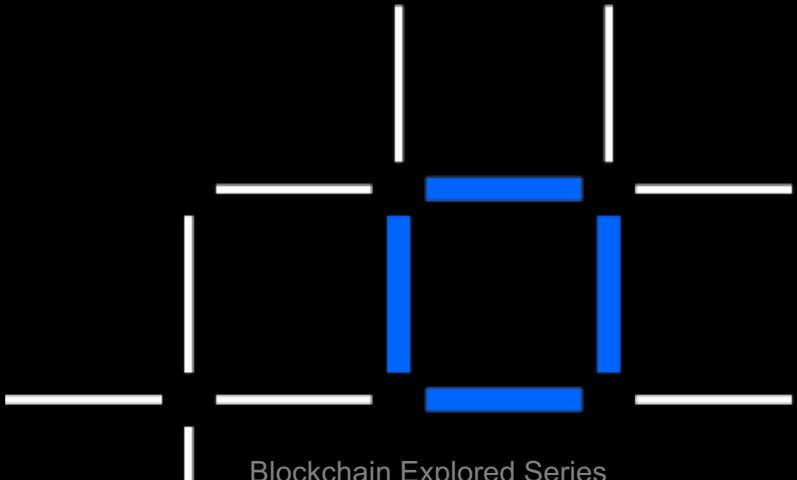


Fabric Explored

A Technical Deep-Dive on Hyperledger Fabric

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Washington Systems Center

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Blockchain Explored Series



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Architectures Explored



Fabric Explored



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What's New

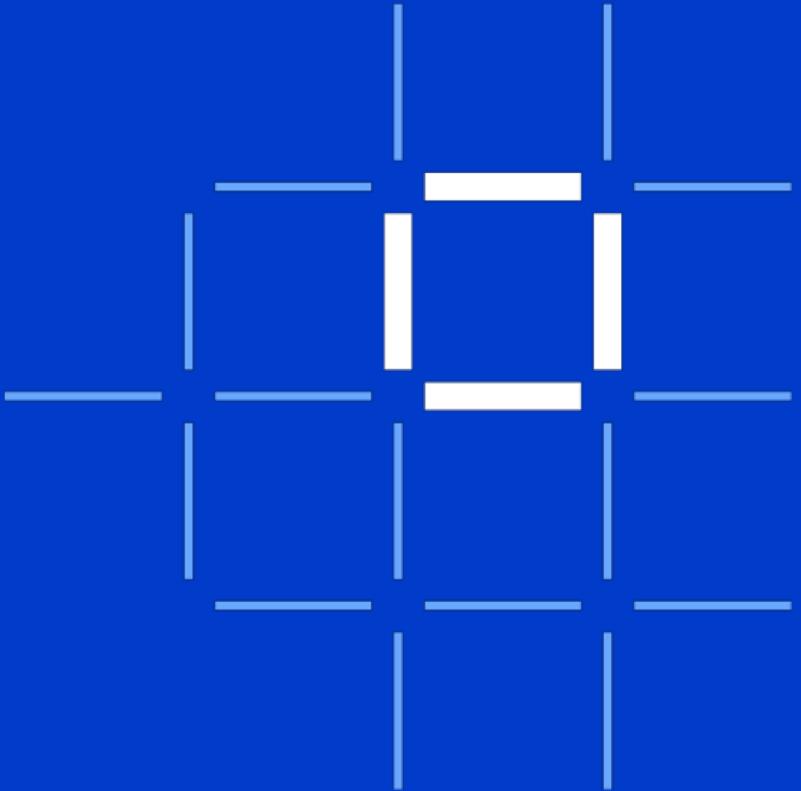
IBM



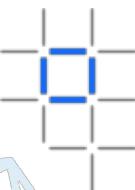
Project Status and
Roadmap



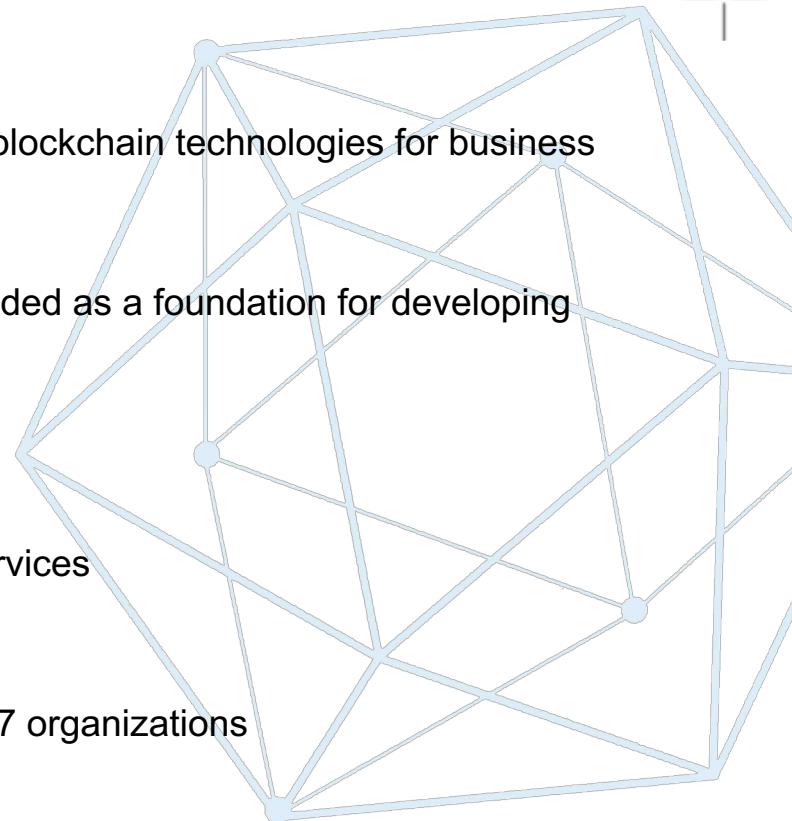
Technical Deep Dive



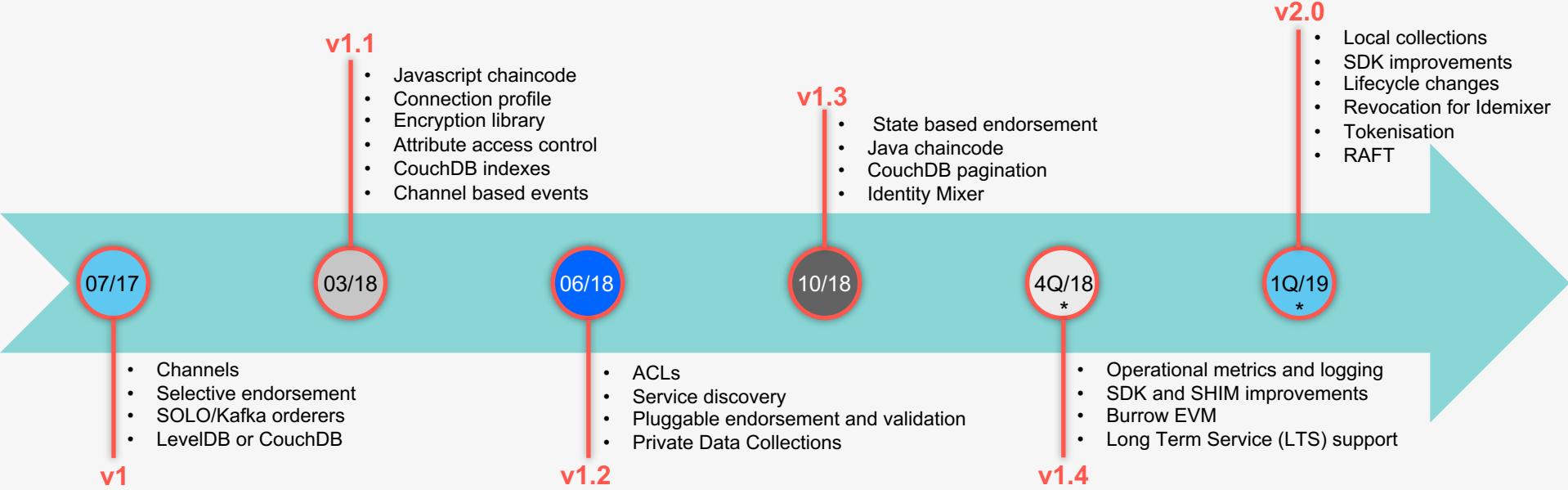
What is Hyperledger Fabric



- 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, replicated ledger
 - 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 of the contributors to Hyperledger Fabric



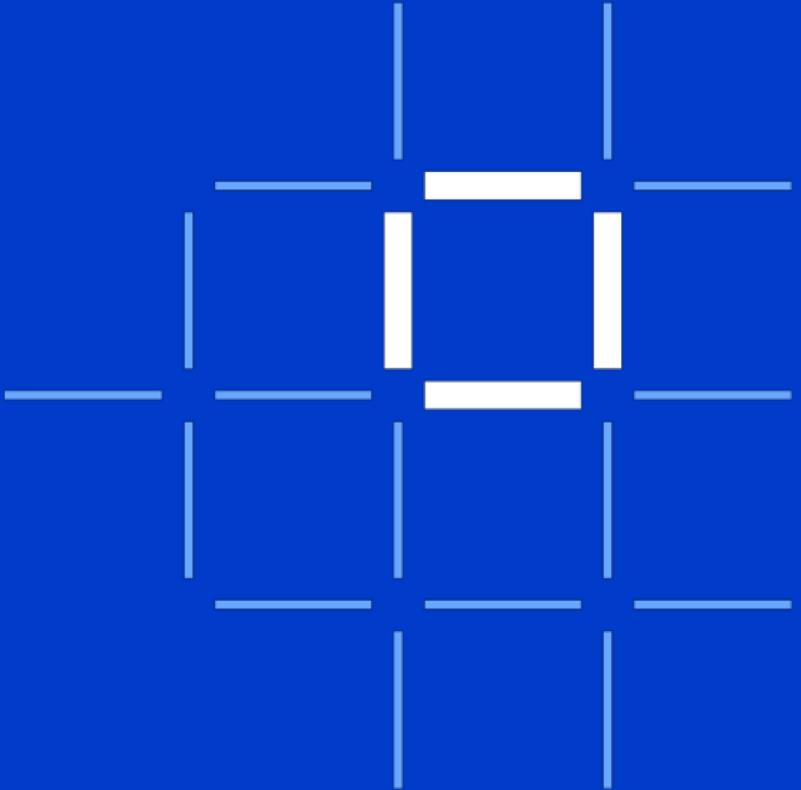
Roadmap



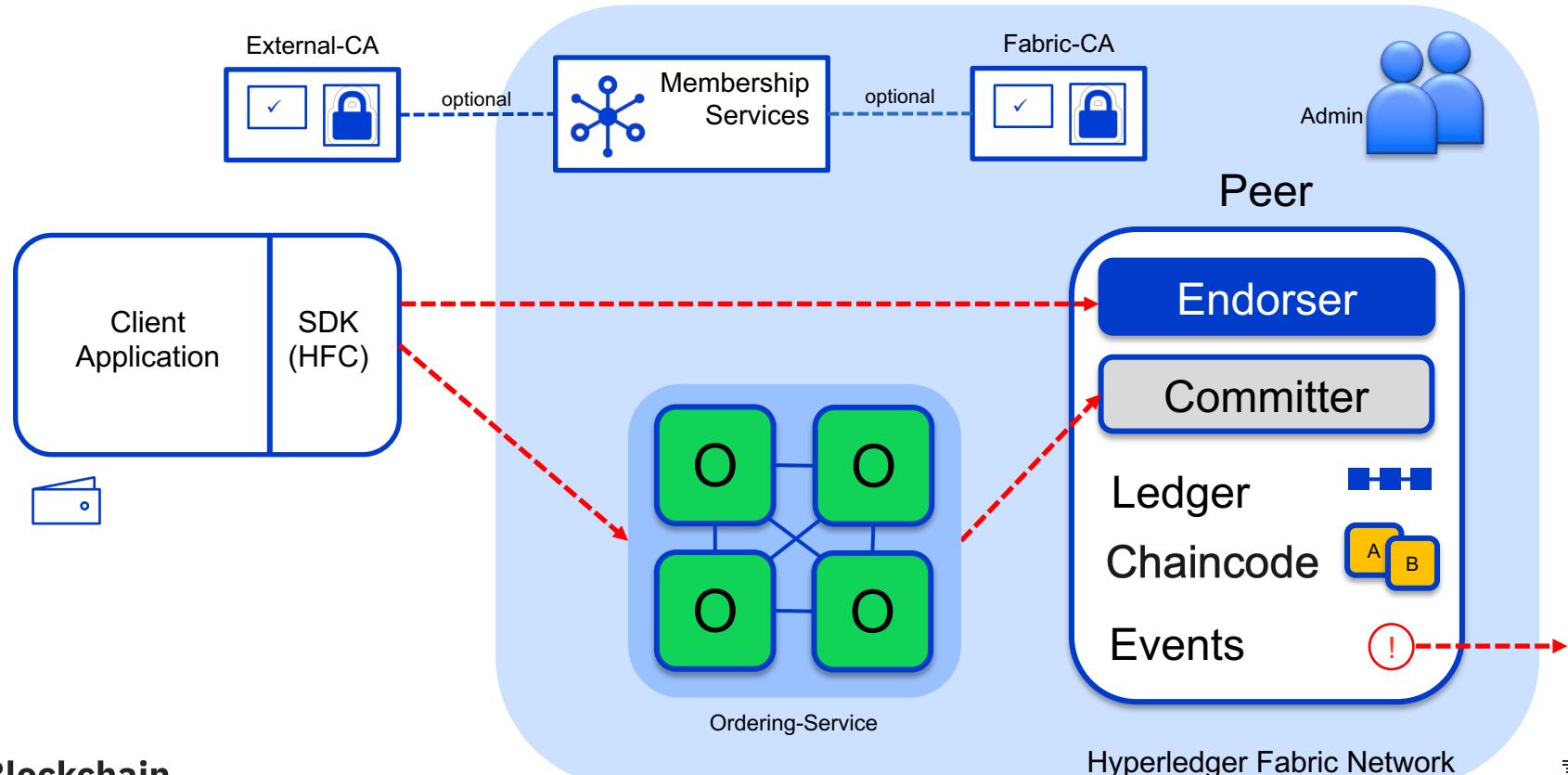
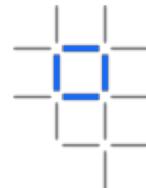


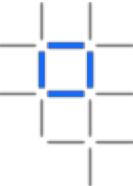
Technical Deep Dive

- [Architectural Overview]
- Network Consensus
- Channels and Ordering Service
- Components
- Network setup
- Endorsement Policies
- Membership Services

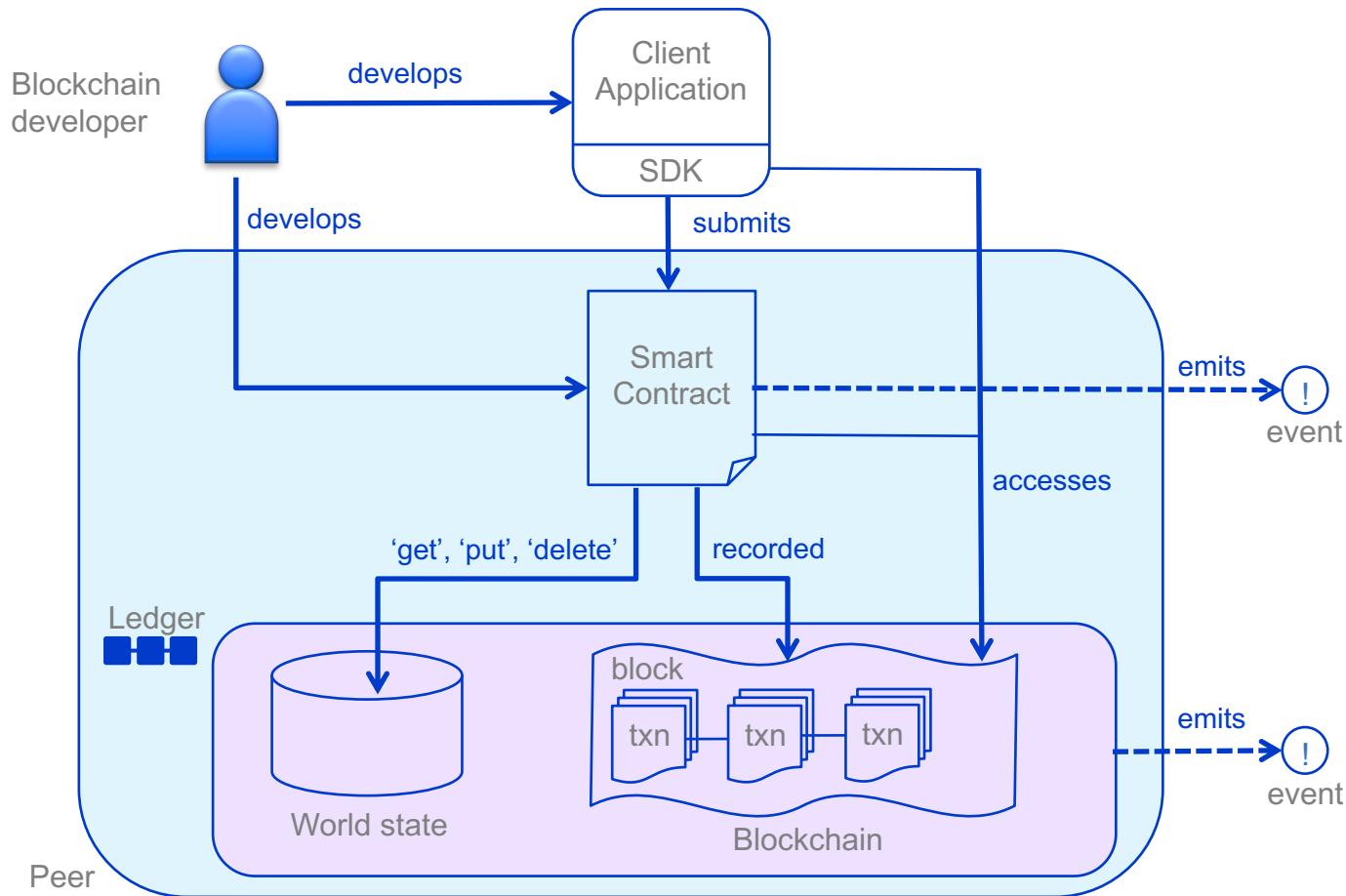


Hyperledger Fabric V1 Architecture





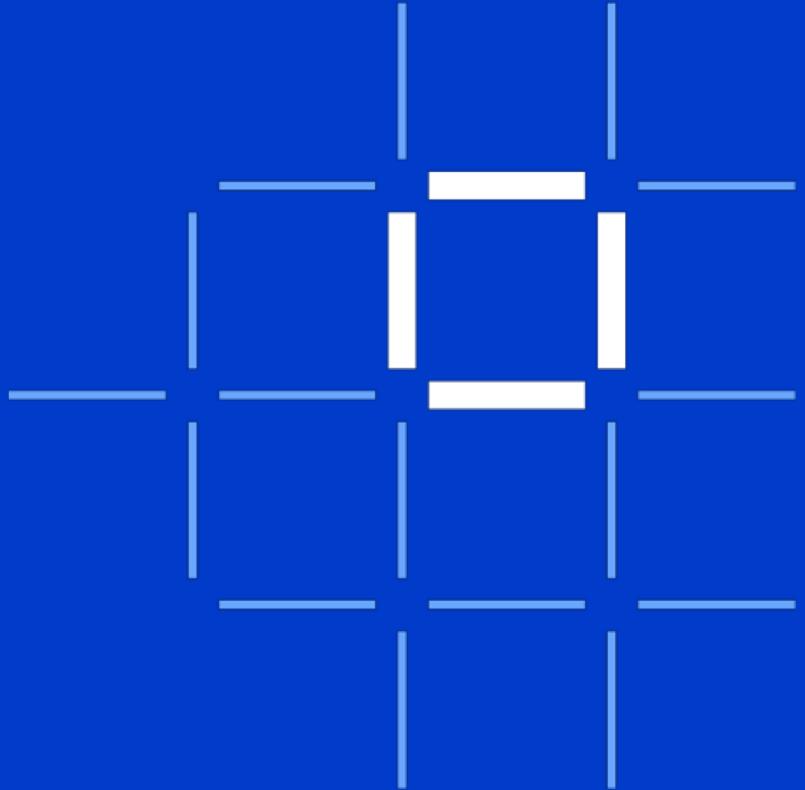
How applications interact with the ledger



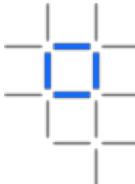


Technical Deep Dive

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- Channels and Ordering Service
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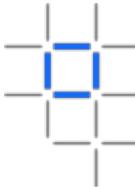


Nodes and roles

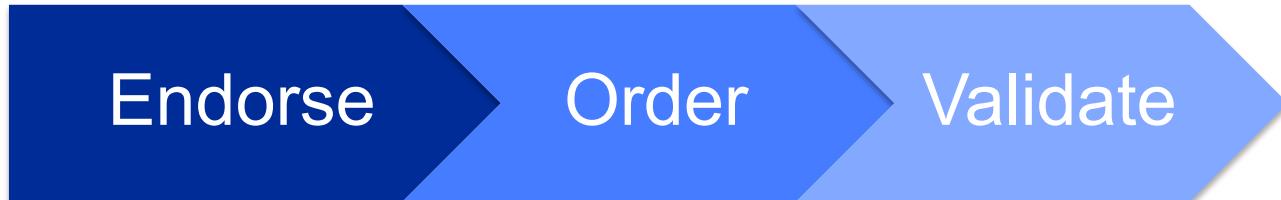


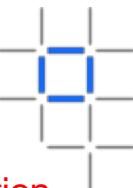
	<p>Peer: Maintains ledger and state. Commits transactions. May hold smart contract (chaincode).</p>
	<p>Endorsing Peer: Specialized peer also endorses transactions by receiving a transaction proposal and responds by granting or denying endorsement. Must hold smart contract.</p>
	<p>Ordering Node: Approves 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.</p>

Hyperledger Fabric Consensus

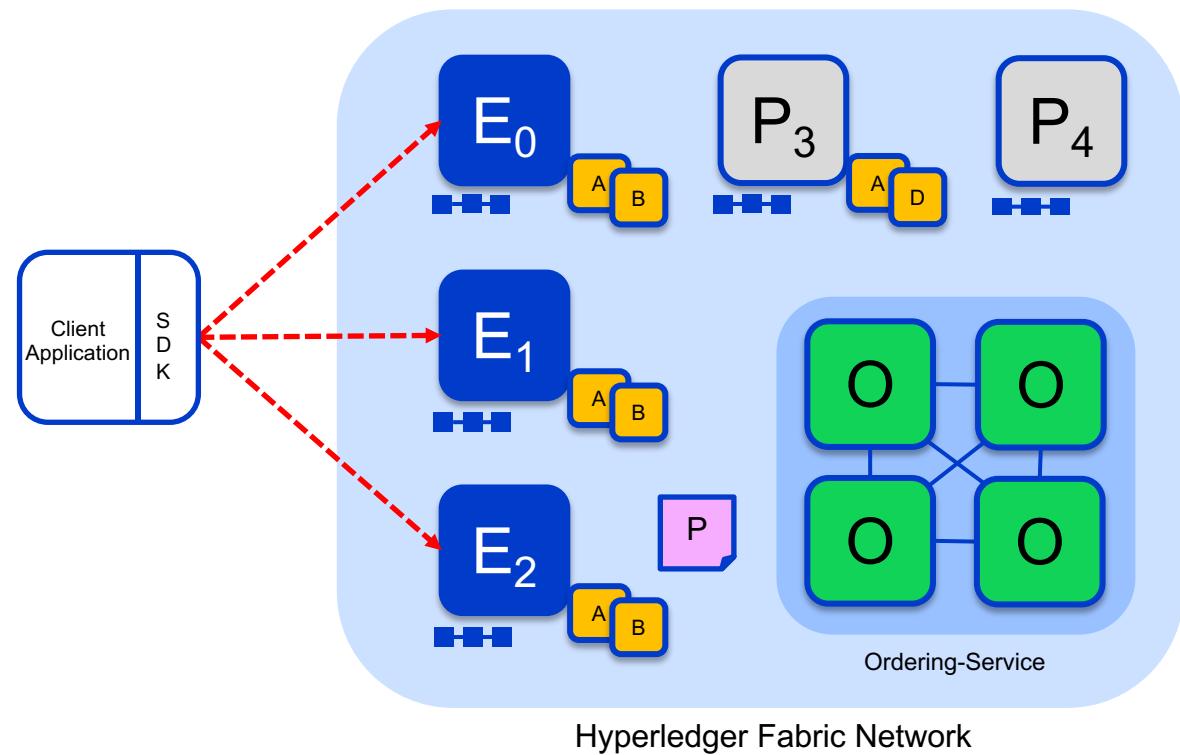


Consensus is achieved using the following transaction flow:





Sample transaction: Step 1/7 – Propose transaction



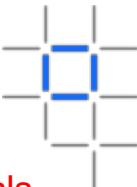
Application proposes transaction

Endorsement policy:
• “ E_0 , E_1 and E_2 must sign”
• (P_3 , P_4 are not part of the policy)

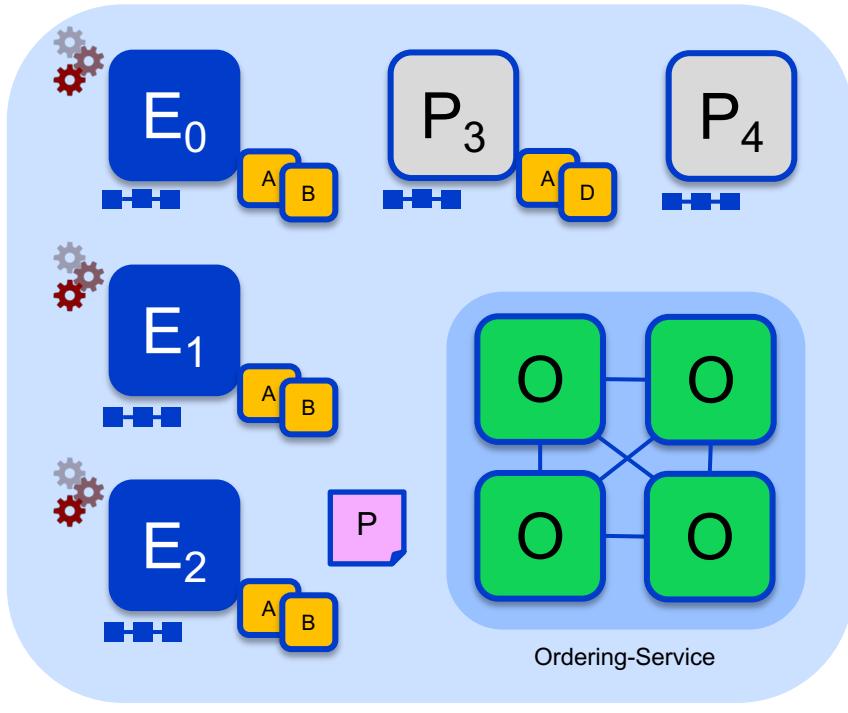
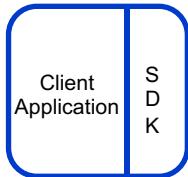
Client application submits a transaction proposal for Smart Contract A. It must target the required peers $\{E_0, E_1, E_2\}$

Key:

Endorser		Ledger
Committing Peer		Application
Ordering Node		
Smart Contract (Chaincode)		Endorsement Policy



Sample transaction: Step 2/7 – Execute proposal



Endorsers Execute Proposals

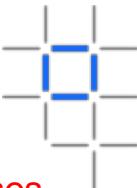
E_0 , E_1 & E_2 will each execute the proposed transaction. None of these executions will update the ledger

Each execution will capture the set of Read and Written data, called RW sets, which will now flow in the fabric.

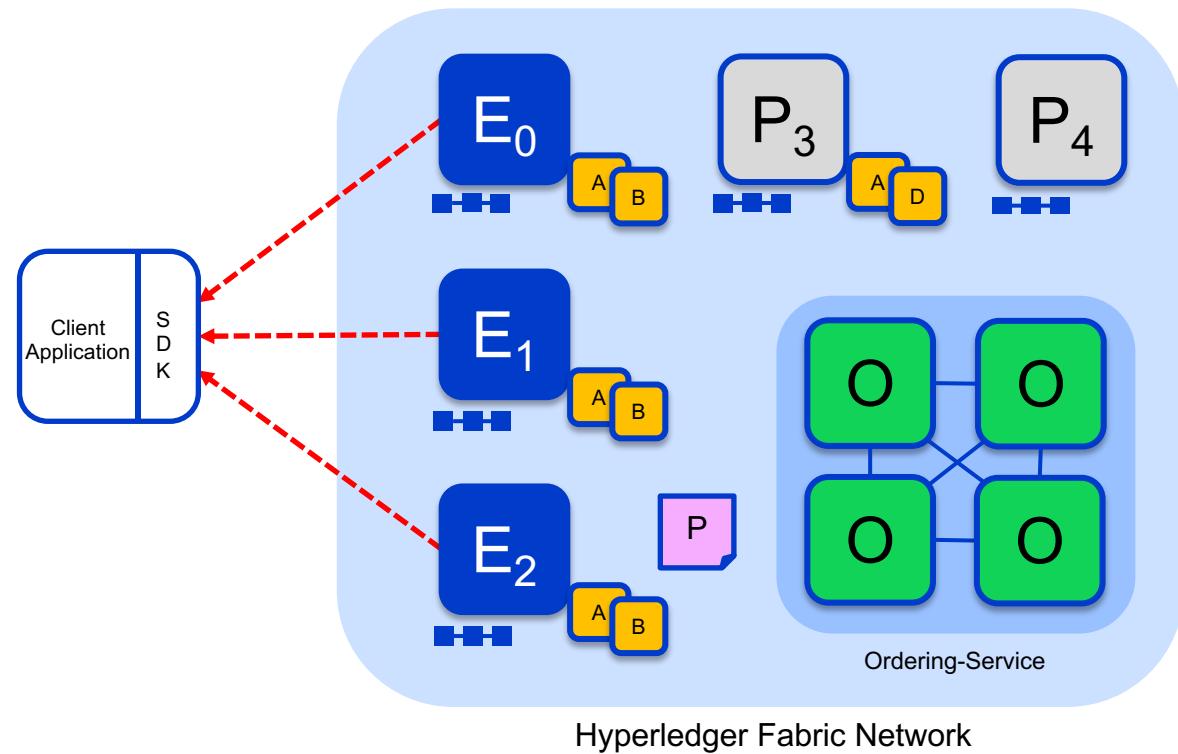
Transactions can be signed & encrypted

Key:

Endorser		Ledger
Committing Peer		Application
Ordering Node		
Smart Contract (Chaincode)		Endorsement Policy



Sample transaction: Step 3/7 – Proposal Response



Application receives responses

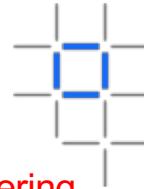
RW sets are asynchronously returned to application

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

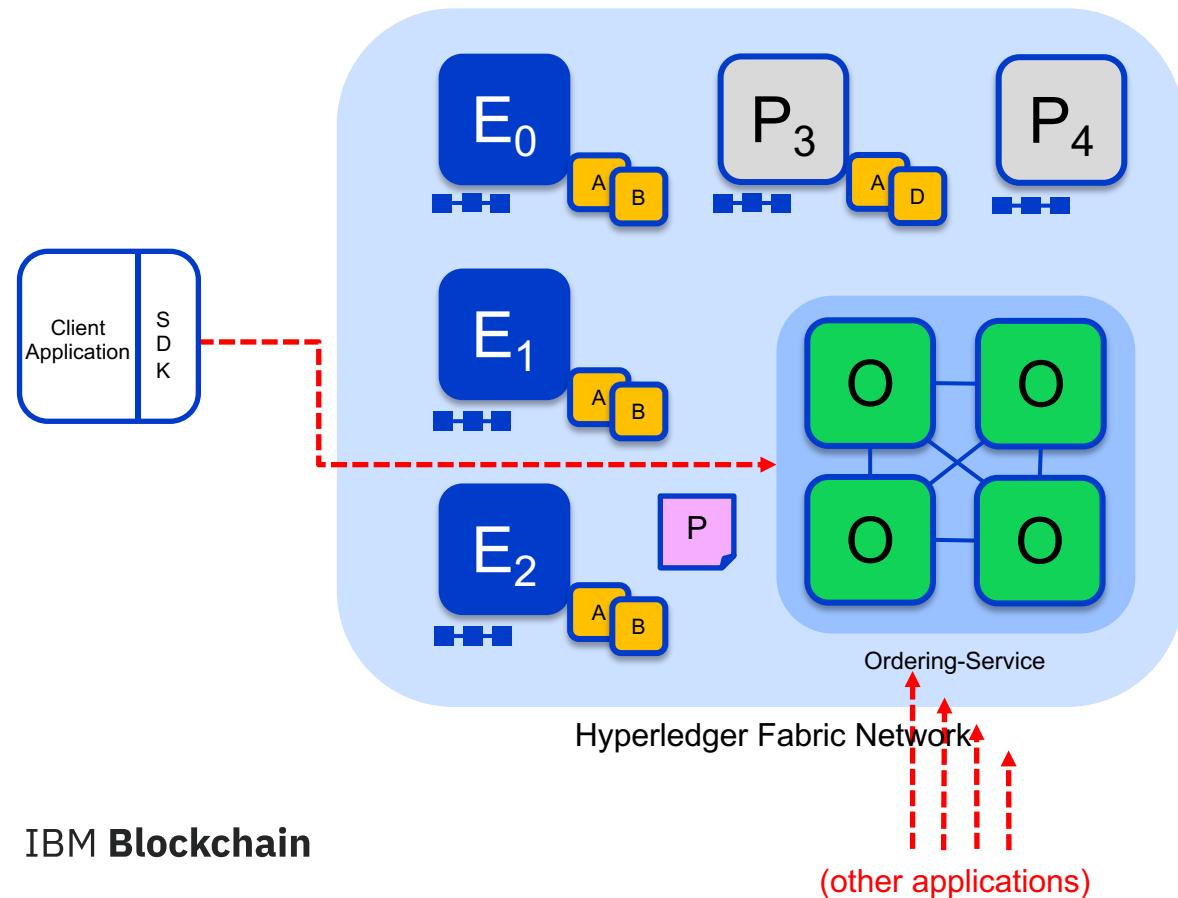
(This information will be checked much later in the consensus process)

Key:

Endorser		Ledger
Committing Peer		Application
Ordering Node		
Smart Contract (Chaincode)		Endorsement Policy



Sample transaction: Step 4/7 – Order Transaction



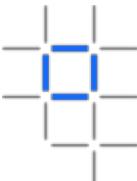
Responses submitted for ordering

Application submits responses as a transaction to be ordered.

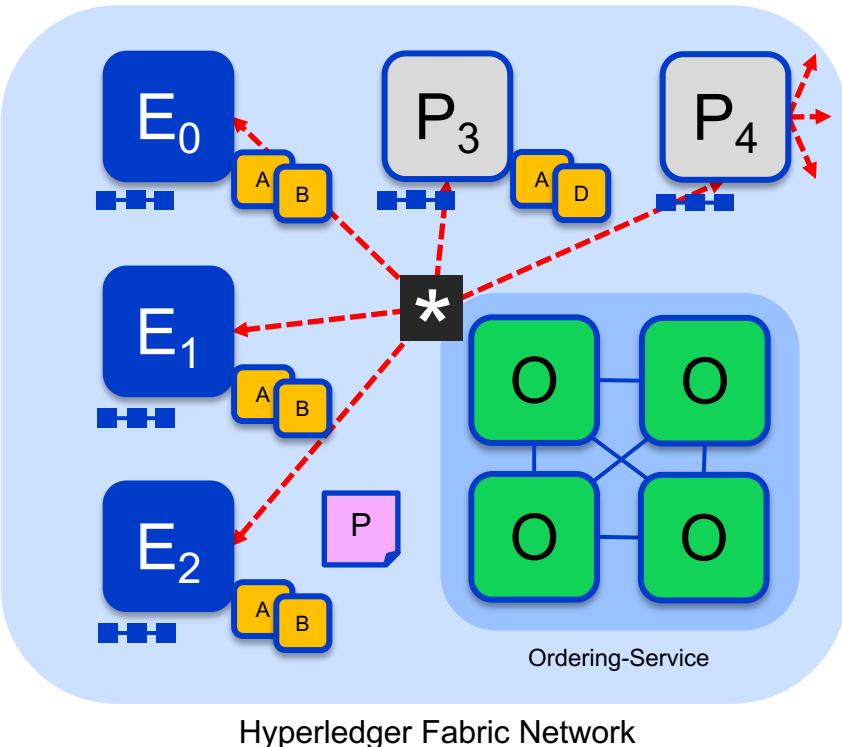
Ordering happens across the fabric in parallel with transactions submitted by other applications

Key:

Endorser		Ledger
Committing Peer		Application
Ordering Node		
Smart Contract (Chaincode)		Endorsement Policy



Sample transaction: Step 5/7 – Deliver Transaction



Orderer delivers to 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)

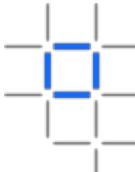
Different ordering algorithms available:

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

Key:

Endorser		Ledger
Committing Peer		Application
Ordering Node		
Smart Contract (Chaincode)		Endorsement Policy

Sample transaction: Step 6/7 – Validate Transaction



Committing peers validate transactions

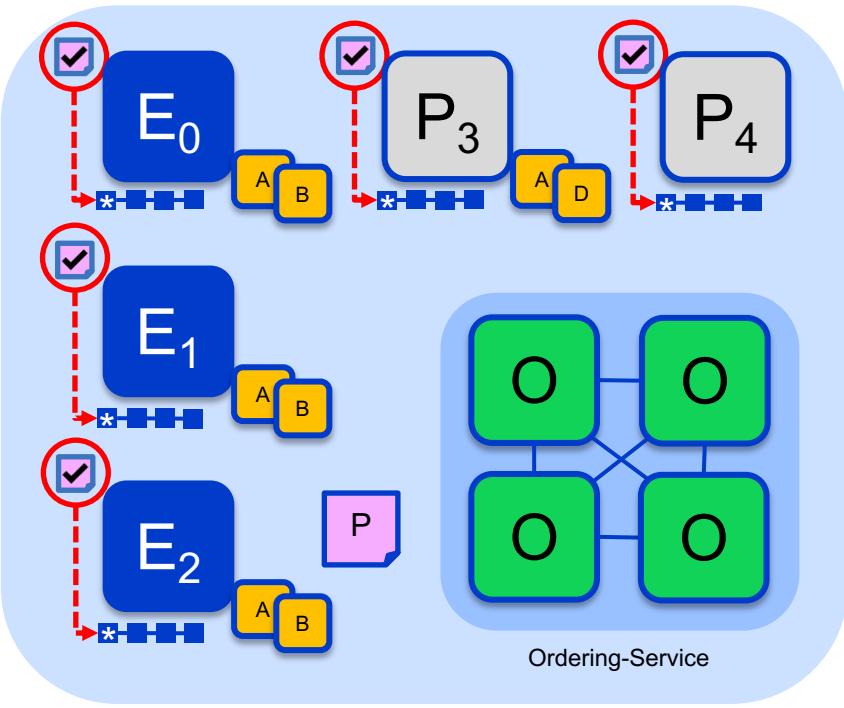
Every committing peer validates against the endorsement policy. Also check RW sets are still valid for current world state

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

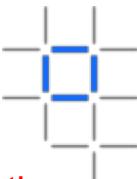
Invalid transactions are also retained on the ledger but do not update world state

Key:

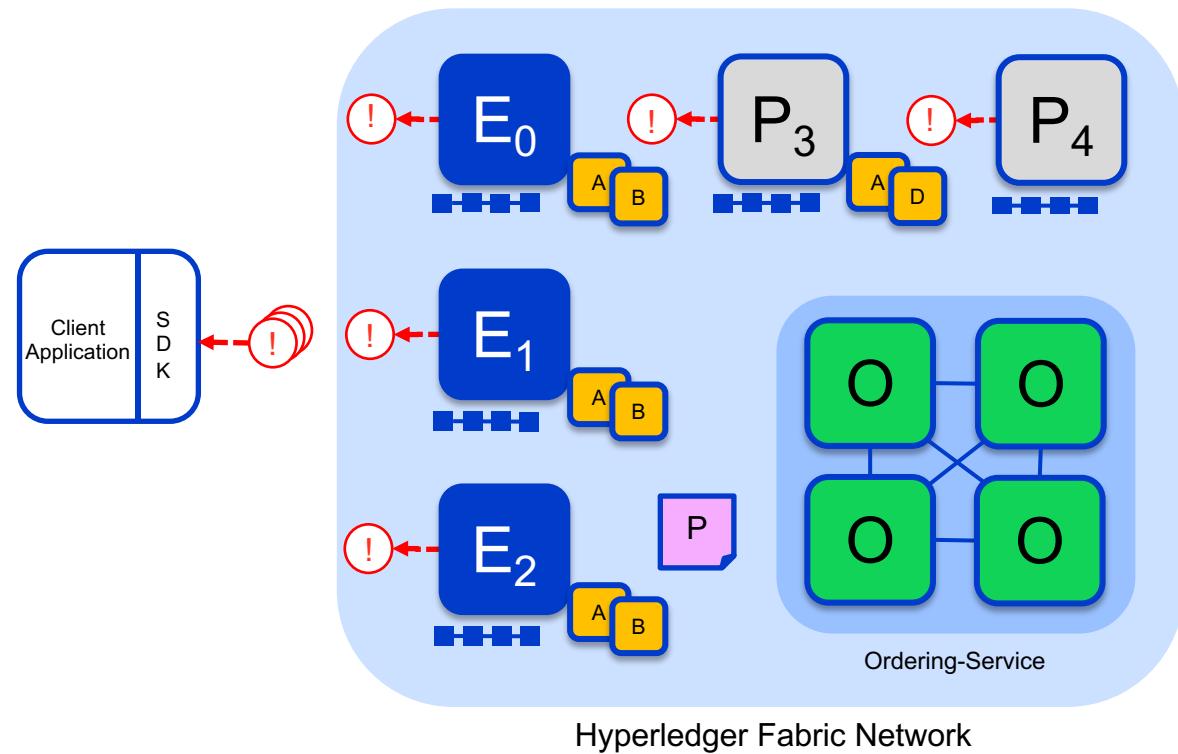
Endorser		Ledger
Committing Peer		Application
Ordering Node		
Smart Contract (Chaincode)		Endorsement Policy



Hyperledger Fabric Network



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

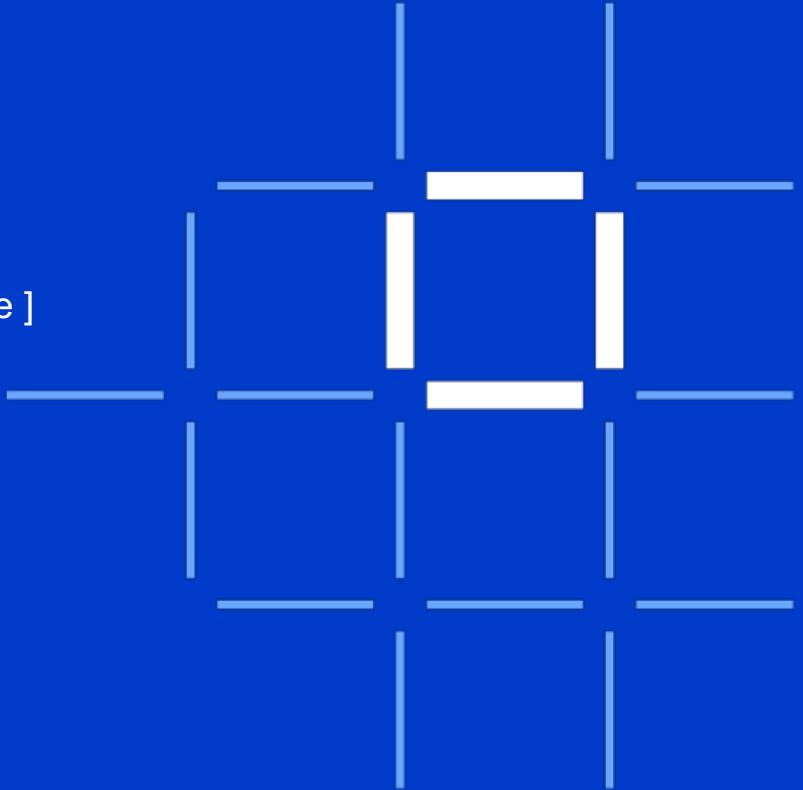
Key:

Endorser		Ledger
Committing Peer		Application
Ordering Node		
Smart Contract (Chaincode)		Endorsement Policy

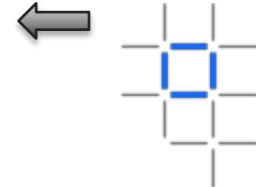


Technical Deep Dive

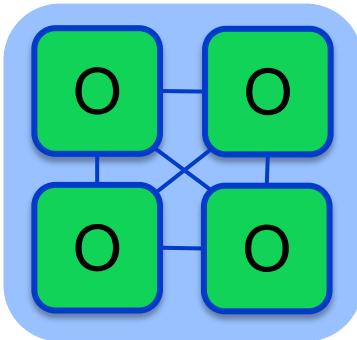
- Architectural Overview
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- [Channels and Ordering Service]
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Ordering Service



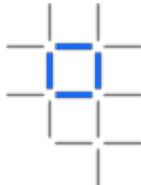
The ordering service packages transactions into blocks to be delivered to peers. Communication with the service is via channels.



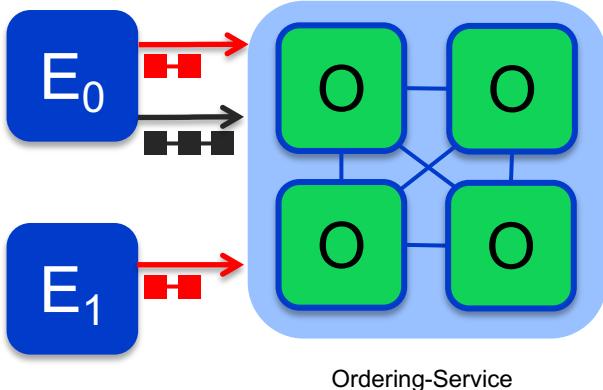
Different configuration options for the ordering service include:

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

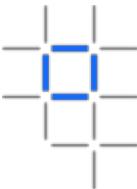
Channels



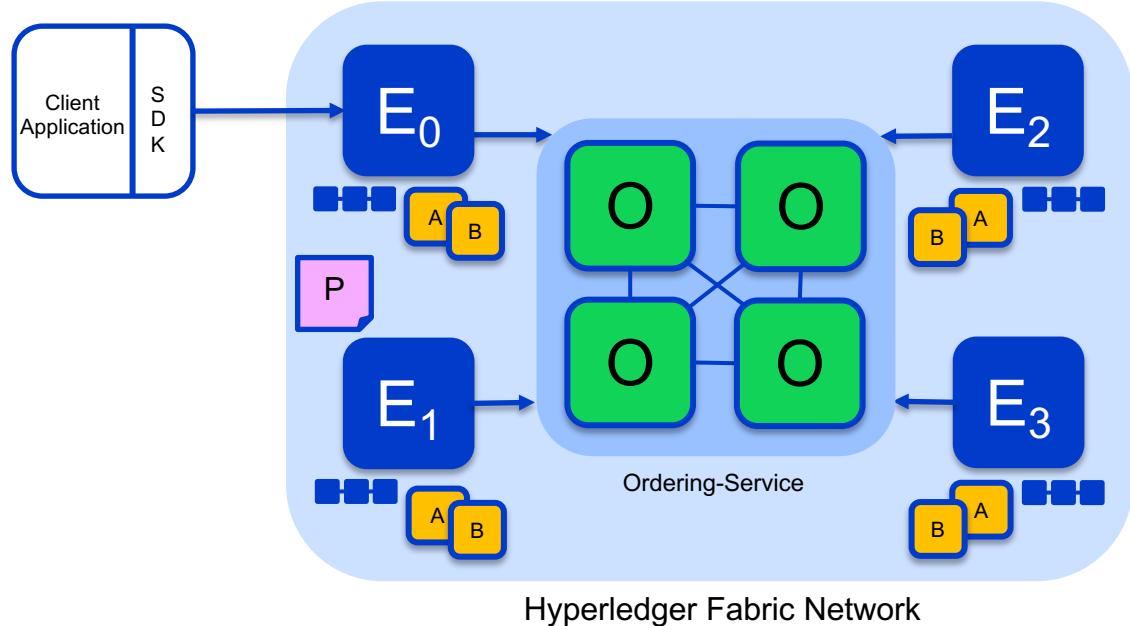
Channels provide privacy between different ledgers



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



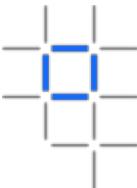
Single Channel Network



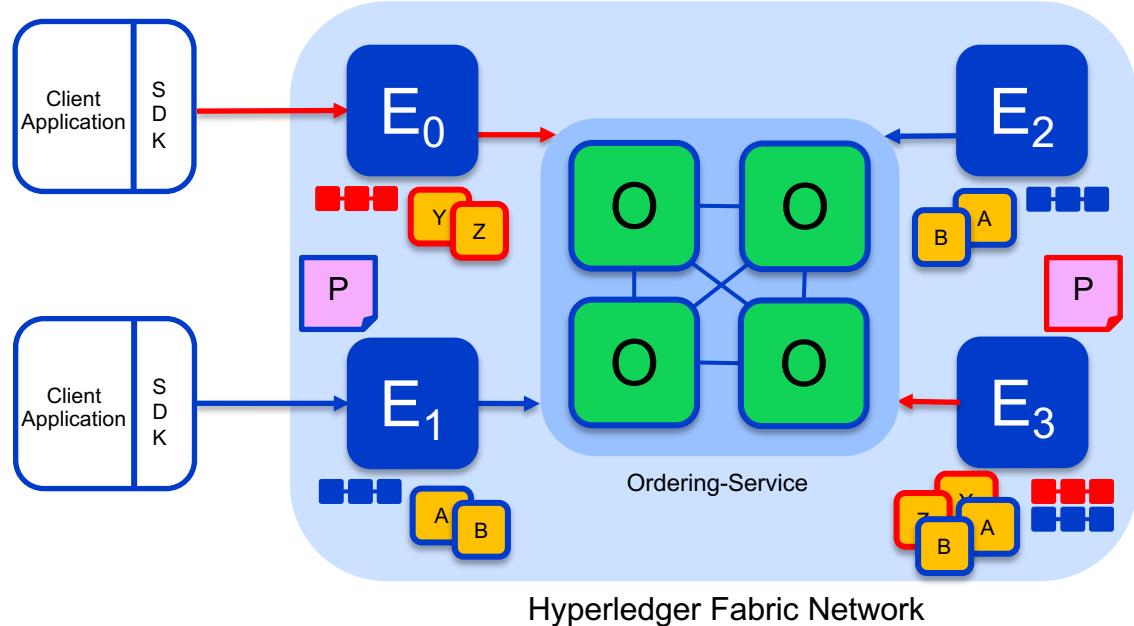
- Similar to v0.6 PBFT model
- All peers connect to the same system channel (blue).
- All peers have the same chaincode and maintain the same ledger
- Endorsement by peers E₀, E₁, E₂ and E₃

Key:

Endorser		Ledger
Committing Peer		Application
Ordering Node		
Smart Contract (Chaincode)		Endorsement Policy



Multi Channel Network



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

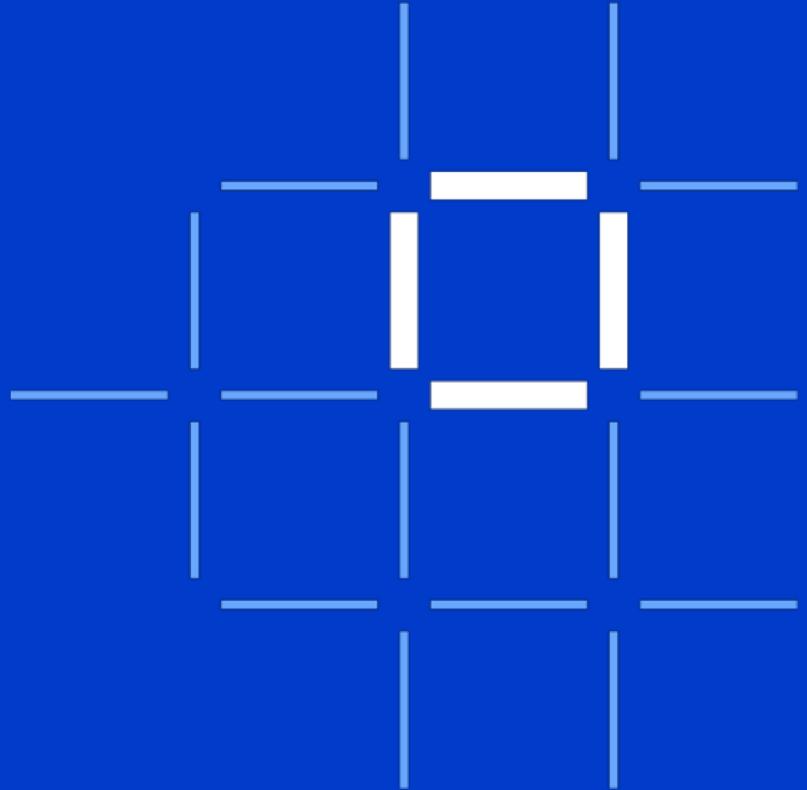
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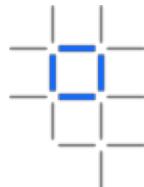


Technical Deep Dive

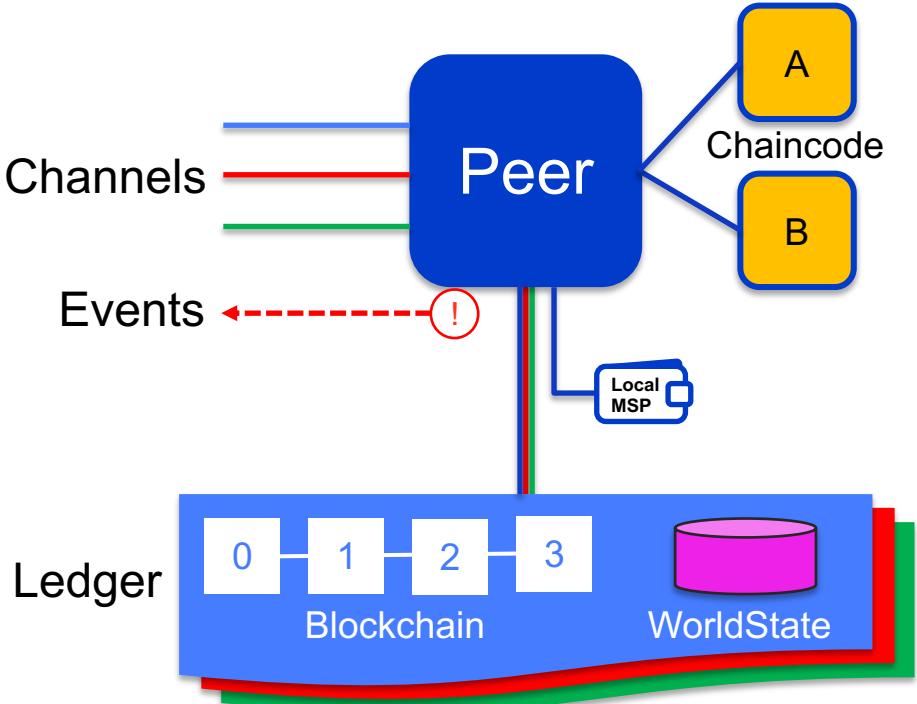
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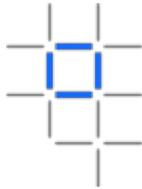
Fabric Peer



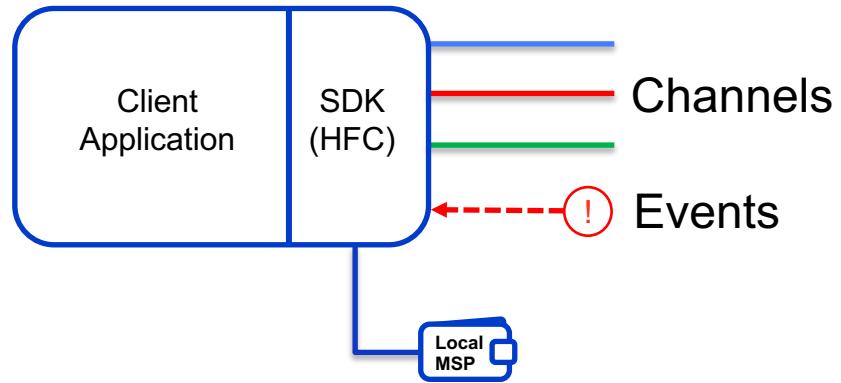
- Each peer:
 - Connects to one or more **channels**
 - Maintains one or more **ledgers** per channel
 - Maintains **installed chaincode**
 - Manages **runtime docker containers** for **instantiated chaincode**
 - Chaincode is instantiated on a channel
 - Runtime docker container shared by channels with same chaincode instantiated (no state stored in container)
 - Has a local MSP (Membership Services Provider) that provides **crypto material**
 - **Emits events** to the client application

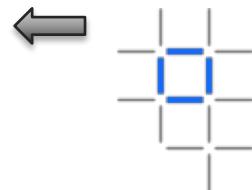


Client Application



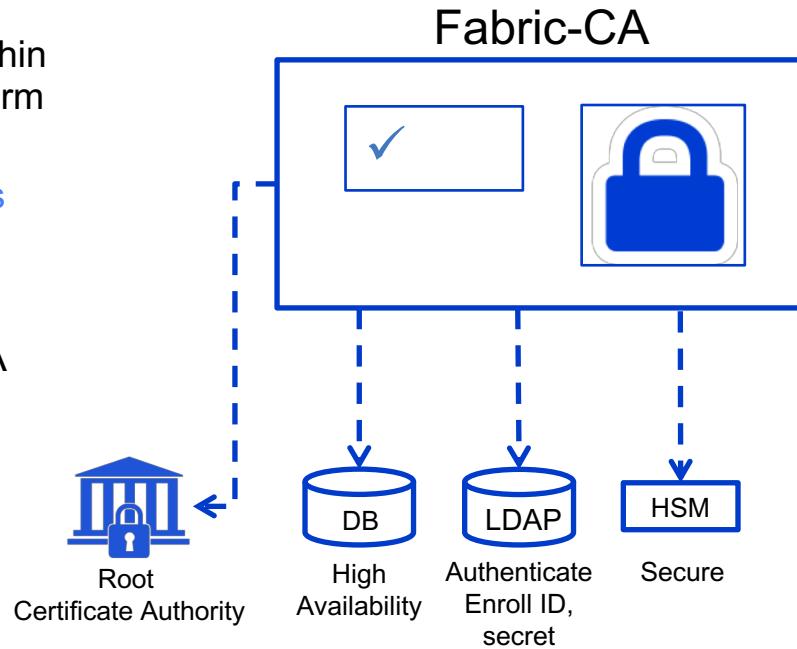
- Each client application uses Fabric SDK to:
 - Connects over channels to one or more peers
 - Connects over channels to one or more orderer nodes
 - Receives events from peers
 - Local MSP provides client *crypto material*
- Client can be written in different languages
(Node.js, Go, Java, Python?)





Fabric-CA

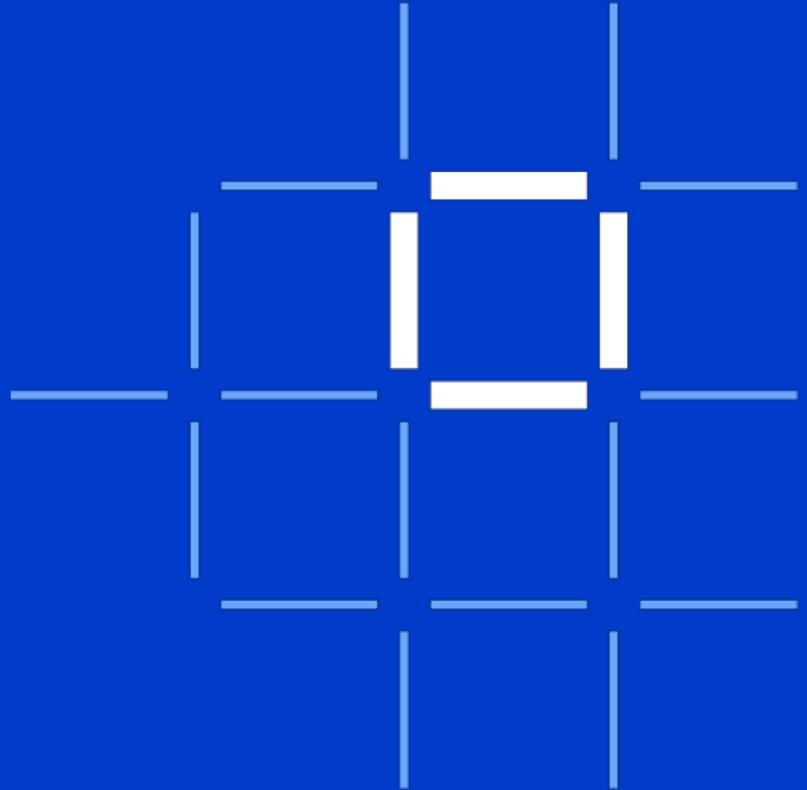
- Default (optional) Certificate Authority within Fabric network for issuing **Ecerts** (long-term identity)
- Supports clustering for **HA** characteristics
- Supports LDAP for **user authentication**
- Supports HSM for **security**
- Can be configured as an intermediate CA



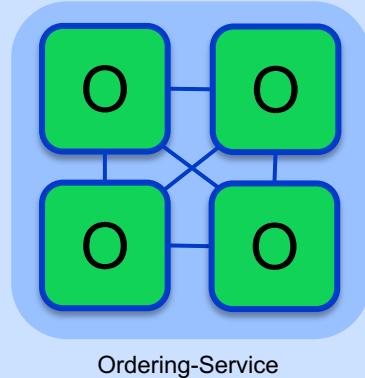
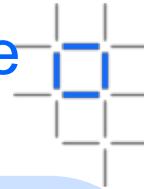


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Bootstrap Network (1/6) - Configure & Start Ordering Service

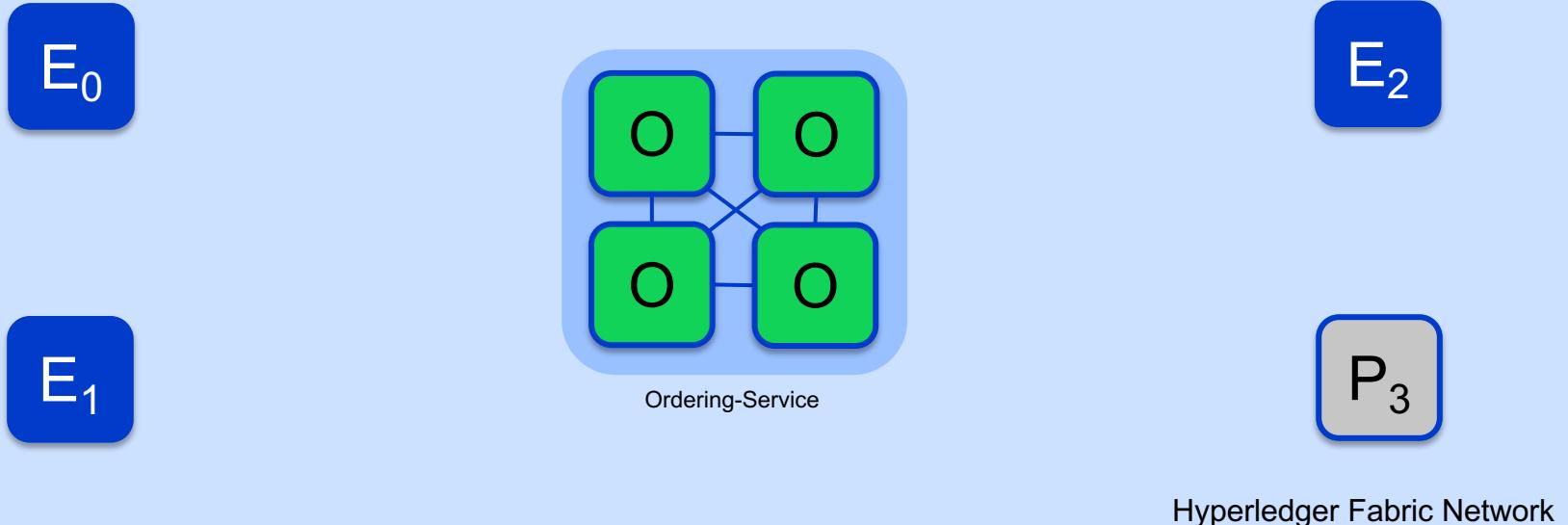
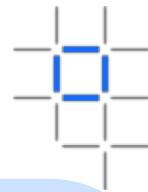


Hyperledger Fabric Network

An Ordering Service is configured and started for the network:

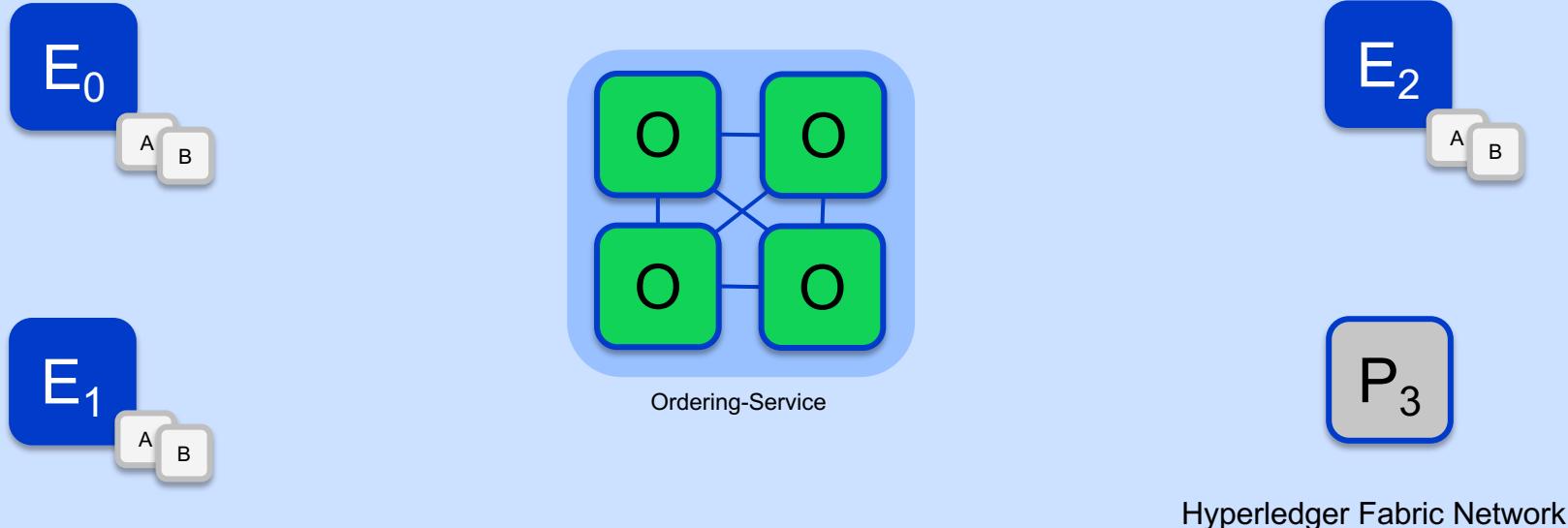
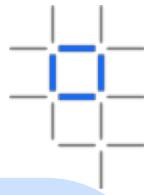
\$ docker-compose [-f orderer.yml] ...

Bootstrap 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 ...

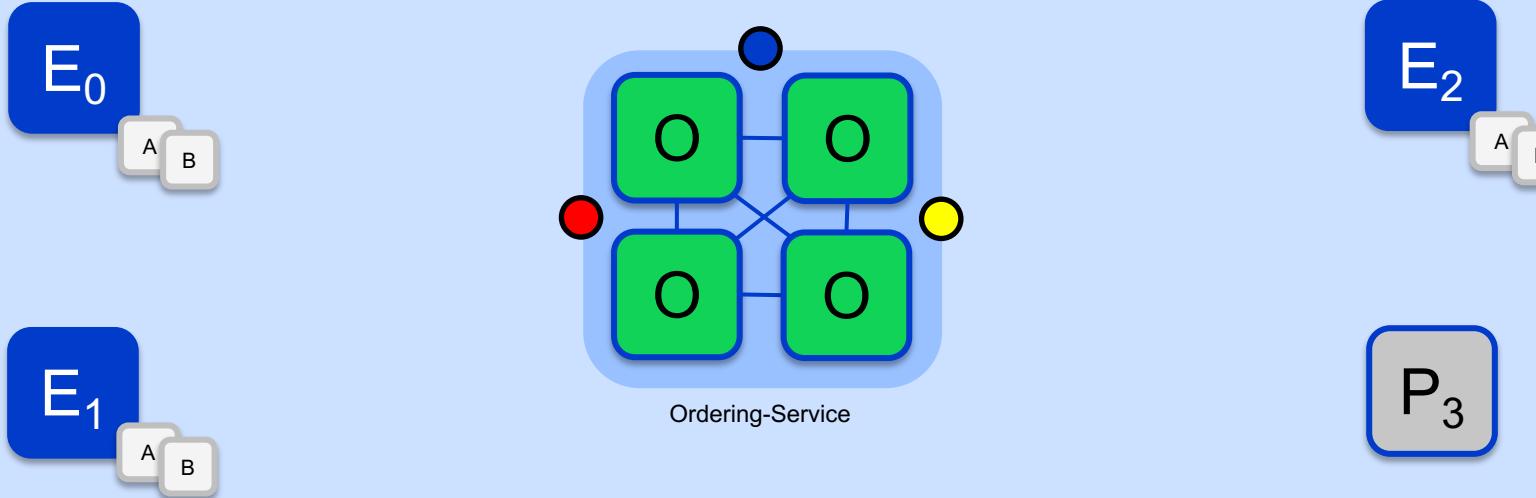
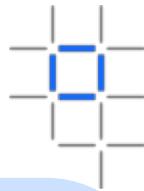
Bootstrap Network (3/6) - Install Chaincode



Chaincode is installed onto each Endorsing Peer that needs to execute it:

\$ peer chaincode install ...

Bootstrap Network (4/6) – Create Channels

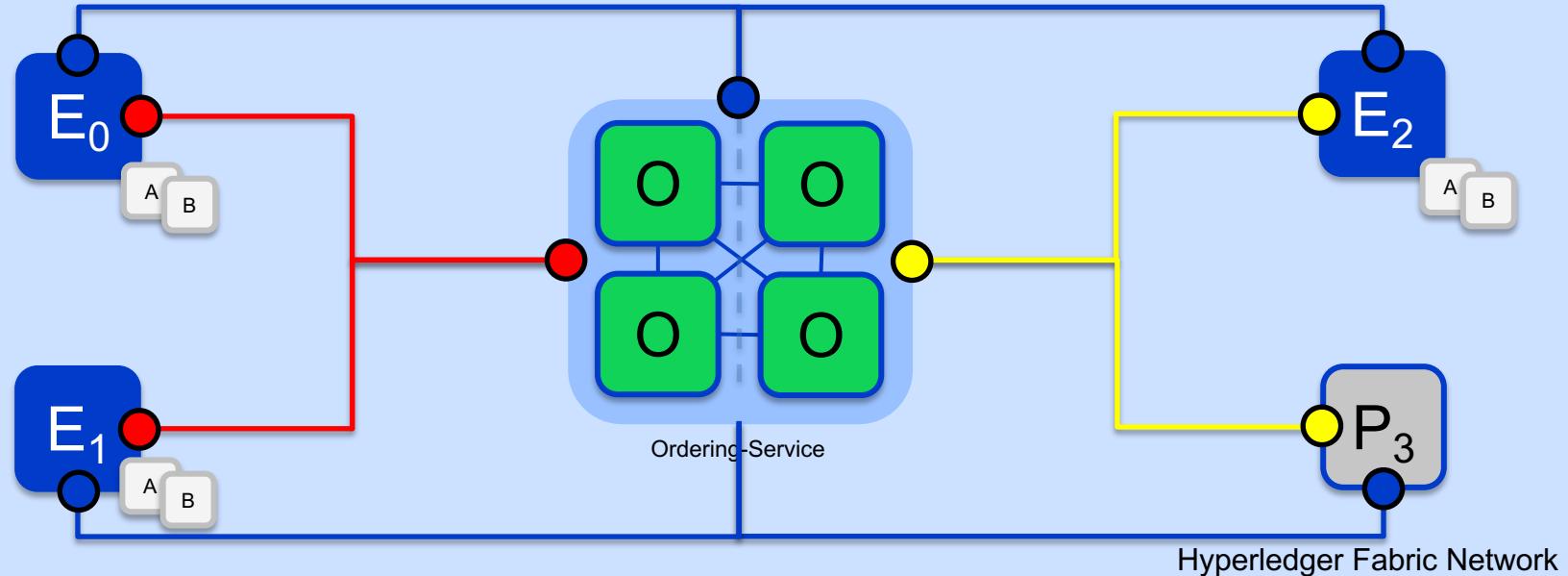
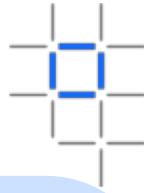


Channels are created on the ordering service:

```
$ peer channel create -o [orderer] ...
```

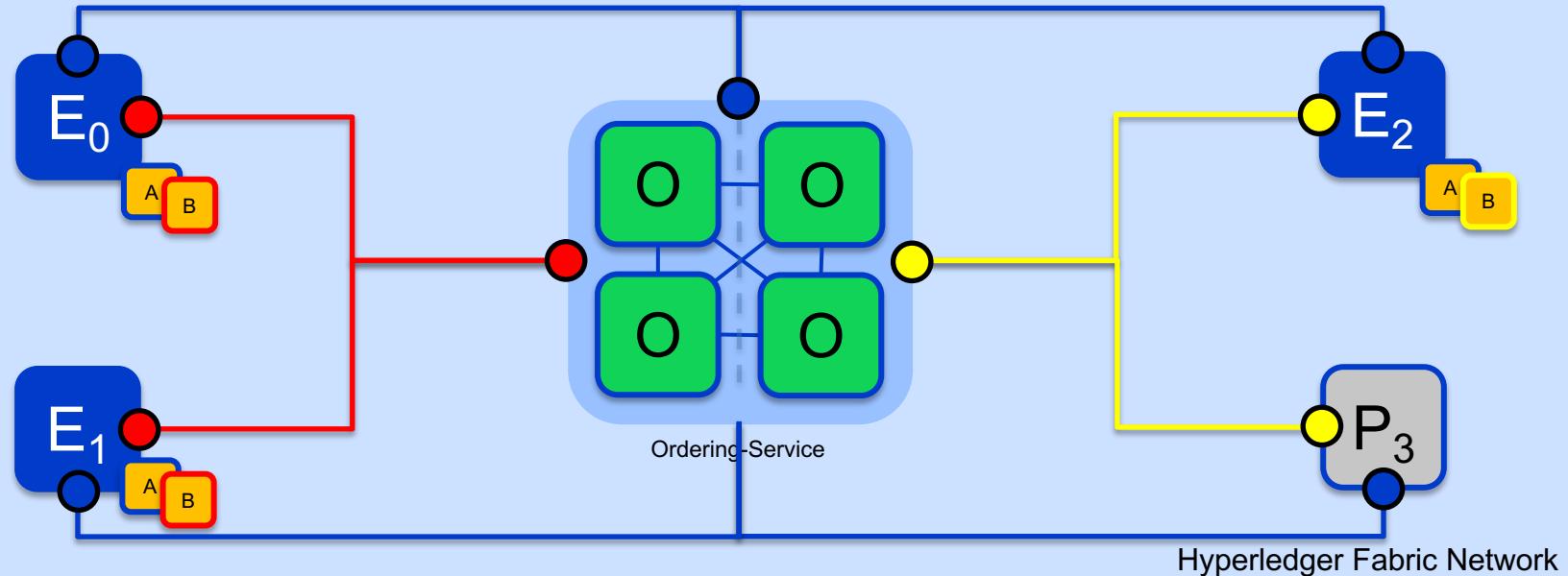
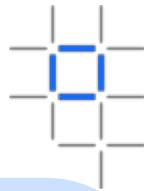
Hyperledger Fabric Network

Bootstrap Network (5/6) – Join Channels



Peers that are permissioned can then join the channels they want to transact on:
\$ peer channel join ...

Bootstrap Network (6/6) – Instantiate Chaincode

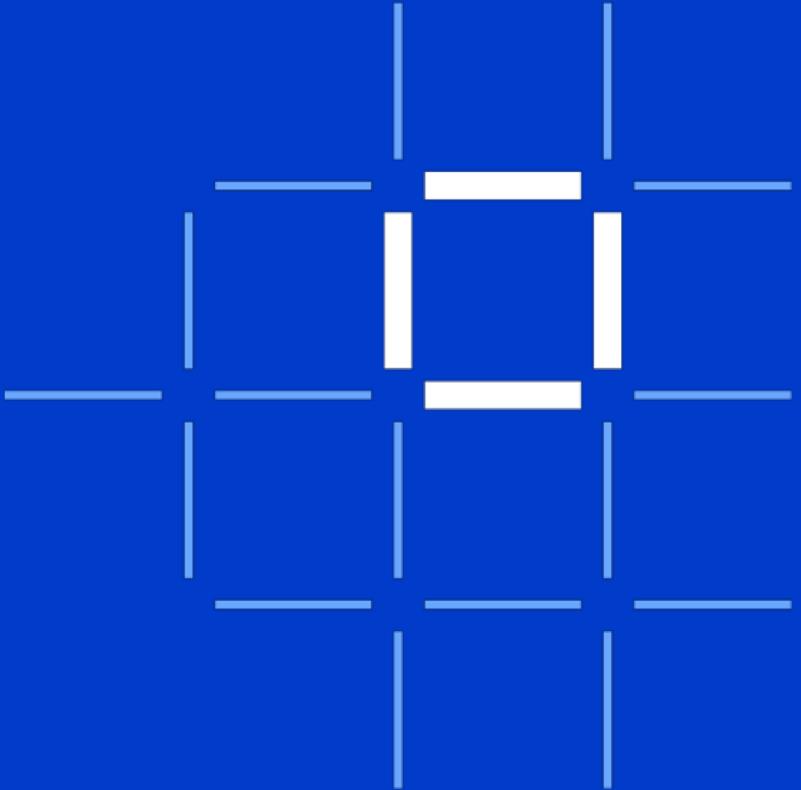


Peers finally instantiate the Chaincode on the channels they want to transact on:
\$ peer chaincode instantiate ... -P 'policy'

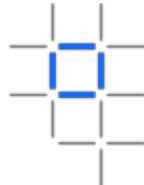


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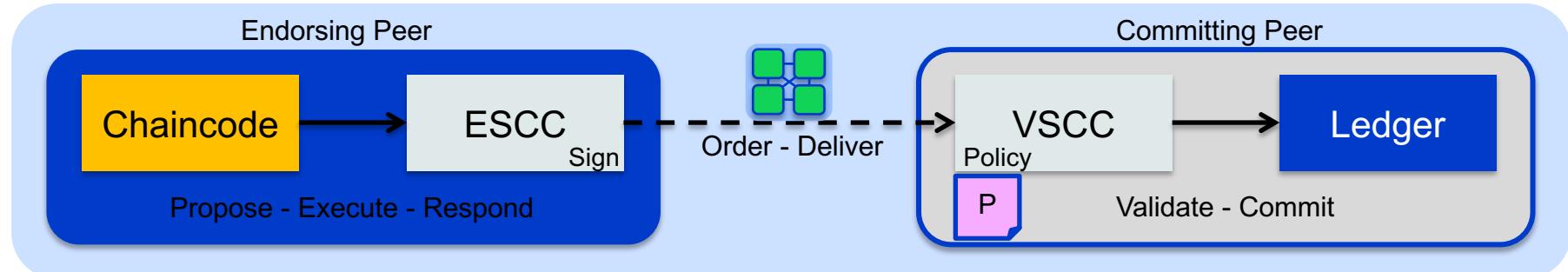


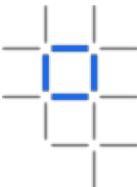
Endorsement Policies



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 deployed with an Endorsement 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')"
```

Instantiate the chaincode [mycc](#) on channel [mychannel](#) with the policy [AND\('Org1MSP.member'\)](#)

Policy Syntax: [EXPR\(E\[, E...\]\)](#)

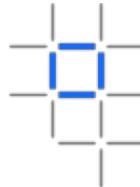
Where [EXPR](#) is either AND or OR and [E](#) is either a principal or nested EXPR

Principal Syntax: [MSP.ROLE](#)

Supported roles are: member and admin

Where [MSP](#) is the MSP ID, and [ROLE](#) is either “member” or “admin”

Endorsement Policy Examples



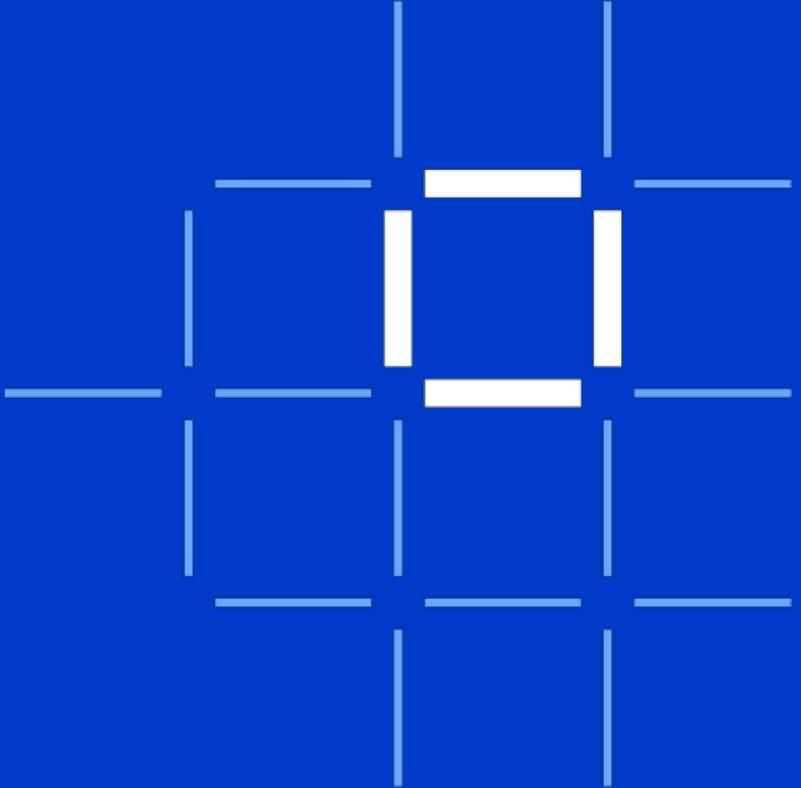
Examples of policies:

- 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'))`

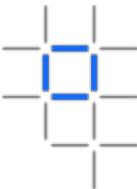


Technical Deep Dive

- Architectural Overview
- Network Consensus
- Channels and Ordering Service
- Components
- Network setup
- Endorsement Policies
- [Membership Services]

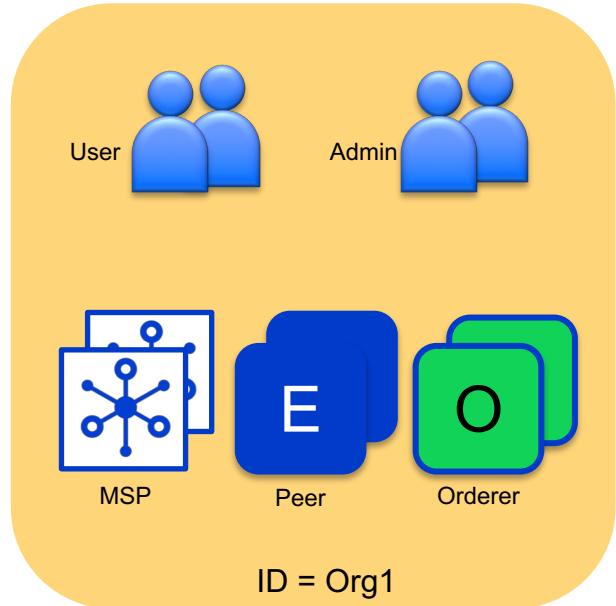


Organisations

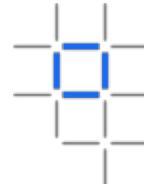


Organisations define boundaries within a Fabric Blockchain Network

- Each organisation defines:
 - Membership Services Provider (MSP) for identities
 - Administrator(s)
 - Users
 - Peers
 - Orderers (optional)
- A network can include many organisations representing a consortium
- Each organisation has an ID

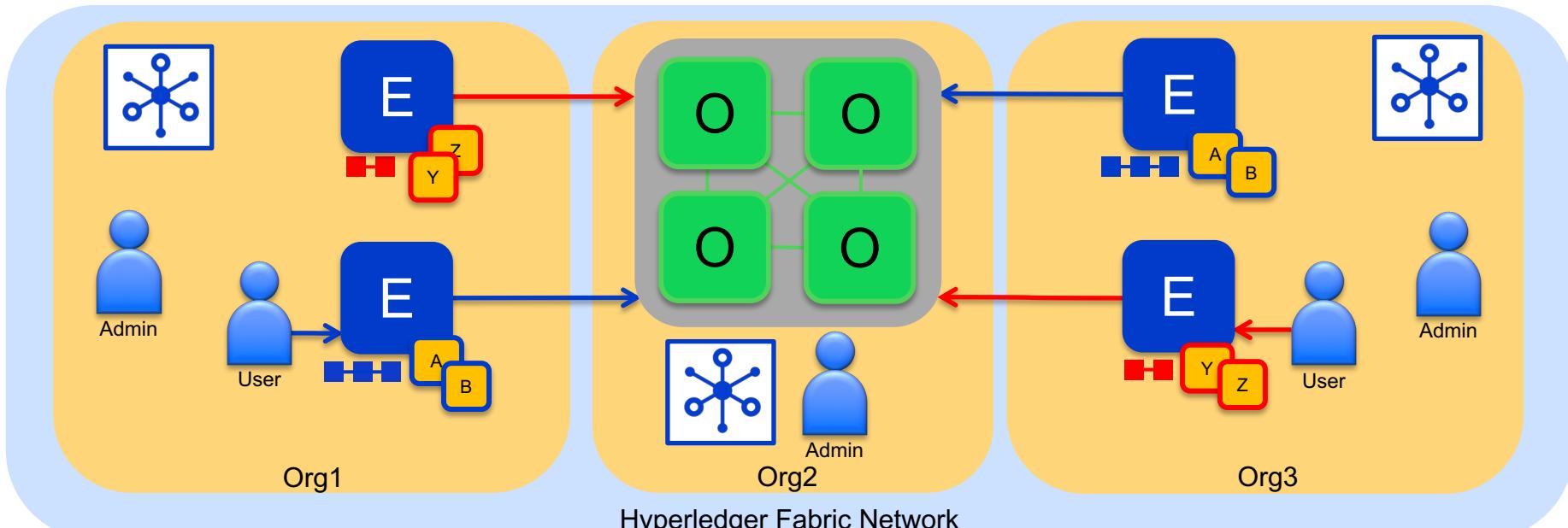


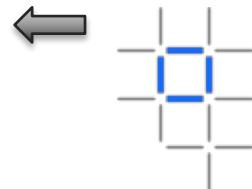
Consortium Network



An example consortium network of 3 organisations

- Orgs 1 and 3 run peers
- Org 2 provides the ordering service only

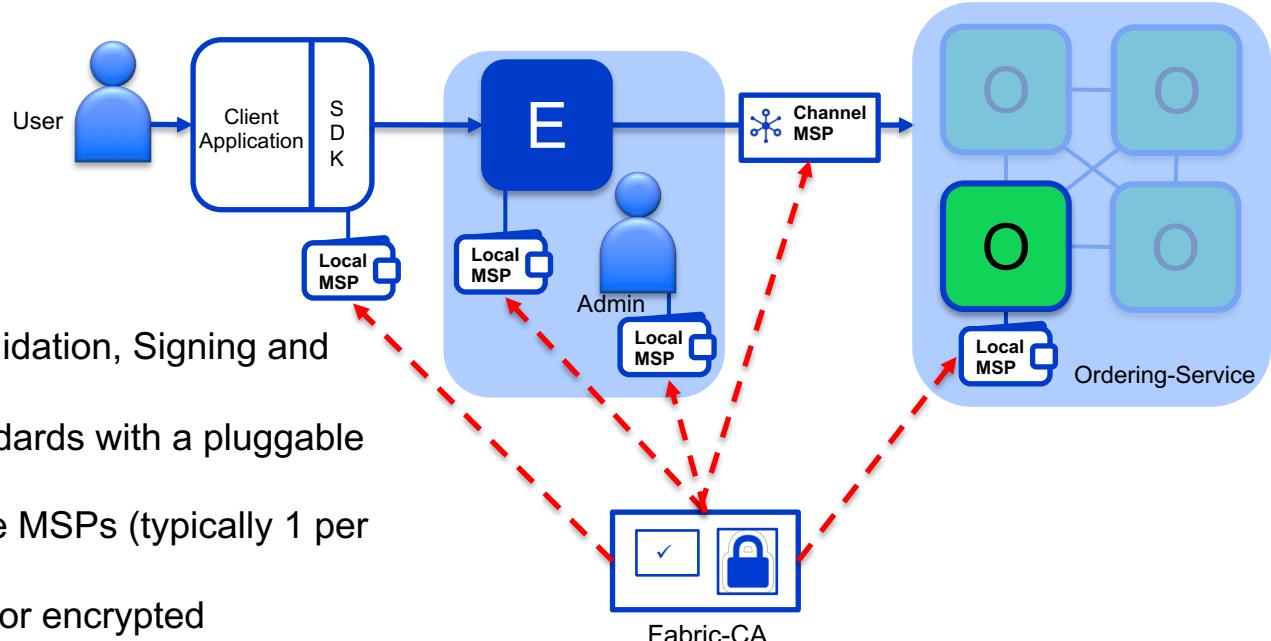




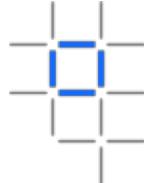
Membership Services Provider - Overview

A MSP manages a set of identities within a distributed Fabric network

- Provides identity for:
 - Peers and Orderers
 - Client Applications
 - Administrators
- Identities can be issued by:
 - Fabric-CA
 - An external CA
- Provides: Authentication, Validation, Signing and Issuance
- Supports different crypto standards with a pluggable interface
- A network can include multiple MSPs (typically 1 per org)
- Includes TLS crypto material for encrypted communications

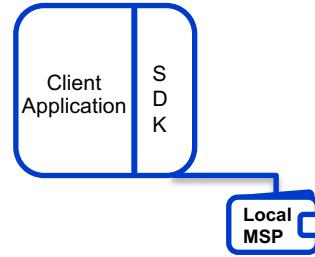


User Identities



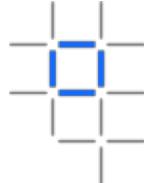
Each client application has a local MSP to store user identities

- Each local MSP includes:
 - **Keystore**
 - **Private key** for signing transactions
 - **Signcert**
 - **Public x.509 certificate**
- May also include TLS credentials
- Can be backed by a Hardware Security Module (HSM)



user@org1.example.com	
keystore	<private key>
signcert	user@org1.example.com-cert.pem

Admin Identities



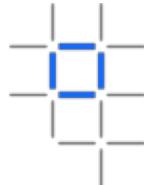
Each Administrator has a local MSP to store their identity

- Each local MSP includes:
 - **Keystore**
 - **Private key** for signing transactions
 - **Signcert**
 - **Public x.509 certificate**
- May also include TLS credentials
- Can be backed by a Hardware Security Module (HSM)



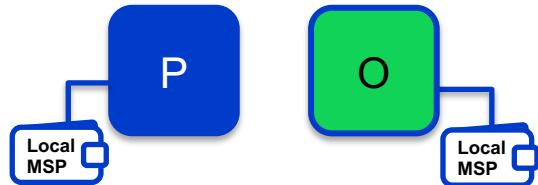
admin@org1.example.com	
keystore	<private key>
signcert	admin@org1.example.com-cert.pem

Peer and Orderer Identities



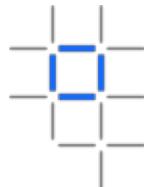
Each peer and orderer has a local MSP

- Each local MSP includes:
 - **keystore**
 - **Private key** for signing transactions
 - **signcert**
 - **Public x.509 certificate**
- In addition Peer/Orderer MSPs identify authorized administrators:
 - **admincerts**
 - List of **administrator certificates**
 - **cacerts**
 - The **CA public cert** for verification
 - **crls**
 - List of **revoked certificates**
- Peers and Orderers also receive channel MSP info
- Can be backed by a Hardware Security Module (HSM)



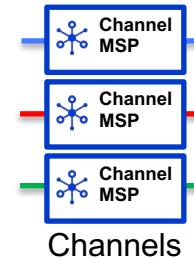
peer@org1.example.com	
admincerts	admin@org1.example.com-cert.pem
cacerts	ca.org1.example.com-cert.pem
keystore	<private key>
signcert	peer@org1.example.com-cert.pem
crls	<list of revoked admin certificates>

Channel MSP information

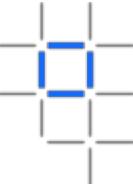


Channels include additional organisational MSP information

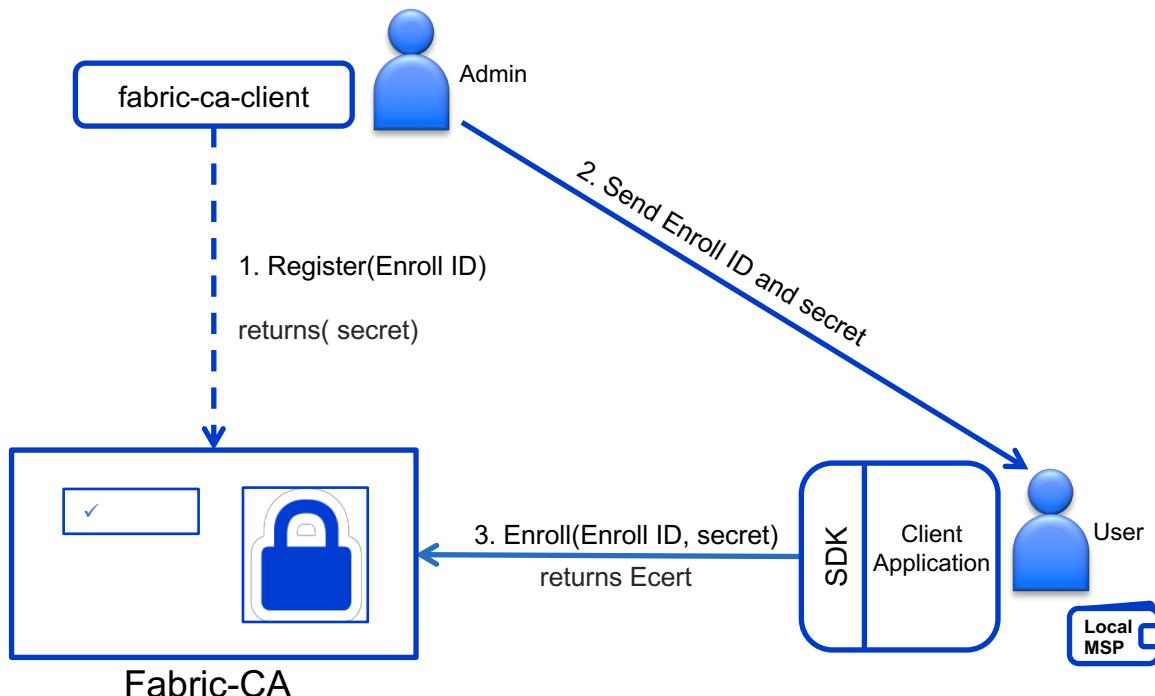
- Determines which orderers or peers can join the channel
- Determines client applications read or write access to the channel
- Stored in configuration blocks in the ledger
- Each channel MSP includes:
 - **admincerts**
 - Any public certificates for administrators
 - **cacerts**
 - The CA public certificate for this MSP
 - **crls**
 - List of revoked certificates
- Does not include any private keys for identity



ID = MSP1	
admincerts	admin.org1.example.com-cert.pem
cacerts	ca.org1.example.com-cert.pem
crls	<list of revoked admin certificates>

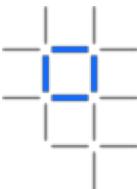


New User Registration and Enrollment



Registration and Enrollment

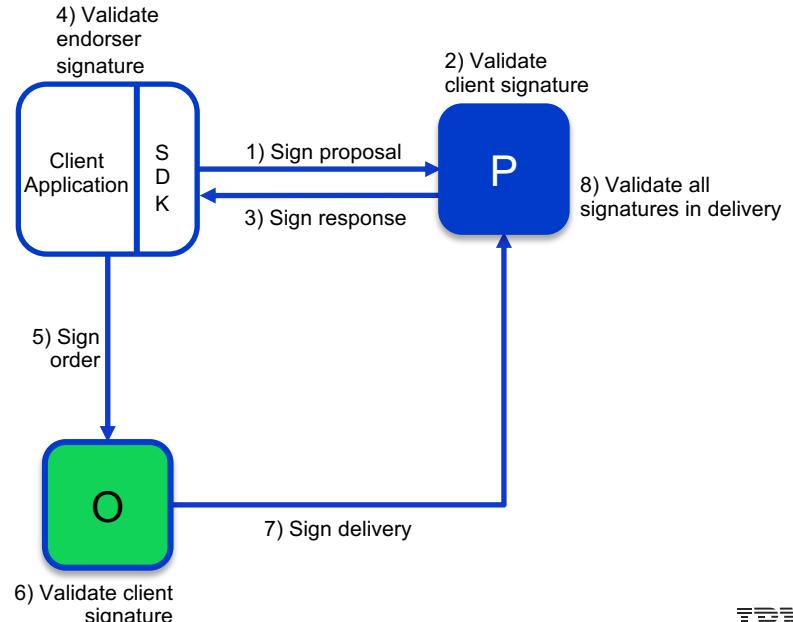
- Admin registers new user with Enroll ID
- User enrolls and receives credentials
- Additional offline registration and enrollment options available

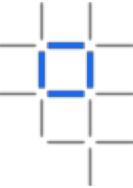


Transaction Signing

All transactions within a Hyperledger Fabric network are signed by permissioned actors, and those signatures validated

- Actors sign transactions with their enrolment private key
 - Stored in their local MSP
- Components validate transactions and certificates
 - Root CA certificates and CRLs stored in local MSP
 - Root CA certificates and CRLs stored in Org MSP in channel

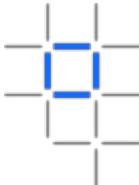




Summary and Next Steps

- Apply shared ledgers and smart contracts to your Business Network
- Think about your participants, assets and business processes
- Spend time thinking about realistic business use cases
- Get some hands-on experience with the technology
- Start with a First Project
- IBM can help with your journey

Further Hyperledger Fabric Information



- Project Home: <https://www.hyperledger.org/projects/fabric>
- GitHub Repo: <https://github.com/hyperledger/fabric>
- Latest Docs: <https://hyperledger-fabric.readthedocs.io/en/latest/>
- Community Chat: <https://chat.hyperledger.org/channel/fabric>
- Project Wiki: <https://wiki.hyperledger.org/projects/fabric>
- Design Docs: <https://wiki.hyperledger.org/community/fabric-design-docs>

Thank you

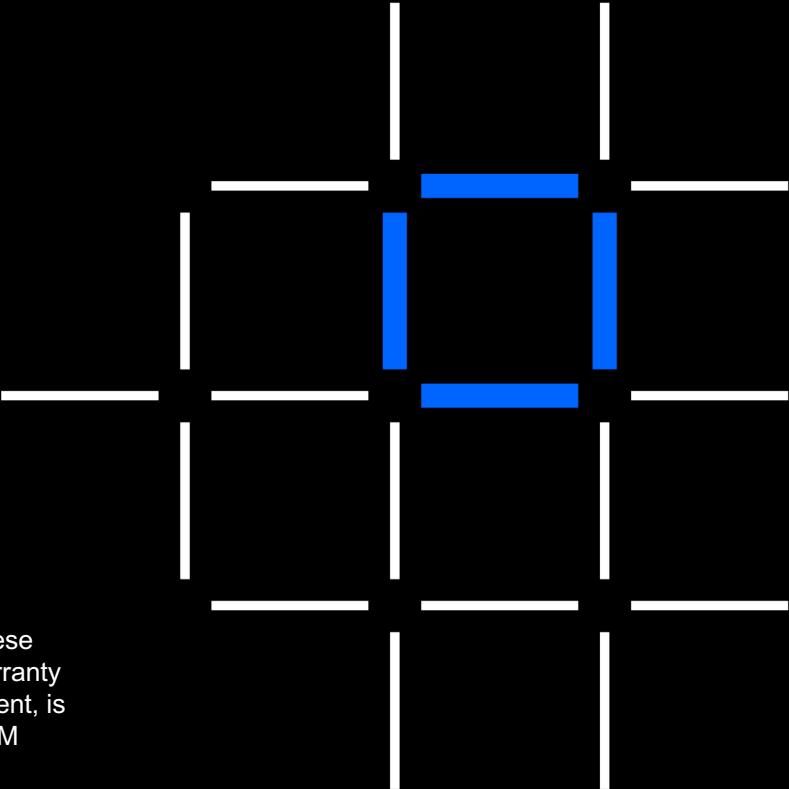
Barry Silliman
silliman@us.ibm.com

IBM Blockchain

www.ibm.com/blockchain

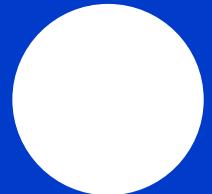
developer.ibm.com/blockchain

www.hyperledger.org

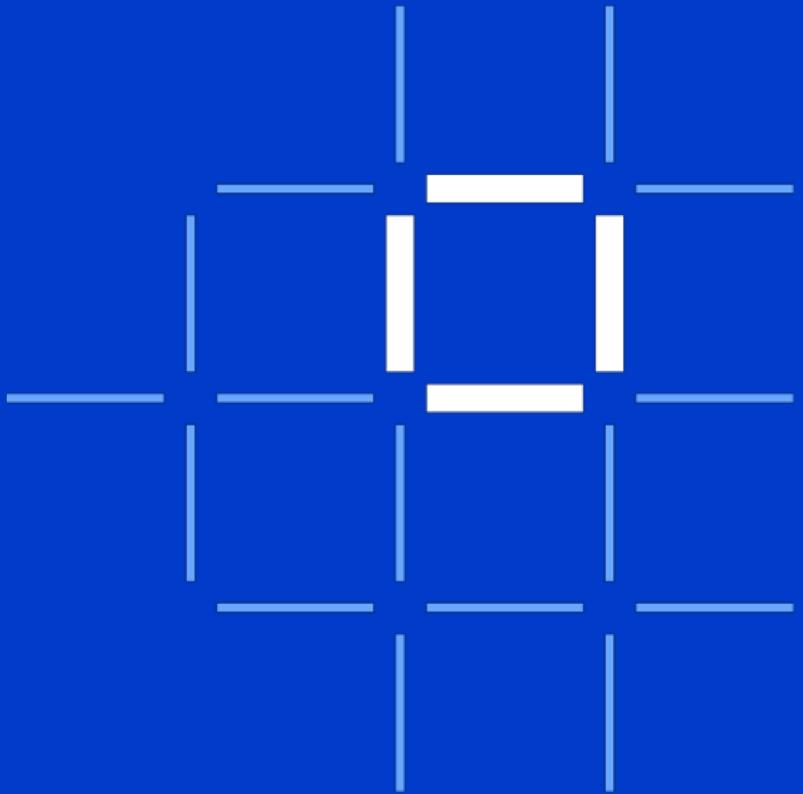


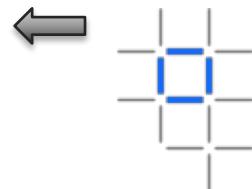
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Appendix

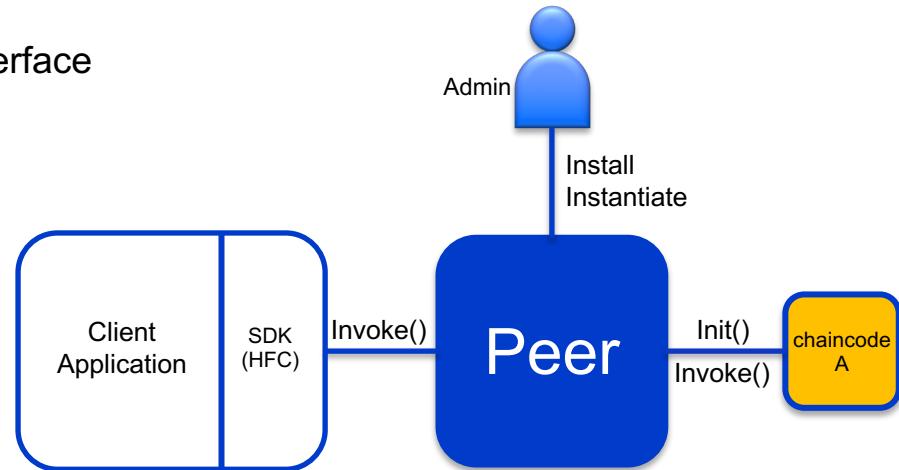


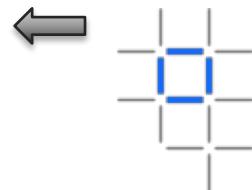


Chaincode (a.k.a Smart Contract)

Chaincode contains business logic deployed to peers

- Installed on peers and instantiated on channels
- Run in secured docker images separate to the peer
- Interact with the worldstate through the Fabric shim interface
- Each chaincode has its own scoped worldstate
- Language support for:
 - Golang
 - **Node.js (new in Fabric 1.1)**
 - Java (Future FAB-8063)
- Implements:
 - `Init()` - Called on instantiate and upgrade
 - `Invoke()` – Called from client application

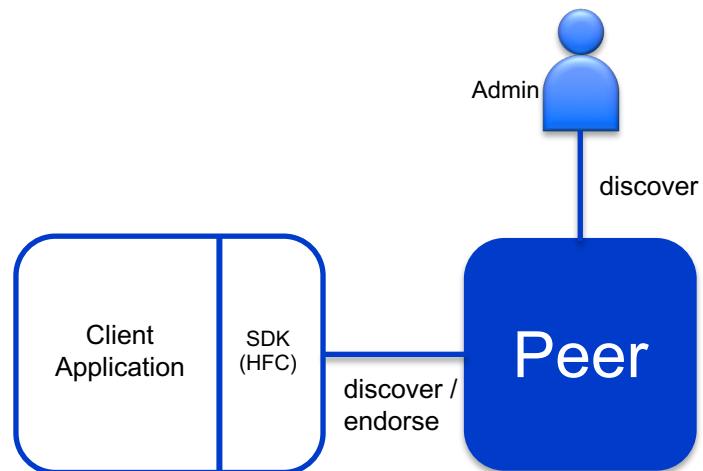




Service Discovery

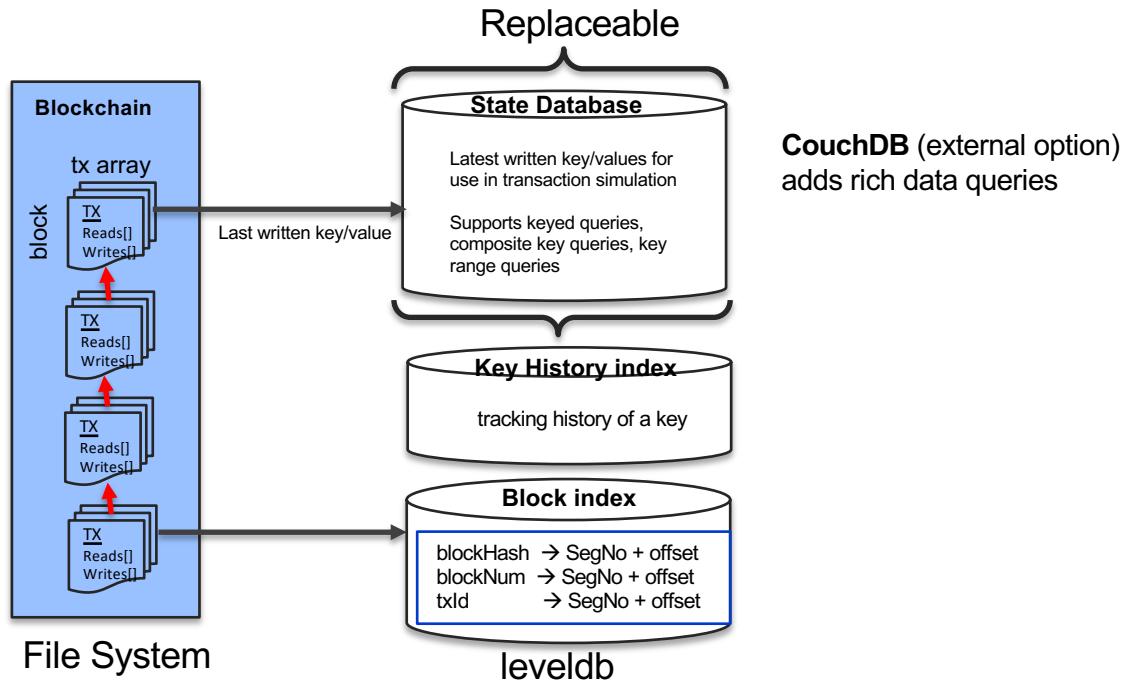
Dynamically query peers to discover network service information

- Network metadata is shared between peers over GOSSIP
- Peers dynamically compute the following:
 - Configuration : MSP for all orgs in a channel
 - Peers : Peers that have joined a channel
 - Endorsers : Endorses for a specific channel/chaincode
- SDK sends dynamic query to peer to establish service connection information (including: endorsement policy, peers endpoints, TLS, CA and orderer endpoints).
- Administrator uses **discover** CLI to discover service information

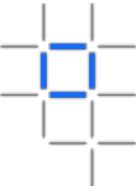




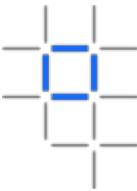
More ledger legerdemain



Fabric Commands

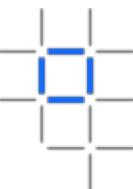


- Fabric has the following commands:
 - **peer** ... (For operating and configuring a peer)
 - **peer chaincode** ... (Manages chaincode on the peer)
 - **peer channel** ... (Manages channels on the peer)
 - **peer node** ... (Manages the peer)
 - **peer version** (Returns the peer version)
 - **cryptogen** ... (Utility for generating crypto material)
 - **configtxgen** ... (Creates configuration data such as the genesis block)
 - **configtxlator** ... (Utility for generating channel configurations)
 - **fabric-ca-client** ... (Manages identities)
 - **fabric-ca-server** ... (Manages the Fabric-CA server)

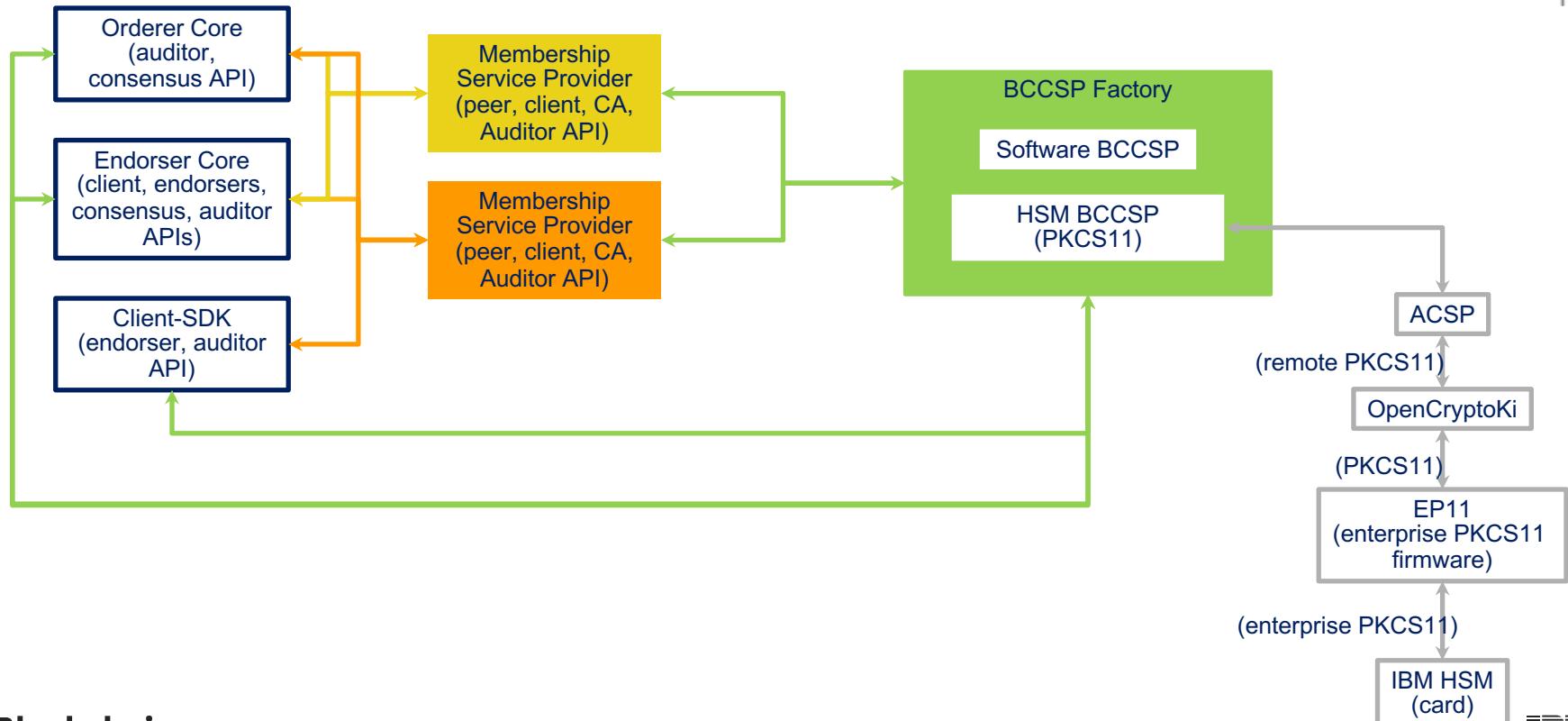


Configuration Detail

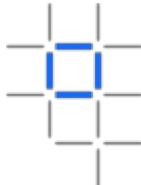
Path	MSP ID	Attributes	Attributes
config -> channel_group -> groups -> application -> groups	Org1MSP	mod_policy	Admins
		policies -> Admins	mod_policy
			Admins
		policy -> value -> identities	Org1MSP, Admin
		Policy -> value -> rule	n_out_of
	Policies -> Readers	Mod_policy	Admins
		Policy -> value -> identities	Org1MSP
		Policy -> value -> rule	N_out_of
	Policies -> Writers	Mod_policy	Admins
		Policy -> value -> identities	Org1MSP
		Policy -> value -> rule	N_out_of



MSP and BCCSP (Modularity and Decentralisation)



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

Thank you

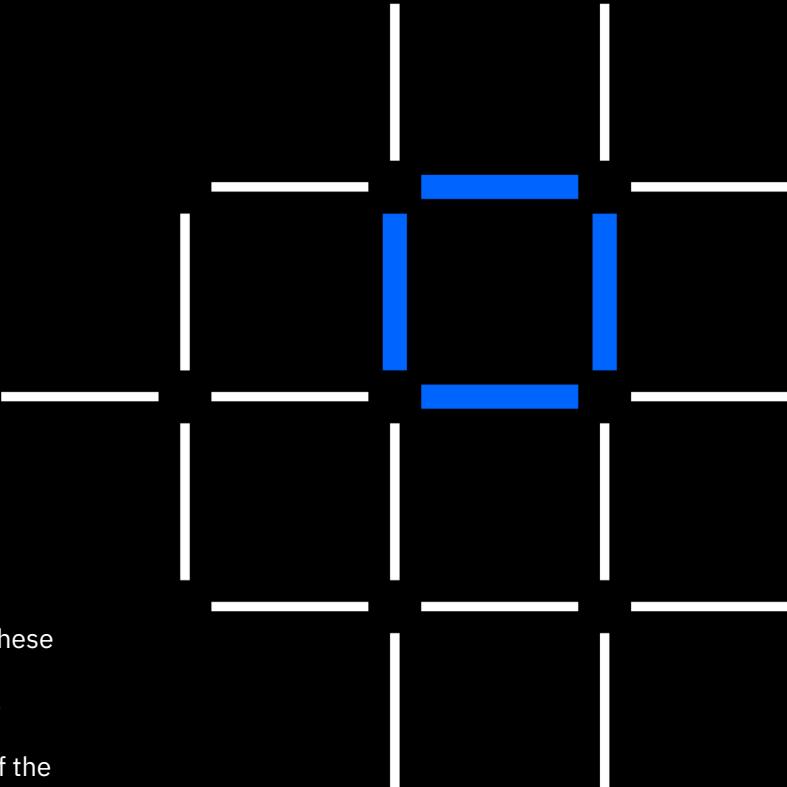
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IBM Blockchain

www.ibm.com/blockchain

developer.ibm.com/blockchain

www.hyperledger.org



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