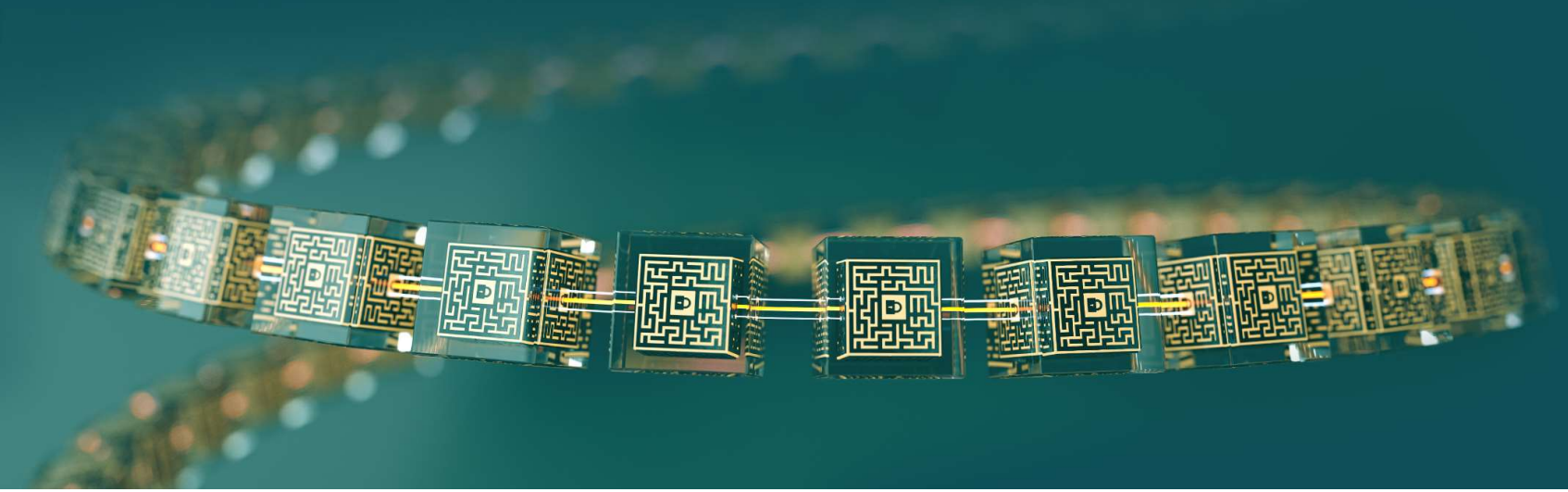
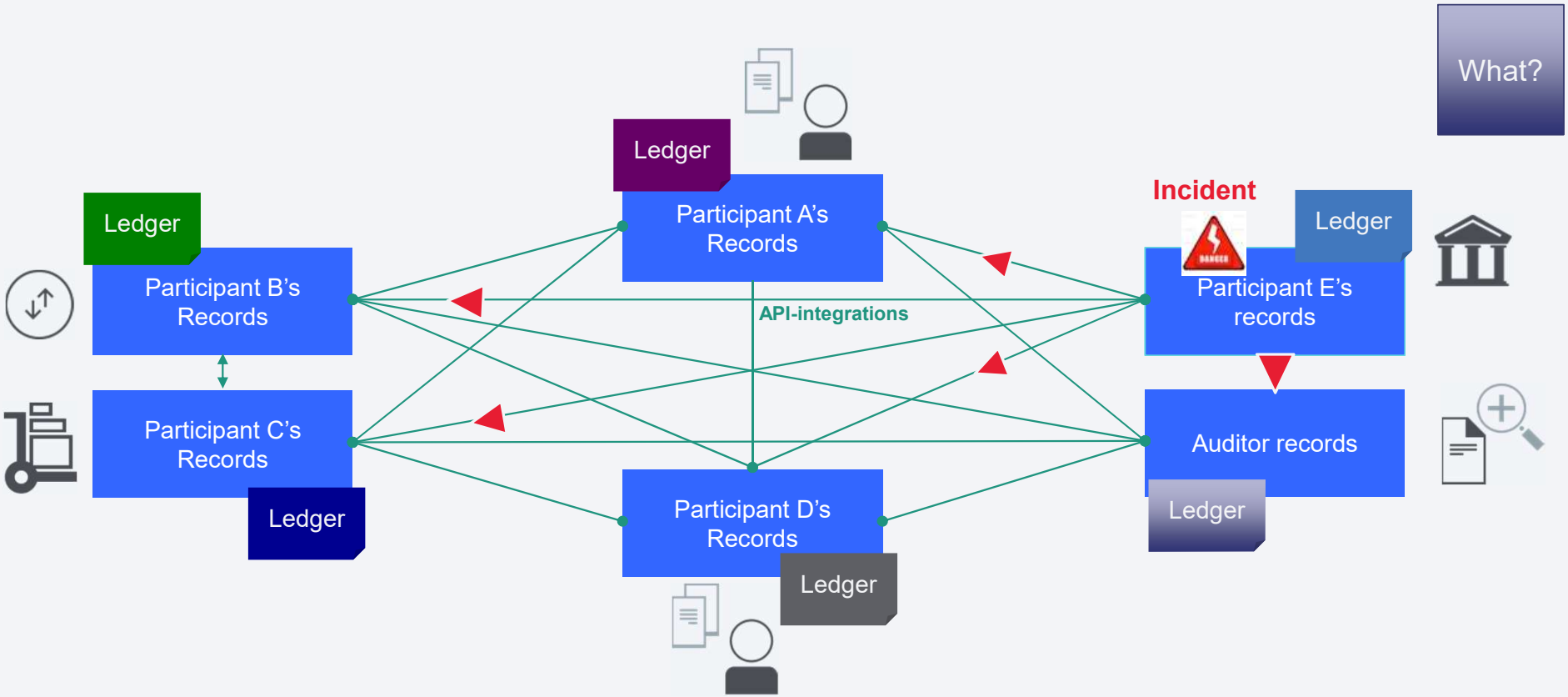
IBM Blockchain

August 2017

Blockchain Explored

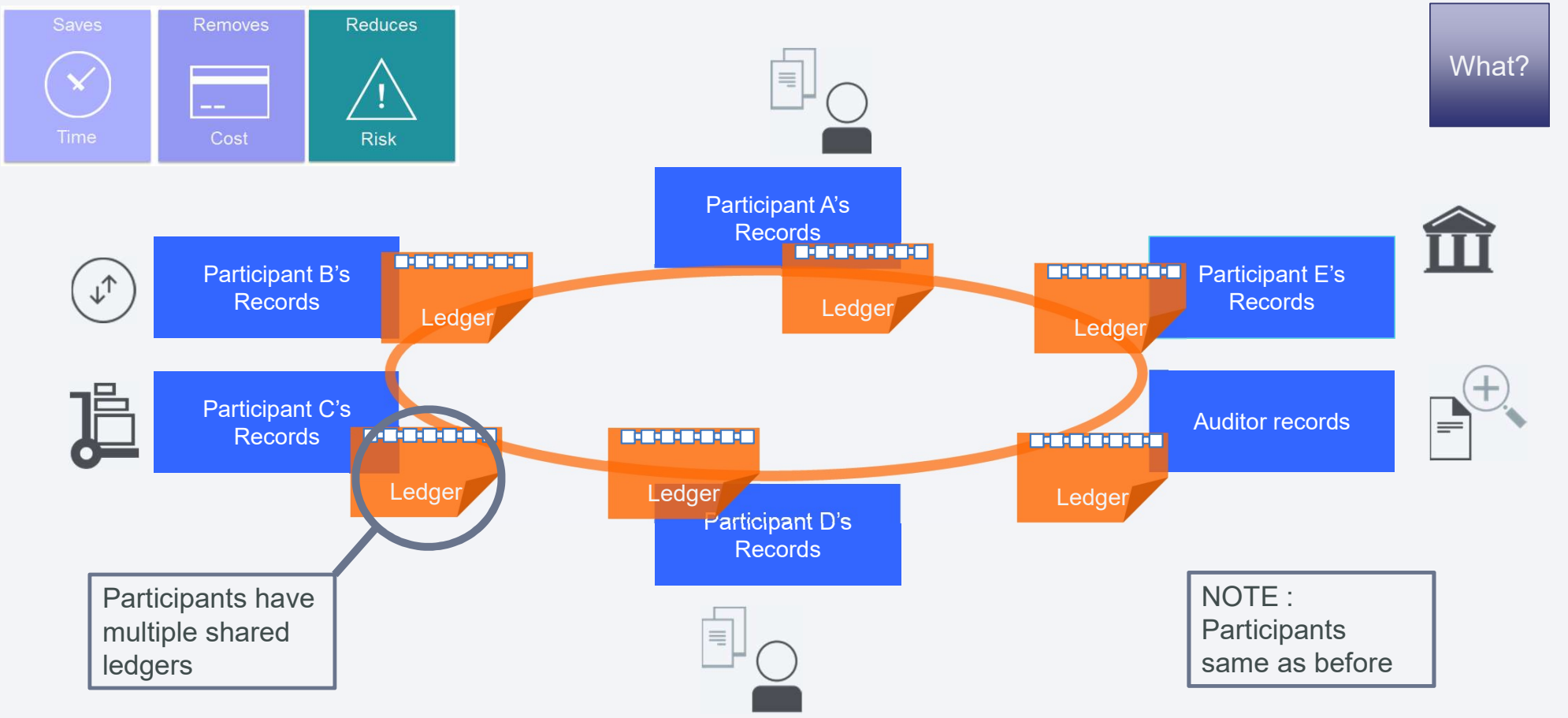


Problem - Difficult to monitor asset ownership and transfers in a trusted business network



Inefficient, expensive, vulnerable

Solution – shared, replicated, permissioned ledger



Consensus, provenance, immutability, finality

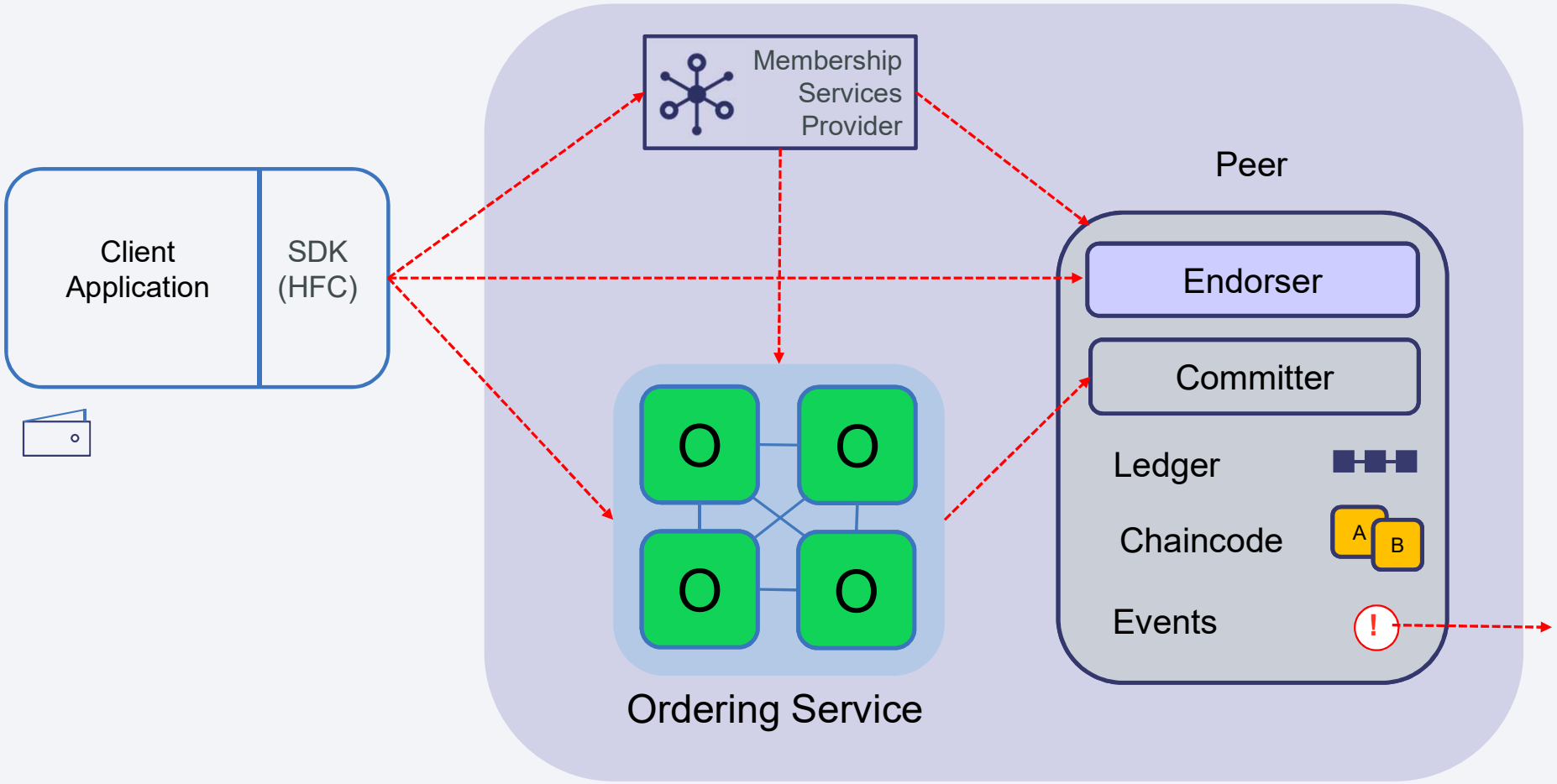
What is Hyperledger Fabric

- Linux Foundation Hyperledger
  - A collaborative effort created to advance cross-industry blockchain technologies for business

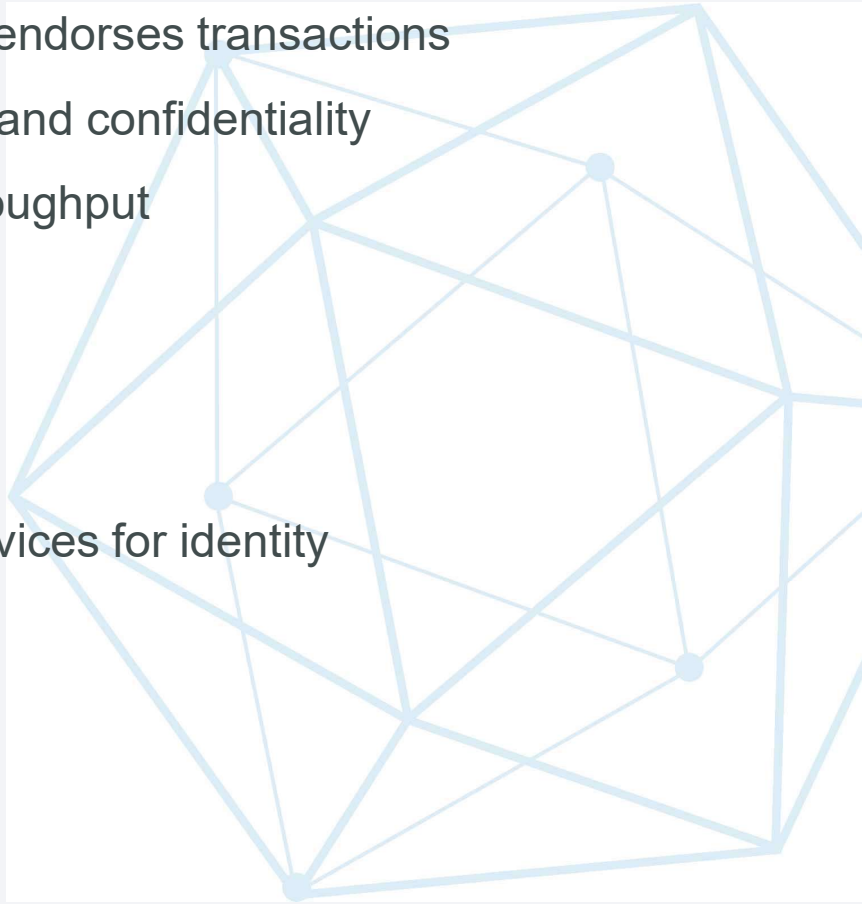
- Hyperledger Fabric
  - An implementation of blockchain technology that is intended as a foundation for developing blockchain applications
  - Key technical features:
    - A shared ledger and smart contracts implemented as “chaincode”
    - Privacy and permissioning through membership services
    - Modular architecture and flexible hosting options

- V1.0 released July 2017: contributions by 159 engineers from 27 organizations
  - IBM is one contributor to Hyperledger Fabric

Hyperledger Fabric V1 Architecture

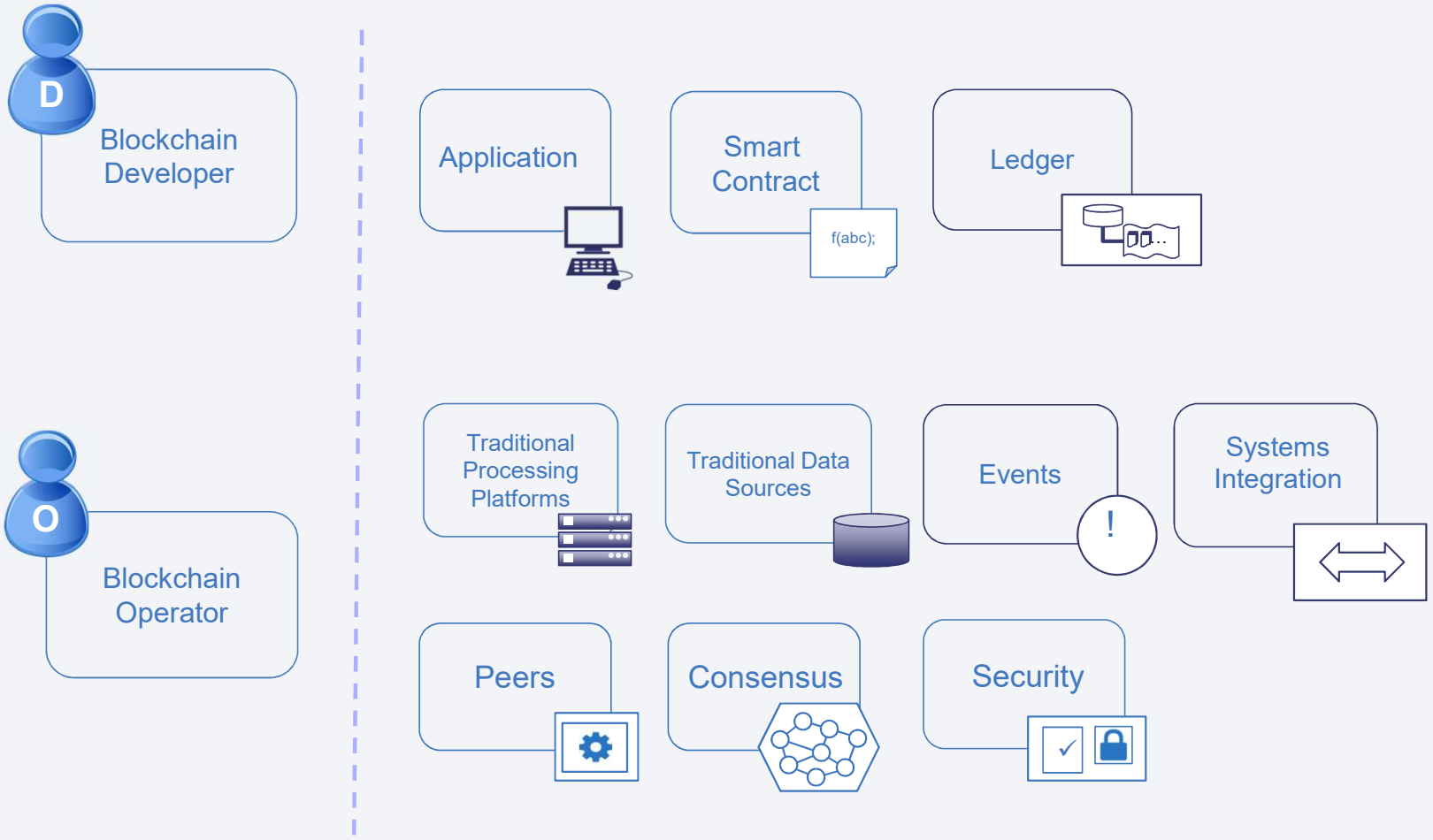


Overview of Hyperledger Fabric v1 – Design Goals

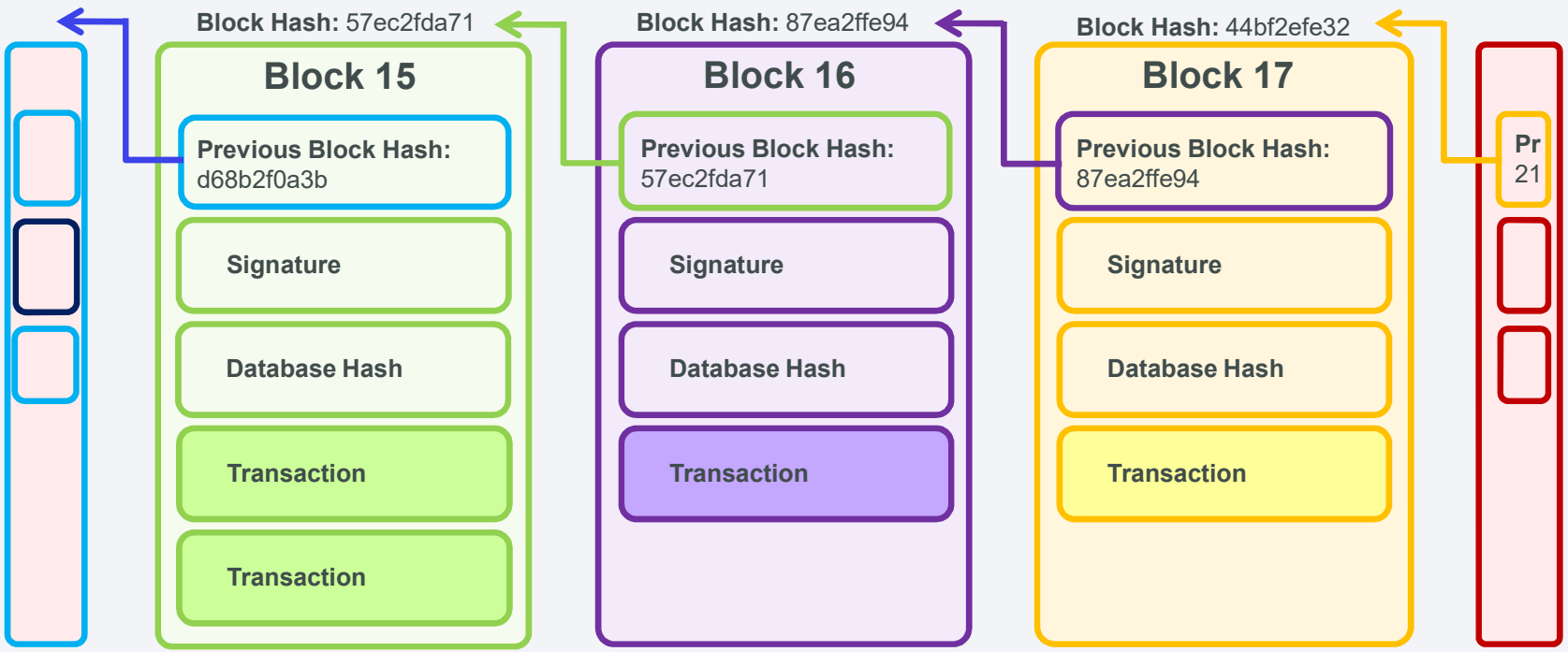


- Better reflect business processes by specifying who endorses transactions
- Support broader regulatory requirements for privacy and confidentiality
- Scale the number of participants and transaction throughput
- Eliminate non deterministic transactions
- Support rich data queries of the ledger
- Dynamically upgrade the network and chaincode
- Support for multiple credential and cryptographic services for identity
- Support for ”bring your own identity”

Recall Key Blockchain Concepts



What is a Blockchain ?



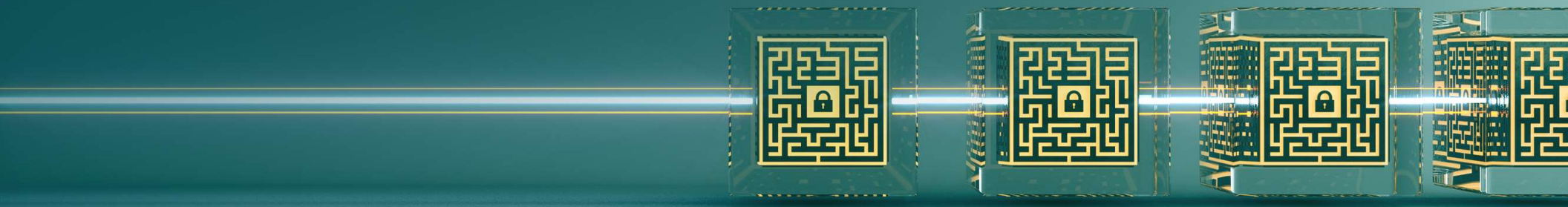
Made up of a series of blocks added in **chronological order**

All **blocks must contain at least 1 transaction** as a new block will not be formed unless one is present

Hyperledger Fabric V1 - Deep Dive Topics

- Network Consensus
- Channels and Ordering Service
- Network setup
- Endorsement Policies
- Permissioned ledger access
- Pluggable world-state

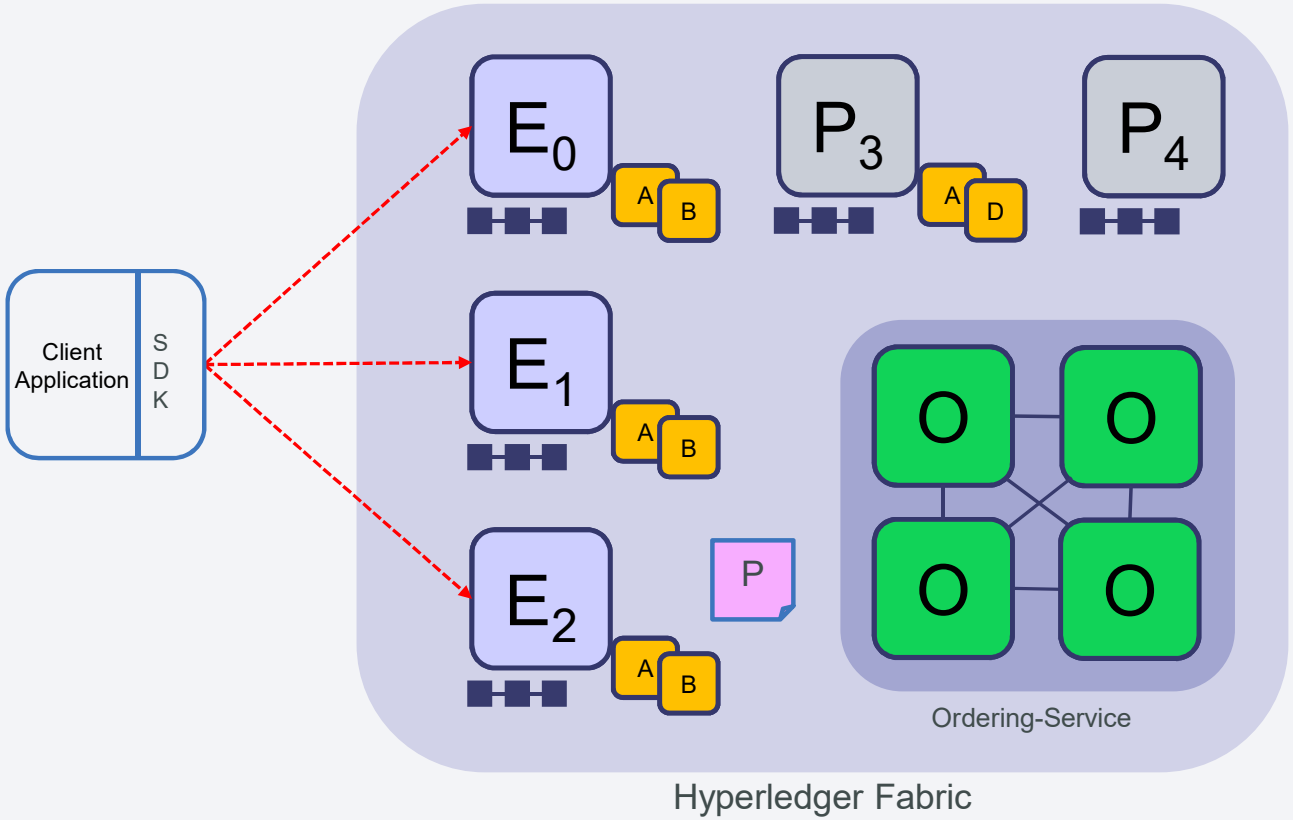
Network Consensus



Nodes and roles

	**Committing Peer**: Maintains ledger and state. Commits transactions. May hold smart contract (chaincode).
	**Endorsing Peer**: Specialized committing peer that receives a transaction proposal for endorsement, responds granting or denying endorsement. Must hold smart contract
	**Ordering Nodes (service)**: Approves the inclusion of transaction blocks into the ledger and communicates with committing and endorsing peer nodes. Does not hold smart contract. Does not hold ledger.

Sample transaction: Step 1/7 – Propose transaction

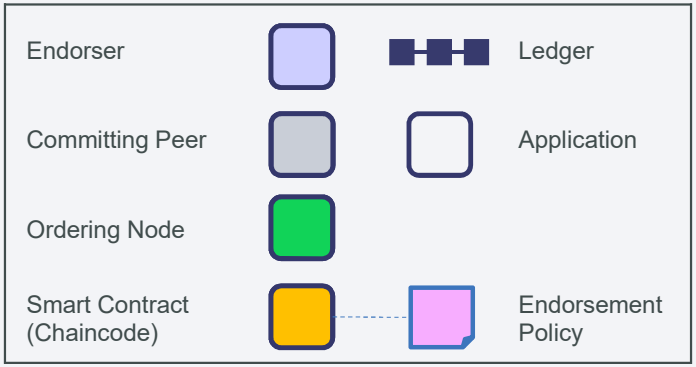


Application proposes transaction

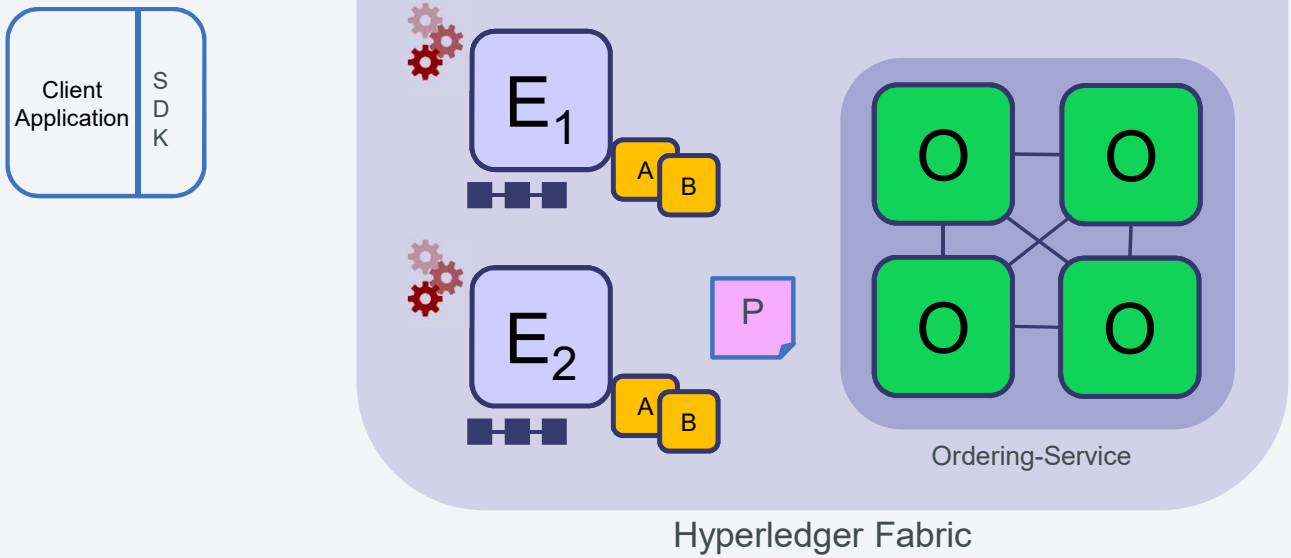
Endorsement policy:
- "**E_0, E_1** and **E_2** must sign"
- (**P_3, P_4** are not part of the policy)

Client application submits a transaction proposal for **Smart Contract A.** It must target the required peers {**E_0, E_1, E_2**}

Key:



Sample transaction: Step 2/7 – Execute proposal



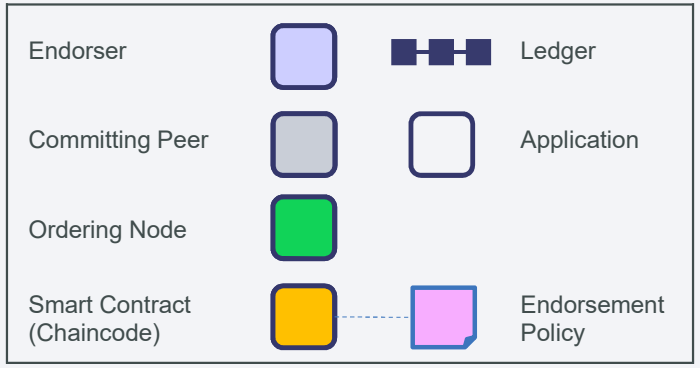
Endorsers Execute Proposals

E_0, E_1 & E_2 will each execute the *proposed* transaction. None of these executions will update the ledger

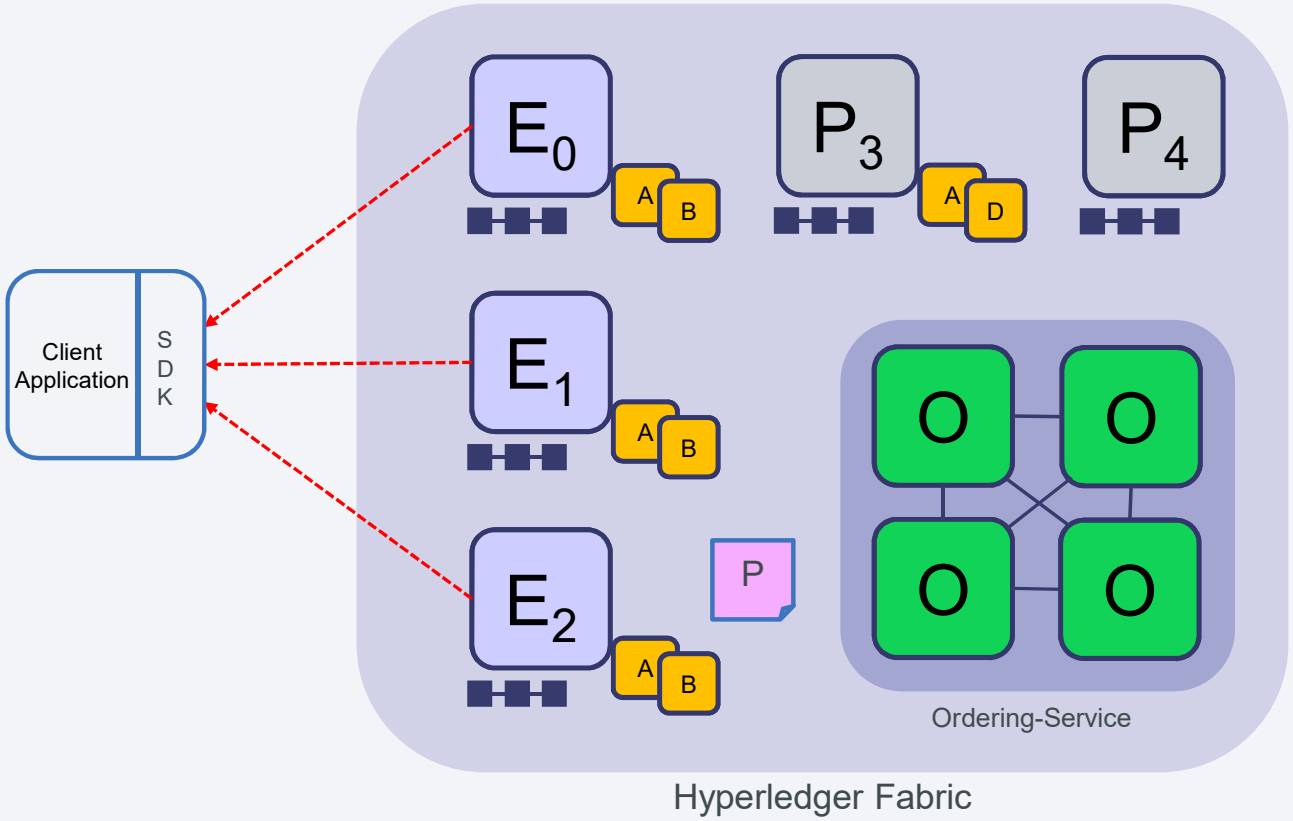
Each execution will capture the set of **R**ead and **W**ritten data, called **RW sets,** which will now flow in the fabric.

Transactions can be signed & encrypted

Key:



Sample transaction: Step 3/7 – Proposal Response



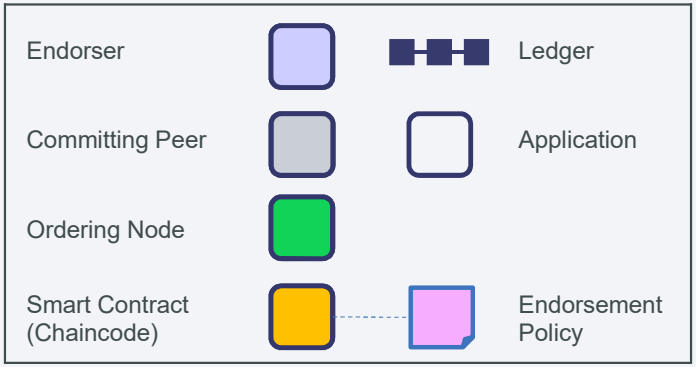
Application receives responses

RW sets are asynchronously returned to application

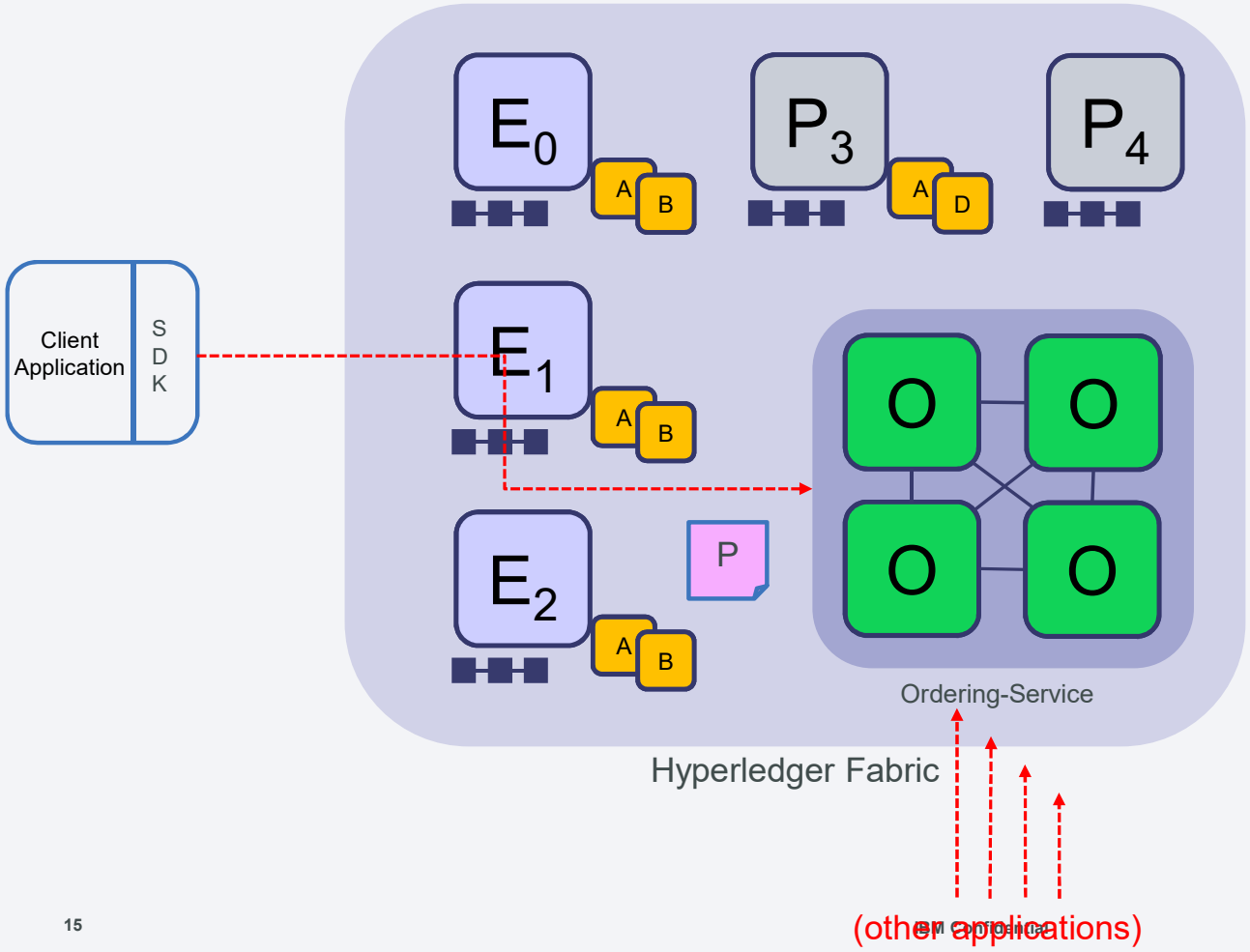
The RW sets are signed by each endorser, and also includes each record version number

(This information will be checked much later in the consensus process)

Key:



Sample transaction: Step 4/7 – Order Transaction

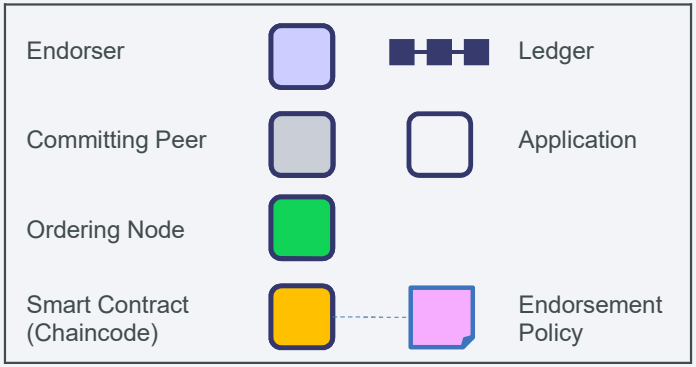


Application submits responses for ordering

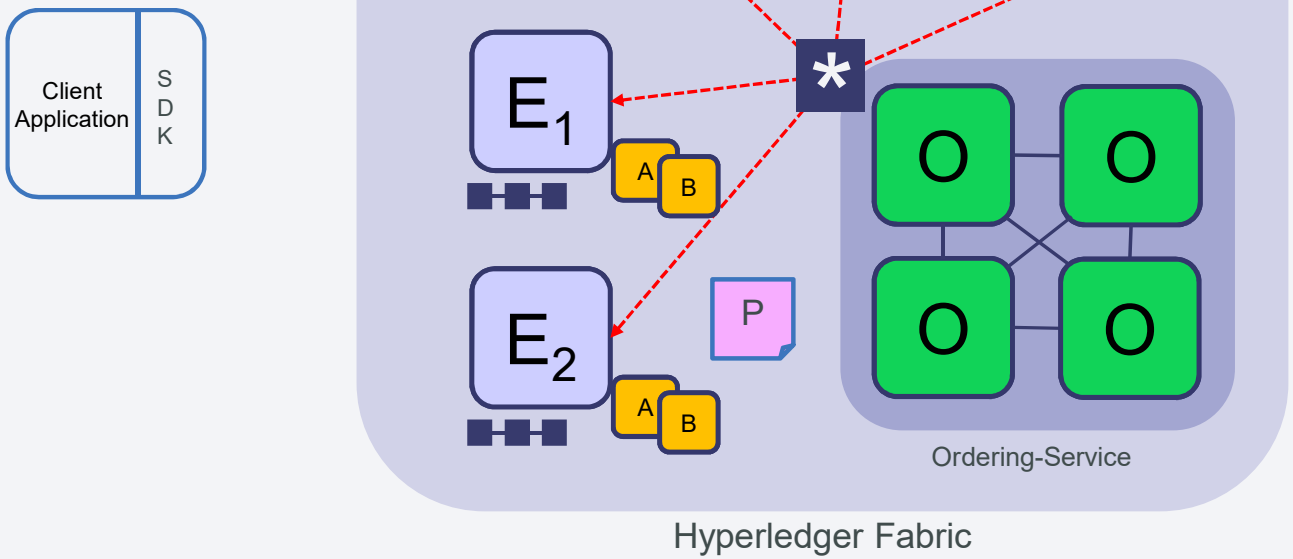
Application submits responses as a **transaction** to be ordered.

Ordering happens across the fabric in parallel with transactions submitted by other applications

Key:



Sample transaction: Step 5/7 – Deliver Transaction



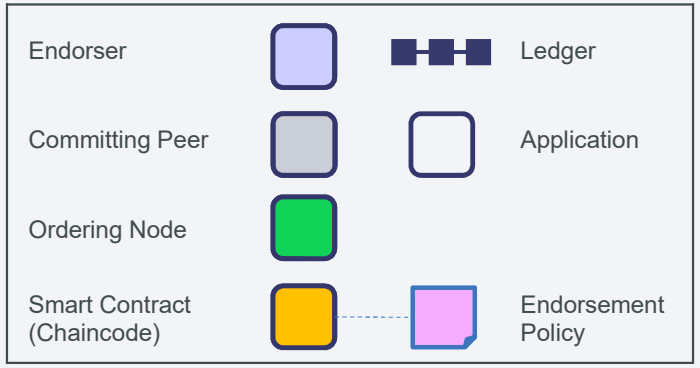
Orderer delivers to all committing peers

Ordering service collects transactions into proposed blocks for distribution to committing peers. Peers can deliver to other peers in a hierarchy (not shown)

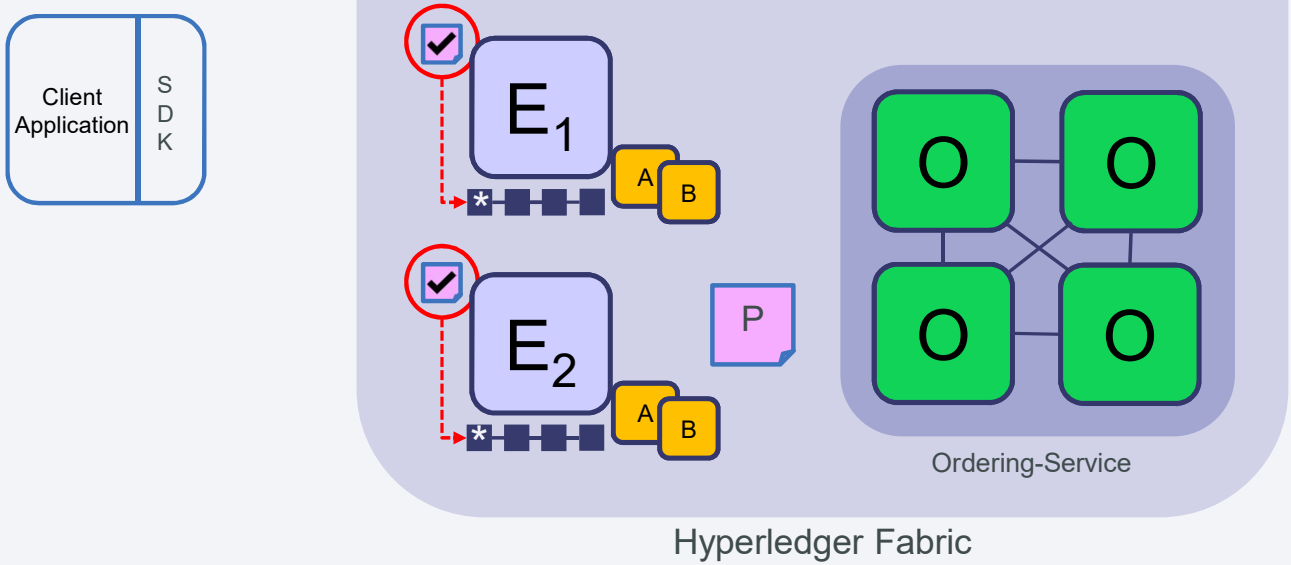
Different ordering algorithms available:

- SOLO (Single node, development)
- Kafka (Crash fault tolerance)

Key:



Sample transaction: Step 6/7 – Validate Transaction



Committing peers validate transactions

Every committing peer validates against the endorsement policy. Also check RW sets are still valid for current world state

Validated transactions are applied to the world state and retained on the ledger

Invalid transactions are also retained on the ledger but do not update world state

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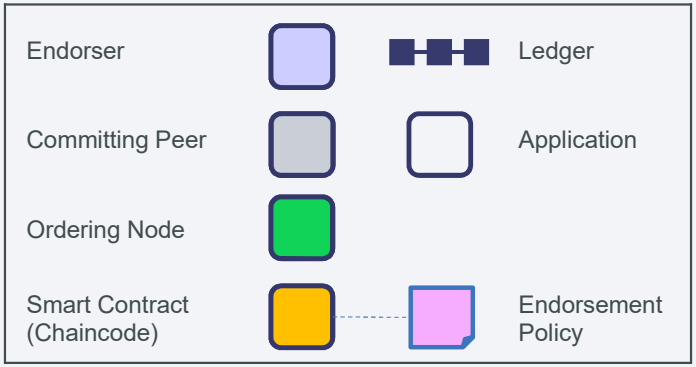
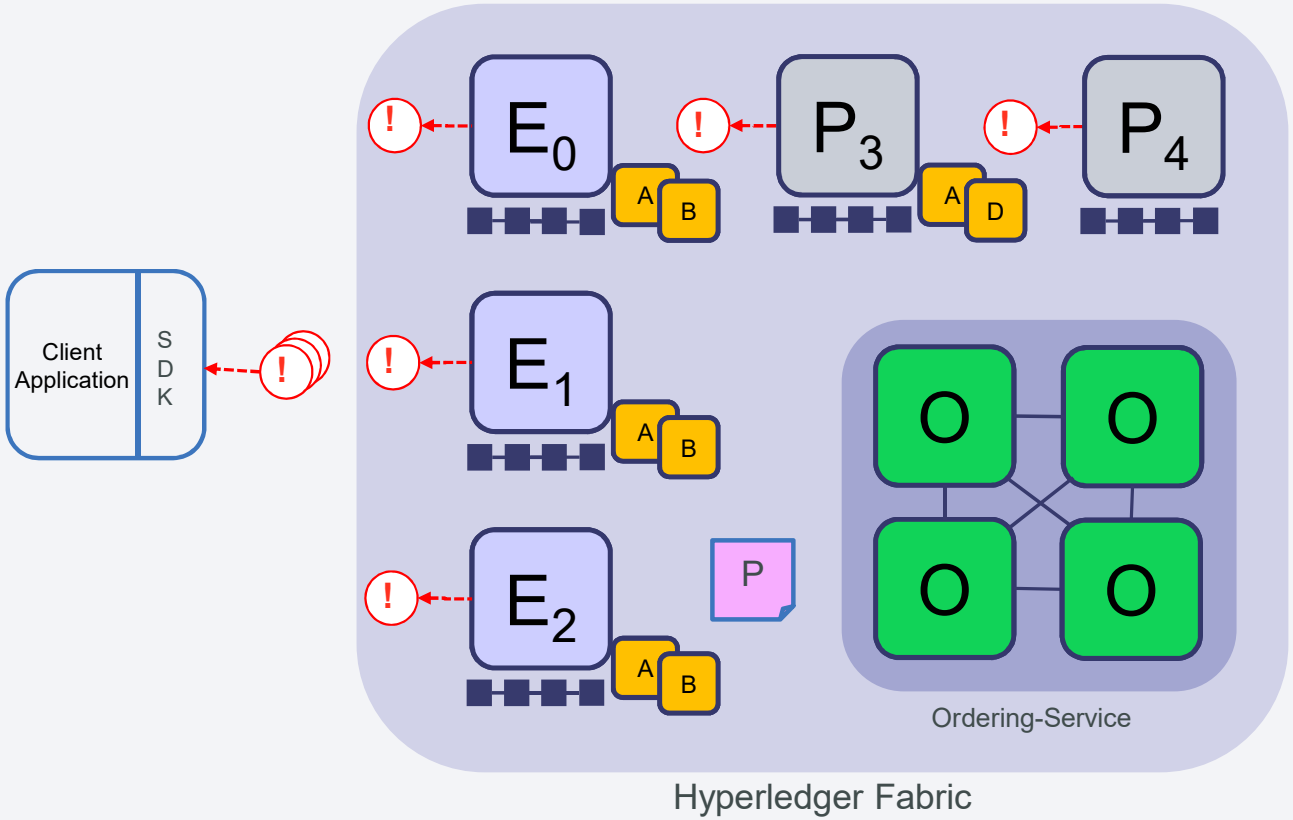


Sample transaction: Step 7/7 – Notify Transaction

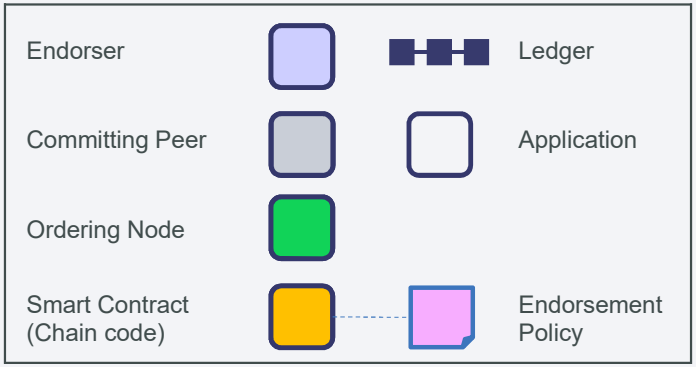


Committing peers notify applications

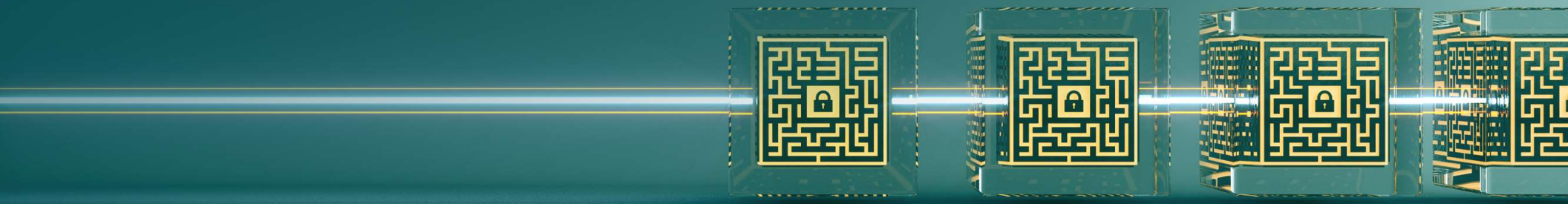
Applications can register to be notified when transactions succeed or fail, and when blocks are added to the ledger

Applications will be notified by each peer to which they are connected

Key:

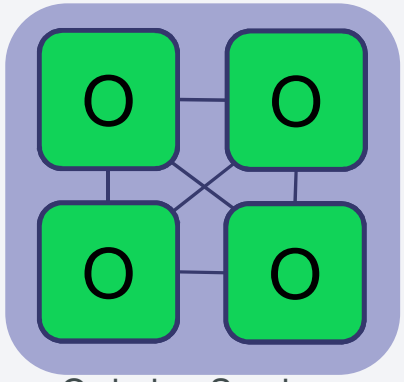


Channels and Ordering Service



Ordering Service

The ordering service packages transactions into blocks to be delivered to peers. Communication with the service is via channels.

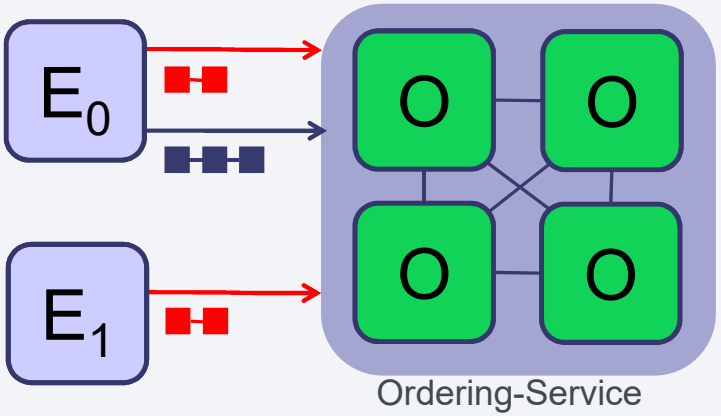


Ordering-Service

Different configuration options for the ordering service include:

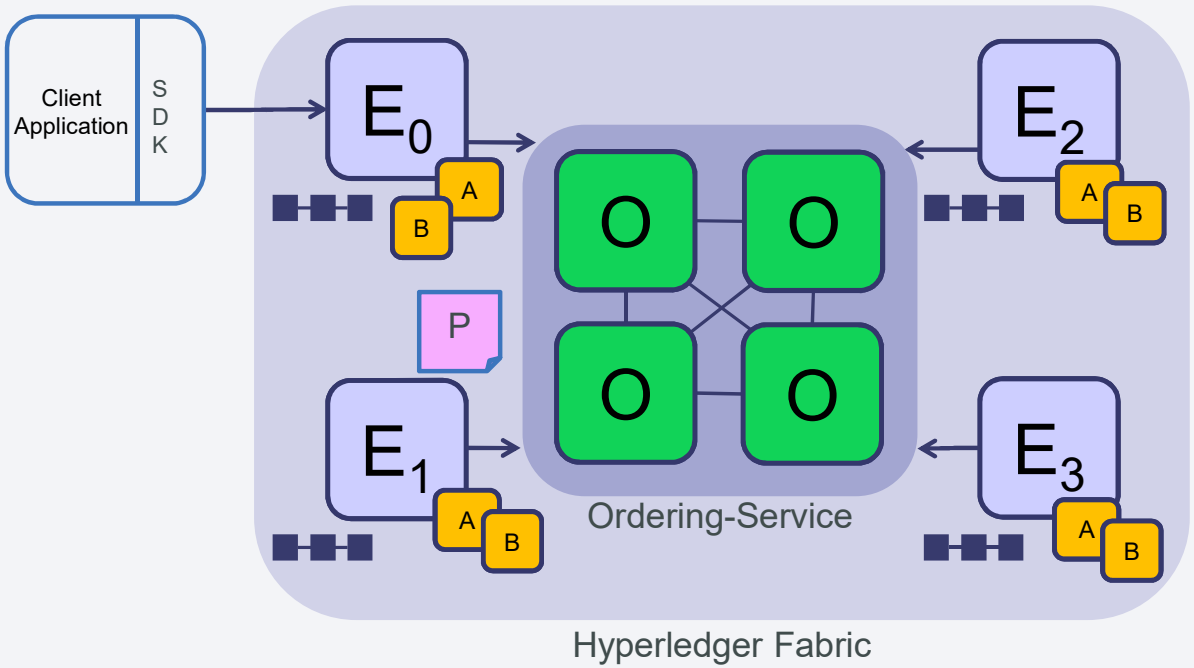
- **SOLO**
  - Single node for development
- **Kafka :** Crash fault tolerant consensus
  - 3 nodes minimum
  - Odd number of nodes recommended

Separate channels isolate transactions on different ledgers

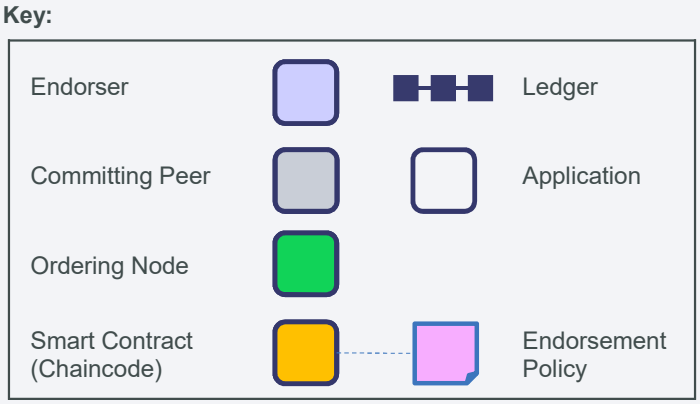


- Chaincode is installed on peers that need to access the worldstate
- Chaincode is instantiated on specific channels for specific peers
- Ledgers exist in the scope of a channel
  - Ledgers can be shared across an entire network of peers
  - Ledgers can be included only on a specific set of participants
- Peers can participate in multiple channels
- Concurrent execution for performance and scalability

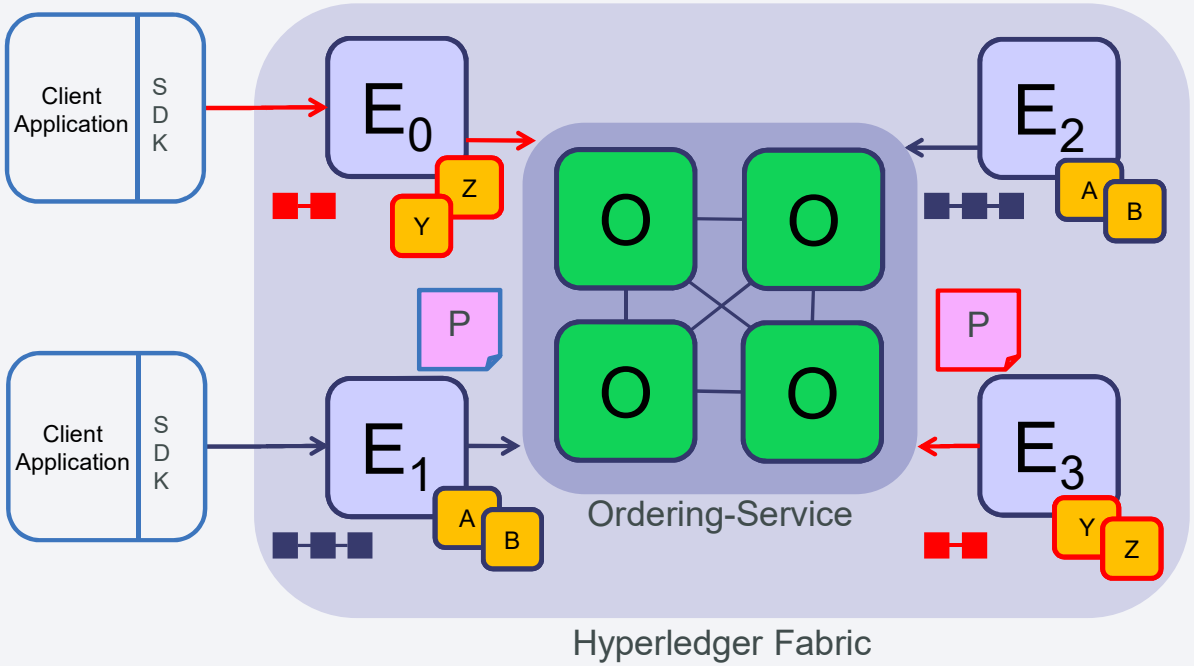
Single Channel Network



- Similar to v0.6 PBFT model
- All peers connect to the same system channel (blue).
- All peers have the same chaincode and maintain the same ledger
- Endorsement by peers E_0, E_1, E_2 and E_3



Multi Channel Network



- Peers E_0 and E_3 connect to the red channel for chaincodes **Y** and **Z**
- Peers E_1 and E_2 connect to the blue channel for chaincodes **A** and **B**

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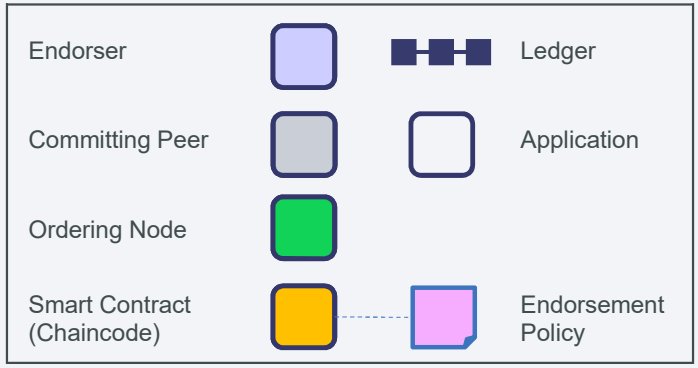
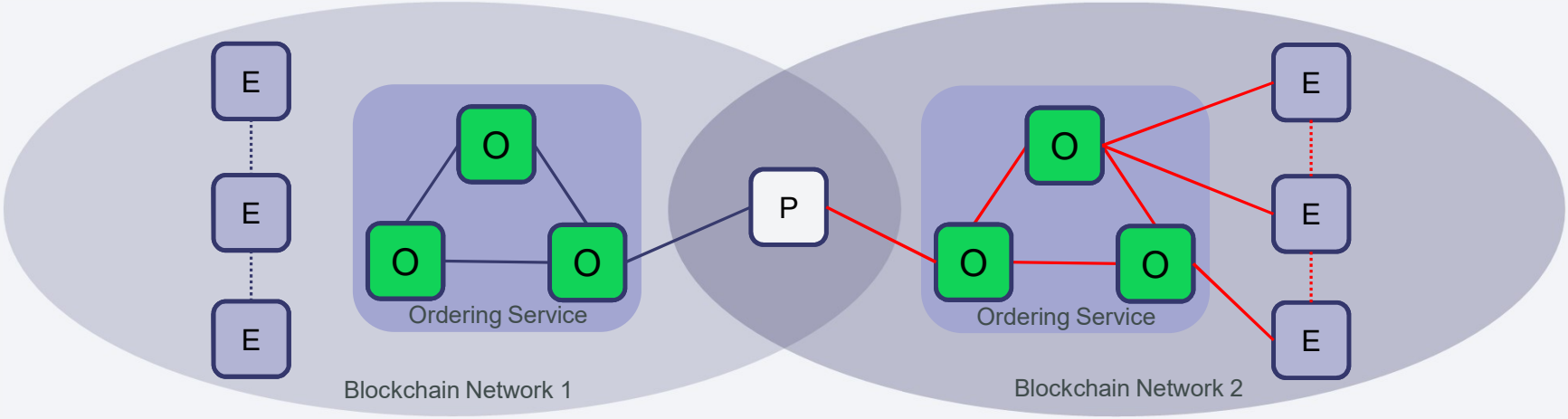


Future 2 network topology



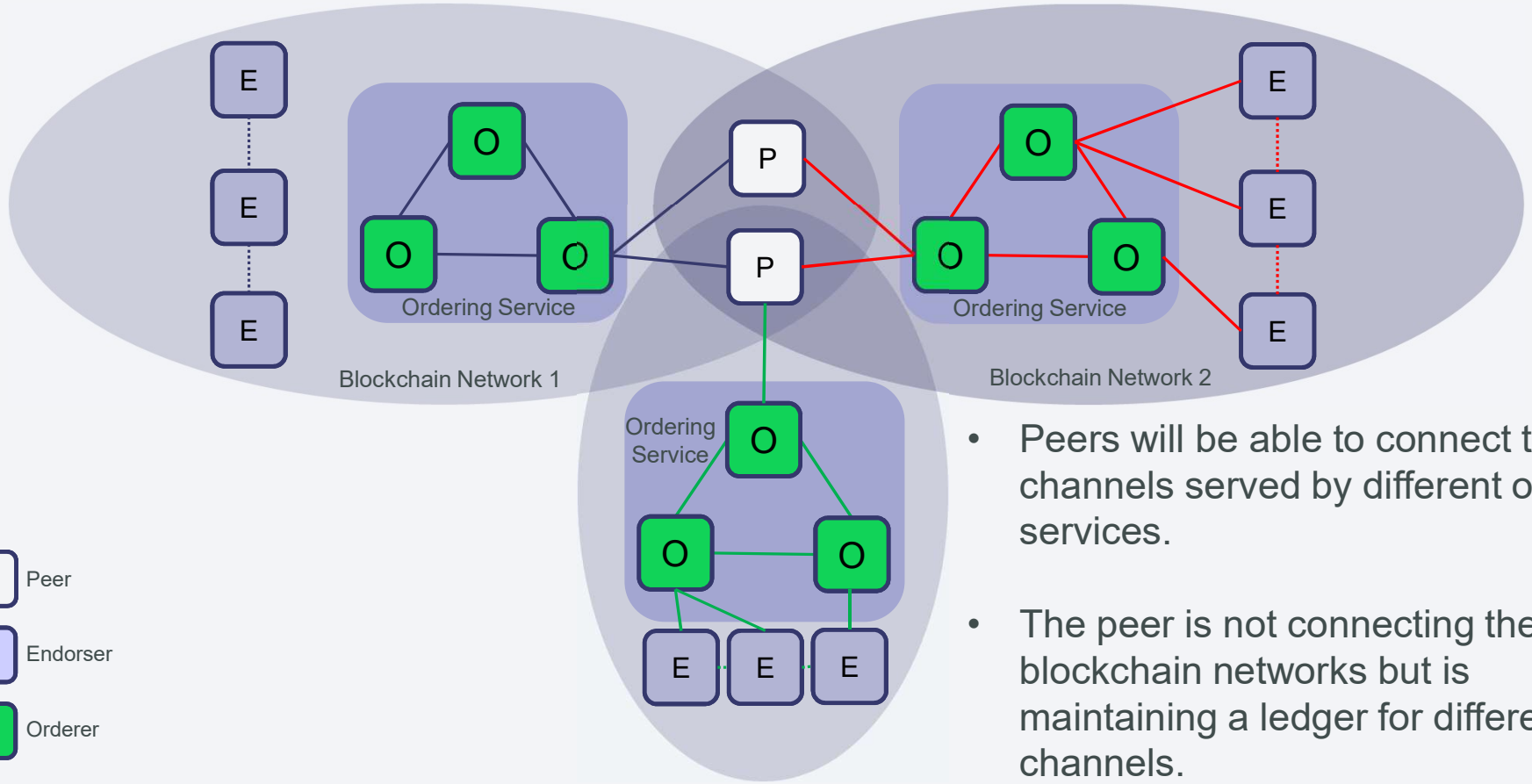
Peer

Endorser

Orderer

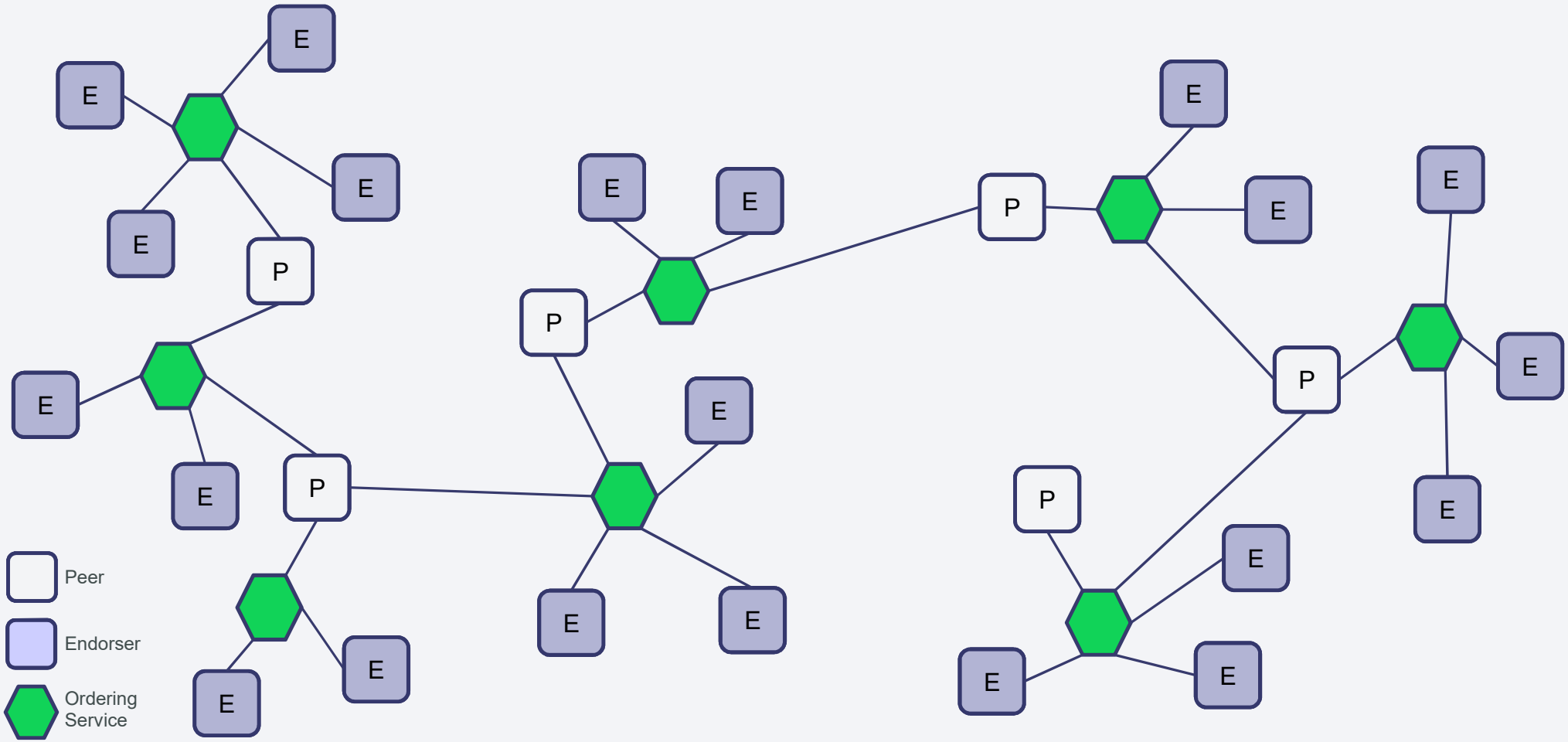
- Peers will be able to connect to channels served by different ordering services.
- The peer is not connecting the three Blockchain networks but is maintaining a ledger for different channels.

Future 3 network topology

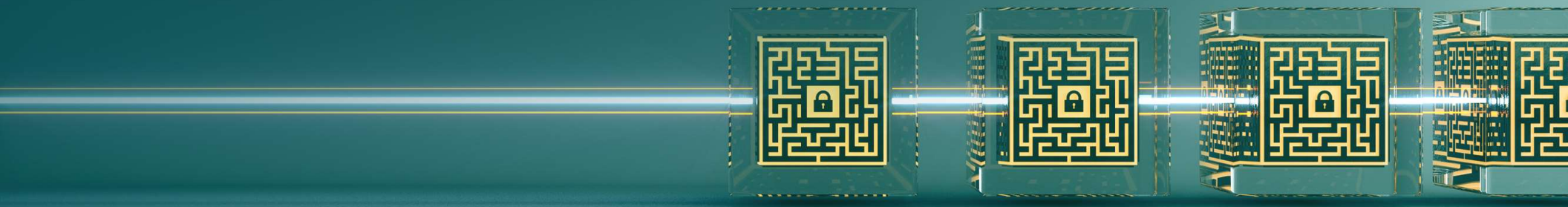


- Peers will be able to connect to channels served by different ordering services.
- The peer is not connecting the three blockchain networks but is maintaining a ledger for different channels.

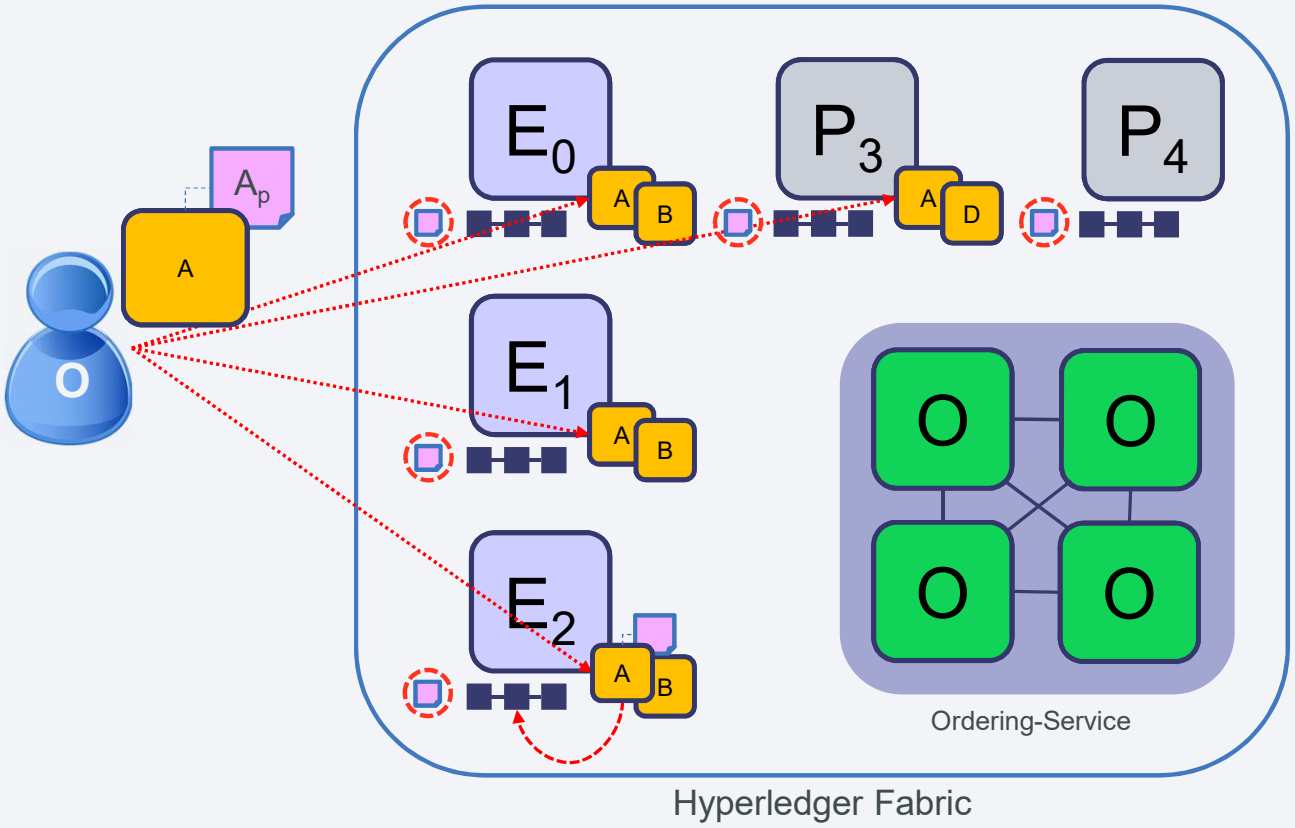
Future Network of Networks



Network Setup



Installing and instantiating smart contract Chaincode



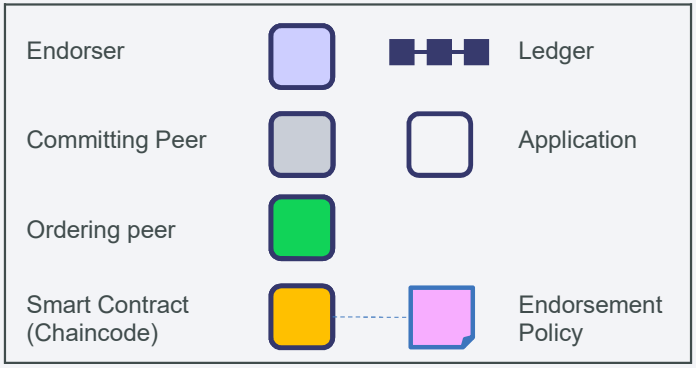
Operator installs then instantiates

Operator **installs** smart contracts with endorsement policies to appropriate peers: **E_0**, **E_1**, **E_2**, **P_3**, and not **P_4**

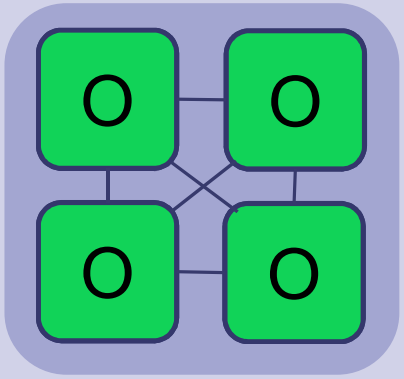
Operator **instantiates** smart contract on given channel. One-time initialization

Policy subsequently available to all peers on channel, e.g. including **P_4**

Key:



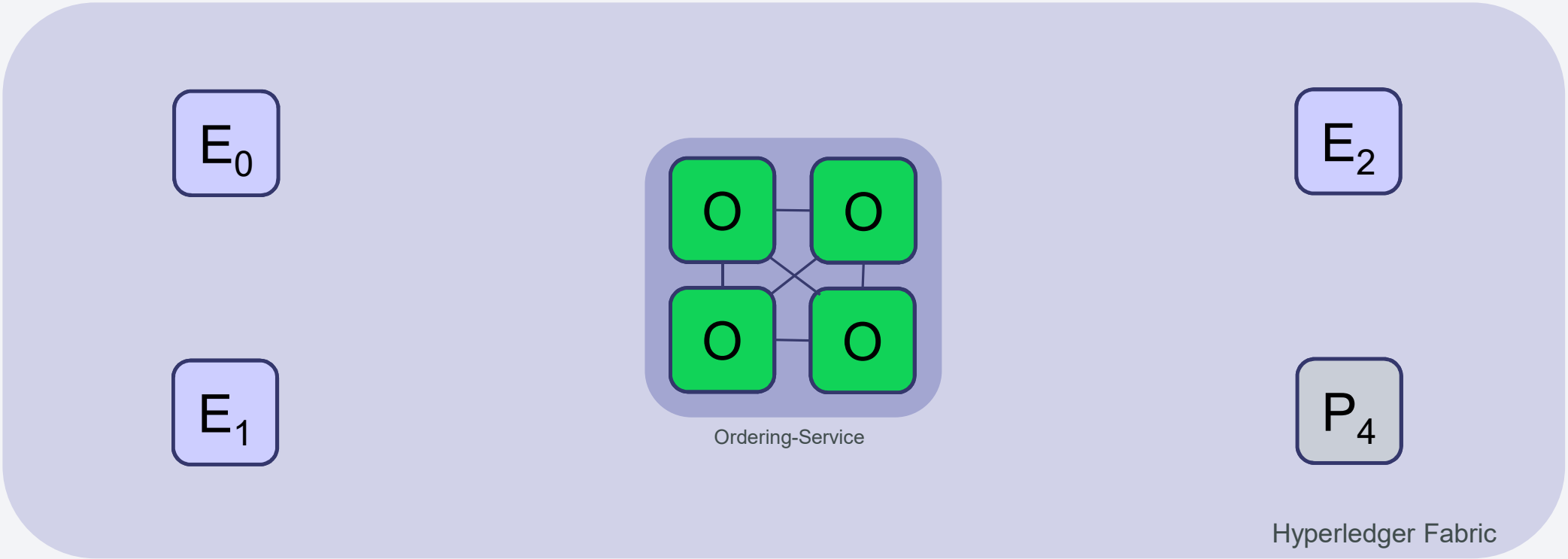
Bootstrapping the Network (1/6) – Configure & start Ordering Service



Hyperledger Fabric

- An Ordering Service is **configured** and started for other network peers to use
  `$ docker-compose [-f orderer.yml] ...`

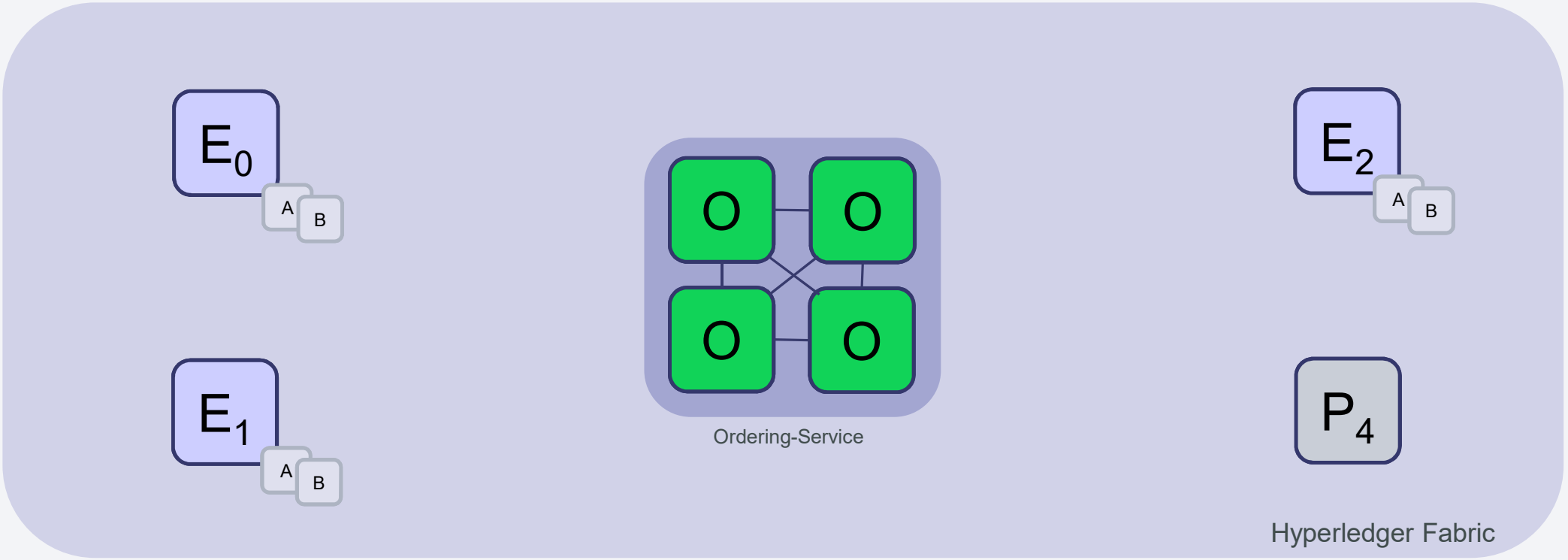
Bootstrapping the Network (2/6) – Configure and Start Peer Nodes



- A peer is configured and **started** for each Endorser or Committer in the network

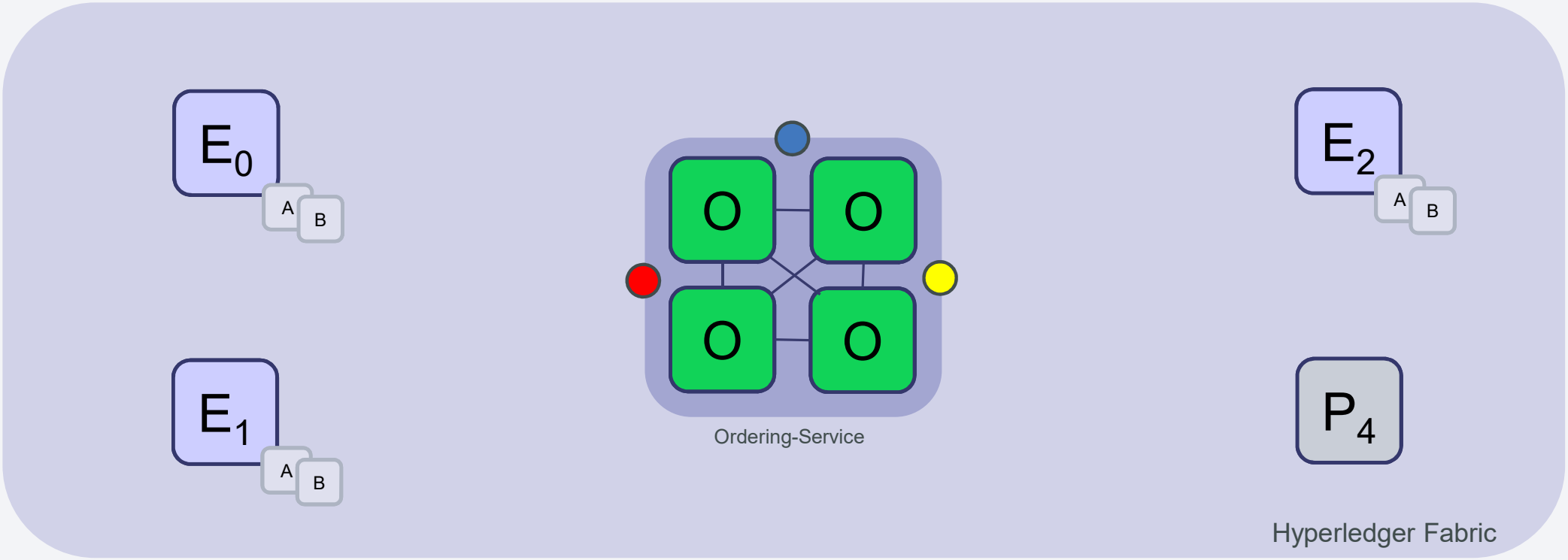
```
$ peer node start ...
```

Bootstrapping the Network (3/6) – Install Chaincode



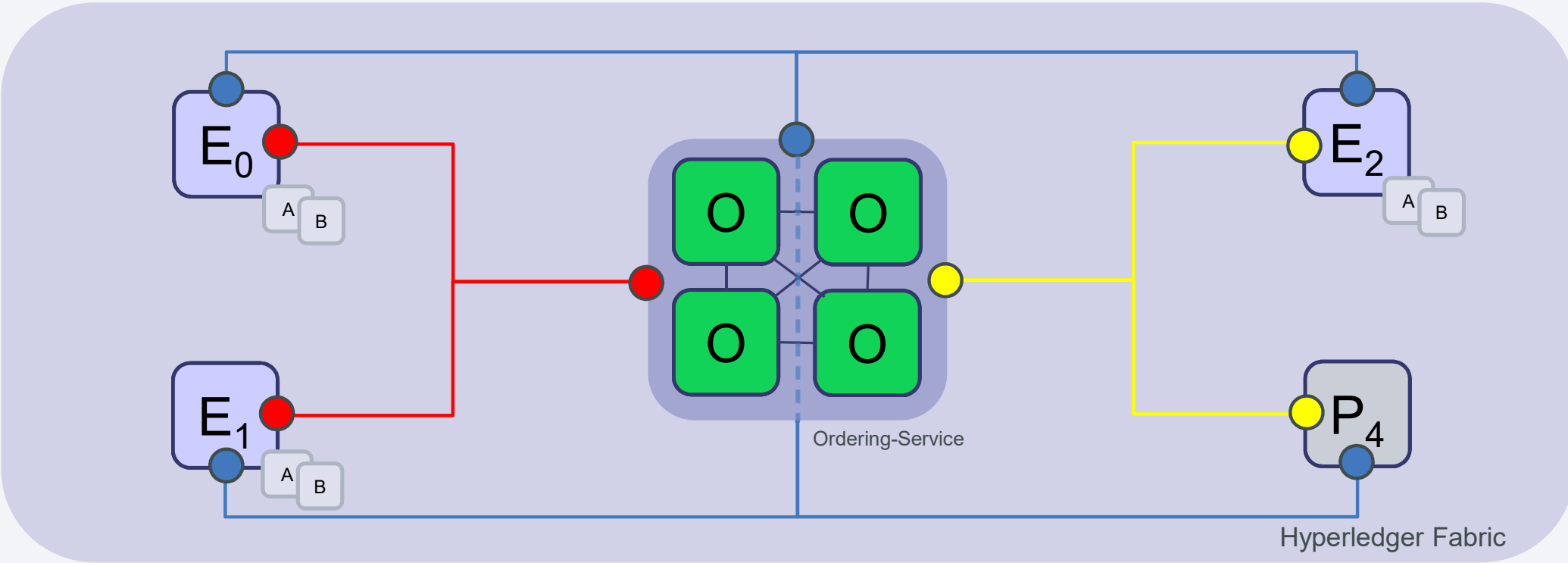
- Chaincode is **installed** onto each Endorsing Peer that needs to execute it
  `$ peer chaincode install ...`

Bootstrapping the Network (4/6) – Create Channels



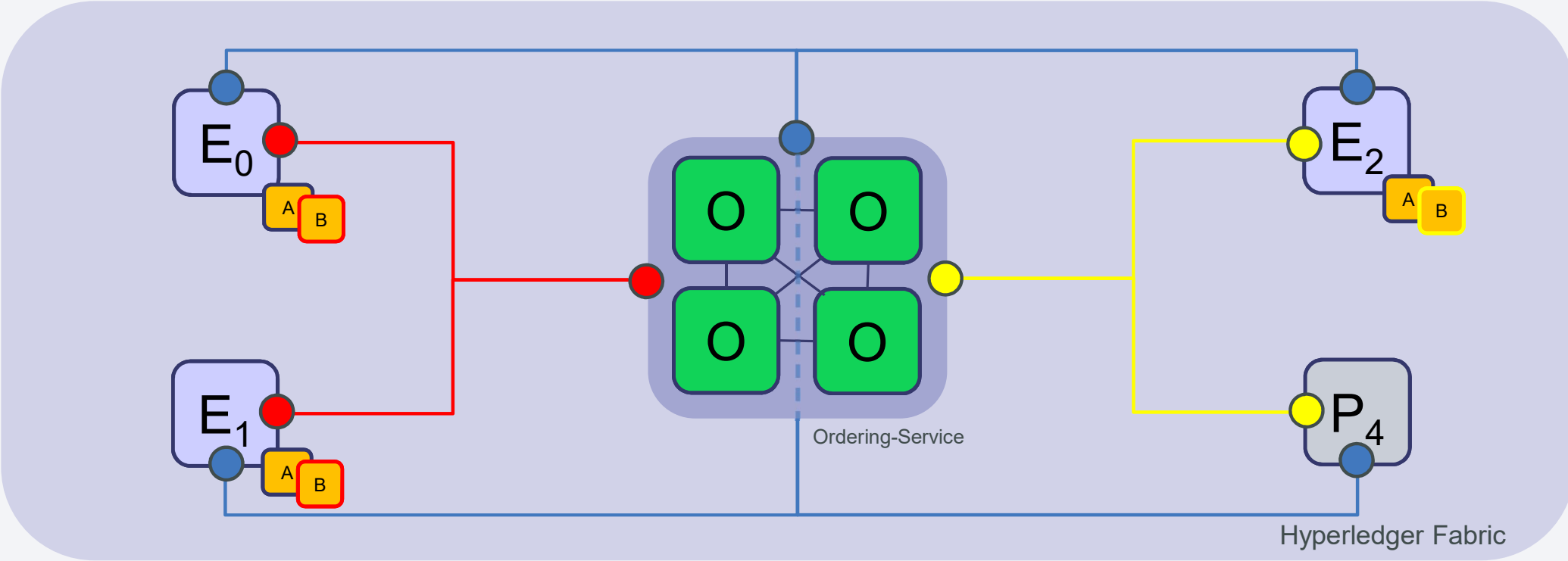
- Channels are **created** on the ordering service
  `$ peer channel create -o [orderer] ...`

Bootstrapping the Network (5/6) – Join Channels



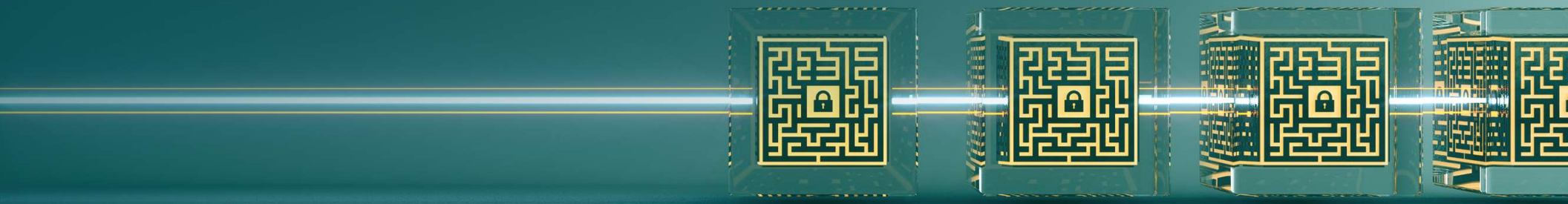
- Peers that are permissioned can then **join** the channels they want to transact on
  `$ peer channel join ...`

Bootstrapping the Network (6/6) – Instantiate Chaincode



- Peers finally **instantiate** the Chaincode on the channels they want to transact on
  `$ peer channel instantiate ... -P 'policy'`
- Once instantiated a Chaincode is live and can process transaction requests
- Endorsement Policy is specified at instantiation time

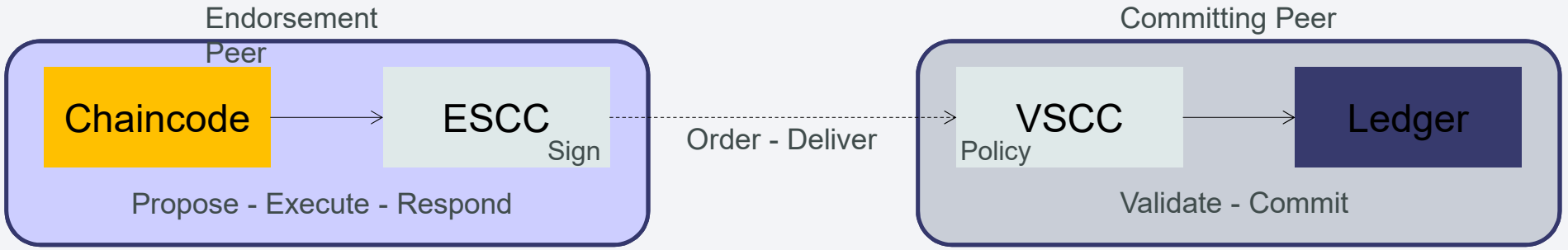
Endorsement Policies



Endorsement Policies

An endorsement policy describes the conditions by which a transaction can be endorsed. A transaction can only be considered valid if it has been endorsed according to its policy.

- Each chaincode is associated with an Endorsement Policy
- Default implementation: Simple declarative language for the policy
- ESCC (Endorsement System ChainCode) signs the proposal response on the endorsing peer
- VSCC (Validation System ChainCode) validates the endorsements



Endorsement Policy Syntax

```
$ peer chaincode instantiate
-C mychannel
-n mycc
-v 1.0
-p chaincode_example02
-c '{"Args":["init","a", "100", "b","200"]}'
-P "AND('Org1MSP.member')“
```

This command instantiates the chaincode *mycc* on channel *mychannel* with the policy AND('Org1MSP.member')

Policy Syntax: **EXPR(E[, E…])**

Where **EXPR** is either **AND** or **OR** and **E** is either a principal or nested EXPR.

Principal Syntax: **MSP.ROLE**

Supported roles are: **member** and **admin**.

Where **MSP** is the MSP ID required, and **ROLE** is either “member” or “admin”.

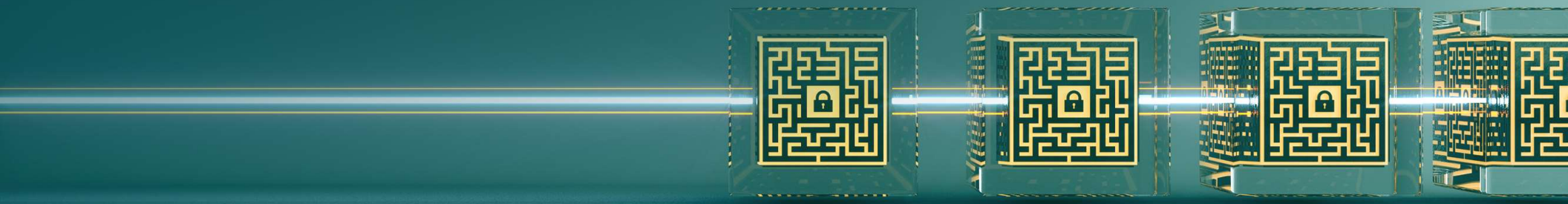
Endorsement Policy Examples

Examples of policies:

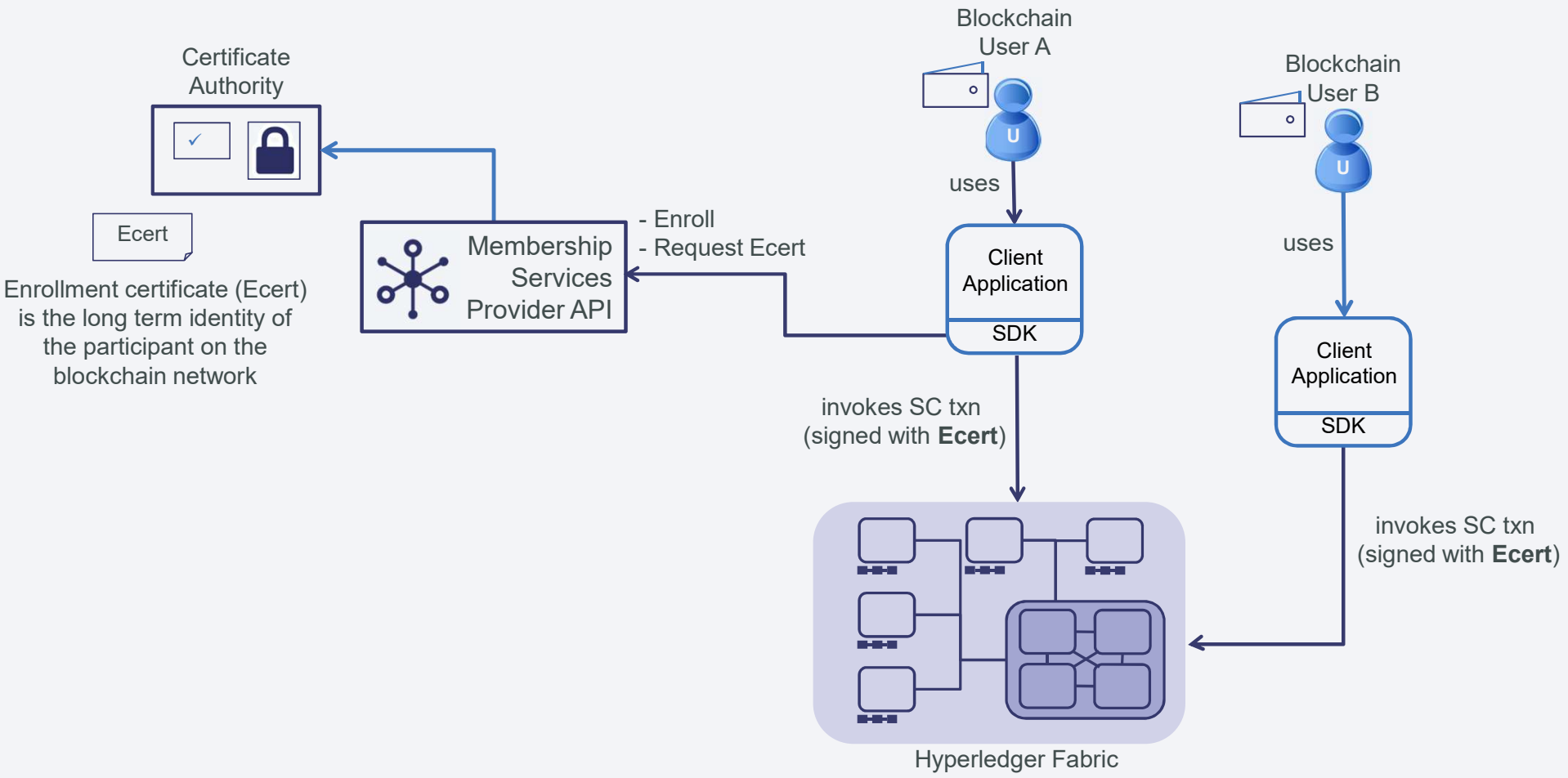
- Request 1 signature from all three principals
  - AND('Org1.member', 'Org2.member', 'Org3.member')
- Request 1 signature from either one of the two principals
  - OR('Org1.member', 'Org2.member')
- Request either one signature from a member of the Org1 MSP or (1 signature from a member of the Org2 MSP and 1 signature from a member of the Org3 MSP)
  - OR('Org1.member', AND('Org2.member', 'Org3.member'))

Permissioned Ledger Access

Transaction and identity privacy



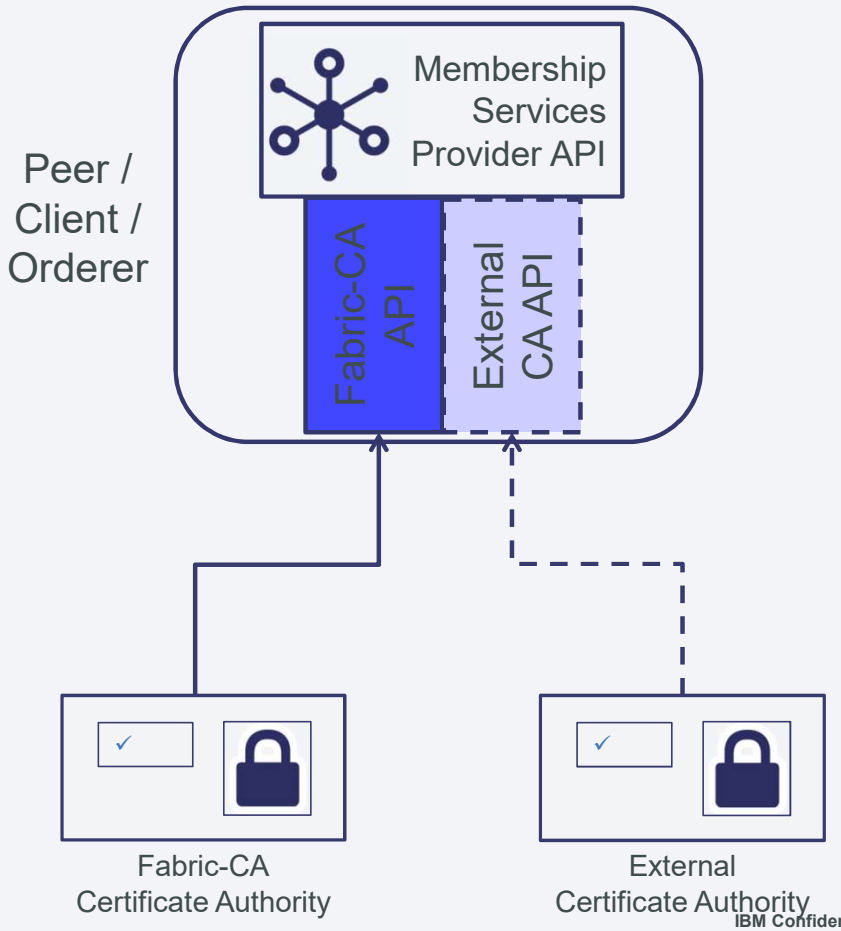
Membership Services Overview



Transaction and Identity Privacy

- Enrollment Certificates, Ecerts
  - Long term identity
  - Can be obtained offline, bring-your-own-identity
- Permissioned Interactions
  - Users sign with their Ecert
- Membership Services
  - Abstract layer to credential providers

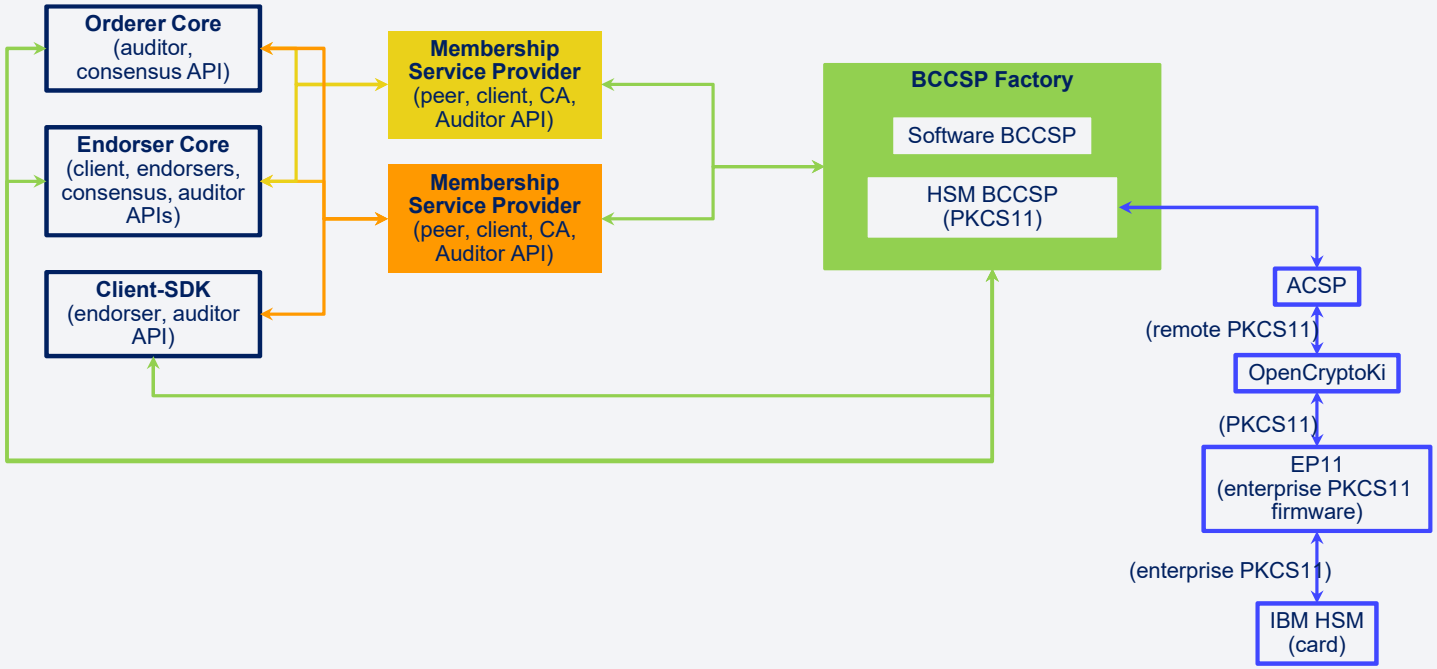
Membership Services Provider API



Membership Services Provider API

- Pluggable interface supporting a range of credential architectures
- Default implementation calls Fabric-CA.
- Governs identity for Peers and Users.
- Provides:
  - User authentication
  - User credential validation
  - Signature generation and verification
  - Optional credential issuance
- Additional offline enrollment options possible (eg File System).

MSP and BCCSP (Modularity and Decentralization)



Membership Services Provider (MSP)

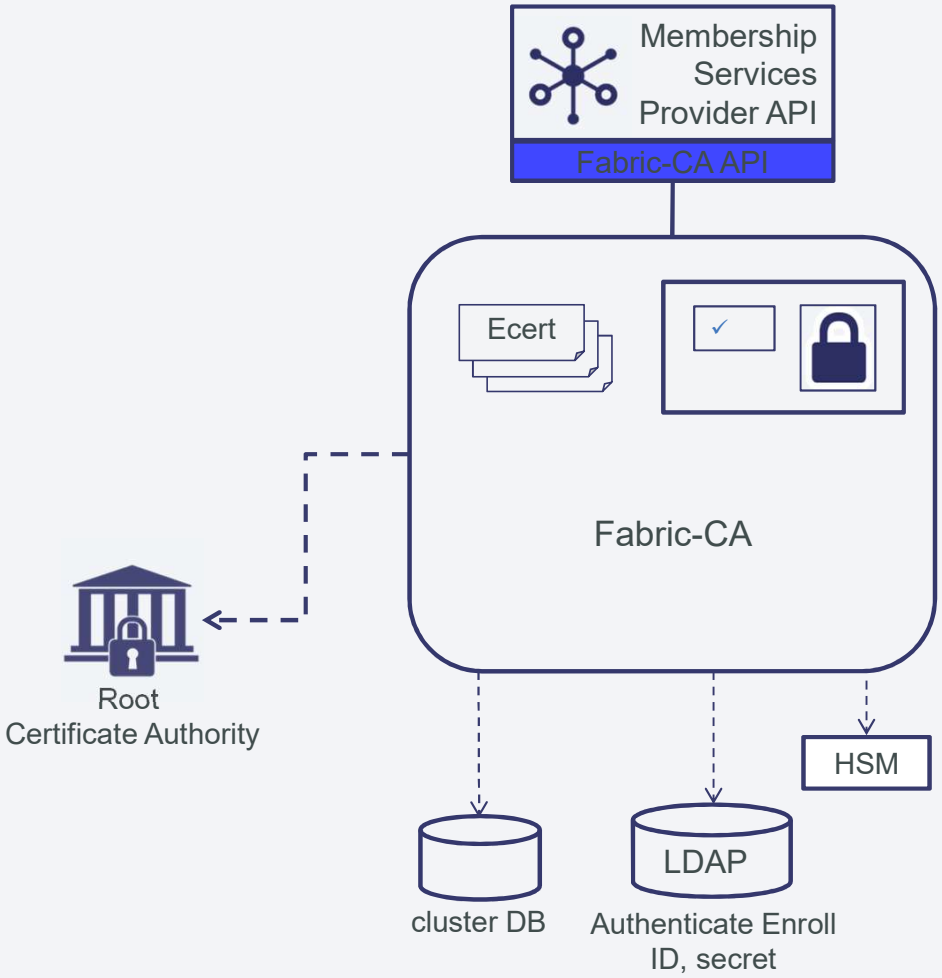
- An abstraction to represent a membership authority and its operations on issuing and management of Hyperledger Fabric membership credentials in a modular & pluggable way
  - Allows for the co-existence of a variety of credential management architectures
  - Allows for easy organizational separation in credential management/administration operations according to business rules at a technical level
  - Potential to smoothly easily support different standards and membership implementations
  - Easy and straight-forward interface that the core can understand

- Described by a generic interface to cover:
  - User credential validation
  - User (anonymous but traceable) authentication: signature generation and verification
  - User attribute authentication: attribute ownership proof generation, and verification
  - (optionally) User credential issue

Blockchain Crypto Service Provider (BCCSP)

- Pluggable implementation of cryptographic standards and algorithms.
- Pluggability
  - alternate implementations of crypto interface can be used within the Hyperledger Fabric code, **without modifying** the core
- Support for Multiple CSPs
  - Easy addition of more types of CSPs, e.g., of different HSM types
  - Enable the use of different CSP on different system components transparently
- International Standards Support
  - E.g., via a new/separate CSP
  - Interoperability among standards is not necessarily guaranteed

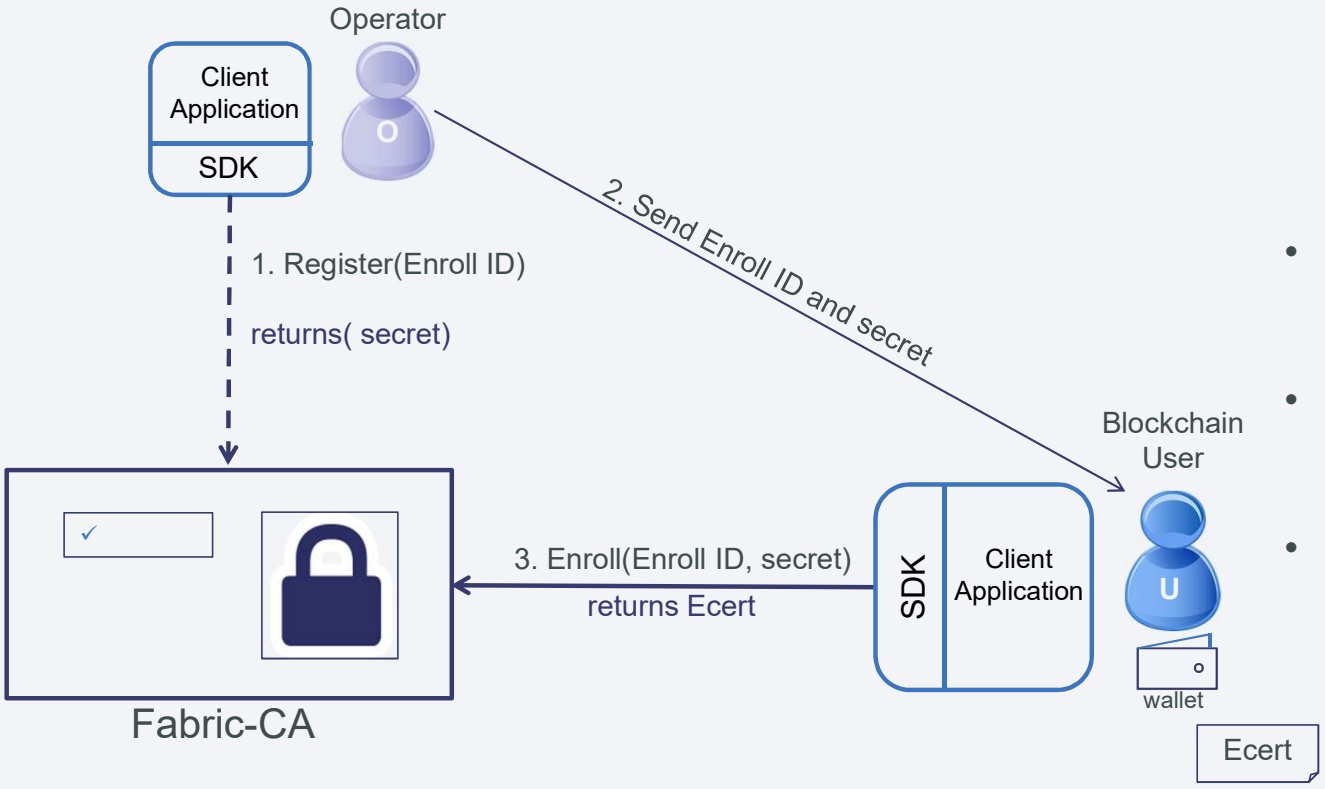
Fabric-CA Details



Fabric-CA

- Default implementation of the Membership Services Provider Interface.
- Issues Ecerts (long-term identity
- Supports clustering for HA characteristics
- Supports LDAP for user authentication
- Supports HSM

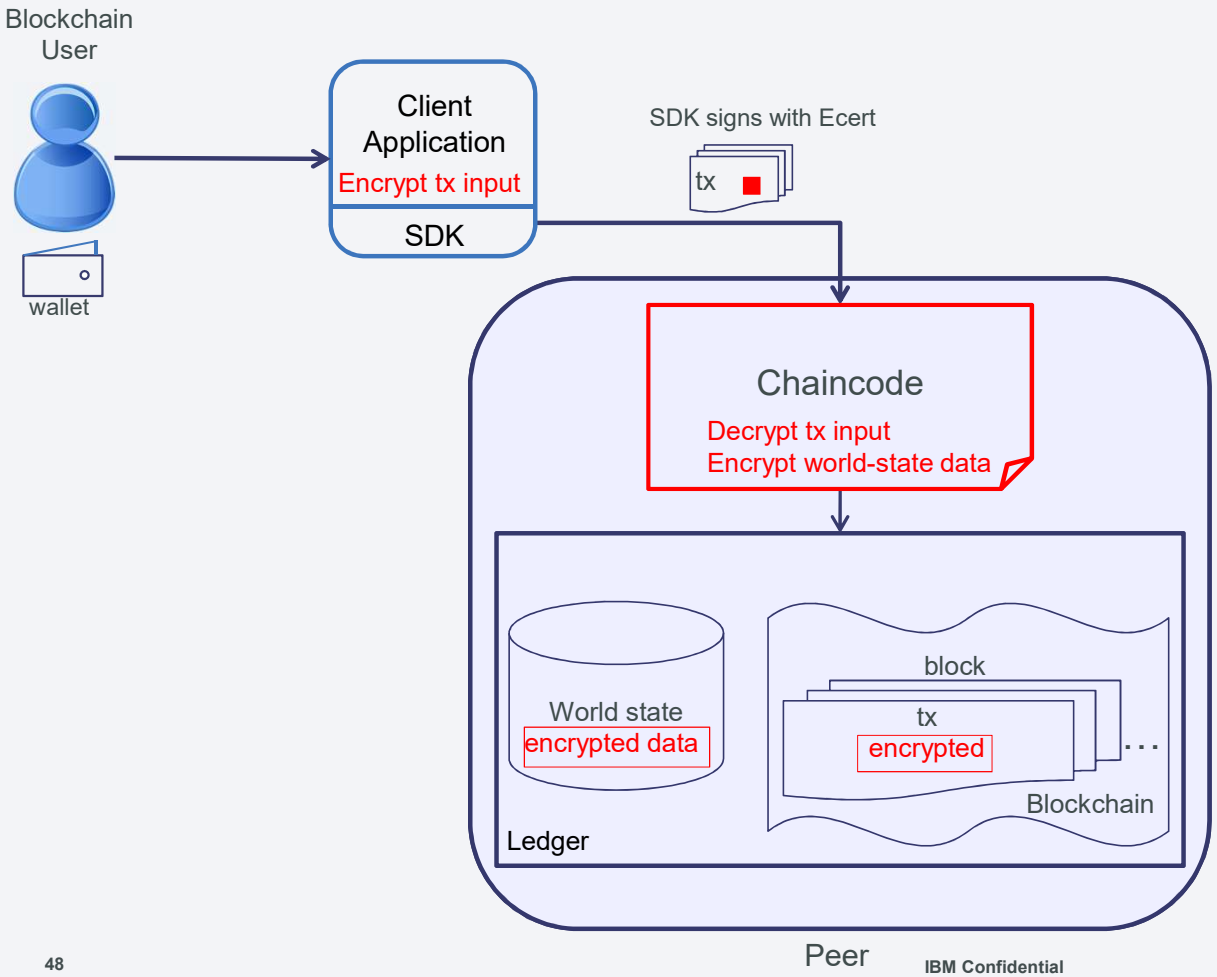
New User Registration and Enrollment



Registration and Enrollment

- Admin registers new user with Enroll ID
- User enrolls and receives credentials
- Additional offline registration and enrollment options available

Application Level Encryption



Data Encryption

Handled in the application domain.

Multiple options for encrypting:

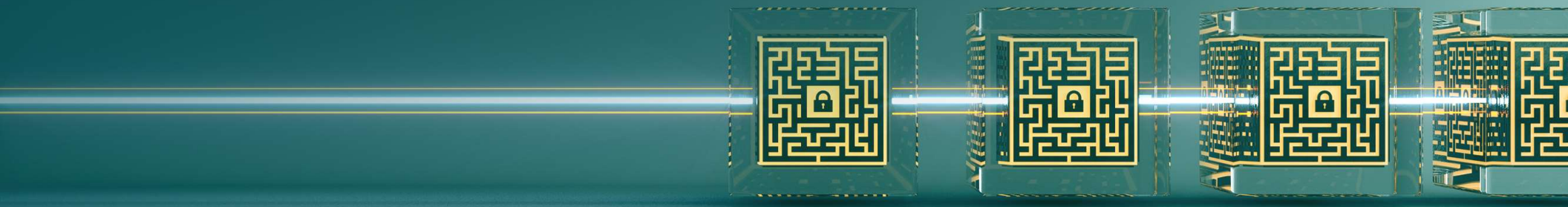
- Transaction Data
- Chaincode*
- World-State data

Chaincode optionally deployed with cryptographic material, or receive it in the transaction from the client application using the *transient* data field (not stored on the ledger).

*Encryption of application chaincode requires additional development of system chaincode.

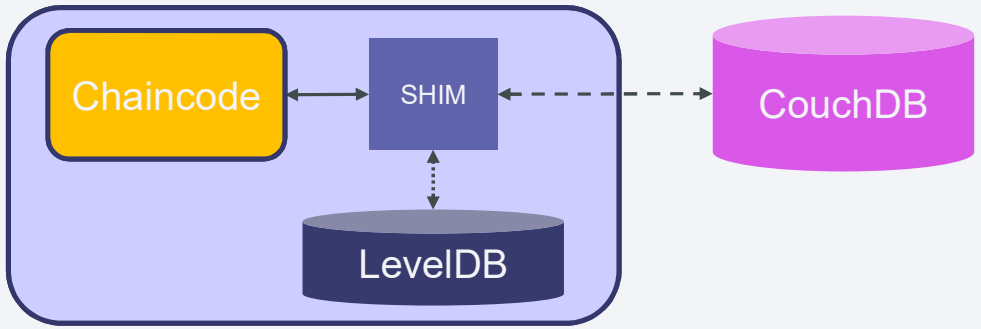
Pluggable world state

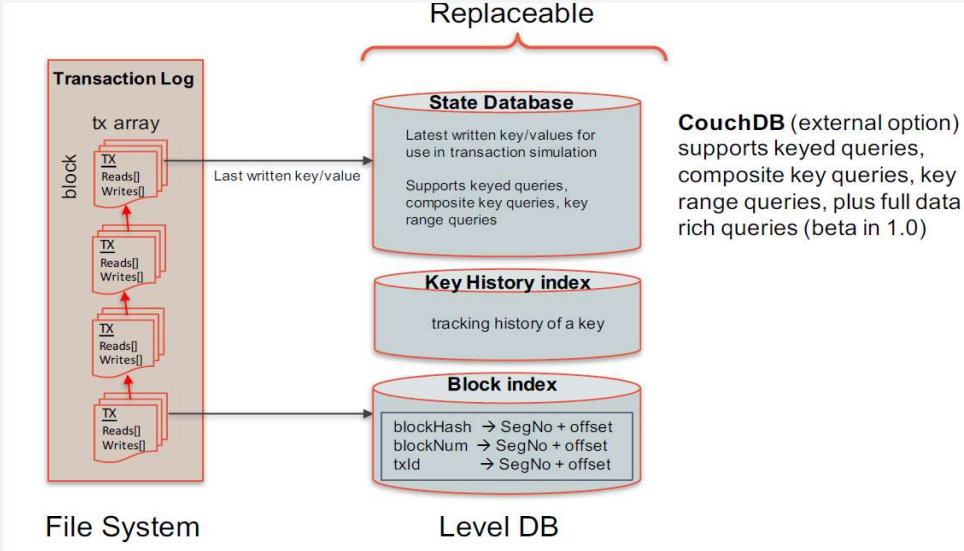
How is data managed on the ledger?



World State Database

- Pluggable worldstate database
- Default embedded key/value implementation using Level DB
  - Support for keyed queries, but cannot query on value
- Support for Apache CouchDB
  - Full query support on key and value (JSON documents)
  - Meets a large range of chaincode, auditing, and reporting requirements
  - Will support reporting and analytics via data replication to an analytics engine such as Spark (future)
  - Id/document data model compatible with existing chaincode key/value programming model





Not for all . . .

Why?

Blockchain is NOT

- ✗ Suited to high performance (millisecond) transactions
- ✗ For just one participant (no business network)
- ✗ A replicated database replacement
- ✗ A messaging solution
- ✗ A transaction processing replacement
- ✗ Suited for low value, high volume transactions

Potential Use Cases include . .

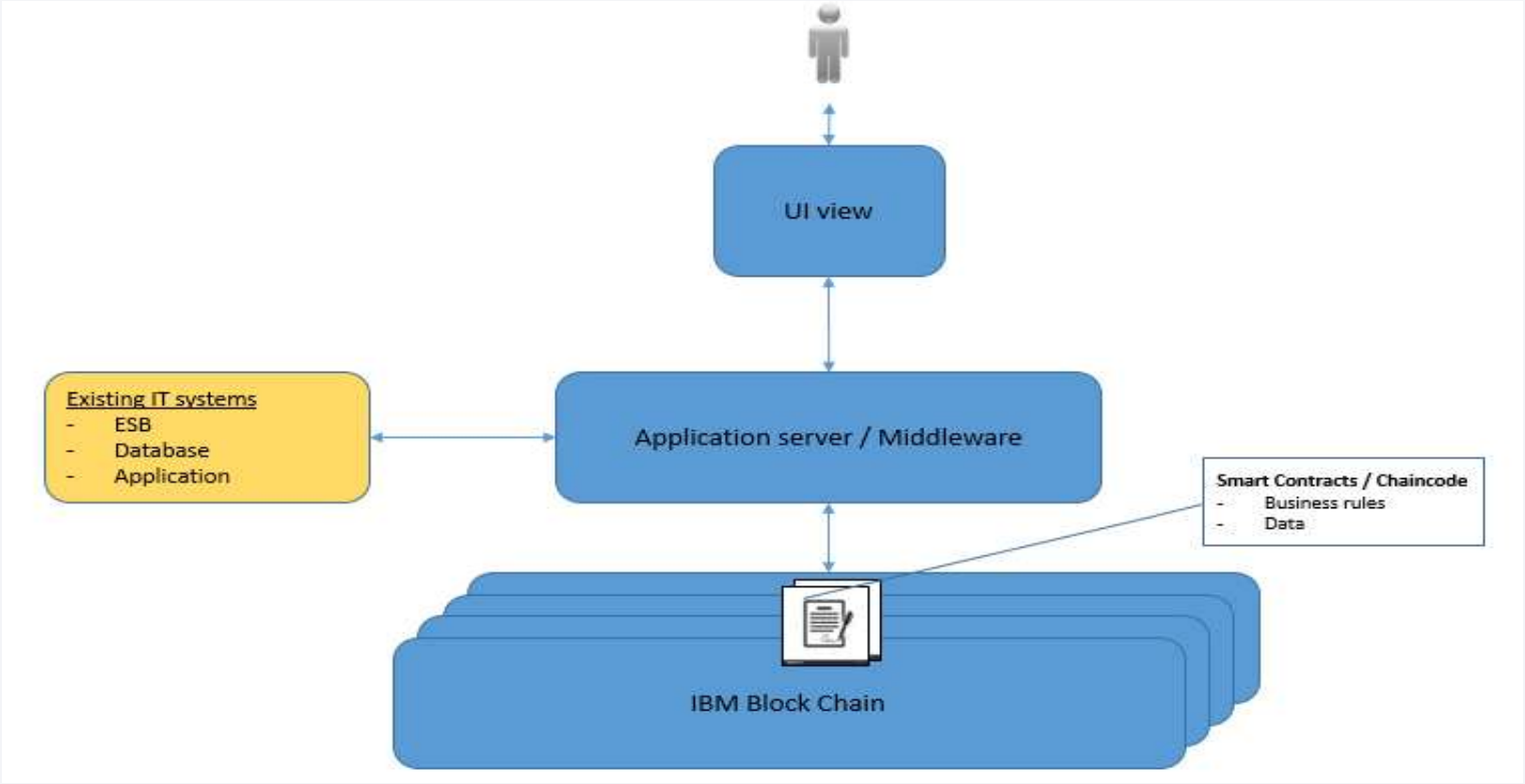
- **Securities**
  - Post-trade settlement
  - Derivative contracts
- **Trade Finance**
  - Bill of Lading
  - Cross-currency payment
- **Supply Chain**

- **Retail Banking**
  - Cross border remittances
  - Mortgage verification & contracts
- **Public Records**
  - Real estate records
  - Vehicle registrations
  - KYC
  - Voting System
  - e-Governance
- **Digital Property Management**
  - Music
  - Video
  - Books

Why?

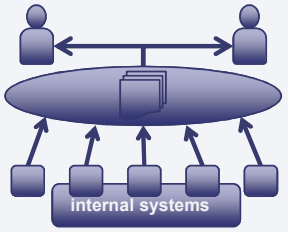
- Luxury and medical goods authentication
  - Diamonds verification
- Repository of identities for Refugees
- Lightweight financial systems
  - Peer-to-peer payments
- Internet of Things (IoT)
- Collaborative Transport
- Prediction platforms and online gaming

Architecture Overview – Typical Blockchain Application

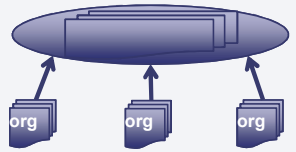


Customer Adoption: Categories and their Description

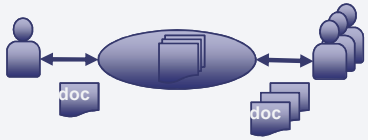
1. **INTERNAL LEDGER**
   – A ledger primarily for internal reporting, audit and compliance, serving as a low-barrier starting point for Blockchain within a large organization. Populated from internal systems to provide a consistent view of key business assets, where provenance, immutability and finality are more important than consensus. Can extend access to auditor and regulator to provide transparency.



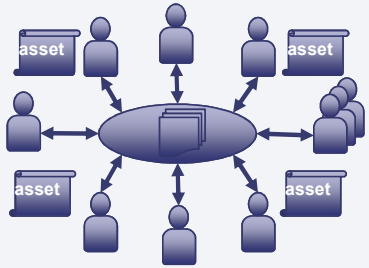
2. **CONSORTIUM SHARED LEDGER**
   – A ledger created by a relatively small set of industry participants to share reference data between themselves and consumers. Provides consistent real-time view of previously partitioned which was distributed in ad-hoc manner.



3. **INFORMATION HUB**
   – A ledger set up around a single organization (e.g. government department) to facilitate the sharing of information between many counterparties, for example, for corporate actions (voting, dividend notification). The exchanged assets do not have a significant financial value, but represent important assets which require provenance, immutability and finality.



4. **HIGH VALUE MARKET**
   – A full ledger for the transfer of high financial value assets between many counterparties in a market. Requires all enterprise features of Blockchain given value of assets transferred.



Blockchain Fabric Comparison Matrix

	Hyperledger	Ethereum	Ripple	Bitcoin
Description	General purpose Blockchain	General purpose Blockchain	Payments Blockchain	Payments Blockchain
Governance	Linux Foundation	Ethereum Developers	Ripple Labs	Bitcoin Developers
Currency	None	Ether	XRP	BTC
Mining Reward	N/A	Yes	No	Yes
State	Key-value database	Account data	None	Transaction data
Consensus Network	Pluggable : PBFT	Mining	Ripple Protocol	Mining
Network	Private or Public	Public or Private	Public	Public
Privacy	Open to Private	Open	Open	Open
Smart Contracts	Multiple programming languages	'Solidity' programming language	None	Possible, but not obvious

Blockchain Fabrics are rapidly evolving. Please check to ensure the most current information.

June 2017

Thank You!