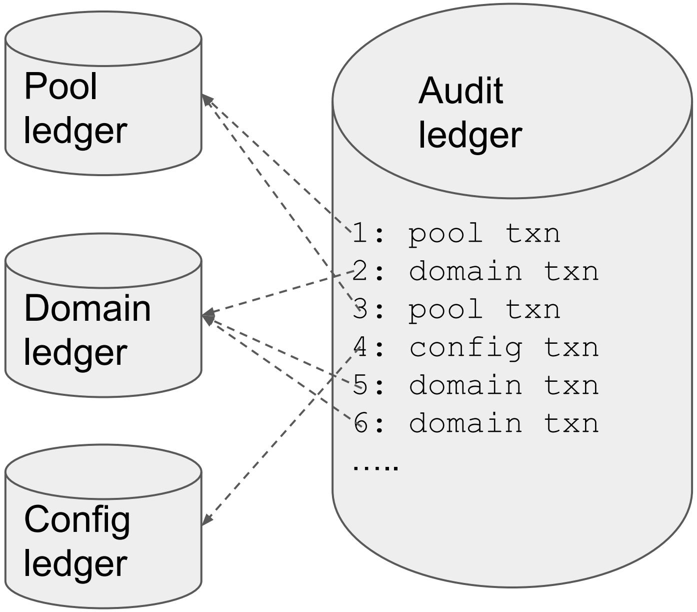
Ledger: Pool Ledger

- A new Pool is built from genesis transactions
- Nodes can be added and removed from the Pool by sending a NODE txn to the Pool Ledger
- Node's data can be modified by sending a NODE txn to the Pool Ledger



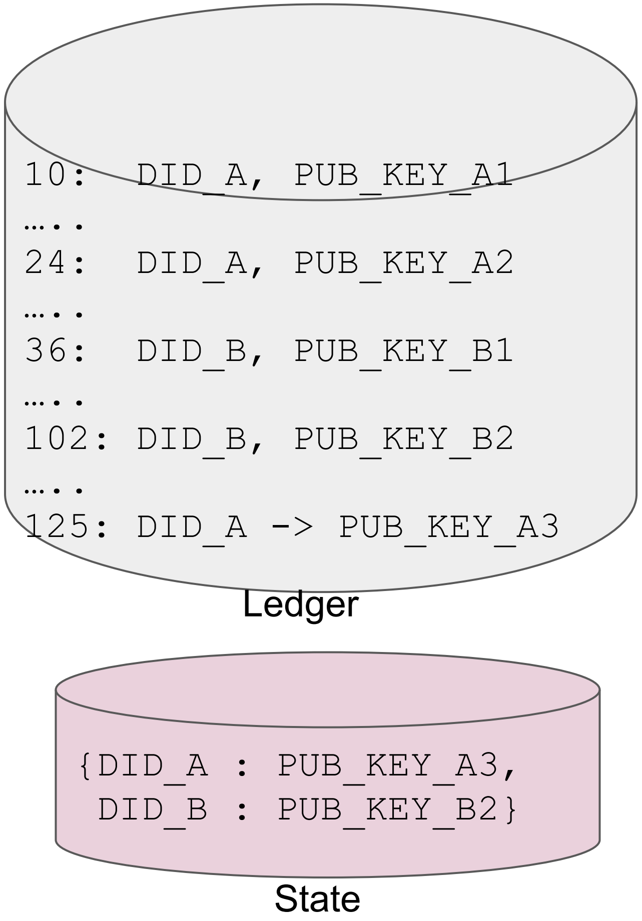
Ledger: Audit Ledger

- Why
  - Synchronization between ledgers
    - Global sequence number between ledgers
    - Ledgers are caught up sequentially and one by one
  - Recovering of pool state after startup
  - External audit
- Audit transaction as a Block:
  - Batch seq no
  - View no
  - Corresponding ledger root hash
  - Corresponding ledger size
  - Current Primaries



State

- Each Ledger (except Audit Ledger) has a State
    - Pool State
    - Config State
    - Domain State
- Map ordered list of transactions to the current state as dictionary
    - Dynamic Validation
    - Read requests.
- Merkle Patricia Trie (as in Ethereum)
    - Radix Tree + Merkle Tree
    - Ledger Merkle Tree for Lists (ordered txn log)
    - Patricia Merkle Trie for Dicts
- Key-value storage - RocksDB.



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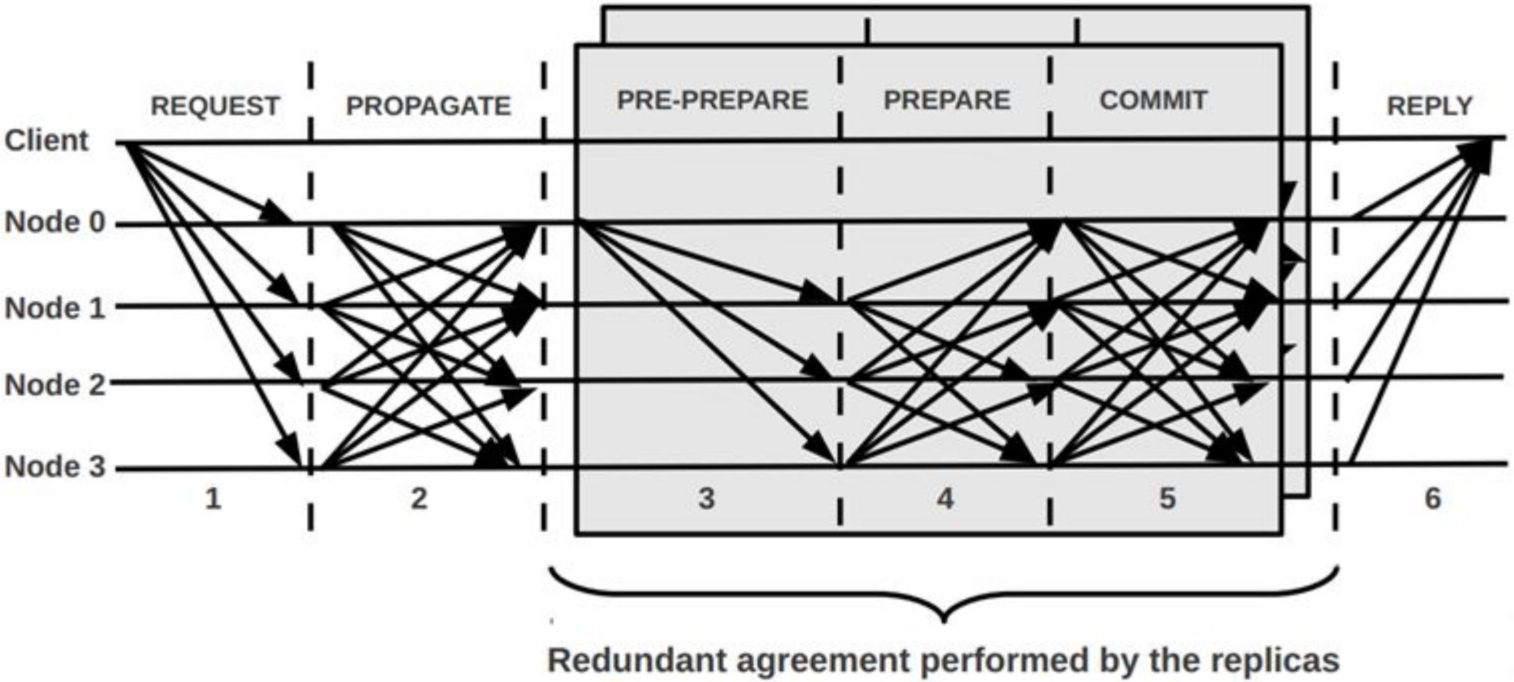
Consensus Protocol: BFT

- No generals trust any other one general
- Each independently decides to attack, if two others also commit to attack
- With four generals, we can have one faulty general, and we can still agree

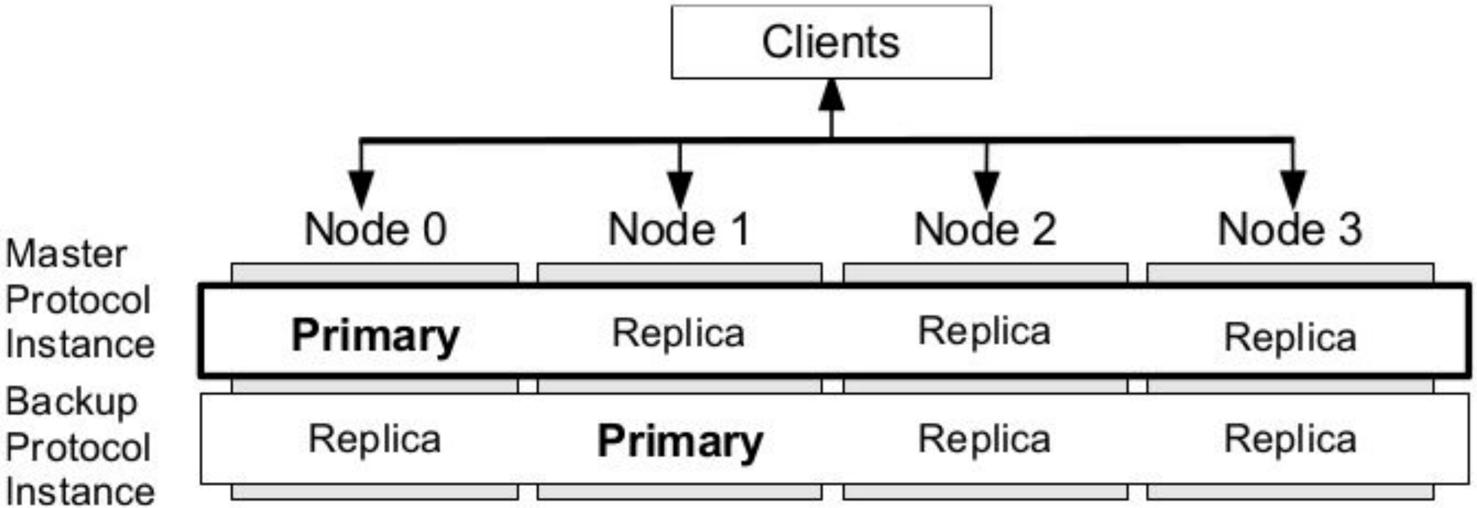
Consensus Protocol: RBFT

- Byzantine Fault Tolerance
  - Built on RBFT: Redundant Byzantine Fault Tolerance.
  - Improves over PBFT (by Miguel Castro and Barbara Liskov) by executing several protocol instances in parallel
- Better throughput, lower latency than proof-of-work
- Performs better compared to its predecessors under dynamic load and under attack

Consensus Protocol: RBFT Three Phase Commit



Consensus Protocol: RBFT Redundancy with Active Monitoring



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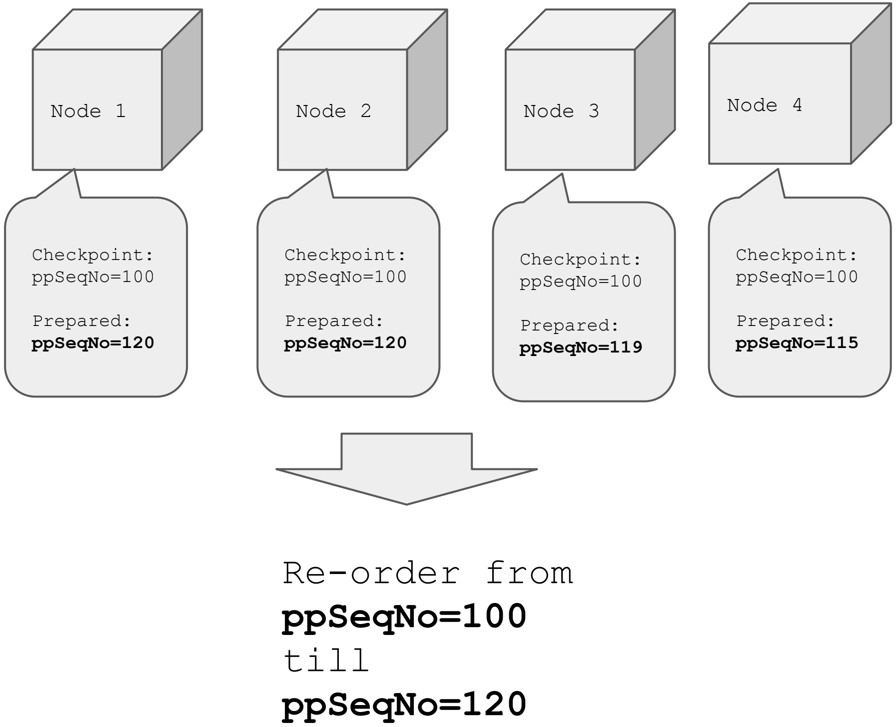
Consensus Protocol: View Change

- Protocol is leader-based
- Leader may behave maliciously
  - Disconnected/Stopped
  - Degraded performance
  - Inconsistent Data (Ledger/State)
- If the Pool realizes that a Leader needs to be changed, it starts a View Change process
  - RBFT has multiple instance of the protocol that compare performance, and decide if master protocol is degraded
- View Change is implemented the same way as in original PBFT paper
  - A variant without digital signatures
- Plenum has a couple of enhancements to make sure the data is consistent during the View Change

Consensus Protocol: View Change

- All transactions that could be potentially ordered on at least one correct Node are eventually ordered on all Nodes
- View Change procedure:
  - Each node propagates its prepared certificate to other nodes (that is transaction it could potentially ordered)
  - A new Leader decides which transactions need to be re-ordered and do the re-ordering



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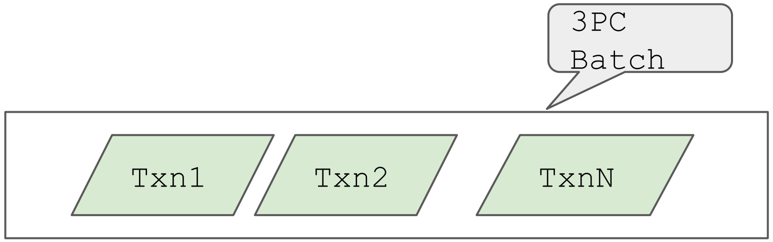
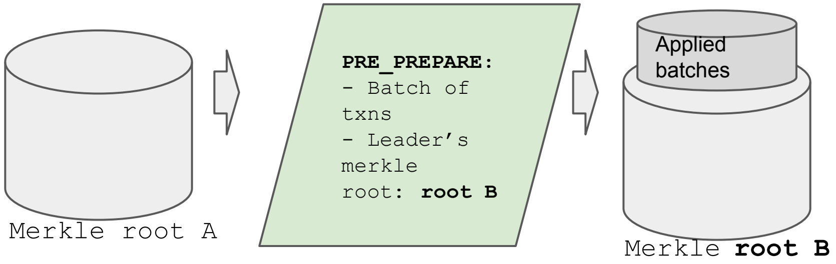
Consensus Protocol: Moving to Aardvark

- Although RBFT protocol may be quite sensitive to malicious Leaders in some conditions, it’s slower than other PBFT-like protocols
  - N^3 vs N^2
- We are expecting to change consensus protocol to Aardvark
  - PBFT-like protocol with the same view change implementation
  - Has just 1 protocol instance (like in PBFT and unlike RBFT)
  - Does regular View Changes
  - Probability of View Change depends on the Leader’s performance

Plenum Protocol Specific

- **3PC Batching**
  - Multiple transactions are ordered as one in a batch
- **Data Consistency check as part of Consensus Protocol**
  - Apply batches as proposed by the Leader to the Ledgers and States => `uncommitted merkle root`
  - Compare `uncommitted merkle root` hash with the Leader's one (in PrePrepare message)
  - This guarantees Data Consistency
  - If Leader sends inconsistent Data - View Change happens





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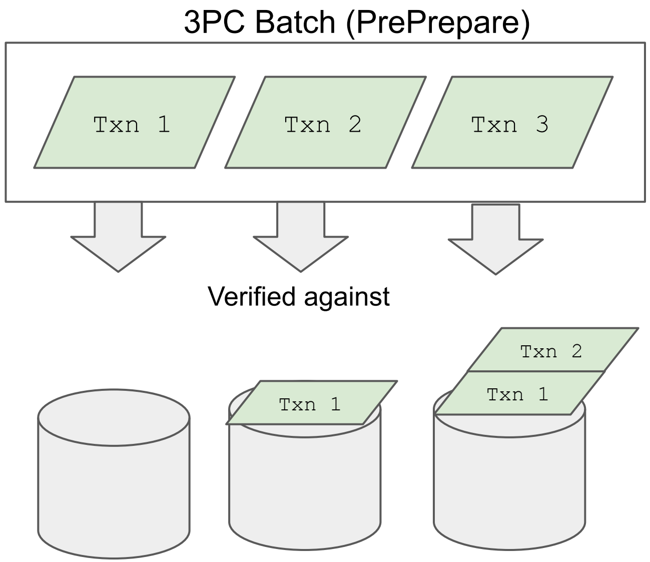
Plenum Protocol Specific

- **Dynamic validation based on the current uncommitted state**
  - When a PrePrepare is applied, each transaction must pass the dynamic validation
  - Dynamic validation is performed against the current uncommitted Ledger or State

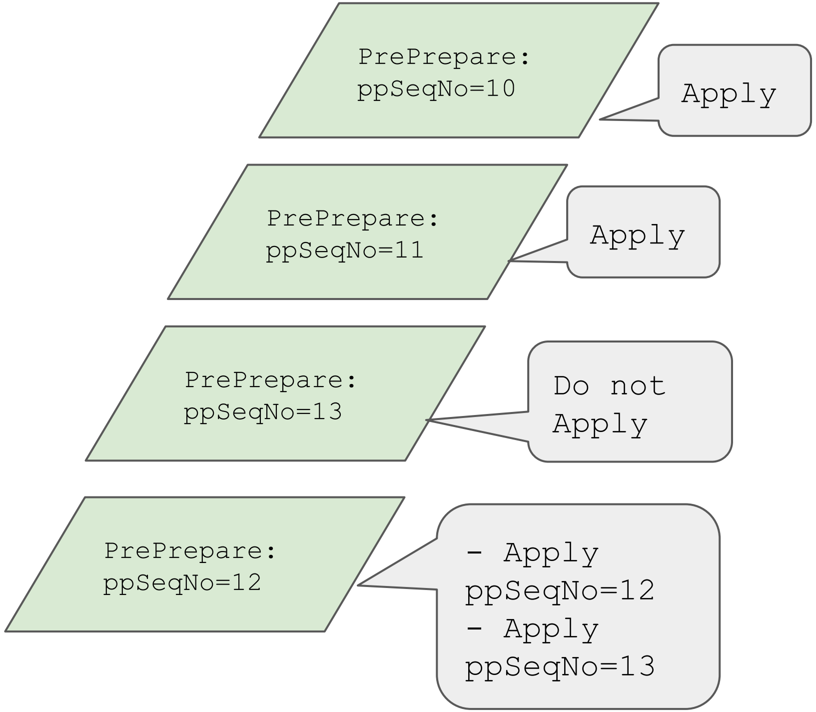
- **Usage of Audit Ledger**
  - Audit Ledger is used to confirm data consistency as part of consensus
  - Audit Ledger’s root is used Checkpoint



Plenum Protocol Specific

- **Sequential applying of PrePrepares**
  - We may have more than one Batch (PrePrepare) in flight, but all PrePrepares are applied sequentially (no gaps) to check data consistency

- **Message Requests**
  - If a message from a Node is lost/missing, it's requested from this Node

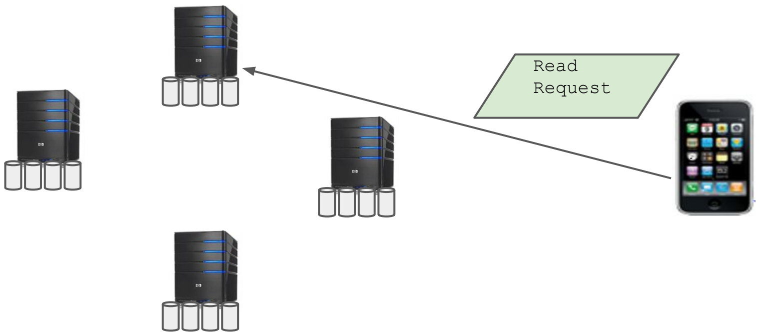


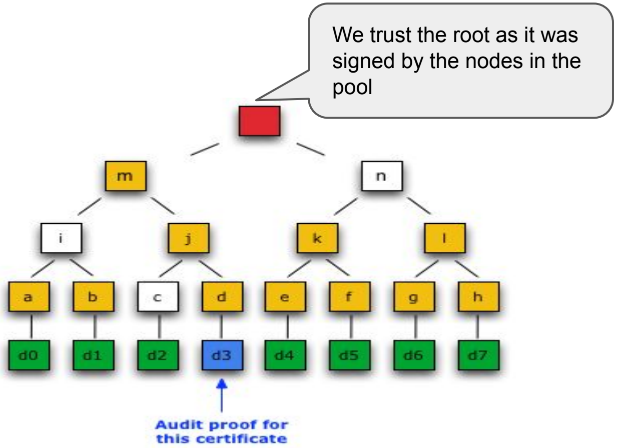
Plenum Protocol Specific: BLS multi-signature

Sufficient to send Read requests to just one Node:

- State (Audit) Proof
  - Merkle Tree Proof that the result belongs to a State (Ledger) Merkle Tree with the given root
- BLS multi-signature against the merkle tree root
  - All nodes multi-sign the merkle tree root of Ledgers and States as part of Consensus Procedure

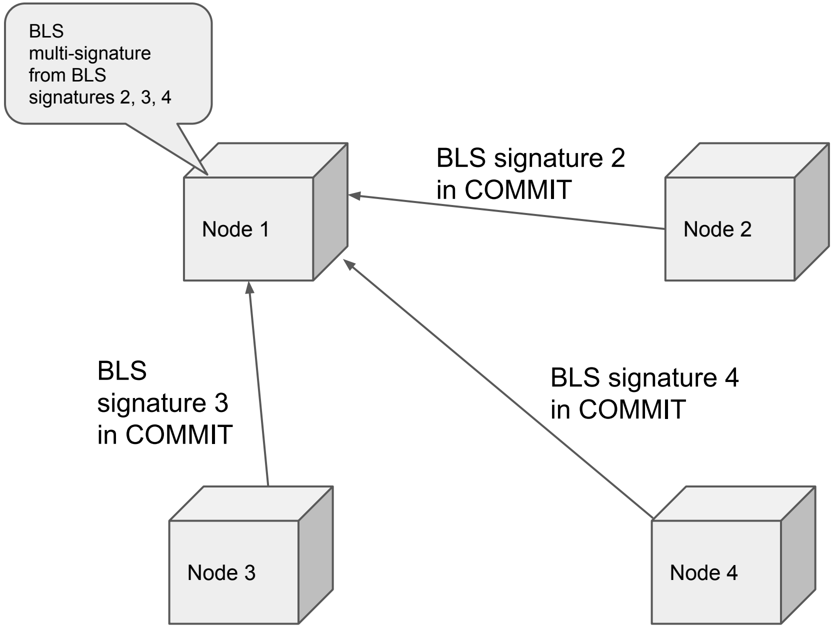
The client verifies State (Audit) Proof and BLS multi-sig





Plenum Protocol Specific: BLS multi-signature

- **BLS multi-signature as part of Consensus Protocol**
  - Each Node BLS signs data during Consensus
    - Ledger merkle root hash
    - State merkle root hash
    - Timestamp
  - BLS multi-signature is calculated once the Batch is ordered
  - If there is no requests in the Pool, a PrePrepare with no requests is sent to update the BLS multi-signature



Example of BLS multi-sig calculation for Node 1
The same is applied to every Replica

Cryptography Summary

- Ledgers:
  - **Merkle Tree** (Ledger)
  - **Patricia Merkle Trie** (State)
- Node-to-Node Communication
  - ZMQ (libsodium) as secure transport
    - **CurveCP** handshake
    - Authenticated Encryption
      - Authentication: **Poly1305 MAC**
      - Symmetric key crypto: **XSalsa20**
      - Public Key Crypto: **Curve25519**
    - No Digital Signatures
  - **BLS** multi-signature to sign merkle roots
- Client-to-Node communication
  - **Ed25519** Digital Signatures

Summary

- Ledger purpose-built for Identity
- Indy has its own Ledger and consensus protocol implementation
- Indy is in production (Sovrin network) for more than 2 years
- Indy Consensus Protocol:
    - RBFT consensus protocol with a plan to move to Aardvark
- Indy Ledger:
    - Multiple Ledgers (each with Merkle Tree)
    - States for efficient reads and validation
    - Authentication, Authorization and dynamic validation is based on the information from the Ledger
    - Audit Ledger synchronizes the ledgers and introduces blocks

Summary

- Efficient Read
  - Read data from one Node due to BLS multi-signatures and state proofs
- Specific of the Protocol:
  - 3PC Batching
  - Data Consistency check as part of Consensus Protocol
  - Dynamic validation based on the current uncommitted state
  - Usage of Audit Ledger
  - Sequential applying of PrePrepares
  - BLS multi-signature as part of Consensus Protocol

Links

- Plenum and Node:
    - https://github.com/hyperledger/indy-plenum/blob/master/README.md
    - https://github.com/hyperledger/indy-plenum/tree/master/docs/source
    - https://github.com/hyperledger/indy-node/blob/master/README.md
    - https://github.com/hyperledger/indy-node/tree/master/docs/source
- RBFT:
    - https://pakupaku.me/plaublin/rbft/5000a297.pdf
- Aardvark:
    - https://www.usenix.org/legacy/events/nsdi09/tech/full_papers/clement/clement.pdf
- PBFT:
    - https://www.microsoft.com/en-us/research/wp-content/uploads/2017/01/p398-castro-bft-tocs.pdf