hyperledger-fabricdocs Documentation

Release master

hyperledger

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Hyperledger Fabric is a platform for distributed ledger solutions, underpinned by a modular architecture delivering high degrees of confidentiality, resiliency, flexibility and scalability. It is designed to support pluggable implementations of different components, and accommodate the complexity and intricacies that exist across the economic ecosystem.

Hyperledger Fabric delivers a uniquely elastic and extensible architecture, distinguishing it from alternative blockchain solutions. Planning for the future of enterprise blockchain requires building on top of a fully-vetted, open source architecture; Hyperledger Fabric is your starting point.

It's recommended for first-time users to begin by going through the *Getting Started* section in order to gain familiarity with the Hyperledger Fabric components and the basic transaction flow. Once comfortable, continue exploring the library for demos, technical specifications, APIs, etc.

Note: If you have questions not addressed by this documentation, or run into issues with any of the tutorials, please visit the *Still Have Questions?* page for some tips on where to find additional help.

Before diving in, watch how Hyperledger Fabric is Building a Blockchain for Business:

CHAPTER 1

Prerequisites

Install cURL

Download the latest version of the cURL tool if it is not already installed or if you get errors running the curl commands from the documentation.

Note: If you're on Windows please see the specific note on *Windows extras* below.

Docker and Docker Compose

You will need the following installed on the platform on which you will be operating, or developing on (or for), Hyperledger Fabric:

- MacOSX, *nix, or Windows 10: Docker Docker version 17.03.0-ce or greater is required.
- Older versions of Windows: Docker Toolbox - again, Docker version Docker 17.03.0-ce or greater is required.

You can check the version of Docker you have installed with the following command from a terminal prompt:

```
docker --version
```

Note: Installing Docker for Mac or Windows, or Docker Toolbox will also install Docker Compose. If you already had Docker installed, you should check that you have Docker Compose version 1.8 or greater installed. If not, we recommend that you install a more recent version of Docker.

You can check the version of Docker Compose you have installed with the following command from a terminal prompt:

```
docker-compose --version
```

Go Programming Language

Hyperledger Fabric uses the Go programming language 1.7.x for many of its components.

Given that we are writing a Go chaincode program, we need to be sure that the source code is located somewhere within the `$GOPATH` tree. First, you will need to check that you have set your `$GOPATH` environment variable.

```
echo $GOPATH
/Users/xxx/go
```

If nothing is displayed when you echo `$GOPATH` , you will need to set it. Typically, the value will be a directory tree child of your development workspace, if you have one, or as a child of your $HOME directory. Since we'll be doing a bunch of coding in Go, you might want to add the following to your `~/.bashrc` :

```
export GOPATH=$HOME/go
export PATH=$PATH:$GOPATH/bin
```

Node.js Runtime and NPM

If you will be developing applications for Hyperledger Fabric leveraging the Hyperledger Fabric SDK for Node.js, you will need to have version 6.9.x of Node.js installed.

Note: Node.js version 7.x is not supported at this time.

- Node.js - version 6.9.x or greater

Note: Installing Node.js will also install NPM, however it is recommended that you confirm the version of NPM installed. You can upgrade the `npm` tool with the following command:

```
npm install npm@3.10.10 -g
```

Windows extras

If you are developing on Windows, you will want to work within the Docker Quickstart Terminal which provides a better alternative to the built-in Windows such as Git Bash which you typically get as part of installing Docker Toolbox on Windows 7.

However experience has shown this to be a poor development environment with limited functionality. It is suitable to run Docker based scenarios, such as *Getting Started*, but you may have difficulties with operations involving the `make` command.

Before running any `git clone` commands, run the following commands:

```
git config --global core.autocrlf false
git config --global core.longpaths true
```

You can check the setting of these parameters with the following commands:

```
git config --get core.autocrlf
git config --get core.longpaths
```

These need to be `false` and `true` respectively.

The `curl` command that comes with Git and Docker Toolbox is old and does not handle properly the redirect used in *Getting Started*. Make sure you install and use a newer version from the cURL downloads page

For Node.js you also need the necessary Visual Studio C++ Build Tools which are freely available and can be installed with the following command:

```
npm install --global windows-build-tools
```

See the NPM windows-build-tools page for more details.

Once this is done, you should also install the NPM GRPC module with the following command:

```
npm install --global grpc
```

Your environment should now be ready to go through the *Getting Started* samples and tutorials.

Note: If you have questions not addressed by this documentation, or run into issues with any of the tutorials, please visit the *Still Have Questions?* page for some tips on where to find additional help.

CHAPTER 2

Getting Started

Install Prerequisites

Before we begin, if you haven't already done so, you may wish to check that you have all the *Prerequisites* installed on the platform(s) on which you'll be developing blockchain applications and/or operating Hyperledger Fabric.

Install Binaries and Docker Images

While we work on developing real installers for the Hyperledger Fabric binaries, we provide a script that will *Download Platform-specific Binaries* to your system. The script also will download the Docker images to your local registry.

Hyperledger Fabric Samples

We offer a set of sample applications that you may wish to install these *Hyperledger Fabric Samples* before starting with the tutorials as the tutorials leverage the sample code.

API Documentation

The API documentation for Hyperledger Fabric's Golang APIs can be found on the godoc site for Fabric. If you plan on doing any development using these APIs, you may want to bookmark those links now.

Hyperledger Fabric SDKs

Hyperledger Fabric intends to offer a number of SDKs for a wide variety of programming languages. The first two delivered SDKs are the Node.js and Java SDKs. We hope to provide Python and Go SDKs soon after the 1.0.0 release.

- Hyperledger Fabric Node SDK documentation.
- Hyperledger Fabric Java SDK documentation.

Hyperledger Fabric CA

Hyperledger Fabric provides an optional certificate authority service that you may choose to use to generate the certificates and key material to configure and manage identity in your blockchain network. However, any CA that can generate ECDSA certificates may be used.

Tutorials

We offer four initial tutorials to get you started with Hyperledger Fabric. The first is oriented to the Hyperledger Fabric **application developer**, *Writing Your First Application*. It takes you through the process of writing your first blockchain application for Hyperledger Fabric using the Hyperledger Fabric Node SDK.

The second tutorial is oriented towards the Hyperledger Fabric network operators, *Building Your First Network*. This one walks you through the process of establishing a blockchain network using Hyperledger Fabric and provides a basic sample application to test it out.

Finally, we offer two chaincode tutorials. One oriented to developers, *Chaincode for Developers*, and the other oriented to operators, *Chaincode for Operators*.

..note:: If you have questions not addressed by this documentation, or run into issues with any of the tutorials, please visit the *Still Have Questions?* page for some tips on where to find additional help.

CHAPTER 3

Hyperledger Fabric Samples

Note: If you are running on **Windows** you will want to make use of the Docker Quickstart Terminal for the upcoming terminal commands. Please visit the *Prerequisites* if you haven't previously installed it.

If you are using Docker Toolbox on Windows 7 or macOS, you will need to use a location under `C:\Users` (Windows 7) or `/Users` (macOS) when installing and running the samples.

If you are using Docker for Mac, you will need to use a location under `/Users` , `/Volumes` , `/private` , or `/tmp` . To use a different location, please consult the Docker documentation for file sharing.

If you are using Docker for Windows, please consult the Docker documentation for shared drives and use a location under one of the shared drives.

Determine a location on your machine where you want to place the Hyperledger Fabric samples applications repository and open that in a terminal window. Then, execute the following commands:

```
git clone https://github.com/hyperledger/fabric-samples.git
cd fabric-samples
```

Download Platform-specific Binaries

Next, we will install the Hyperledger Fabric platform-specific binaries. This process was designed to complement the Hyperledger Fabric Samples above, but can be used independently. If you are not installing the samples above, then simply create and enter a directory into which to extract the contents of the platform-specific binaries.

Please execute the following command from within the directory into which you will extract the platform-specific binaries:

```
curl -sSL https://goo.gl/iX9dek | bash
```

Note: If you get an error running the above curl command, you may have too old a version of curl. Please visit the *Prerequisites* page for additional information on where to find the latest version.

The curl command above downloads and executes a bash script that will download and extract all of the platform-specific binaries you will need to set up your network and place them into the cloned repo you created above. It retrieves four platform-specific binaries:

- `cryptogen` ,

- `configtxgen`,
- `configtxlator`, and
- `peer`

and places them in the `bin` sub-directory of the current working directory.

You may want to add that to your PATH environment variable so that these can be picked up without fully qualifying the path to each binary. e.g.:

```
export PATH=<path to download location>/bin:$PATH
```

Finally, the script will download the Hyperledger Fabric docker images from Docker Hub into your local Docker registry and tag them as 'latest'.

The script lists out the Docker images installed upon conclusion.

Look at the names for each image; these are the components that will ultimately comprise our Hyperledger Fabric network. You will also notice that you have two instances of the same image ID - one tagged as "x86_64-1.0.0" and one tagged as "latest".

Note: On different architectures, the x86_64 would be replaced with the string identifying your architecture.

Note: If you have questions not addressed by this documentation, or run into issues with any of the tutorials, please visit the *Still Have Questions?* page for some tips on where to find additional help.

CHAPTER 4

Introduction

Hyperledger Fabric is a platform for distributed ledger solutions underpinned by a modular architecture delivering high degrees of confidentiality, resiliency, flexibility and scalability. It is designed to support pluggable implementations of different components and accommodate the complexity and intricacies that exist across the economic ecosystem.

Hyperledger Fabric delivers a uniquely elastic and extensible architecture, distinguishing it from alternative blockchain solutions. Planning for the future of enterprise blockchain requires building on top of a fully vetted, open-source architecture; Hyperledger Fabric is your starting point.

We recommended first-time users begin by going through the rest of the introduction below in order to gain familiarity with how blockchains work and with the specific features and components of Hyperledger Fabric.

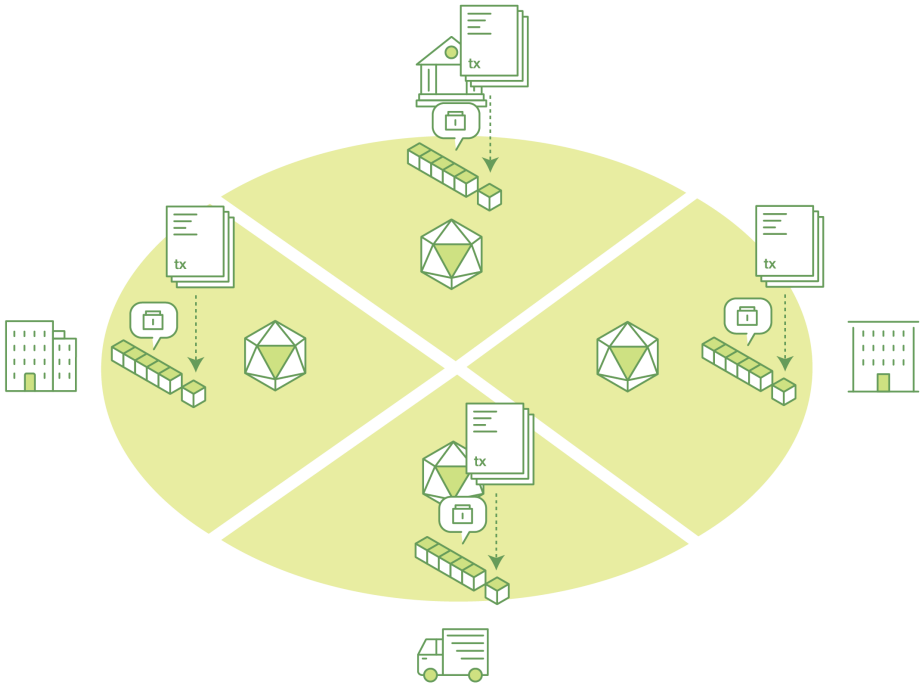
Once comfortable – or if you're already familiar with blockchain and Hyperledger Fabric – go to *Getting Started* and from there explore the demos, technical specifications, APIs, etc.

What is a Blockchain?

A Distributed Ledger

At the heart of a blockchain network is a distributed ledger that records all the transactions that take place on the network.

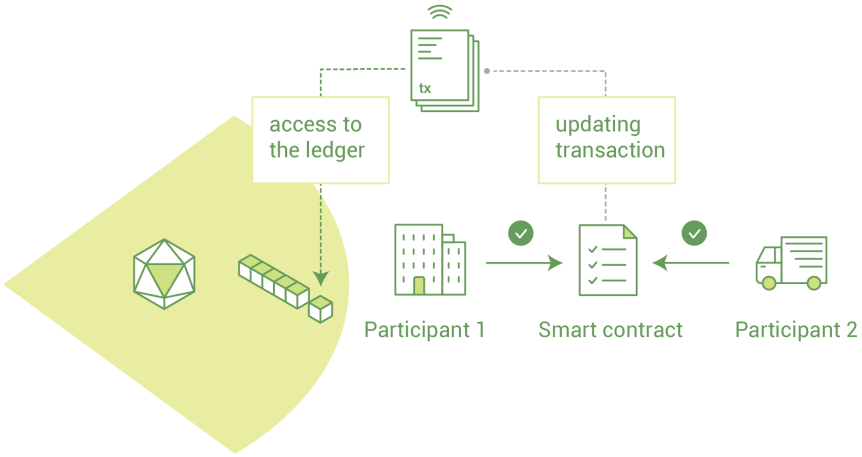
A blockchain ledger is often described as **decentralized** because it is replicated across many network participants, each of whom **collaborate** in its maintenance. We'll see that decentralization and collaboration are powerful attributes that mirror the way businesses exchange goods and services in the real world.



In addition to being decentralized and collaborative, the information recorded to a blockchain is append-only, using cryptographic techniques that guarantee that once a transaction has been added to the ledger it cannot be modified. This property of immutability makes it simple to determine the provenance of information because participants can be sure information has not been changed after the fact. It's why blockchains are sometimes described as **systems of proof**.

Smart Contracts

To support the consistent update of information – and to enable a whole host of ledger functions (transacting, querying, etc) – a blockchain network uses **smart contracts** to provide controlled access to the ledger.

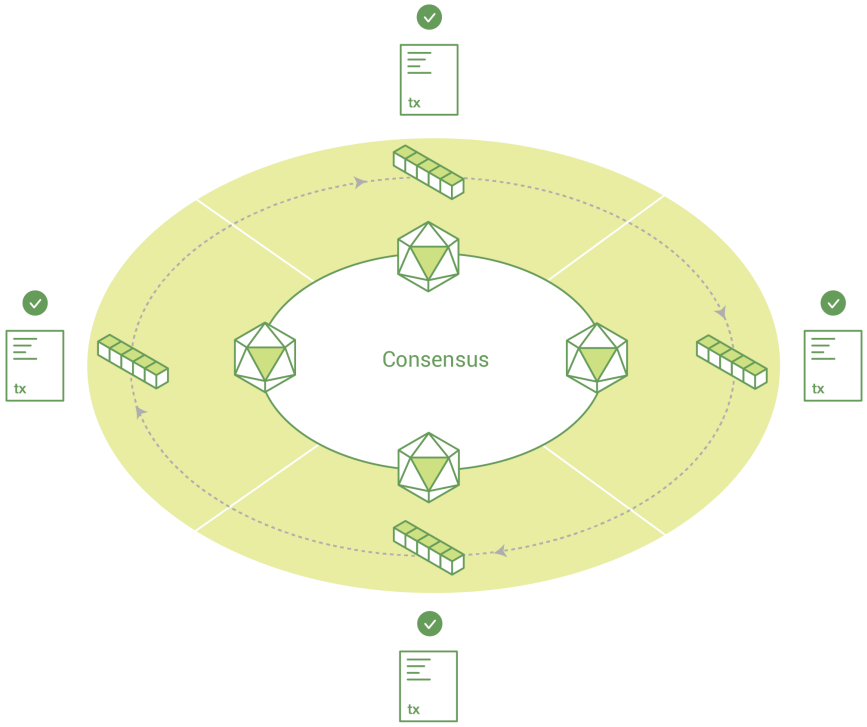


Smart contracts are not only a key mechanism for encapsulating information and keeping it simple across the network, they can also be written to allow participants to execute certain aspects of transactions automatically.

A smart contract can, for example, be written to stipulate the cost of shipping an item that changes depending on when it arrives. With the terms agreed to by both parties and written to the ledger, the appropriate funds change hands automatically when the item is received.

Consensus

The process of keeping the ledger transactions synchronized across the network – to ensure that ledgers only update when transactions are approved by the appropriate participants, and that when ledgers do update, they update with the same transactions in the same order – is called **consensus**.



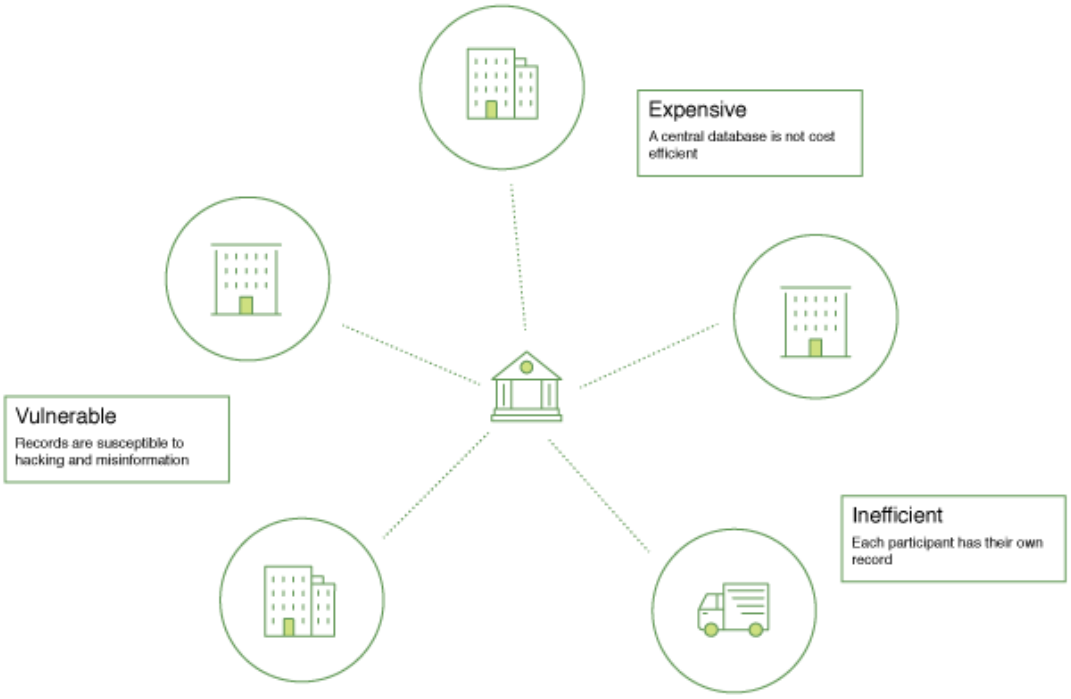
We'll learn a lot more about ledgers, smart contracts and consensus later. For now, it's enough to think of a blockchain as a shared, replicated transaction system which is updated via smart contracts and kept consistently synchronized through a collaborative process called consensus.

Why is a Blockchain useful?

Today's Systems of Record

The transactional networks of today are little more than slightly updated versions of networks that have existed since business records have been kept. The members of a **Business Network** transact with each other, but they maintain separate records of their transactions. And the things they're transacting – whether it's Flemish tapestries in the 16th century or the securities of today – must have their provenance established each time they're sold to ensure that the business selling an item possesses a chain of title verifying their ownership of it.

What you're left with is a business network that looks like this:



Modern technology has taken this process from stone tablets and paper folders to hard drives and cloud platforms, but the underlying structure is the same. Unified systems for managing the identity of network participants do not exist, establishing provenance is so laborious it takes days to clear securities transactions (the world volume of which is numbered in the many trillions of dollars), contracts must be signed and executed manually, and every database in the system contains unique information and therefore represents a single point of failure.

It's impossible with today's fractured approach to information and process sharing to build a system of record that spans a business network, even though the needs of visibility and trust are clear.

The Blockchain Difference

What if instead of the rat's nest of inefficiencies represented by the "modern" system of transactions, business networks had standard methods for establishing identity on the network, executing transactions, and storing data? What if establishing the provenance of an asset could be determined by looking through a list of transactions that, once written, cannot be changed, and can therefore be trusted?

That business network would look more like this:

This is a blockchain network. Every participant in it has their own replicated copy of the ledger. In addition to ledger information being shared, the processes which update the ledger are also shared. Unlike today's systems, where a participant's **private** programs are used to update their **private** ledgers, a blockchain system has **shared** programs to update **shared** ledgers.

With the ability to coordinate their business network through a shared ledger, blockchain networks can reduce the time, cost, and risk associated with private information and processing while improving trust and visibility.

You now know what blockchain is and why it's useful. There are a lot of other details that are important, but they all relate to these fundamental ideas of the sharing of information and processes.

What is Hyperledger Fabric?

The Linux Foundation founded Hyperledger in 2015 to advance cross-industry blockchain technologies. Rather than declaring a single blockchain standard, it encourages a collaborative approach to developing blockchain technologies via a community process, with intellectual property rights that encourage open development and the adoption of key standards over time.

Hyperledger Fabric is a one of the blockchain projects within Hyperledger. Like other blockchain technologies, it has a ledger, uses smart contracts, and is a system by which participants manage their transactions.

Where Hyperledger Fabric breaks from some other blockchain systems is that it is **private** and **permissioned**. Rather than the "proof of work" some blockchain networks use to verify identity (allowing anyone who meets those criteria to join the network), the members of a Hyperledger Fabric network enroll through a **membership services provider**.

Hyperledger Fabric also offers several pluggable options. Ledger data can be stored in multiple formats, consensus mechanisms can be switched in and out, and different MSPs are supported.

Hyperledger Fabric also offers the ability to create **channels**, allowing a group of participants to create a separate ledger of transactions. This is an especially important option for networks where some participants might be competitors and not want every transaction they make - a special price they're offering to some participants and not others, for example - known to every participant. If two participants form a channel, then those participants – and no others – have copies of the ledger for that channel.

Shared Ledger

Hyperledger Fabric has a ledger subsystem comprising two components: the **world state** and the **transaction log**. Each participant has a copy of the ledger to every Hyperledger Fabric network they belong to.

The world state component describes the state of the ledger at a given point in time. It's the database of the ledger. The transaction log component records all transactions which have resulted in the current value of the world state. It's the update history for the world state. The ledger, then, is a combination of the world state database and the transaction log history.

The ledger has a replaceable data store for the world state. By default, this is a LevelDB key-value store database. The transaction log does not need to be pluggable. It simply records the before and after values of the ledger database being used by the blockchain network.

Smart Contracts

Hyperledger Fabric smart contracts are written in **chaincode** and are invoked by an application external to the blockchain when that application needs to interact with the ledger. In most cases chaincode only interacts with the database component of the ledger, the world state (querying it, for example), and not the transaction log.

Chaincode can be implemented in several programming languages. The currently supported chaincode language is Go with support for Java and other languages coming in future releases.

Privacy

Depending on the needs of a network, participants in a Business-to-Business (B2B) network might be extremely sensitive about how much information they share. For other networks, privacy will not be a top concern.

Hyperledger Fabric supports networks where privacy (using channels) is a key operational requirement as well as networks that are comparatively open.

Consensus

Transactions must be written to the ledger in the order in which they occur, even though they might be between different sets of participants within the network. For this to happen, the order of transactions must be established and a method for rejecting bad transactions that have been inserted into the ledger in error (or maliciously) must be put into place.

This is a thoroughly researched area of computer science, and there are many ways to achieve it, each with different trade-offs. For example, PBFT (Practical Byzantine Fault Tolerance) can provide a mechanism for file replicas to communicate with each other to keep each copy consistent, even in the event of corruption. Alternatively, in Bitcoin, ordering happens through a process called mining where competing computers race to solve a cryptographic puzzle which defines the order that all processes subsequently build upon.

Hyperledger Fabric has been designed to allow network starters to choose a consensus mechanism that best represents the relationships that exist between participants. As with privacy, there is a spectrum of needs; from networks that are highly structured in their relationships to those that are more peer-to-peer.

We'll learn more about the Hyperledger Fabric consensus mechanisms, which currently include SOLO, Kafka, and will soon extend to SBFT (Simplified Byzantine Fault Tolerance), in another document.

Where can I learn more?

Getting Started

We provide a number of tutorials where you'll be introduced to most of the key components within a blockchain network, learn more about how they interact with each other, and then you'll actually get the code and run some simple transactions against a running blockchain network. We also provide tutorials for those of you thinking of operating a blockchain network using Hyperledger Fabric.

Hyperledger Fabric Model

A deeper look at the components and concepts brought up in this introduction as well as a few others and describes how they work together in a sample transaction flow.

CHAPTER 5

Hyperledger Fabric Capabilities

Hyperledger Fabric is a unique implementation of distributed ledger technology (DLT) that delivers enterprise-ready network security, scalability, confidentiality and performance, in a modular blockchain architecture. Hyperledger Fabric delivers the following blockchain network capabilities:

Identity management

To enable permissioned networks, Hyperledger Fabric provides a membership identity service that manages user IDs and authenticates all participants on the network. Access control lists can be used to provide additional layers of permission through authorization of specific network operations. For example, a specific user ID could be permitted to invoke a chaincode application, but blocked from deploying new chaincode. One truism about Hyperledger Fabric networks is that members know each other (identity), but they do not know what each other are doing (privacy and confidentiality).

Privacy and confidentiality

Hyperledger Fabric enables competing business interests, and any groups that require private, confidential transactions, to coexist on the same permissioned network. Private **channels** are restricted messaging paths that can be used to provide transaction privacy and confidentiality for specific subsets of network members. All data, including transaction, member and channel information, on a channel are invisible and inaccessible to any network members not explicitly granted access to that channel.

Efficient processing

Hyperledger Fabric assigns network roles by node type. To provide concurrency and parallelism to the network, transaction execution is separated from transaction ordering and commitment. Executing transactions prior to ordering them enables each peer node to process multiple transactions simultaneously. This concurrent execution increases processing efficiency on each peer and accelerates delivery of transactions to the ordering service.

In addition to enabling parallel processing, the division of labor unburdens ordering nodes from the demands of transaction execution and ledger maintenance, while peer nodes are freed from ordering (consensus) workloads. This bifurcation of roles also limits the processing required for authorization and authentication; all peer nodes do not have to trust all ordering nodes, and vice versa, so processes on one can run independently of verification by the other.

Chaincode functionality

Chaincode applications encode logic that is invoked by specific types of transactions on the channel. Chaincode that defines parameters for a change of asset ownership, for example, ensures that all transactions that transfer ownership are subject to the same rules and requirements. **System chaincode** is distinguished as chaincode that defines operating parameters for the entire channel. Lifecycle and configuration system chaincode defines the rules for the channel; endorsement and validation system chaincode defines the requirements for endorsing and validating transactions.

Modular design

Hyperledger Fabric implements a modular architecture to provide functional choice to network designers. Specific algorithms for identity, ordering (consensus) and encryption, for example, can be plugged in to any Hyperledger Fabric network. The result is a universal blockchain architecture that any industry or public domain can adopt, with the assurance that its networks will be interoperable across market, regulatory and geographic boundaries. By contrast, current alternatives to Hyperledger Fabric are largely partisan, constrained and industry-specific.

CHAPTER 6

Hyperledger Fabric Model

This section outlines the key design features woven into Hyperledger Fabric that fulfill its promise of a comprehensive, yet customizable, enterprise blockchain solution:

- *Assets* - Asset definitions enable the exchange of almost anything with monetary value over the network, from whole foods to antique cars to currency futures.
- *Chaincode* - Chaincode execution is partitioned from transaction ordering, limiting the required levels of trust and verification across node types, and optimizing network scalability and performance.
- *Ledger Features* - The immutable, shared ledger encodes the entire transaction history for each channel, and includes SQL-like query capability for efficient auditing and dispute resolution.
- *Privacy through Channels* - Channels enable multi-lateral transactions with the high degrees of privacy and confidentiality required by competing businesses and regulated industries that exchange assets on a common network.
- *Security & Membership Services* - Permissioned membership provides a trusted blockchain network, where participants know that all transactions can be detected and traced by authorized regulators and auditors.
- *Consensus* - a unique approach to consensus enables the flexibility and scalability needed for the enterprise.

Assets

Assets can range from the tangible (real estate and hardware) to the intangible (contracts and intellectual property). Hyperledger Fabric provides the ability to modify assets using chaincode transactions.

Assets are represented in Hyperledger Fabric as a collection of key-value pairs, with state changes recorded as transactions on a *Channel* ledger. Assets can be represented in binary and/or JSON form.

You can easily define and use assets in your Hyperledger Fabric applications using the Hyperledger Composer tool.

Chaincode

Chaincode is software defining an asset or assets, and the transaction instructions for modifying the asset(s). In other words, it's the business logic. Chaincode enforces the rules for reading or altering key value pairs or other state database information. Chaincode functions execute against the ledger current state database and are initiated through a transaction proposal. Chaincode execution results in a set of key value writes (write set) that can be submitted to the network and applied to the ledger on all peers.

Ledger Features

The ledger is the sequenced, tamper-resistant record of all state transitions in the fabric. State transitions are a result of chaincode invocations ('transactions') submitted by participating parties. Each transaction results in a set of asset key-value pairs that are committed to the ledger as creates, updates, or deletes.

The ledger is comprised of a blockchain ('chain') to store the immutable, sequenced record in blocks, as well as a state database to maintain current fabric state. There is one ledger per channel. Each peer maintains a copy of the ledger for each channel of which they are a member.

- Query and update ledger using key-based lookups, range queries, and composite key queries
- Read-only queries using a rich query language (if using CouchDB as state database)
- Read-only history queries - Query ledger history for a key, enabling data provenance scenarios
- Transactions consist of the versions of keys/values that were read in chaincode (read set) and keys/values that were written in chaincode (write set)
- Transactions contain signatures of every endorsing peer and are submitted to ordering service
- Transactions are ordered into blocks and are "delivered" from an ordering service to peers on a channel
- Peers validate transactions against endorsement policies and enforce the policies
- Prior to appending a block, a versioning check is performed to ensure that states for assets that were read have not changed since chaincode execution time
- There is immutability once a transaction is validated and committed
- A channel's ledger contains a configuration block defining policies, access control lists, and other pertinent information
- Channel's contain *Membership Service Provider* instances allowing for crypto materials to be derived from different certificate authorities

See the *Ledger* topic for a deeper dive on the databases, storage structure, and "query-ability."

Privacy through Channels

Hyperledger Fabric employs an immutable ledger on a per-channel basis, as well as chaincodes that can manipulate and modify the current state of assets (i.e. update key value pairs). A ledger exists in the scope of a channel - it can be shared across the entire network (assuming every participant is operating on one common channel) - or it can be privatized to only include a specific set of participants.

In the latter scenario, these participants would create a separate channel and thereby isolate/segregate their transactions and ledger. In order to solve scenarios that want to bridge the gap between total transparency and privacy, chaincode can be installed only on peers that need to access the asset states to perform reads and writes (in other words, if a chaincode is not installed on a peer, it will not be able to properly interface with the ledger). To further obfuscate the data, values within chaincode can be encrypted (in part or in total) using common cryptographic algorithms such as AES before appending to the ledger.

Security & Membership Services

Hyperledger Fabric underpins a transactional network where all participants have known identities. Public Key Infrastructure is used to generate cryptographic certificates which are tied to organizations, network components, and end users or client applications. As a result, data access control can be manipulated and governed on the broader network

and on channel levels. This "permissioned" notion of Hyperledger Fabric, coupled with the existence and capabilities of channels, helps address scenarios where privacy and confidentiality are paramount concerns.

See the *Membership Service Providers (MSP)* topic to better understand cryptographic implementations, and the sign, verify, authenticate approach used in Hyperledger Fabric.

Consensus

In distributed ledger technology, consensus has recently become synonymous with a specific algorithm, within a single function. However, consensus encompasses more than simply agreeing upon the order of transactions, and this differentiation is highlighted in Hyperledger Fabric through its fundamental role in the entire transaction flow, from proposal and endorsement, to ordering, validation and commitment. In a nutshell, consensus is defined as the full-circle verification of the correctness of a set of transactions comprising a block.

Consensus is ultimately achieved when the order and results of a block's transactions have met the explicit policy criteria checks. These checks and balances take place during the lifecycle of a transaction, and include the usage of endorsement policies to dictate which specific members must endorse a certain transaction class, as well as system chaincodes to ensure that these policies are enforced and upheld. Prior to commitment, the peers will employ these system chaincodes to make sure that enough endorsements are present, and that they were derived from the appropriate entities. Moreover, a versioning check will take place during which the current state of the ledger is agreed or consented upon, before any blocks containing transactions are appended to the ledger. This final check provides protection against double spend operations and other threats that might compromise data integrity, and allows for functions to be executed against non-static variables.

In addition to the multitude of endorsement, validity and versioning checks that take place, there are also ongoing identity verifications happening in all directions of the transaction flow. Access control lists are implemented on hierarchal layers of the network (ordering service down to channels), and payloads are repeatedly signed, verified and authenticated as a transaction proposal passes through the different architectural components. To conclude, consensus is not merely limited to the agreed upon order of a batch of transactions, but rather, it is an overarching characterization that is achieved as a byproduct of the ongoing verifications that take place during a transaction's journey from proposal to commitment.

Check out the *Transaction Flow* diagram for a visual representation of consensus.

CHAPTER 7

Use Cases

The Hyperledger Requirements WG is documenting a number of blockchain use cases and maintaining an inventory here.

CHAPTER 8

Building Your First Network

Note: These instructions have been verified to work against the version "1.0.0" tagged Docker images and the pre-compiled setup utilities within the supplied tar file. If you run these commands with images or tools from the current master branch, it is possible that you will see configuration and panic errors.

The build your first network (BYFN) scenario provisions a sample Hyperledger Fabric network consisting of two organizations, each maintaining two peer nodes, and a "solo" ordering service.

Install prerequisites

Before we begin, if you haven't already done so, you may wish to check that you have all the *Prerequisites* installed on the platform(s) on which you'll be developing blockchain applications and/or operating Hyperledger Fabric.

You will also need to download and install the *Hyperledger Fabric Samples*. You will notice that there are a number of samples included in the `fabric-samples` repository. We will be using the `first-network` sample. Let's open that sub-directory now.

```
cd first-network
```

Note: The supplied commands in this documentation **MUST** be run from your `first-network` sub-directory of the `fabric-samples` repository clone. If you elect to run the commands from a different location, the various provided scripts will be unable to find the binaries.

Want to run it now?

We provide a fully annotated script - `byfn.sh` - that leverages these Docker images to quickly bootstrap a Hyperledger Fabric network comprised of 4 peers representing two different organizations, and an orderer node. It will also launch a container to run a scripted execution that will join peers to a channel, deploy and instantiate chaincode and drive execution of transactions against the deployed chaincode.

Here's the help text for the `byfn.sh` script:

```
./byfn.sh -h
Usage:
  byfn.sh -m up|down|restart|generate [-c <channel name>] [-t <timeout>]
```

```
  byfn.sh -h|--help (print this message)
    -m <mode> - one of 'up', 'down', 'restart' or 'generate'
      - 'up' - bring up the network with docker-compose up
      - 'down' - clear the network with docker-compose down
      - 'restart' - restart the network
      - 'generate' - generate required certificates and genesis block
    -c <channel name> - config name to use (defaults to "mychannel")
    -t <timeout> - CLI timeout duration in microseconds (defaults to 10000)

Typically, one would first generate the required certificates and
genesis block, then bring up the network. e.g.:

  byfn.sh -m generate -c <channelname>
  byfn.sh -m up -c <channelname>
```

If you choose not to supply a channel name, then the script will use a default name of `mychannel` . The CLI timeout parameter (specified with the -t flag) is an optional value; if you choose not to set it, then your CLI container will exit upon conclusion of the script.

Generate Network Artifacts

Ready to give it a go? Okay then! Execute the following command:

```
./byfn.sh -m generate
```

You will see a brief description as to what will occur, along with a yes/no command line prompt. Respond with a `y` to execute the described action.

```
Generating certs and genesis block for with channel 'mychannel' and CLI timeout of
 ↪'10000'
Continue (y/n)?y
proceeding ...
/Users/xxx/dev/fabric-samples/bin/cryptogen

############################################################
##### Generate certificates using cryptogen tool #########
############################################################
org1.example.com
2017-06-12 21:01:37.334 EDT [bccsp] GetDefault -> WARN 001 Before using BCCSP, please␣
 ↪call InitFactories(). Falling back to bootBCCSP.
...

/Users/xxx/dev/fabric-samples/bin/configtxgen
############################################################
#########  Generating Orderer Genesis block ##############
############################################################
2017-06-12 21:01:37.558 EDT [common/configtx/tool] main -> INFO 001 Loading␣
 ↪configuration
2017-06-12 21:01:37.562 EDT [msp] getMspConfig -> INFO 002 intermediate certs folder␣
 ↪not found at [/Users/xxx/dev/byfn/crypto-config/ordererOrganizations/example.com/
 ↪msp/intermediatecerts]. Skipping.: [stat /Users/xxx/dev/byfn/crypto-config/
 ↪ordererOrganizations/example.com/msp/intermediatecerts: no such file or directory]
...
2017-06-12 21:01:37.588 EDT [common/configtx/tool] doOutputBlock -> INFO 00b␣
 ↪Generating genesis block
2017-06-12 21:01:37.590 EDT [common/configtx/tool] doOutputBlock -> INFO 00c Writing␣
 ↪genesis block
```

```
#################################################################
### Generating channel configuration transaction 'channel.tx' ###
#################################################################
2017-06-12 21:01:37.634 EDT [common/configtx/tool] main -> INFO 001 Loading␣
↪configuration
2017-06-12 21:01:37.644 EDT [common/configtx/tool] doOutputChannelCreateTx -> INFO␣
↪002 Generating new channel configtx
2017-06-12 21:01:37.645 EDT [common/configtx/tool] doOutputChannelCreateTx -> INFO␣
↪003 Writing new channel tx

#################################################################
#######    Generating anchor peer update for Org1MSP   ##########
#################################################################
2017-06-12 21:01:37.674 EDT [common/configtx/tool] main -> INFO 001 Loading␣
↪configuration
2017-06-12 21:01:37.678 EDT [common/configtx/tool] doOutputAnchorPeersUpdate -> INFO␣
↪002 Generating anchor peer update
2017-06-12 21:01:37.679 EDT [common/configtx/tool] doOutputAnchorPeersUpdate -> INFO␣
↪003 Writing anchor peer update

#################################################################
#######    Generating anchor peer update for Org2MSP   ##########
#################################################################
2017-06-12 21:01:37.700 EDT [common/configtx/tool] main -> INFO 001 Loading␣
↪configuration
2017-06-12 21:01:37.704 EDT [common/configtx/tool] doOutputAnchorPeersUpdate -> INFO␣
↪002 Generating anchor peer update
2017-06-12 21:01:37.704 EDT [common/configtx/tool] doOutputAnchorPeersUpdate -> INFO␣
↪003 Writing anchor peer update
```

This first step generates all of the certificates and keys for all our various network entities, the `genesis block` used to bootstrap the ordering service, and a collection of configuration transactions required to configure a *Channel*.

Bring Up the Network

Next, you can bring the network up with the following command:

```
./byfn.sh -m up
```

Once again, you will be prompted as to whether you wish to continue or abort. Respond with a `y` :

```
Starting with channel 'mychannel' and CLI timeout of '10000'
Continue (y/n)?y
proceeding ...
Creating network "net_byfn" with the default driver
Creating peer0.org1.example.com
Creating peer1.org1.example.com
Creating peer0.org2.example.com
Creating orderer.example.com
Creating peer1.org2.example.com
Creating cli


 ____    _____      _      ____    _____
/ ___|  |_   _|    / \    |  _ \  |_   _|
\___ \    | |     / _ \   | |_) |   | |
```

```
 ___) |    | |     / ___ \   |  _ <     | |
|_____/     |_|    /_/   \_\ |_| \_\    |_|

Channel name : mychannel
Creating channel...
```

The logs will continue from there. This will launch all of the containers, and then drive a complete end-to-end application scenario. Upon successful completion, it should report the following in your terminal window:

```
2017-05-16 17:08:01.366 UTC [msp] GetLocalMSP -> DEBU 004 Returning existing local MSP
2017-05-16 17:08:01.366 UTC [msp] GetDefaultSigningIdentity -> DEBU 005 Obtaining␣
↪default signing identity
2017-05-16 17:08:01.366 UTC [msp/identity] Sign -> DEBU 006 Sign: plaintext:␣
↪0AB1070A6708031A0C08F1E3ECC80510...6D7963631A0A0A0571756572790A0161
2017-05-16 17:08:01.367 UTC [msp/identity] Sign -> DEBU 007 Sign: digest:␣
↪E61DB37F4E8B0D32C9FE10E3936BA9B8CD278FAA1F3320B08712164248285C54
Query Result: 90
2017-05-16 17:08:15.158 UTC [main] main -> INFO 008 Exiting.....
===================== Query on PEER3 on channel 'mychannel' is successful␣
↪=====================

===================== All GOOD, BYFN execution completed =====================


 _____   _   _   ____
| ____| | \ | | |  _ \
|  _|   |  \| | | | | |
| |___  | |\  | | |_| |
|_____| |_| \_| |____/
```

You can scroll through these logs to see the various transactions. If you don't get this result, then jump down to the *Troubleshooting* section and let's see whether we can help you discover what went wrong.

Bring Down the Network

Finally, let's bring it all down so we can explore the network setup one step at a time. The following will kill your containers, remove the crypto material and four artifacts, and delete the chaincode images from your Docker Registry:

```
./byfn.sh -m down
```

Once again, you will be prompted to continue, respond with a `y` :

```
Stopping with channel 'mychannel' and CLI timeout of '10000'
Continue (y/n)?y
proceeding ...
WARNING: The CHANNEL_NAME variable is not set. Defaulting to a blank string.
WARNING: The TIMEOUT variable is not set. Defaulting to a blank string.
Removing network net_byfn
468aaa6201ed
...
Untagged: dev-peer1.org2.example.com-mycc-1.0:latest
Deleted: sha256:ed3230614e64e1c83e510c0c282e982d2b06d148b1c498bbdcc429e2b2531e91
...
```

If you'd like to learn more about the underlying tooling and bootstrap mechanics, continue reading. In these next sections we'll walk through the various steps and requirements to build a fully-functional Hyperledger Fabric network.

Crypto Generator

We will use the `cryptogen` tool to generate the cryptographic material (x509 certs) for our various network entities. These certificates are representative of identities, and they allow for sign/verify authentication to take place as our entities communicate and transact.

How does it work?

Cryptogen consumes a file - `crypto-config.yaml` - that contains the network topology and allows us to generate a set of certificates and keys for both the Organizations and the components that belong to those Organizations. Each Organization is provisioned a unique root certificate (`ca-cert`) that binds specific components (peers and orderers) to that Org. By assigning each Organization a unique CA certificate, we are mimicking a typical network where a participating *Member* would use its own Certificate Authority. Transactions and communications within Hyperledger Fabric are signed by an entity's private key (`keystore`), and then verified by means of a public key (`signcerts`).

You will notice a `count` variable within this file. We use this to specify the number of peers per Organization; in our case there are two peers per Org. We won't delve into the minutiae of x.509 certificates and public key infrastructure right now. If you're interested, you can peruse these topics on your own time.

Before running the tool, let's take a quick look at a snippet from the `crypto-config.yaml` . Pay specific attention to the "Name", "Domain" and "Specs" parameters under the `OrdererOrgs` header:

```
OrdererOrgs:
#---------------------------------------------------------
# Orderer
# ---------------------------------------------------------
- Name: Orderer
  Domain: example.com
  # ---------------------------------------------------------
  # "Specs" - See PeerOrgs below for complete description
# ---------------------------------------------------------
  Specs:
    - Hostname: orderer
# ---------------------------------------------------------
# "PeerOrgs" - Definition of organizations managing peer nodes
# ---------------------------------------------------------
PeerOrgs:
# ---------------------------------------------------------
# Org1
# ---------------------------------------------------------
- Name: Org1
  Domain: org1.example.com
```

The naming convention for a network entity is as follows - "{{.Hostname}}.{{.Domain}}". So using our ordering node as a reference point, we are left with an ordering node named - `orderer.example.com` that is tied to an MSP ID of `Orderer` . This file contains extensive documentation on the definitions and syntax. You can also refer to the *Membership Service Providers (MSP)* documentation for a deeper dive on MSP.

After we run the `cryptogen` tool, the generated certificates and keys will be saved to a folder titled `crypto-config` .

Configuration Transaction Generator

The `configtxgen tool` is used to create four configuration artifacts:

- orderer `genesis block`,
- channel `channel configuration transaction`,
- and two `anchor peer transactions` - one for each Peer Org.

Please see *Channel Configuration (configtxgen)* for a complete description of the use of this tool.

The orderer block is the *Genesis Block* for the ordering service, and the channel transaction file is broadcast to the orderer at *Channel* creation time. The anchor peer transactions, as the name might suggest, specify each Org's *Anchor Peer* on this channel.

How does it work?

Configtxgen consumes a file - `configtx.yaml` - that contains the definitions for the sample network. There are three members - one Orderer Org (`OrdererOrg`) and two Peer Orgs (`Org1` & `Org2`) each managing and maintaining two peer nodes. This file also specifies a consortium - `SampleConsortium` - consisting of our two Peer Orgs. Pay specific attention to the "Profiles" section at the top of this file. You will notice that we have two unique headers. One for the orderer genesis block - `TwoOrgsOrdererGenesis` - and one for our channel - `TwoOrgsChannel`.

These headers are important, as we will pass them in as arguments when we create our artifacts.

Note: Notice that our `SampleConsortium` is defined in the system-level profile and then referenced by our channel-level profile. Channels exist within the purview of a consortium, and all consortia must be defined in the scope of the network at large.

This file also contains two additional specifications that are worth noting. Firstly, we specify the anchor peers for each Peer Org (`peer0.org1.example.com` & `peer0.org2.example.com`). Secondly, we point to the location of the MSP directory for each member, in turn allowing us to store the root certificates for each Org in the orderer genesis block. This is a critical concept. Now any network entity communicating with the ordering service can have its digital signature verified.

Run the tools

You can manually generate the certificates/keys and the various configuration artifacts using the `configtxgen` and `cryptogen` commands. Alternately, you could try to adapt the byfn.sh script to accomplish your objectives.

Manually generate the artifacts

You can refer to the `generateCerts` function in the byfn.sh script for the commands necessary to generate the certificates that will be used for your network configuration as defined in the `crypto-config.yaml` file. However, for the sake of convenience, we will also provide a reference here.

First let's run the `cryptogen` tool. Our binary is in the `bin` directory, so we need to provide the relative path to where the tool resides.

```
../bin/cryptogen generate --config=./crypto-config.yaml
```

You will likely see the following warning. It's innocuous, ignore it:

```
[bccsp] GetDefault -> WARN 001 Before using BCCSP, please call InitFactories().␣
↪Falling back to bootBCCSP.
```

Next, we need to tell the `configtxgen` tool where to look for the `configtx.yaml` file that it needs to ingest. We will tell it look in our present working directory:

First, we need to set an environment variable to specify where `configtxgen` should look for the configtx.yaml configuration file:

```
export FABRIC_CFG_PATH=$PWD
```

Then, we'll invoke the `configtxgen` tool which will create the orderer genesis block:

```
../bin/configtxgen -profile TwoOrgsOrdererGenesis -outputBlock ./channel-artifacts/
↪genesis.block
```

You can ignore the log warnings regarding intermediate certificates, certificate revocation lists (crls) and MSP configurations. We are not using any of those in this sample network.

Next, we need to create the channel transaction artifact. Be sure to replace $CHANNEL_NAME or set CHANNEL_NAME as an environment variable that can be used throughout these instructions:

```
export CHANNEL_NAME=mychannel

# this file contains the definitions for our sample channel
../bin/configtxgen -profile TwoOrgsChannel -outputCreateChannelTx ./channel-artifacts/
↪channel.tx -channelID $CHANNEL_NAME
```

Next, we will define the anchor peer for Org1 on the channel that we are constructing. Again, be sure to replace $CHANNEL_NAME or set the environment variable for the following commands:

```
../bin/configtxgen -profile TwoOrgsChannel -outputAnchorPeersUpdate ./channel-
↪artifacts/Org1MSPanchors.tx -channelID $CHANNEL_NAME -asOrg Org1MSP
```

Now, we will define the anchor peer for Org2 on the same channel:

```
../bin/configtxgen -profile TwoOrgsChannel -outputAnchorPeersUpdate ./channel-
↪artifacts/Org2MSPanchors.tx -channelID $CHANNEL_NAME -asOrg Org2MSP
```

Start the network

We will leverage a docker-compose script to spin up our network. The docker-compose file references the images that we have previously downloaded, and bootstraps the orderer with our previously generated `genesis.block`.

```
working_dir: /opt/gopath/src/github.com/hyperledger/fabric/peer
# command: /bin/bash -c './scripts/script.sh ${CHANNEL_NAME}; sleep $TIMEOUT'
volumes
```

If left uncommented, that script will exercise all of the CLI commands when the network is started, as we describe in the *What's happening behind the scenes?* section. However, we want to go through the commands manually in order to expose the syntax and functionality of each call.

Pass in a moderately high value for the `TIMEOUT` variable (specified in seconds); otherwise the CLI container, by default, will exit after 60 seconds.

Start your network:

```
CHANNEL_NAME=$CHANNEL_NAME TIMEOUT=<pick_a_value> docker-compose -f docker-compose-
↪cli.yaml up -d
```

If you want to see the realtime logs for your network, then do not supply the `-d` flag. If you let the logs stream, then you will need to open a second terminal to execute the CLI calls.

Environment variables

For the following CLI commands against `peer0.org1.example.com` to work, we need to preface our commands with the four environment variables given below. These variables for `peer0.org1.example.com` are baked into the CLI container, therefore we can operate without passing them. **HOWEVER**, if you want to send calls to other peers or the orderer, then you will need to provide these values accordingly. Inspect the `docker-compose-base.yaml` for the specific paths:

```
# Environment variables for PEER0

CORE_PEER_MSPCONFIGPATH=/opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
 ↪peerOrganizations/org1.example.com/users/Admin@org1.example.com/msp
CORE_PEER_ADDRESS=peer0.org1.example.com:7051
CORE_PEER_LOCALMSPID="Org1MSP"
CORE_PEER_TLS_ROOTCERT_FILE=/opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
 ↪peerOrganizations/org1.example.com/peers/peer0.org1.example.com/tls/ca.crt
```

Create & Join Channel

We will enter the CLI container using the `docker exec` command:

```
docker exec -it cli bash
```

If successful you should see the following:

```
root@0d78bb69300d:/opt/gopath/src/github.com/hyperledger/fabric/peer#
```

Recall that we used the configtxgen tool to generate a channel configuration artifact - `channel.tx` . We are going to pass in this artifact to the orderer as part of the create channel request.

Note: Notice the `--cafile` that we pass as part of this command. It is the local path to the orderer's root cert, allowing us to verify the TLS handshake.

We specify our channel name with the `-c` flag and our channel configuration transaction with the `-f` flag. In this case it is `channel.tx` , however you can mount your own configuration transaction with a different name.

```
export CHANNEL_NAME=mychannel

# the channel.tx file is mounted in the channel-artifacts directory within your CLI␣
 ↪container
# as a result, we pass the full path for the file
# we also pass the path for the orderer ca-cert in order to verify the TLS handshake
# be sure to replace the $CHANNEL_NAME variable appropriately

peer channel create -o orderer.example.com:7050 -c $CHANNEL_NAME -f ./channel-
 ↪artifacts/channel.tx --tls $CORE_PEER_TLS_ENABLED --cafile /opt/gopath/src/github.
 ↪com/hyperledger/fabric/peer/crypto/ordererOrganizations/example.com/orderers/
 ↪orderer.example.com/msp/tlscacerts/tlsca.example.com-cert.pem
```

This command returns a genesis block - `<channel-ID.block>` - which we will use to join the channel. It contains the configuration information specified in `channel.tx`.

Note: You will remain in the CLI container for the remainder of these manual commands. You must also remember to preface all commands with the corresponding environment variables when targeting a peer other than `peer0.org1.example.com`.

Now let's join `peer0.org1.example.com` to the channel.

```
# By default, this joins ``peer0.org1.example.com`` only
# the <channel-ID.block> was returned by the previous command

 peer channel join -b <channel-ID.block>
```

You can make other peers join the channel as necessary by making appropriate changes in the four environment variables.

Install & Instantiate Chaincode

Note: We will utilize a simple existing chaincode. To learn how to write your own chaincode, see the *Chaincode for Developers* tutorial.

Applications interact with the blockchain ledger through `chaincode`. As such we need to install the chaincode on every peer that will execute and endorse our transactions, and then instantiate the chaincode on the channel.

First, install the sample Go code onto one of the four peer nodes. This command places the source code onto our peer's filesystem.

```
peer chaincode install -n mycc -v 1.0 -p github.com/hyperledger/fabric/examples/
↪chaincode/go/chaincode_example02
```

Next, instantiate the chaincode on the channel. This will initialize the chaincode on the channel, set the endorsement policy for the chaincode, and launch a chaincode container for the targeted peer. Take note of the `-P` argument. This is our policy where we specify the required level of endorsement for a transaction against this chaincode to be validated.

In the command below you'll notice that we specify our policy as `-P "OR ('Org0MSP.member','Org1MSP.member')"`. This means that we need "endorsement" from a peer belonging to Org1 **OR** Org2 (i.e. only one endorsement). If we changed the syntax to `AND` then we would need two endorsements.

```
# be sure to replace the $CHANNEL_NAME environment variable
# if you did not install your chaincode with a name of mycc, then modify that␣
↪argument as well

peer chaincode instantiate -o orderer.example.com:7050 --tls $CORE_PEER_TLS_ENABLED --
↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
↪example.com-cert.pem -C $CHANNEL_NAME -n mycc -v 1.0 -c '{"Args":["init","a", "100
↪", "b","200"]}' -P "OR ('Org1MSP.member','Org2MSP.member')"
```

See the endorsement policies documentation for more details on policy implementation.

Query

Let's query for the value of `a` to make sure the chaincode was properly instantiated and the state DB was populated. The syntax for query is as follows:

```
# be sure to set the -C and -n flags appropriately

peer chaincode query -C $CHANNEL_NAME -n mycc -c '{"Args":["query","a"]}'
```

Invoke

Now let's move `10` from `a` to `b`. This transaction will cut a new block and update the state DB. The syntax for invoke is as follows:

```
# be sure to set the -C and -n flags appropriately

peer chaincode invoke -o orderer.example.com:7050  --tls $CORE_PEER_TLS_ENABLED --
↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
↪example.com-cert.pem  -C $CHANNEL_NAME -n mycc -c '{"Args":["invoke","a","b","10"]}'
```

Query

Let's confirm that our previous invocation executed properly. We initialized the key `a` with a value of `100` and just removed `10` with our previous invocation. Therefore, a query against `a` should reveal `90`. The syntax for query is as follows.

```
# be sure to set the -C and -n flags appropriately

peer chaincode query -C $CHANNEL_NAME -n mycc -c '{"Args":["query","a"]}'
```

We should see the following:

```
Query Result: 90
```

Feel free to start over and manipulate the key value pairs and subsequent invocations.

What's happening behind the scenes?

Note: These steps describe the scenario in which `script.sh` is not commented out in the docker-compose-cli.yaml file. Clean your network with `./byfn.sh -m down` and ensure this command is active. Then use the same docker-compose prompt to launch your network again

- A script - `script.sh` - is baked inside the CLI container. The script drives the `createChannel` command against the supplied channel name and uses the channel.tx file for channel configuration.
- The output of `createChannel` is a genesis block - `<your_channel_name>.block` - which gets stored on the peers' file systems and contains the channel configuration specified from channel.tx.
- The `joinChannel` command is exercised for all four peers, which takes as input the previously generated genesis block. This command instructs the peers to join `<your_channel_name>` and create a chain starting with `<your_channel_name>.block`.

- Now we have a channel consisting of four peers, and two organizations. This is our `TwoOrgsChannel` profile.
- `peer0.org1.example.com` and `peer1.org1.example.com` belong to Org1; `peer0.org2.example.com` and `peer1.org2.example.com` belong to Org2
- These relationships are defined through the `crypto-config.yaml` and the MSP path is specified in our docker compose.
- The anchor peers for Org1MSP (`peer0.org1.example.com`) and Org2MSP (`peer0.org2.example.com`) are then updated. We do this by passing the `Org1MSPanchors.tx` and `Org2MSPanchors.tx` artifacts to the ordering service along with the name of our channel.
- A chaincode - **chaincode_example02** - is installed on `peer0.org1.example.com` and `peer0.org2.example.com`
- The chaincode is then "instantiated" on `peer0.org2.example.com`. Instantiation adds the chaincode to the channel, starts the container for the target peer, and initializes the key value pairs associated with the chaincode. The initial values for this example are ["a","100" "b","200"]. This "instantiation" results in a container by the name of `dev-peer0.org2.example.com-mycc-1.0` starting.
- The instantiation also passes in an argument for the endorsement policy. The policy is defined as `-P "OR ('Org1MSP.member','Org2MSP.member')"`, meaning that any transaction must be endorsed by a peer tied to Org1 or Org2.
- A query against the value of "a" is issued to `peer0.org1.example.com`. The chaincode was previously installed on `peer0.org1.example.com`, so this will start a container for Org1 peer0 by the name of `dev-peer0.org1.example.com-mycc-1.0`. The result of the query is also returned. No write operations have occurred, so a query against "a" will still return a value of "100".
- An invoke is sent to `peer0.org1.example.com` to move "10" from "a" to "b"
- The chaincode is then installed on `peer1.org2.example.com`
- A query is sent to `peer1.org2.example.com` for the value of "a". This starts a third chaincode container by the name of `dev-peer1.org2.example.com-mycc-1.0`. A value of 90 is returned, correctly reflecting the previous transaction during which the value for key "a" was modified by 10.

What does this demonstrate?

Chaincode **MUST** be installed on a peer in order for it to successfully perform read/write operations against the ledger. Furthermore, a chaincode container is not started for a peer until an `init` or traditional transaction - read/write - is performed against that chaincode (e.g. query for the value of "a"). The transaction causes the container to start. Also, all peers in a channel maintain an exact copy of the ledger which comprises the blockchain to store the immutable, sequenced record in blocks, as well as a state database to maintain a snapshot of the current state. This includes those peers that do not have chaincode installed on them (like `peer1.org1.example.com` in the above example). Finally, the chaincode is accessible after it is installed (like `peer1.org2.example.com` in the above example) because it has already been instantiated.

How do I see these transactions?

Check the logs for the CLI Docker container.

```
docker logs -f cli
```

You should see the following output:

```
2017-05-16 17:08:01.366 UTC [msp] GetLocalMSP -> DEBU 004 Returning existing local MSP
2017-05-16 17:08:01.366 UTC [msp] GetDefaultSigningIdentity -> DEBU 005 Obtaining␣
↪default signing identity
2017-05-16 17:08:01.366 UTC [msp/identity] Sign -> DEBU 006 Sign: plaintext:␣
↪0AB1070A6708031A0C08F1E3ECC80510...6D7963631A0A0A0571756572790A0161
2017-05-16 17:08:01.367 UTC [msp/identity] Sign -> DEBU 007 Sign: digest:␣
↪E61DB37F4E8B0D32C9FE10E3936BA9B8CD278FAA1F3320B08712164248285C54
Query Result: 90
2017-05-16 17:08:15.158 UTC [main] main -> INFO 008 Exiting.....
===================== Query on PEER3 on channel 'mychannel' is successful␣
↪=====================

===================== All GOOD, BYFN execution completed =====================


 _____   _   _   ____
| ____| | \ | | |  _ \
|  _|   |  \| | | | | |
| |___  | |\  | | |_| |
|_____| |_| \_| |____/
```

You can scroll through these logs to see the various transactions.

How can I see the chaincode logs?

Inspect the individual chaincode containers to see the separate transactions executed against each container. Here is the combined output from each container:

```
$ docker logs dev-peer0.org2.example.com-mycc-1.0
04:30:45.947 [BCCSP_FACTORY] DEBU : Initialize BCCSP [SW]
ex02 Init
Aval = 100, Bval = 200

$ docker logs dev-peer0.org1.example.com-mycc-1.0
04:31:10.569 [BCCSP_FACTORY] DEBU : Initialize BCCSP [SW]
ex02 Invoke
Query Response:{"Name":"a","Amount":"100"}
ex02 Invoke
Aval = 90, Bval = 210

$ docker logs dev-peer1.org2.example.com-mycc-1.0
04:31:30.420 [BCCSP_FACTORY] DEBU : Initialize BCCSP [SW]
ex02 Invoke
Query Response:{"Name":"a","Amount":"90"}
```

Understanding the Docker Compose topology

The BYFN sample offers us two flavors of Docker Compose files, both of which are extended from the `docker-compose-base.yaml` (located in the `base` folder). Our first flavor, `docker-compose-cli.yaml`, provides us with a CLI container, along with an orderer, four peers. We use this file for the entirety of the instructions on this page.

Note: the remainder of this section covers a docker-compose file designed for the SDK. Refer to the Node SDK repo

for details on running these tests.

The second flavor, `docker-compose-e2e.yaml` , is constructed to run end-to-end tests using the Node.js SDK. Aside from functioning with the SDK, its primary differentiation is that there are containers for the fabric-ca servers. As a result, we are able to send REST calls to the organizational CAs for user registration and enrollment.

If you want to use the `docker-compose-e2e.yaml` without first running the byfn.sh script, then we will need to make four slight modifications. We need to point to the private keys for our Organization's CA's. You can locate these values in your crypto-config folder. For example, to locate the private key for Org1 we would follow this path - `crypto-config/peerOrganizations/org1.example.com/ca/` . The private key is a long hash value followed by `_sk` . The path for Org2 would be - `crypto-config/peerOrganizations/org2.example.com/ca/` .

In the `docker-compose-e2e.yaml` update the FABRIC_CA_SERVER_TLS_KEYFILE variable for ca0 and ca1. You also need to edit the path that is provided in the command to start the ca server. You are providing the same private key twice for each CA container.

Using CouchDB

The state database can be switched from the default (goleveldb) to CouchDB. The same chaincode functions are available with CouchDB, however, there is the added ability to perform rich and complex queries against the state database data content contingent upon the chaincode data being modeled as JSON.

To use CouchDB instead of the default database (goleveldb), follow the same procedures outlined earlier for generating the artifacts, except when starting the network pass `docker-compose-couch.yaml` as well:

```
CHANNEL_NAME=$CHANNEL_NAME TIMEOUT=<pick_a_value> docker-compose -f docker-compose-
↪cli.yaml -f docker-compose-couch.yaml up -d
```

chaincode_example02 should now work using CouchDB underneath.

Note: If you choose to implement mapping of the fabric-couchdb container port to a host port, please make sure you are aware of the security implications. Mapping of the port in a development environment makes the CouchDB REST API available, and allows the visualization of the database via the CouchDB web interface (Fauxton). Production environments would likely refrain from implementing port mapping in order to restrict outside access to the CouchDB containers.

You can use **chaincode_example02** chaincode against the CouchDB state database using the steps outlined above, however in order to exercise the CouchDB query capabilities you will need to use a chaincode that has data modeled as JSON, (e.g. **marbles02**). You can locate the **marbles02** chaincode in the `fabric/examples/chaincode/go` directory.

We will follow the same process to create and join the channel as outlined in the *Create & Join Channel* section above. Once you have joined your peer(s) to the channel, use the following steps to interact with the **marbles02** chaincode:

- Install and instantiate the chaincode on `peer0.org1.example.com` :

```
# be sure to modify the $CHANNEL_NAME variable accordingly for the instantiate command

peer chaincode install -n marbles -v 1.0 -p github.com/hyperledger/fabric/examples/
↪chaincode/go/marbles02
peer chaincode instantiate -o orderer.example.com:7050 --tls $CORE_PEER_TLS_ENABLED --
↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
↪example.com-cert.pem -C $CHANNEL_NAME -n marbles -v 1.0 -c '{"Args":["init"]}' -P
↪"OR ('Org0MSP.member','Org1MSP.member')"
```

- Create some marbles and move them around:

```
# be sure to modify the $CHANNEL_NAME variable accordingly

peer chaincode invoke -o orderer.example.com:7050 --tls $CORE_PEER_TLS_ENABLED --
 ↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
 ↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
 ↪example.com-cert.pem -C $CHANNEL_NAME -n marbles -c '{"Args":["initMarble","marble1
 ↪","blue","35","tom"]}'
peer chaincode invoke -o orderer.example.com:7050 --tls $CORE_PEER_TLS_ENABLED --
 ↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
 ↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
 ↪example.com-cert.pem -C $CHANNEL_NAME -n marbles -c '{"Args":["initMarble","marble2
 ↪","red","50","tom"]}'
peer chaincode invoke -o orderer.example.com:7050 --tls $CORE_PEER_TLS_ENABLED --
 ↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
 ↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
 ↪example.com-cert.pem -C $CHANNEL_NAME -n marbles -c '{"Args":["initMarble","marble3
 ↪","blue","70","tom"]}'
peer chaincode invoke -o orderer.example.com:7050 --tls $CORE_PEER_TLS_ENABLED --
 ↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
 ↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
 ↪example.com-cert.pem -C $CHANNEL_NAME -n marbles -c '{"Args":["transferMarble",
 ↪"marble2","jerry"]}'
peer chaincode invoke -o orderer.example.com:7050 --tls $CORE_PEER_TLS_ENABLED --
 ↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
 ↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
 ↪example.com-cert.pem -C $CHANNEL_NAME -n marbles -c '{"Args":[
 ↪"transferMarblesBasedOnColor","blue","jerry"]}'
peer chaincode invoke -o orderer.example.com:7050 --tls $CORE_PEER_TLS_ENABLED --
 ↪cafile /opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/
 ↪ordererOrganizations/example.com/orderers/orderer.example.com/msp/tlscacerts/tlsca.
 ↪example.com-cert.pem -C $CHANNEL_NAME -n marbles -c '{"Args":["delete","marble1"]}'
```

- If you chose to map the CouchDB ports in docker-compose, you can now view the state database through the CouchDB web interface (Fauxton) by opening a browser and navigating to the following URL:

  `http://localhost:5984/_utils`

You should see a database named `mychannel` (or your unique channel name) and the documents inside it.

Note: For the below commands, be sure to update the $CHANNEL_NAME variable appropriately.

You can run regular queries from the CLI (e.g. reading `marble2`):

```
peer chaincode query -C $CHANNEL_NAME -n marbles -c '{"Args":["readMarble","marble2"]}
 ↪'
```

The output should display the details of `marble2` :

```
Query Result: {"color":"red","docType":"marble","name":"marble2","owner":"jerry","size
 ↪":50}
```

You can retrieve the history of a specific marble - e.g. `marble1` :

```
peer chaincode query -C $CHANNEL_NAME -n marbles -c '{"Args":["getHistoryForMarble",
↪"marble1"]}'
```

The output should display the transactions on `marble1` :

```
Query Result: [{"TxId":
↪"1c3d3caf124c89f91a4c0f353723ac736c58155325f02890adebaa15e16e6464", "Value":{
↪"docType":"marble","name":"marble1","color":"blue","size":35,"owner":"tom"}},{"TxId
↪":"755d55c281889eaeebf405586f9e25d71d36eb3d35420af833a20a2f53a3eefd", "Value":{
↪"docType":"marble","name":"marble1","color":"blue","size":35,"owner":"jerry"}},{
↪"TxId":"819451032d813dde6247f85e56a89262555e04f14788ee33e28b232eef36d98f", "Value":}
↪]
```

You can also perform rich queries on the data content, such as querying marble fields by owner `jerry` :

```
peer chaincode query -C $CHANNEL_NAME -n marbles -c '{"Args":["queryMarblesByOwner",
↪"jerry"]}'
```

The output should display the two marbles owned by `jerry` :

```
Query Result: [{"Key":"marble2", "Record":{"color":"red","docType":"marble","name":
↪"marble2","owner":"jerry","size":50}},{"Key":"marble3", "Record":{"color":"blue",
↪"docType":"marble","name":"marble3","owner":"jerry","size":70}}]
```

A Note on Data Persistence

If data persistence is desired on the peer container or the CouchDB container, one option is to mount a directory in the docker-host into a relevant directory in the container. For example, you may add the following two lines in the peer container specification in the `docker-compose-base.yaml` file:

```
volumes:
 - /var/hyperledger/peer0:/var/hyperledger/production
```

For the CouchDB container, you may add the following two lines in the CouchDB container specification:

```
volumes:
 - /var/hyperledger/couchdb0:/opt/couchdb/data
```

Troubleshooting

- Always start your network fresh. Use the following command to remove artifacts, crypto, containers and chaincode images:

```
./byfn.sh -m down
```

- **YOU WILL SEE ERRORS IF YOU DO NOT REMOVE CONTAINERS AND IMAGES**
- If you see Docker errors, first check your version (should be 17.03.1 or above), and then try restarting your Docker process. Problems with Docker are oftentimes not immediately recognizable. For example, you may see errors resulting from an inability to access crypto material mounted within a container.
- If they persist remove your images and start from scratch:

```
docker rm -f $(docker ps -aq)
docker rmi -f $(docker images -q)
```

- If you see errors on your create, instantiate, invoke or query commands, make sure you have properly updated the channel name and chaincode name. There are placeholder values in the supplied sample commands.
- If you see the below error:

```
Error: Error endorsing chaincode: rpc error: code = 2 desc = Error installing␣
↪chaincode code mycc:1.0(chaincode /var/hyperledger/production/chaincodes/mycc.1.0␣
↪exits)
```

You likely have chaincode images (e.g. `dev-peer1.org2.example.com-mycc-1.0` or `dev-peer0.org1.example.com-mycc-1.0`) from prior runs. Remove them and try again.

```
docker rmi -f $(docker images | grep peer[0-9]-peer[0-9] | awk '{print $3}')
```

- If you see something similar to the following:

```
Error connecting: rpc error: code = 14 desc = grpc: RPC failed fast due to transport␣
↪failure
Error: rpc error: code = 14 desc = grpc: RPC failed fast due to transport failure
```

Make sure you are running your network against the "1.0.0" images that have been retagged as "latest".

If you see the below error:

```
[configtx/tool/localconfig] Load -> CRIT 002 Error reading configuration: Unsupported␣
↪Config Type ""
panic: Error reading configuration: Unsupported Config Type ""
```

Then you did not set the `FABRIC_CFG_PATH` environment variable properly. The configtxgen tool needs this variable in order to locate the configtx.yaml. Go back and execute an `export FABRIC_CFG_PATH=$PWD` , then recreate your channel artifacts.

- To cleanup the network, use the `down` option:

```
./byfn.sh -m down
```

- If you see an error stating that you still have "active endpoints", then prune your Docker networks. This will wipe your previous networks and start you with a fresh environment:

```
docker network prune
```

You will see the following message:

```
WARNING! This will remove all networks not used by at least one container.
Are you sure you want to continue? [y/N]
```

Select `y` .

- If you continue to see errors, share your logs on the **# fabric-questions** channel on Hyperledger Rocket Chat.

CHAPTER 9

Writing Your First Application

The goal of this document is to show the tasks and provide a baseline for writing your first application against a Hyperledger Fabric network.

At the most basic level, applications on a blockchain network are what enable users to **query** a ledger (asking for specific records it contains), or to **update** it (adding records to it).

Our application, composed in Javascript, leverages the Node.js SDK to interact with the network (where our ledger exists). This tutorial will guide you through the three steps involved in writing your first application.

1. Starting a test Hyperledger Fabric blockchain network. We need some basic components in our network in order to query and update the ledger. These components – a peer node, ordering node and Certificate Authority – serve as the backbone of our network; we'll also have a CLI container used for a few administrative commands. A single script will download and launch this test network.

2. Learning the parameters of the sample smart contract our app will use. Our smart contracts contain various functions that allow us to interact with the ledger in different ways. For example, we can read data holistically or on a more granular level.

3. Developing the application to be able to query and update records. We provide two sample applications – one for querying the ledger and another for updating it. Our apps will use the SDK APIs to interact with the network and ultimately call these functions.

After completing this tutorial, you should have a basic understanding of how an application, using the Hyperledger Fabric SDK for Node.js, is programmed in conjunction with a smart contract to interact with the ledger on a Hyperledger Fabric network.

First, let's launch our test network...

Getting a Test Network

Visit the *Prerequisites* page and ensure you have the necessary dependencies installed on your machine.

Now determine a working directory where you want to clone the fabric-samples repo. Issue the clone command and change into the `fabcar` subdirectory

```
git clone https://github.com/hyperledger/fabric-samples.git
cd fabric-samples/fabcar
```

This subdirectory – `fabcar` – contains the scripts and application code to run the sample app. Issue an `ls` from this directory. You should see the following:

```
chaincode    invoke.js       network         package.json    query.js        ␣
↪startFabric.sh
```

Now use the `startFabric.sh` script to launch the network.

Note: The following command downloads and extracts the Hyperledger Fabric Docker images, so it will take a few minutes to complete.

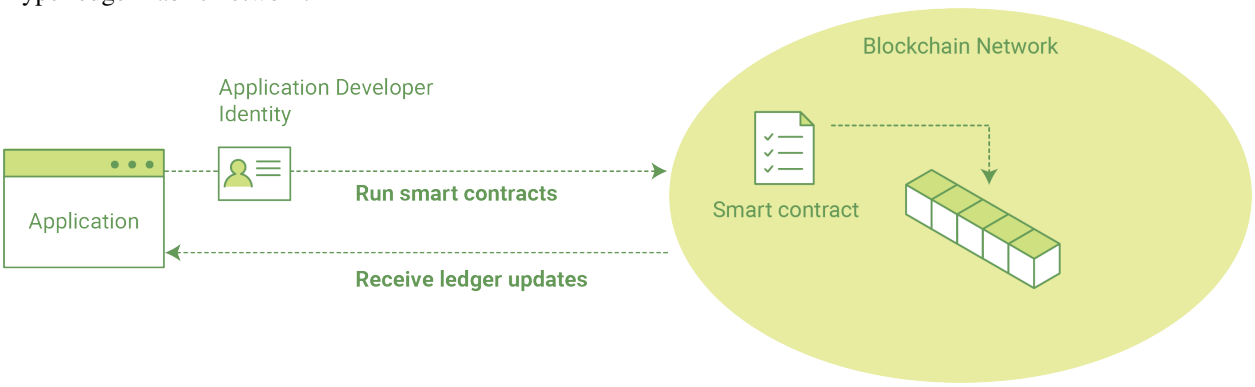
```
./startFabric.sh
```

For the sake of brevity, we won't delve into the details of what's happening with this command. Here's a quick synopsis:

- launches a peer node, ordering node, Certificate Authority and CLI container
- creates a channel and joins the peer to the channel
- installs smart contract (i.e. chaincode) onto the peer's file system and instantiates said chaincode on the channel; instantiate starts a chaincode container
- calls the `initLedger` function to populate the channel ledger with 10 unique cars

Note: These operations will typically be done by an organizational or peer admin. The script uses the CLI to execute these commands, however there is support in the SDK as well. Refer to the Hyperledger Fabric Node SDK repo for example scripts.

Issue a `docker ps` command to reveal the processes started by the `startFabric.sh` script. You can learn more about the details and mechanics of these operations in the *Building Your First Network* section. Here we'll just focus on the application. The following picture provides a simplistic representation of how the application interacts with the Hyperledger Fabric network.



Alright, now that you've got a sample network and some code, let's take a look at how the different pieces fit together.

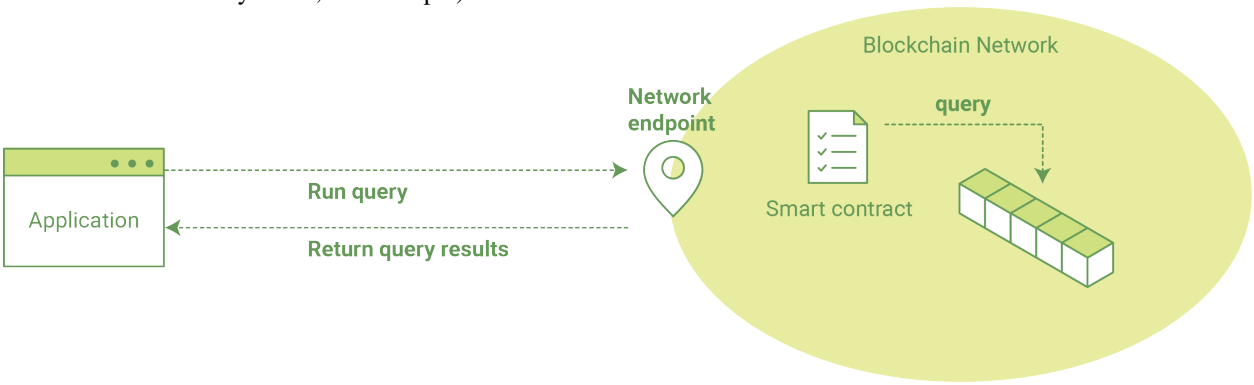
How Applications Interact with the Network

Applications use **APIs** to invoke smart contracts (referred to as "chaincode"). These smart contracts are hosted in the network and identified by name and version. For example, our chaincode container is titled - `dev-peer0.org1.example.com-fabcar-1.0` - where the name is `fabcar` , the version is `1.0` and the peer it is running against is `dev-peer0.org1.example.com` .

APIs are accessible with a software development kit (SDK). For purposes of this exercise, we'll be using the Hyperledger Fabric Node SDK though there is also a Java SDK and CLI that can be used to develop applications.

Querying the Ledger

Queries are how you read data from the ledger. You can query for the value of a single key, multiple keys, or – if the ledger is written in a rich data storage format like JSON – perform complex searches against it (looking for all assets that contain certain keywords, for example).



As we said earlier, our sample network has an active chaincode container and a ledger that has been primed with 10 different cars. We also have some sample Javascript code - `query.js` - in the `fabcar` directory that can be used to query the ledger for details on the cars.

Before we take a look at how that app works, we need to install the SDK node modules in order for our program to function. From your `fabcar` directory, issue the following:

```
npm install
```

Note: You will issue all subsequent commands from the `fabcar` directory.

Now we can run our javascript programs. First, let's run our `query.js` program to return a listing of all the cars on the ledger. A function that will query all the cars, `queryAllCars` , is pre-loaded in the app, so we can simply run the program as is:

```
node query.js
```

It should return something like this:

```
Query result count =  1
Response is  [{"Key":"CAR0", "Record":{"colour":"blue","make":"Toyota","model":"Prius
↪","owner":"Tomoko"}},
{"Key":"CAR1",   "Record":{"colour":"red","make":"Ford","model":"Mustang","owner":
↪"Brad"}},
{"Key":"CAR2", "Record":{"colour":"green","make":"Hyundai","model":"Tucson","owner":
↪"Jin Soo"}},
{"Key":"CAR3", "Record":{"colour":"yellow","make":"Volkswagen","model":"Passat","owner
↪":"Max"}},
{"Key":"CAR4", "Record":{"colour":"black","make":"Tesla","model":"S","owner":"Adriana
↪"}},
{"Key":"CAR5", "Record":{"colour":"purple","make":"Peugeot","model":"205","owner":
↪"Michel"}},
{"Key":"CAR6", "Record":{"colour":"white","make":"Chery","model":"S22L","owner":"Aarav
↪"}},
```

```
{"Key":"CAR7", "Record":{"colour":"violet","make":"Fiat","model":"Punto","owner":"Pari
↪"}},
{"Key":"CAR8", "Record":{"colour":"indigo","make":"Tata","model":"Nano","owner":
↪"Valeria"}},
{"Key":"CAR9", "Record":{"colour":"brown","make":"Holden","model":"Barina","owner":
↪"Shotaro"}}]
```

These are the 10 cars. A black Tesla Model S owned by Adriana, a red Ford Mustang owned by Brad, a violet Fiat Punto owned by someone named Pari, and so on. The ledger is key/value based and in our implementation the key is `CAR0` through `CAR9` . This will become particularly important in a moment.

Now let's see what it looks like under the hood (if you'll forgive the pun). Use an editor (e.g. atom or visual studio) and open the `query.js` program.

The inital section of the application defines certain variables such as chaincode ID, channel name and network endpoints:

```
var options = {
      wallet_path : path.join(__dirname, './network/creds'),
      user_id: 'PeerAdmin',
      channel_id: 'mychannel',
      chaincode_id: 'fabcar',
      network_url: 'grpc://localhost:7051',
```

This is the chunk where we construct our query:

```
// queryCar - requires 1 argument, ex: args: ['CAR4'],
// queryAllCars - requires no arguments , ex: args: [''],
const request = {
   chaincodeId: options.chaincode_id,
   txId: transaction_id,
   fcn: 'queryAllCars',
   args: ['']
```

We define the `chaincode_id` variable as `fabcar` – allowing us to target this specific chaincode – and then call the `queryAllCars` function defined within that chaincode.

When we issued the `node query.js` command earlier, this specific function was called to query the ledger. However, this isn't the only function that we can pass.

To take a look at the others, navigate to the `chaincode` subdirectory and open `fabcar.go` in your editor. You'll see that we have the following functions available to call - `initLedger` , `queryCar` , `queryAllCars` , `createCar` and `changeCarOwner` . Let's take a closer look at the `queryAllCars` function to see how it interacts with the ledger.

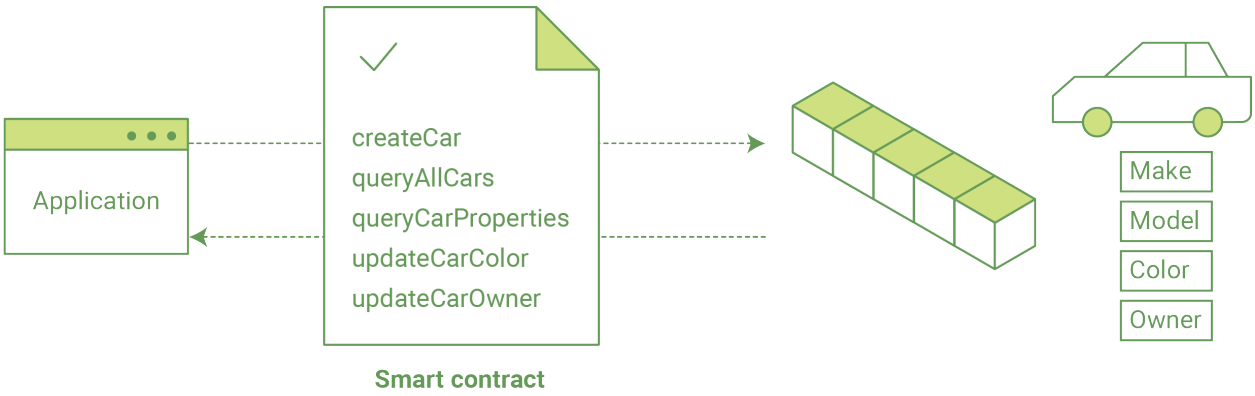
```
func (s *SmartContract) queryAllCars(APIstub shim.ChaincodeStubInterface) sc.Response
↪{

     startKey := "CAR0"
     endKey := "CAR999"

     resultsIterator, err := APIstub.GetStateByRange(startKey, endKey)
```

The function uses the shim interface function `GetStateByRange` to return ledger data between the args of `startKey` and `endKey` . Those keys are defined as `CAR0` and `CAR999` respectively. Therefore, we could theoretically create 1,000 cars (assuming the keys are tagged properly) and a `queryAllCars` would reveal every one.

Below is a representation of how an app would call different functions in chaincode.



We can see our `queryAllCars` function up there, as well as one called `createCar` that will allow us to update the ledger and ultimately append a new block to the chain. But first, let's do another query.

Go back to the `query.js` program and edit the constructor request to query a specific car. We'll do this by changing the function from `queryAllCars` to `queryCar` and passing a specific "Key" to the args parameter. Let's use `CAR4` here. So our edited `query.js` program should now contain the following:

```
const request = {
      chaincodeId: options.chaincode_id,
      txId: transaction_id,
      fcn: 'queryCar',
      args: ['CAR4']
```

Save the program and navigate back to your `fabcar` directory. Now run the program again:

```
node query.js
```

You should see the following:

```
{"colour":"black","make":"Tesla","model":"S","owner":"Adriana"}
```

So we've gone from querying all cars to querying just one, Adriana's black Tesla Model S. Using the `queryCar` function, we can query against any key (e.g. `CAR0`) and get whatever make, model, color, and owner correspond to that car.

Great. Now you should be comfortable with the basic query functions in the chaincode, and the handful of parameters in the query program. Time to update the ledger...

Updating the Ledger

Now that we've done a few ledger queries and added a bit of code, we're ready to update the ledger. There are a lot of potential updates we could make, but let's just create a new car for starters.

Ledger updates start with an application generating a transaction proposal. Just like query, a request is constructed to identify the channel ID, function, and specific smart contract to target for the transaction. The program then calls the `channel.SendTransactionProposal` API to send the transaction proposal to the peer(s) for endorsement.

The network (i.e. endorsing peer) returns a proposal response, which the application uses to build and sign a transaction request. This request is sent to the ordering service by calling the `channel.sendTransaction` API. The ordering service will bundle the transaction into a block and then "deliver" the block to all peers on a channel for validation. (In our case we have only the single endorsing peer.)

Finally the application uses the `eh.setPeerAddr` API to connect to the peer's event listener port, and calls `eh.registerTxEvent` to register events associated with a specific transaction ID. This API allows the application to know the fate of a transaction (i.e. successfully committed or unsuccessful). Think of it as a notification mechanism.

Note: We don't go into depth here on a transaction's lifecycle. Consult the *Transaction Flow* documentation for lower level details on how a transaction is ultimately committed to the ledger.

The goal with our initial invoke is to simply create a new asset (car in this case). We have a separate javascript program - `invoke.js` - that we will use for these transactions. Just like query, use an editor to open the program and navigate to the codeblock where we construct our invocation:

```
// createCar - requires 5 args, ex: args: ['CAR11', 'Honda', 'Accord', 'Black', 'Tom
↪'],
// changeCarOwner - requires 2 args , ex: args: ['CAR10', 'Barry'],
// send proposal to endorser
var request = {
    targets: targets,
    chaincodeId: options.chaincode_id,
    fcn: '',
    args: [''],
    chainId: options.channel_id,
    txId: tx_id
```

You'll see that we can call one of two functions - `createCar` or `changeCarOwner`. Let's create a red Chevy Volt and give it to an owner named Nick. We're up to `CAR9` on our ledger, so we'll use `CAR10` as the identifying key here. The updated codeblock should look like this:

```
var request = {
    targets: targets,
    chaincodeId: options.chaincode_id,
    fcn: 'createCar',
    args: ['CAR10', 'Chevy', 'Volt', 'Red', 'Nick'],
    chainId: options.channel_id,
    txId: tx_id
```

Save it and run the program:

```
node invoke.js
```

There will be some output in the terminal about Proposal Response and Transaction ID. However, all we're concerned with is this message:

```
The transaction has been committed on peer localhost:7053
```

The peer emits this event notification, and our application receives it thanks to our `eh.registerTxEvent` API. So now if we go back to our `query.js` program and call the `queryCar` function against an arg of `CAR10`, we should see the following:

```
Response is  {"colour":"Red","make":"Chevy","model":"Volt","owner":"Nick"}
```

Finally, let's call our last function - `changeCarOwner`. Nick is feeling generous and he wants to give his Chevy Volt to a man named Barry. So, we simply edit `invoke.js` to reflect the following:

```
var request = {
   targets: targets,
```

```
  chaincodeId: options.chaincode_id,
  fcn: 'changeCarOwner',
  args: ['CAR10', 'Barry'],
  chainId: options.channel_id,
  txId: tx_id
```

Execute the program again - `node invoke.js` - and then run the query app one final time. We are still querying against `CAR10` , so we should see:

```
Response is  {"colour":"Red","make":"Chevy","model":"Volt","owner":"Barry"}
```

Additional Resources

The Hyperledger Fabric Node SDK repo is an excellent resource for deeper documentation and sample code. You can also consult the Hyperledger Fabric community and component experts on Hyperledger Rocket Chat.

CHAPTER 10

Chaincode Tutorials

What is Chaincode?

Chaincode is a program, written in Go, and eventually in other programming languages such as Java, that implements a prescribed interface. Chaincode runs in a secured Docker container isolated from the endorsing peer process. Chaincode initializes and manages ledger state through transactions submitted by applications.

A chaincode typically handles business logic agreed to by members of the network, so it may be considered as a "smart contract". State created by a chaincode is scoped exclusively to that chaincode and can't be accessed directly by another chaincode. However, within the same network, given the appropriate permission a chaincode may invoke another chaincode to access its state.

Two Personas

We offer two different perspectives on chaincode. One, from the perspective of an application developer developing a blockchain application/solution entitled *Chaincode for Developers*, and the other, *Chaincode for Operators* oriented to the blockchain network operator who is responsible for managing a blockchain network, and who would leverage the Hyperledger Fabric API to install, instantiate, and upgrade chaincode, but would likely not be involved in the development of a chaincode application.

CHAPTER 11

Chaincode for Developers

What is Chaincode?

Chaincode is a program, written in Go that implements a prescribed interface. Eventually, other programming languages such as Java, will be supported. Chaincode runs in a secured Docker container isolated from the endorsing peer process. Chaincode initializes and manages the ledger state through transactions submitted by applications.

A chaincode typically handles business logic agreed to by members of the network, so it similar to a "smart contract". Ledger state created by a chaincode is scoped exclusively to that chaincode and can't be accessed directly by another chaincode. Given the appropriate permission, a chaincode may invoke another chaincode to access its state within the same network.

In the following sections, we will explore chaincode through the eyes of an application developer. We'll present a simple chaincode sample application and walk through the purpose of each method in the Chaincode Shim API.

Chaincode API

Every chaincode program must implement the Chaincode interface whose methods are called in response to received transactions. In particular the `Init` method is called when a chaincode receives an `instantiate` or `upgrade` transaction so that the chaincode may perform any necessary initialization, including initialization of application state. The `Invoke` method is called in response to receiving an `invoke` transaction to process transaction proposals.

The other interface in the chaincode "shim" APIs is the ChaincodeStubInterface which is used to access and modify the ledger, and to make invocations between chaincodes.

In this tutorial, we will demonstrate the use of these APIs by implementing a simple chaincode application that manages simple "assets".

Simple Asset Chaincode

Our application is a basic sample chaincode to create assets (key-value pairs) on the ledger.

Choosing a Location for the Code

If you haven't been doing programming in Go, you may want to make sure that you have *Go Programming Language* installed and your system properly configured.

Now, you will want to create a directory for your chaincode application as a child directory of `$GOPATH/src/`.

To keep things simple, let's use the following command:

```
mkdir -p $GOPATH/src/sacc && cd $GOPATH/src/sacc
```

Now, let's create the source file that we'll fill in with code:

```
touch sacc.go
```

Housekeeping

First, let's start with some housekeeping. As with every chaincode, it implements the Chaincode interface in particular, `Init` and `Invoke` functions. So, let's add the go import statements for the necessary dependencies for our chaincode. We'll import the chaincode shim package and the peer protobuf package.

```
package main

import (
    "fmt"

    "github.com/hyperledger/fabric/core/chaincode/shim"
    "github.com/hyperledger/fabric/protos/peer"
)
```

Initializing the Chaincode

Next, we'll implement the `Init` function.

```
// Init is called during chaincode instantiation to initialize any data.
func (t *SimpleAsset) Init(stub shim.ChaincodeStubInterface) peer.Response {

}
```

Note: Note that chaincode upgrade also calls this function. When writing a chaincode that will upgrade an existing one, make sure to modify the `Init` function appropriately. In particular, provide an empty "Init" method if there's no "migration" or nothing to be initialized as part of the upgrade.

Next, we'll retrieve the arguments to the `Init` call using the ChaincodeStubInterface.GetStringArgs function and check for validity. In our case, we are expecting a key-value pair.

```
// Init is called during chaincode instantiation to initialize any
// data. Note that chaincode upgrade also calls this function to reset
// or to migrate data, so be careful to avoid a scenario where you
// inadvertently clobber your ledger's data!
func (t *SimpleAsset) Init(stub shim.ChaincodeStubInterface) peer.Response {
  // Get the args from the transaction proposal
  args := stub.GetStringArgs()
  if len(args) != 2 {
    return shim.Error("Incorrect arguments. Expecting a key and a value")
  }
}
```

Next, now that we have established that the call is valid, we'll store the initial state in the ledger. To do this, we will call ChaincodeStubInterface.PutState with the key and value passed in as the arguments. Assuming all went well, return a peer.Response object that indicates the initialization was a success.

```
// Init is called during chaincode instantiation to initialize any
// data. Note that chaincode upgrade also calls this function to reset
// or to migrate data, so be careful to avoid a scenario where you
// inadvertently clobber your ledger's data!
func (t *SimpleAsset) Init(stub shim.ChaincodeStubInterface) peer.Response {
  // Get the args from the transaction proposal
  args := stub.GetStringArgs()
  if len(args) != 2 {
    return shim.Error("Incorrect arguments. Expecting a key and a value")
  }

  // Set up any variables or assets here by calling stub.PutState()

  // We store the key and the value on the ledger
  err := stub.PutState(args[0], []byte(args[1]))
  if err != nil {
    return shim.Error(fmt.Sprintf("Failed to create asset: %s", args[0]))
  }
  return shim.Success(nil)
}
```

Invoking the Chaincode

First, let's add the `Invoke` function's signature.

```
// Invoke is called per transaction on the chaincode. Each transaction is
// either a 'get' or a 'set' on the asset created by Init function. The 'set'
// method may create a new asset by specifying a new key-value pair.
func (t *SimpleAsset) Invoke(stub shim.ChaincodeStubInterface) peer.Response {

}
```

As with the `Init` function above, we need to extract the arguments from the `ChaincodeStubInterface`. The `Invoke` function's arguments will be the name of the chaincode application function to invoke. In our case, our application will simply have two functions: `set` and `get`, that allow the value of an asset to be set or its current state to be retrieved. We first call ChaincodeStubInterface.GetFunctionAndParameters to extract the function name and the parameters to that chaincode application function.

```
// Invoke is called per transaction on the chaincode. Each transaction is
// either a 'get' or a 'set' on the asset created by Init function. The Set
// method may create a new asset by specifying a new key-value pair.
func (t *SimpleAsset) Invoke(stub shim.ChaincodeStubInterface) peer.Response {
    // Extract the function and args from the transaction proposal
    fn, args := stub.GetFunctionAndParameters()

}
```

Next, we'll validate the function name as being either `set` or `get`, and invoke those chaincode application functions, returning an appropriate response via the `shim.Success` or `shim.Error` functions that will serialize the response into a gRPC protobuf message.

```
// Invoke is called per transaction on the chaincode. Each transaction is
// either a 'get' or a 'set' on the asset created by Init function. The Set
// method may create a new asset by specifying a new key-value pair.
func (t *SimpleAsset) Invoke(stub shim.ChaincodeStubInterface) peer.Response {
    // Extract the function and args from the transaction proposal
    fn, args := stub.GetFunctionAndParameters()

    var result string
    var err error
    if fn == "set" {
            result, err = set(stub, args)
    } else {
            result, err = get(stub, args)
    }
    if err != nil {
            return shim.Error(err.Error())
    }

    // Return the result as success payload
    return shim.Success([]byte(result))
}
```

Implementing the Chaincode Application

As noted, our chaincode application implements two functions that can be invoked via the `Invoke` function. Let's implement those functions now. Note that as we mentioned above, to access the ledger's state, we will leverage the ChaincodeStubInterface.PutState and ChaincodeStubInterface.GetState functions of the chaincode shim API.

```
// Set stores the asset (both key and value) on the ledger. If the key exists,
// it will override the value with the new one
func set(stub shim.ChaincodeStubInterface, args []string) (string, error) {
    if len(args) != 2 {
            return "", fmt.Errorf("Incorrect arguments. Expecting a key and a value")
    }

    err := stub.PutState(args[0], []byte(args[1]))
    if err != nil {
            return "", fmt.Errorf("Failed to set asset: %s", args[0])
    }
    return args[1], nil
}

// Get returns the value of the specified asset key
func get(stub shim.ChaincodeStubInterface, args []string) (string, error) {
    if len(args) != 1 {
            return "", fmt.Errorf("Incorrect arguments. Expecting a key")
    }

    value, err := stub.GetState(args[0])
    if err != nil {
            return "", fmt.Errorf("Failed to get asset: %s with error: %s", args[0],␣
↪err)
    }
    if value == nil {
            return "", fmt.Errorf("Asset not found: %s", args[0])
    }
```

```
    return string(value), nil
}
```

Pulling it All Together

Finally, we need to add the `main` function, which will call the shim.Start function. Here's the whole chaincode program source.

```
package main

import (
    "fmt"

    "github.com/hyperledger/fabric/core/chaincode/shim"
    "github.com/hyperledger/fabric/protos/peer"
)

// SimpleAsset implements a simple chaincode to manage an asset
type SimpleAsset struct {
}

// Init is called during chaincode instantiation to initialize any
// data. Note that chaincode upgrade also calls this function to reset
// or to migrate data.
func (t *SimpleAsset) Init(stub shim.ChaincodeStubInterface) peer.Response {
    // Get the args from the transaction proposal
    args := stub.GetStringArgs()
    if len(args) != 2 {
            return shim.Error("Incorrect arguments. Expecting a key and a value")
    }

    // Set up any variables or assets here by calling stub.PutState()

    // We store the key and the value on the ledger
    err := stub.PutState(args[0], []byte(args[1]))
    if err != nil {
            return shim.Error(fmt.Sprintf("Failed to create asset: %s", args[0]))
    }
    return shim.Success(nil)
}

// Invoke is called per transaction on the chaincode. Each transaction is
// either a 'get' or a 'set' on the asset created by Init function. The Set
// method may create a new asset by specifying a new key-value pair.
func (t *SimpleAsset) Invoke(stub shim.ChaincodeStubInterface) peer.Response {
    // Extract the function and args from the transaction proposal
    fn, args := stub.GetFunctionAndParameters()

    var result string
    var err error
    if fn == "set" {
            result, err = set(stub, args)
    } else { // assume 'get' even if fn is nil
            result, err = get(stub, args)
    }
    if err != nil {
```

```
            return shim.Error(err.Error())
    }

    // Return the result as success payload
    return shim.Success([]byte(result))
}

// Set stores the asset (both key and value) on the ledger. If the key exists,
// it will override the value with the new one
func set(stub shim.ChaincodeStubInterface, args []string) (string, error) {
    if len(args) != 2 {
            return "", fmt.Errorf("Incorrect arguments. Expecting a key and a value")
    }

    err := stub.PutState(args[0], []byte(args[1]))
    if err != nil {
            return "", fmt.Errorf("Failed to set asset: %s", args[0])
    }
    return args[1], nil
}

// Get returns the value of the specified asset key
func get(stub shim.ChaincodeStubInterface, args []string) (string, error) {
    if len(args) != 1 {
            return "", fmt.Errorf("Incorrect arguments. Expecting a key")
    }

    value, err := stub.GetState(args[0])
    if err != nil {
            return "", fmt.Errorf("Failed to get asset: %s with error: %s", args[0],␣
↪err)
    }
    if value == nil {
            return "", fmt.Errorf("Asset not found: %s", args[0])
    }
    return string(value), nil
}

// main function starts up the chaincode in the container during instantiate
func main() {
    if err := shim.Start(new(SimpleAsset)); err != nil {
            fmt.Printf("Error starting SimpleAsset chaincode: %s", err)
    }
}
```

Building Chaincode

Now let's compile your chaincode.

```
go get -u --tags nopkcs11 github.com/hyperledger/fabric/core/chaincode/shim
go build --tags nopkcs11
```

Assuming there are no errors, now we can proceed to the next step, testing your chaincode.

Testing Using dev mode

Normally chaincodes are started and maintained by peer. However in "dev mode", chaincode is built and started by the user. This mode is useful during chaincode development phase for rapid code/build/run/debug cycle turnaround.

We start "dev mode" by leveraging pre-generated orderer and channel artifacts for a sample dev network. As such, the user can immediately jump into the process of compiling chaincode and driving calls.

Install Hyperledger Fabric Samples

If you haven't already done so, please install the *Hyperledger Fabric Samples*.

Navigate to the `chaincode-docker-devmode` directory of the `fabric-samples` clone:

```
cd chaincode-docker-devmode
```

Download Docker images

We need four Docker images in order for "dev mode" to run against the supplied docker compose script. If you installed the `fabric-samples` repo clone and followed the instructions to download-platform-specific-binaries, then you should have the necessary Docker images installed locally.

Note: If you choose to manually pull the images then you must retag them as `latest` .

Issue a `docker images` command to reveal your local Docker Registry. You should see something similar to following:

```
docker images
REPOSITORY                    TAG                                 IMAGE ID
↪  CREATED              SIZE
hyperledger/fabric-tools      latest                              e09f38f8928d
↪  4 hours ago          1.32 GB
hyperledger/fabric-tools      x86_64-1.0.0                        e09f38f8928d
↪  4 hours ago          1.32 GB
hyperledger/fabric-orderer    latest                              0df93ba35a25
↪  4 hours ago          179 MB
hyperledger/fabric-orderer    x86_64-1.0.0                        0df93ba35a25
↪  4 hours ago          179 MB
hyperledger/fabric-peer       latest                              533aec3f5a01
↪  4 hours ago          182 MB
hyperledger/fabric-peer       x86_64-1.0.0                        533aec3f5a01
↪  4 hours ago          182 MB
hyperledger/fabric-ccenv      latest                              4b70698a71d3
↪  4 hours ago          1.29 GB
hyperledger/fabric-ccenv      x86_64-1.0.0                        4b70698a71d3
↪  4 hours ago          1.29 GB
```

Note: If you retrieved the images through the download-platform-specific-binaries, then you will see additional images listed. However, we are only concerned with these four.

Now open three terminals and navigate to your `chaincode-docker-devmode` directory in each.

Terminal 1 - Start the network

```
docker-compose -f docker-compose-simple.yaml up
```

The above starts the network with the `SingleSampleMSPSolo` orderer profile and launches the peer in "dev mode". It also launches two additional containers - one for the chaincode environment and a CLI to interact with the chaincode. The commands for create and join channel are embedded in the CLI container, so we can jump immediately to the chaincode calls.

Terminal 2 - Build & start the chaincode

```
docker exec -it chaincode bash
```

You should see the following:

```
root@d2629980e76b:/opt/gopath/src/chaincode#
```

Now, compile your chaincode:

```
cd sacc
go build
```

Now run the chaincode:

```
CORE_PEER_ADDRESS=peer:7051 CORE_CHAINCODE_ID_NAME=mycc:0 ./sacc
```

The chaincode is started with peer and chaincode logs indicating successful registration with the peer. Note that at this stage the chaincode is not associated with any channel. This is done in subsequent steps using the `instantiate` command.

Terminal 3 - Use the chaincode

Even though you are in `--peer-chaincodedev` mode, you still have to install the chaincode so the life-cycle system chaincode can go through its checks normally. This requirement may be removed in future when in `--peer-chaincodedev` mode.

We'll leverage the CLI container to drive these calls.

```
docker exec -it cli bash
```

```
peer chaincode install -p chaincodedev/chaincode/sacc -n mycc -v 0
peer chaincode instantiate -n mycc -v 0 -c '{"Args":["a","10"]}' -C myc
```

Now issue an invoke to change the value of "a" to "20".

```
peer chaincode invoke -n mycc -c '{"Args":["set", "a", "20"]}' -C myc
```

Finally, query `a` . We should see a value of `20` .

```
peer chaincode query -n mycc -c '{"Args":["query","a"]}' -C myc
```

Testing new chaincode

By default, we mount only `sacc` . However, you can easily test different chaincodes by adding them to the `chaincode` subdirectory and relaunching your network. At this point they will be accessible in your `chaincode` container.

CHAPTER 12

Chaincode for Operators

What is Chaincode?

Chaincode is a program, written in Go, and eventually in other programming languages such as Java, that implements a prescribed interface. Chaincode runs in a secured Docker container isolated from the endorsing peer process. Chaincode initializes and manages ledger state through transactions submitted by applications.

A chaincode typically handles business logic agreed to by members of the network, so it may be considered as a "smart contract". State created by a chaincode is scoped exclusively to that chaincode and can't be accessed directly by another chaincode. However, within the same network, given the appropriate permission a chaincode may invoke another chaincode to access its state.

In the following sections, we will explore chaincode through the eyes of a blockchain network operator, Noah. For Noah's interests, we will focus on chaincode lifecycle operations; the process of packaging, installing, instantiating and upgrading the chaincode as a function of the chaincode's operational lifecycle within a blockchain network.

Chaincode lifecycle

The Hyperledger Fabric API enables interaction with the various nodes in a blockchain network - the peers, orderers and MSPs - and it also allows one to package, install, instantiate and upgrade chaincode on the endorsing peer nodes. The Hyperledger Fabric language-specific SDKs abstract the specifics of the Hyperledger Fabric API to facilitate application development, though it can be used to manage a chaincode's lifecycle. Additionally, the Hyperledger Fabric API can be accessed directly via the CLI, which we will use in this document.

We provide four commands to manage a chaincode's lifecycle: `package` , `install` , `instantiate` , and `upgrade` . In a future release, we are considering adding `stop` and `start` transactions to disable and re-enable a chaincode without having to actually uninstall it. After a chaincode has been successfully installed and instantiated, the chaincode is active (running) and can process transactions via the `invoke` transaction. A chaincode may be upgraded any time after it has been installed.

Packaging

The chaincode package consists of 3 parts:

- the chaincode, as defined by `ChaincodeDeploymentSpec` or CDS. The CDS defines the chaincode package in terms of the code and other properties such as name and version,
- an optional instantiation policy which can be syntactically described by the same policy used for endorsement and described in *Endorsement policies*, and

- a set of signatures by the entities that "own" the chaincode.

The signatures serve the following purposes:

- to establish an ownership of the chaincode,
- to allow verification of the contents of the package, and
- to allow detection of package tampering.

The creator of the instantiation transaction of the chaincode on a channel is validated against the instantiation policy of the chaincode.

Creating the package

There are two approaches to packaging chaincode. One for when you want to have multiple owners of a chaincode, and hence need to have the chaincode package signed by multiple identities. This workflow requires that we initially create a signed chaincode package (a `SignedCDS`) which is subsequently passed serially to each of the other owners for signing.

The simpler workflow is for when you are deploying a SignedCDS that has only the signature of the identity of the node that is issuing the `install` transaction.

We will address the more complex case first. However, you may skip ahead to the *Installing chaincode* section below if you do not need to worry about multiple owners just yet.

To create a signed chaincode package, use the following command:

```
peer chaincode package -n mycc -p github.com/hyperledger/fabric/examples/chaincode/go/
↪chaincode_example02 -v 0 -s -S -i "AND('OrgA.admin')" ccpack.out
```

The `-s` option creates a package that can be signed by multiple owners as opposed to simply creating a raw CDS. When `-s` is specified, the `-S` option must also be specified if other owners are going to need to sign. Otherwise, the process will create a SignedCDS that includes only the instantiation policy in addition to the CDS.

The `-S` option directs the process to sign the package using the MSP identified by the value of the `localMspid` property in `core.yaml` .

The `-S` option is optional. However if a package is created without a signature, it cannot be signed by any other owner using the `signpackage` command.

The optional `-i` option allows one to specify an instantiation policy for the chaincode. The instantiation policy has the same format as an endorsement policy and specifies which identities can instantiate the chaincode. In the example above, only the admin of OrgA is allowed to instantiate the chaincode. If no policy is provided, the default policy is used, which only allows the admin identity of the peer's MSP to instantiate chaincode.

Package signing

A chaincode package that was signed at creation can be handed over to other owners for inspection and signing. The workflow supports out-of-band signing of chaincode package.

The ChaincodeDeploymentSpec may be optionally be signed by the collective owners to create a SignedChaincodeDeploymentSpec (or SignedCDS). The SignedCDS contains 3 elements:

1. The CDS contains the source code, the name, and version of the chaincode.
2. An instantiation policy of the chaincode, expressed as endorsement policies.
3. The list of chaincode owners, defined by means of Endorsement.

Note: Note that this endorsement policy is determined out-of-band to provide proper MSP principals when the chaincode is instantiated on some channels. If the instantiation policy is not specified, the default policy is any MSP administrator of the channel.

Each owner endorses the ChaincodeDeploymentSpec by combining it with that owner's identity (e.g. certificate) and signing the combined result.

A chaincode owner can sign a previously created signed package using the following command:

```
peer chaincode signpackage ccpack.out signedccpack.out
```

Where `ccpack.out` and `signedccpack.out` are the input and output packages, respectively. `signedccpack.out` contains an additional signature over the package signed using the Local MSP.

Installing chaincode

The `install` transaction packages a chaincode's source code into a prescribed format called a `ChaincodeDeploymentSpec` (or CDS) and installs it on a peer node that will run that chaincode.

Note: You must install the chaincode on **each** endorsing peer node of a channel that will run your chaincode.

When the `install` API is given simply a `ChaincodeDeploymentSpec` , it will default the instantiation policy and include an empty owner list.

Note: Chaincode should only be installed on endorsing peer nodes of the owning members of the chaincode to protect the confidentiality of the chaincode logic from other members on the network. Those members without the chaincode, can't be the endorsers of the chaincode's transactions; that is, they can't execute the chaincode. However, they can still validate and commit the transactions to the ledger.

To install a chaincode, send a SignedProposal to the `lifecycle system chaincode` (LSCC) described in the *System Chaincode* section. For example, to install the **sacc** sample chaincode described in section *Simple Asset Chaincode* using the CLI, the command would look like the following:

```
peer chaincode install -n asset_mgmt -v 1.0 -p sacc
```

The CLI internally creates the SignedChaincodeDeploymentSpec for **sacc** and sends it to the local peer, which calls the `Install` method on the LSCC. The argument to the `-p` option specifies the path to the chaincode, which must be located within the source tree of the user's `GOPATH` , e.g. `$GOPATH/src/sacc` . See the *CLI* section for a complete description of the command options.

Note that in order to install on a peer, the signature of the SignedProposal must be from 1 of the peer's local MSP administrators.

Instantiate

The `instantiate` transaction invokes the `lifecycle System Chaincode` (LSCC) to create and initialize a chaincode on a channel. This is a chaincode-channel binding process: a chaincode may be bound to any number of channels and operate on each channel individually and independently. In other words, regardless of how many other channels on which a chaincode might be installed and instantiated, state is kept isolated to the channel to which a transaction is submitted.

The creator of an `instantiate` transaction must satisfy the instantiation policy of the chaincode included in SignedCDS and must also be a writer on the channel, which is configured as part of the channel creation. This is important for the security of the channel to prevent rogue entities from deploying chaincodes or tricking members to execute chaincodes on an unbound channel.

For example, recall that the default instantiation policy is any channel MSP administrator, so the creator of a chaincode instantiate transaction must be a member of the channel administrators. When the transaction proposal arrives at the endorser, it verifies the creator's signature against the instantiation policy. This is done again during the transaction validation before committing it to the ledger.

The instantiate transaction also sets up the endorsement policy for that chaincode on the channel. The endorsement policy describes the attestation requirements for the transaction result to be accepted by members of the channel.

For example, using the CLI to instantiate the **sacc** chaincode and initialize the state with `john` and `0` , the command would look like the following:

```
peer chaincode instantiate -n sacc -v 1.0 -c '{"Args":["john","0"]}' -P "OR ('Org1.
↪member','Org2.member')"
```

Note: Note the endorsement policy (CLI uses polish notation), which requires an endorsement from either member of Org1 or Org2 for all transactions to **sacc**. That is, either Org1 or Org2 must sign the result of executing the *Invoke* on **sacc** for the transactions to be valid.

After being successfully instantiated, the chaincode enters the active state on the channel and is ready to process any transaction proposals of type ENDORSER_TRANSACTION. The transactions are processed concurrently as they arrive at the endorsing peer.

Upgrade

A chaincode may be upgraded any time by changing its version, which is part of the SignedCDS. Other parts, such as owners and instantiation policy are optional. However, the chaincode name must be the same; otherwise it would be considered as a totally different chaincode.

Prior to upgrade, the new version of the chaincode must be installed on the required endorsers. Upgrade is a transaction similar to the instantiate transaction, which binds the new version of the chaincode to the channel. Other channels bound to the old version of the chaincode still run with the old version. In other words, the `upgrade` transaction only affects one channel at a time, the channel to which the transaction is submitted.

Note: Note that since multiple versions of a chaincode may be active simultaneously, the upgrade process doesn't automatically remove the old versions, so user must manage this for the time being.

There's one subtle difference with the `instantiate` transaction: the `upgrade` transaction is checked against the current chaincode instantiation policy, not the new policy (if specified). This is to ensure that only existing members specified in the current instantiation policy may upgrade the chaincode.

Note: Note that during upgrade, the chaincode `Init` function is called to perform any data related updates or re-initialize it, so care must be taken to avoid resetting states when upgrading chaincode.

Stop and Start

Note that `stop` and `start` lifecycle transactions have not yet been implemented. However, you may stop a chaincode manually by removing the chaincode container and the SignedCDS package from each of the endorsers. This is done by deleting the chaincode's container on each of the hosts or virtual machines on which the endorsing peer nodes are running, and then deleting the SignedCDS from each of the endorsing peer nodes:

Note: TODO - in order to delete the CDS from the peer node, you would need to enter the peer node's container, first. We really need to provide a utility script that can do this.

```
docker rm -f <container id>
rm /var/hyperledger/production/chaincodes/<ccname>:<ccversion>
```

Stop would be useful in the workflow for doing upgrade in controlled manner, where a chaincode can be stopped on a channel on all peers before issuing an upgrade.

CLI

Note: We are assessing the need to distribute platform-specific binaries for the Hyperledger Fabric `peer` binary. For the time being, you can simply invoke the commands from within a running docker container.

To view the currently available CLI commands, execute the following command from within a running `fabric-peer` Docker container:

```
docker run -it hyperledger/fabric-peer bash
# peer chaincode --help
```

Which shows output similar to the example below:

```
Usage:
  peer chaincode [command]

Available Commands:
  install     Package the specified chaincode into a deployment spec and save it on␣
↪the peer's path.
  instantiate Deploy the specified chaincode to the network.
  invoke      Invoke the specified chaincode.
  package     Package the specified chaincode into a deployment spec.
  query       Query using the specified chaincode.
  signpackage Sign the specified chaincode package
  upgrade     Upgrade chaincode.

Flags:
      --cafile string     Path to file containing PEM-encoded trusted certificate(s)␣
↪for the ordering endpoint
  -C, --chainID string    The chain on which this command should be executed (default
↪"testchainid")
  -c, --ctor string       Constructor message for the chaincode in JSON format␣
↪(default "{}")
  -E, --escc string       The name of the endorsement system chaincode to be used for␣
↪this chaincode
  -l, --lang string       Language the chaincode is written in (default "golang")
  -n, --name string       Name of the chaincode
```

```
  -o, --orderer string    Ordering service endpoint
  -p, --path string       Path to chaincode
  -P, --policy string     The endorsement policy associated to this chaincode
  -t, --tid string        Name of a custom ID generation algorithm (hashing and␣
↪decoding) e.g. sha256base64
      --tls               Use TLS when communicating with the orderer endpoint
  -u, --username string   Username for chaincode operations when security is enabled
  -v, --version string    Version of the chaincode specified in install/instantiate/
↪upgrade commands
  -V, --vscc string       The name of the verification system chaincode to be used␣
↪for this chaincode

Global Flags:
      --logging-level string       Default logging level and overrides, see core.yaml␣
↪for full syntax
      --test.coverprofile string   Done (default "coverage.cov")

Use "peer chaincode [command] --help" for more information about a command.
```

To facilitate its use in scripted applications, the `peer` command always produces a non-zero return code in the event of command failure.

Example of chaincode commands:

```
peer chaincode install -n mycc -v 0 -p path/to/my/chaincode/v0
peer chaincode instantiate -n mycc -v 0 -c '{"Args":["a", "b", "c"]} -C mychannel
peer chaincode install -n mycc -v 1 -p path/to/my/chaincode/v1
peer chaincode upgrade -n mycc -v 1 -c '{"Args":["d", "e", "f"]} -C mychannel
peer chaincode query -C mychannel -n mycc -c '{"Args":["query","e"]}'
peer chaincode invoke -o orderer.example.com:7050  --tls $CORE_PEER_TLS_ENABLED --
↪cafile $ORDERER_CA -C mychannel -n mycc -c '{"Args":["invoke","a","b","10"]}'
```

System chaincode

System chaincode has the same programming model except that it runs within the peer process rather than in an isolated container like normal chaincode. Therefore, system chaincode is built into the peer executable and doesn't follow the same lifecycle described above. In particular, **install**, **instantiate** and **upgrade** do not apply to system chaincodes.

The purpose of system chaincode is to shortcut gRPC communication cost between peer and chaincode, and tradeoff the flexibility in management. For example, a system chaincode can only be upgraded with the peer binary. It must also register with a fixed set of parameters compiled in and doesn't have endorsement policies or endorsement policy functionality.

System chaincode is used in Hyperledger Fabric to implement a number of system behaviors so that they can be replaced or modified as appropriate by a system integrator.

The current list of system chaincodes:

1. LSCC Lifecycle system chaincode handles lifecycle requests described above.
2. CSCC Configuration system chaincode handles channel configuration on the peer side.
3. QSCC Query system chaincode provides ledger query APIs such as getting blocks and transactions.
4. ESCC Endorsement system chaincode handles endorsement by signing the transaction proposal response.

5. VSCC Validation system chaincode handles the transaction validation, including checking endorsement policy and multiversioning concurrency control.

Care must be taken when modifying or replacing these system chaincodes, especially LSCC, ESCC and VSCC since they are in the main transaction execution path. It is worth noting that as VSCC validates a block before committing it to the ledger, it is important that all peers in the channel compute the same validation to avoid ledger divergence (non-determinism). So special care is needed if VSCC is modified or replaced.

CHAPTER 13

Videos

Refer to the Hyperledger Fabric channel on YouTube

This collection contains developers demonstrating various v1 features and components such as: ledger, channels, gossip, SDK, chaincode, MSP, and more...

CHAPTER 14

Membership Service Providers (MSP)

The document serves to provide details on the setup and best practices for MSPs.

Membership service provider (MSP) is a component that aims to offer an abstraction of a membership operation architecture.

In particular, MSP abstracts away all cryptographic mechanisms and protocols behind issuing and validating certificates, and user authentication. An MSP may define their own notion of identity, and the rules by which those identities are governed (identity validation) and authenticated (signature generation and verification).

A Hyperledger Fabric blockchain network can be governed by one or more MSPs. This provides modularity of membership operations, and interoperability across different membership standards and architectures.

In the rest of this document we elaborate on the setup of the MSP implementation supported by Hyperledger Fabric, and discuss best practices concerning its use.

MSP Configuration

To setup an instance of the MSP, its configuration needs to be specified locally at each peer and orderer (to enable peer, and orderer signing), and on the channels to enable peer, orderer, client identity validation, and respective signature verification (authentication) by and for all channel members.

Firstly, for each MSP a name needs to be specified in order to reference that MSP in the network (e.g. `msp1` , `org2` , and `org3.divA`). This is the name under which membership rules of an MSP representing a consortium, organization or organization division is to be referenced in a channel. This is also referred to as the *MSP Identifier* or *MSP ID*. MSP Identifiers are required to be unique per MSP instance. For example, shall two MSP instances with the same identifier be detected at the system channel genesis, orderer setup will fail.

In the case of default implementation of MSP, a set of parameters need to be specified to allow for identity (certificate) validation and signature verification. These parameters are deduced by RFC5280, and include:

- A list of self-signed (X.509) certificates to constitute the *root of trust*
- A list of X.509 certificates to represent intermediate CAs this provider considers for certificate validation; these certificates ought to be certified by exactly one of the certificates in the root of trust; intermediate CAs are optional parameters
- A list of X.509 certificates with a verifiable certificate path to exactly one of the certificates of the root of trust to represent the administrators of this MSP; owners of these certificates are authorized to request changes to this MSP configuration (e.g. root CAs, intermediate CAs)
- A list of Organizational Units that valid members of this MSP should include in their X.509 certificate; this is an optional configuration parameter, used when, e.g., multiple organisations leverage the same root of trust, and intermediate CAs, and have reserved an OU field for their members

- A list of certificate revocation lists (CRLs) each corresponding to exactly one of the listed (intermediate or root) MSP Certificate Authorities; this is an optional parameter
- A list of self-signed (X.509) certificates to constitute the *TLS root of trust* for TLS certificate.
- A list of X.509 certificates to represent intermediate TLS CAs this provider considers; these certificates ought to be certified by exactly one of the certificates in the TLS root of trust; intermediate CAs are optional parameters.

Valid identities for this MSP instance are required to satisfy the following conditions:

- They are in the form of X.509 certificates with a verifiable certificate path to exactly one of the root of trust certificates
- They are not included in any CRL
- And they *list* one or more of the Organizational Units of the MSP configuration in the `OU` field of their X.509 certificate structure.

For more information on the validity of identities in the current MSP implementation we refer the reader to msp-identity-validity-rules.

In addition to verification related parameters, for the MSP to enable the node on which it is instantiated to sign or authenticate, one needs to specify:

- The signing key used for signing by the node (currently only ECDSA keys are supported), and
- The node's X.509 certificate, that is a valid identity under the verification parameters of this MSP

It is important to note that MSP identities never expire; they can only be revoked by adding them to the appropriate CRLs. Additionally, there is currently no support for enforcing revocation of TLS certificates.

How to generate MSP certificates and their signing keys?

To generate X.509 certificates to feed its MSP configuration, the application can use Openssl. We emphasise that in Hyperledger Fabric there is no support for certificates including RSA keys.

Alternatively one can use `cryptogen` tool, whose operation is explained in *Getting Started*.

Hyperledger Fabric CA can also be used to generate the keys and certificates needed to configure an MSP.

MSP setup on the peer & orderer side

To set up a local MSP (for either a peer or an orderer), the administrator should create a folder (e.g. `$MY_PATH/mspconfig`) that contains six subfolders and a file:

1. a folder `admincerts` to include PEM files each corresponding to an administrator certificate
2. a folder `cacerts` to include PEM files each corresponding to a root CA's certificate
3. (optional) a folder `intermediatecerts` to include PEM files each corresponding to an intermediate CA's certificate
4. (optional) a file `config.yaml` to include information on the considered OUs; the latter are defined as pairs of `<Certificate,OrganizationalUnitIdentifier>` entries of a yaml array called `OrganizationalUnitIdentifiers` , where `Certificate` represents the relative path to the certificate of the certificate authority (root or intermediate) that should be considered for certifying members of this organizational unit (e.g. ./cacerts/cacert.pem), and `OrganizationalUnitIdentifier` represents the actual string as expected to appear in X.509 certificate OU-field (e.g. "COP")
5. (optional) a folder `crls` to include the considered CRLs

6. a folder `keystore` to include a PEM file with the node's signing key; we emphasise that currently RSA keys are not supported
7. a folder `signcerts` to include a PEM file with the node's X.509 certificate
8. (optional) a folder `tlscacerts` to include PEM files each corresponding to a TLS root CA's certificate
9. (optional) a folder `tlsintermediatecerts` to include PEM files each corresponding to an intermediate TLS CA's certificate

In the configuration file of the node (core.yaml file for the peer, and orderer.yaml for the orderer), one needs to specify the path to the mspconfig folder, and the MSP Identifier of the node's MSP. The path to the mspconfig folder is expected to be relative to FABRIC_CFG_PATH and is provided as the value of parameter `mspConfigPath` for the peer, and `LocalMSPDir` for the orderer. The identifier of the node's MSP is provided as a value of parameter `localMspId` for the peer and `LocalMSPID` for the orderer. These variables can be overriden via the environment using the CORE prefix for peer (e.g. CORE_PEER_LOCALMSPID) and the ORDERER prefix for the orderer (e.g. ORDERER_GENERAL_LOCALMSPID). Notice that for the orderer setup, one needs to generate, and provide to the orderer the genesis block of the system channel. The MSP configuration needs of this block are detailed in the next section.

Reconfiguration of a "local" MSP is only possible manually, and requires that the peer or orderer process is restarted. In subsequent releases we aim to offer online/dynamic reconfiguration (i.e. without requiring to stop the node by using a node managed system chaincode).

Channel MSP setup

At the genesis of the system, verification parameters of all the MSPs that appear in the network need to be specified, and included in the system channel's genesis block. Recall that MSP verification parameters consist of the MSP identifier, the root of trust certificates, intermediate CA and admin certificates, as well as OU specifications and CRLs. The system genesis block is provided to the orderers at their setup phase, and allows them to authenticate channel creation requests. Orderers would reject the system genesis block, if the latter includes two MSPs with the same identifier, and consequently the bootstrapping of the network would fail.

For application channels, the verification components of only the MSPs that govern a channel need to reside in the channel's genesis block. We emphasise that it is **the responsibility of the application** to ensure that correct MSP configuration information is included in the genesis blocks (or the most recent configuration block) of a channel prior to instructing one or more of their peers to join the channel.

When bootstrapping a channel with the help of the configtxgen tool, one can configure the channel MSPs by including the verification parameters of MSP in the mspconfig folder, and setting that path in the relevant section in `configtx.yaml`.

Reconfiguration of an MSP on the channel, including announcements of the certificate revocation lists associated to the CAs of that MSP is achieved through the creation of a `config_update` object by the owner of one of the administrator certificates of the MSP. The client application managed by the admin would then announce this update to the channels in which this MSP appears.

Best Practices

In this section we elaborate on best practices for MSP configuration in commonly met scenarios.

1) Mapping between organizations/corporations and MSPs

We recommend that there is a one-to-one mapping between organizations and MSPs. If a different mapping type of mapping is chosen, the following needs to be to considered:

- **One organization employing various MSPs.** This corresponds to the case of an organization including a variety of divisions each represented by its MSP, either for management independence reasons, or for privacy reasons. In this case a peer can only be owned by a single MSP, and will not recognize peers with identities from other MSPs as peers of the same organization. The implication of this is that peers may share through gossip organization-scoped data with a set of peers that are members of the same subdivision, and NOT with the full set of providers constituting the actual organization.
- **Multiple organizations using a single MSP.** This corresponds to a case of a consortium of organisations that are governed by similar membership architecture. One needs to know here that peers would propagate organization-scoped messages to the peers that have an identity under the same MSP regardless of whether they belong to the same actual organization. This is a limitation of the granularity of MSP definition, and/or of the peer's configuration.

2) One organization has different divisions (say organizational units), to which it wants to grant access to different channels.

Two ways to handle this:

- **Define one MSP to accommodate membership for all organization's members**. Configuration of that MSP would consist of a list of root CAs, intermediate CAs and admin certificates; and membership identities would include the organizational unit (`OU`) a member belongs to. Policies can then be defined to capture members of a specific `OU` , and these policies may constitute the read/write policies of a channel or endorsement policies of a chaincode. A limitation of this approach is that gossip peers would consider peers with membership identities under their local MSP as members of the same organization, and would consequently gossip with them organisation-scoped data (e.g. their status).
- **Defining one MSP to represent each division**. This would involve specifying for each division, a set of certificates for root CAs, intermediate CAs, and admin Certs, such that there is no overlapping certification path across MSPs. This would mean that, for example, a different intermediate CA per subdivision is employed. Here the disadvantage is the management of more than one MSPs instead of one, but this circumvents the issue present in the previous approach. One could also define one MSP for each division by leveraging an OU extension of the MSP configuration.

3) Separating clients from peers of the same organization.

In many cases it is required that the "type" of an identity is retrievable from the identity itself (e.g. it may be needed that endorsements are guaranteed to have derived by peers, and not clients or nodes acting solely as orderers).

There is limited support for such requirements.

One way to allow for this separation is to to create a separate intermediate CA for each node type - one for clients and one for peers/orderers; and configure two different MSPs - one for clients and one for peers/orderers. Channels this organization should be accessing would need to include both MSPs, while endorsement policies will leverage only the MSP that refers to the peers. This would ultimately result in the organization being mapped to two MSP instances, and would have certain consequences on the way peers and clients interact.

Gossip would not be drastically impacted as all peers of the same organization would still belong to one MSP. Peers can restrict the execution of certain system chaincodes to local MSP based policies. For example, peers would only execute "joinChannel" request if the request is signed by the admin of their local MSP who can only be a client (end-user should be sitting at the origin of that request). We can go around this inconsistency if we accept that the only clients to be members of a peer/orderer MSP would be the administrators of that MSP.

Another point to be considered with this approach is that peers authorize event registration requests based on membership of request originator within their local MSP. Clearly, since the originator of the request is a client, the request originator is always doomed to belong to a different MSP than the requested peer and the peer would reject the request.

4) Admin and CA certificates.

It is important to set MSP admin certificates to be different than any of the certificates considered by the MSP for `root of trust` , or intermediate CAs. This is a common (security) practice to separate the duties of management

of membership components from the issuing of new certificates, and/or validation of existing ones.

5) Blacklisting an intermediate CA.

As mentioned in previous sections, reconfiguration of an MSP is achieved by reconfiguration mechanisms (manual reconfiguration for the local MSP instances, and via properly constructed `config_update` messages for MSP instances of a channel). Clearly, there are two ways to ensure an intermediate CA considered in an MSP is no longer considered for that MSP's identity validation:

1. Reconfigure the MSP to no longer include the certificate of that intermediate CA in the list of trusted intermediate CA certs. For the locally configured MSP, this would mean that the certificate of this CA is removed from the `intermediatecerts` folder.
2. Reconfigure the MSP to include a CRL produced by the root of trust which denounces the mentioned intermediate CA's certificate.

In the current MSP implementation we only support method (1) as it is simpler and does not require blacklisting the no longer considered intermediate CA.

**5) CAs and TLS CAs

MSP identities' root CAs and MSP TLS certificates' root CAs (and relative intermediate CAs) need to be declared in different folders. This is to avoid confusion between different classes of certificates. It is not forbidden to reuse the same CAs for both MSP identities and TLS certificates but best practices suggest to avoid this in production.

CHAPTER 15

Channel Configuration (configtx)

Shared configuration for a Hyperledger Fabric blockchain network is stored in a collection configuration transactions, one per channel. Each configuration transaction is usually referred to by the shorter name *configtx*.

Channel configuration has the following important properties:

1. **Versioned**: All elements of the configuration have an associated version which is advanced with every modification. Further, every committed configuration receives a sequence number.
2. **Permissioned**: Each element of the configuration has an associated policy which governs whether or not modification to that element is permitted. Anyone with a copy of the previous configtx (and no additional info) may verify the validity of a new config based on these policies.
3. **Hierarchical**: A root configuration group contains sub-groups, and each group of the hierarchy has associated values and policies. These policies can take advantage of the hierarchy to derive policies at one level from policies of lower levels.

Anatomy of a configuration

Configuration is stored as a transaction of type `HeaderType_CONFIG` in a block with no other transactions. These blocks are referred to as *Configuration Blocks*, the first of which is referred to as the *Genesis Block*.

The proto structures for configuration are stored in `fabric/protos/common/configtx.proto`. The Envelope of type `HeaderType_CONFIG` encodes a `ConfigEnvelope` message as the `Payload data` field. The proto for `ConfigEnvelope` is defined as follows:

```
message ConfigEnvelope {
    Config config = 1;
    Envelope last_update = 2;
}
```

The `last_update` field is defined below in the **Updates to configuration** section, but is only necessary when validating the configuration, not reading it. Instead, the currently committed configuration is stored in the `config` field, containing a `Config` message.

```
message Config {
    uint64 sequence = 1;
    ConfigGroup channel_group = 2;
}
```

The `sequence` number is incremented by one for each committed configuration. The `channel_group` field is the root group which contains the configuration. The `ConfigGroup` structure is recursively defined, and builds a tree of groups, each of which contains values and policies. It is defined as follows:

```
message ConfigGroup {
    uint64 version = 1;
    map<string,ConfigGroup> groups = 2;
    map<string,ConfigValue> values = 3;
    map<string,ConfigPolicy> policies = 4;
    string mod_policy = 5;
}
```

Because `ConfigGroup` is a recursive structure, it has hierarchical arrangement. The following example is expressed for clarity in golang notation.

```
// Assume the following groups are defined
var root, child1, child2, grandChild1, grandChild2, grandChild3 *ConfigGroup

// Set the following values
root.Groups["child1"] = child1
root.Groups["child2"] = child2
child1.Groups["grandChild1"] = grandChild1
child2.Groups["grandChild2"] = grandChild2
child2.Groups["grandChild3"] = grandChild3

// The resulting config structure of groups looks like:
// root:
//     child1:
//         grandChild1
//     child2:
//         grandChild2
//         grandChild3
```

Each group defines a level in the config hierarchy, and each group has an associated set of values (indexed by string key) and policies (also indexed by string key).

Values are defined by:

```
message ConfigValue {
    uint64 version = 1;
    bytes value = 2;
    string mod_policy = 3;
}
```

Policies are defined by:

```
message ConfigPolicy {
    uint64 version = 1;
    Policy policy = 2;
    string mod_policy = 3;
}
```

Note that Values, Policies, and Groups all have a `version` and a `mod_policy`. The `version` of an element is incremented each time that element is modified. The `mod_policy` is used to govern the required signatures to modify that element. For Groups, modification is adding or removing elements to the Values, Policies, or Groups maps (or changing the `mod_policy`). For Values and Policies, modification is changing the Value and Policy fields respectively (or changing the `mod_policy`). Each element's `mod_policy` is evaluated in the context of the current level of the config. Consider the following example mod poli-

cies defined at `Channel.Groups["Application"]` (Here, we use the golang map reference syntax, so `Channel.Groups["Application"].Policies["policy1"]` refers to the base `Channel` group's `Application` group's `Policies` map's `policy1` policy.)

- `policy1` maps to `Channel.Groups["Application"].Policies["policy1"]`
- `Org1/policy2` maps to `Channel.Groups["Application"].Groups["Org1"].Policies["policy2"]`
- `/Channel/policy3` maps to `Channel.Policies["policy3"]`

Note that if a `mod_policy` references a policy which does not exist, the item cannot be modified.

Configuration updates

Configuration updates are submitted as an `Envelope` message of type `HeaderType_CONFIG_UPDATE`. The `Payload data` of the transaction is a marshaled `ConfigUpdateEnvelope`. The `ConfigUpdateEnvelope` is defined as follows:

```
message ConfigUpdateEnvelope {
    bytes config_update = 1;
    repeated ConfigSignature signatures = 2;
}
```

The `signatures` field contains the set of signatures which authorizes the config update. Its message definition is:

```
message ConfigSignature {
    bytes signature_header = 1;
    bytes signature = 2;
}
```

The `signature_header` is as defined for standard transactions, while the signature is over the concatenation of the `signature_header` bytes and the `config_update` bytes from the `ConfigUpdateEnvelope` message.

The `ConfigUpdateEnvelope config_update` bytes are a marshaled `ConfigUpdate` message which is defined as follows:

```
message ConfigUpdate {
    string channel_id = 1;
    ConfigGroup read_set = 2;
    ConfigGroup write_set = 3;
}
```

The `channel_id` is the channel ID the update is bound for, this is necessary to scope the signatures which support this reconfiguration.

The `read_set` specifies a subset of the existing configuration, specified sparsely where only the `version` field is set and no other fields must be populated. The particular `ConfigValue value` or `ConfigPolicy policy` fields should never be set in the `read_set`. The `ConfigGroup` may have a subset of its map fields populated, so as to reference an element deeper in the config tree. For instance, to include the `Application` group in the `read_set`, its parent (the `Channel` group) must also be included in the read set, but, the `Channel` group does not need to populate all of the keys, such as the `Orderer group` key, or any of the `values` or `policies` keys.

The `write_set` specifies the pieces of configuration which are modified. Because of the hierarchical nature of the configuration, a write to an element deep in the hierarchy must contain the higher level elements in its `write_set` as well. However, for any element in the `write_set` which is also specified in the `read_set` at the same version, the element should be specified sparsely, just as in the `read_set`.

For example, given the configuration:

```
Channel: (version 0)
    Orderer (version 0)
    Appplication (version 3)
       Org1 (version 2)
```

To submit a configuration update which modifies `Org1` , the `read_set` would be:

```
Channel: (version 0)
    Application: (version 3)
```

and the `write_set` would be

```
Channel: (version 0)
    Application: (version 3)
        Org1 (version 3)
```

When the `CONFIG_UPDATE` is received, the orderer computes the resulting `CONFIG` by doing the following:

1. Verifies the `channel_id` and `read_set` . All elements in the `read_set` must exist at the given versions.
2. Computes the update set by collecting all elements in the `write_set` which do not appear at the same version in the `read_set` .
3. Verifies that each element in the update set increments the version number of the element update by exactly 1.
4. Verifies that the signature set attached to the `ConfigUpdateEnvelope` satisfies the `mod_policy` for each element in the update set.
5. Computes a new complete version of the config by applying the update set to the current config.
6. Writes the new config into a `ConfigEnvelope` which includes the `CONFIG_UPDATE` as the `last_update` field and the new config encoded in the `config` field, along with the incremented `sequence` value.
7. Writes the new `ConfigEnvelope` into a `Envelope` of type `CONFIG` , and ultimately writes this as the sole transaction in a new configuration block.

When the peer (or any other receiver for `Deliver`) receives this configuration block, it should verify that the config was appropriately validated by applying the `last_update` message to the current config and verifying that the orderer-computed `config` field contains the correct new configuration.

Permitted configuration groups and values

Any valid configuration is a subset of the following configuration. Here we use the notation `peer.<MSG>` to define a `ConfigValue` whose `value` field is a marshaled proto message of name `<MSG>` defined in `fabric/protos/peer/configuration.proto` . The notations `common.<MSG>` , `msp.<MSG>` , and `orderer.<MSG>` correspond similarly, but with their messages defined in `fabric/protos/common/configuration.proto` , `fabric/protos/msp/mspconfig.proto` , and `fabric/protos/orderer/configuration.proto` respectively.

Note, that the keys `{{org_name}}` and `{{consortium_name}}` represent arbitrary names, and indicate an element which may be repeated with different names.

```
&ConfigGroup{
    Groups: map<string, *ConfigGroup> {
        "Application":&ConfigGroup{
```

```
            Groups:map<String, *ConfigGroup> {
                {{org_name}}:&ConfigGroup{
                    Values:map<string, *ConfigValue>{
                        "MSP":msp.MSPConfig,
                        "AnchorPeers":peer.AnchorPeers,
                    },
                },
            },
        },
        "Orderer":&ConfigGroup{
            Groups:map<String, *ConfigGroup> {
                {{org_name}}:&ConfigGroup{
                    Values:map<string, *ConfigValue>{
                        "MSP":msp.MSPConfig,
                    },
                },
            },

            Values:map<string, *ConfigValue> {
                "ConsensusType":orderer.ConsensusType,
                "BatchSize":orderer.BatchSize,
                "BatchTimeout":orderer.BatchTimeout,
                "KafkaBrokers":orderer.KafkaBrokers,
            },
        },
        "Consortiums":&ConfigGroup{
            Groups:map<String, *ConfigGroup> {
                {{consortium_name}}:&ConfigGroup{
                    Groups:map<string, *ConfigGroup> {
                        {{org_name}}:&ConfigGroup{
                            Values:map<string, *ConfigValue>{
                                "MSP":msp.MSPConfig,
                            },
                        },
                    },
                    Values:map<string, *ConfigValue> {
                        "ChannelCreationPolicy":common.Policy,
                    }
                },
            },
        },
    },

    Values: map<string, *ConfigValue> {
        "HashingAlgorithm":common.HashingAlgorithm,
        "BlockHashingDataStructure":common.BlockDataHashingStructure,
        "Consortium":common.Consortium,
        "OrdererAddresses":common.OrdererAddresses,
    },
}
```

Orderer system channel configuration

The ordering system channel needs to define ordering parameters, and consortiums for creating channels. There must be exactly one ordering system channel for an ordering service, and it is the first channel to be created (or more

accurately bootstrapped). It is recommended never to define an Application section inside of the ordering system channel genesis configuration, but may be done for testing. Note that any member with read access to the ordering system channel may see all channel creations, so this channel's access should be restricted.

The ordering parameters are defined as the following subset of config:

```
&ConfigGroup{
    Groups: map<string, *ConfigGroup> {
        "Orderer":&ConfigGroup{
            Groups:map<String, *ConfigGroup> {
                {{org_name}}:&ConfigGroup{
                    Values:map<string, *ConfigValue>{
                        "MSP":msp.MSPConfig,
                    },
                },
            },

            Values:map<string, *ConfigValue> {
                "ConsensusType":orderer.ConsensusType,
                "BatchSize":orderer.BatchSize,
                "BatchTimeout":orderer.BatchTimeout,
                "KafkaBrokers":orderer.KafkaBrokers,
            },
        },
    },
```

Each organization participating in ordering has a group element under the `Orderer` group. This group defines a single parameter `MSP` which contains the cryptographic identity information for that organization. The `Values` of the `Orderer` group determine how the ordering nodes function. They exist per channel, so `orderer.BatchTimeout` for instance may be specified differently on one channel than another.

At startup, the orderer is faced with a filesystem which contains information for many channels. The orderer identifies the system channel by identifying the channel with the consortiums group defined. The consortiums group has the following structure.

```
&ConfigGroup{
    Groups: map<string, *ConfigGroup> {
        "Consortiums":&ConfigGroup{
            Groups:map<String, *ConfigGroup> {
                {{consortium_name}}:&ConfigGroup{
                    Groups:map<string, *ConfigGroup> {
                        {{org_name}}:&ConfigGroup{
                            Values:map<string, *ConfigValue>{
                                "MSP":msp.MSPConfig,
                            },
                        },
                    },
                    Values:map<string, *ConfigValue> {
                        "ChannelCreationPolicy":common.Policy,
                    }
                },
            },
        },
    },
},
```

Note that each consortium defines a set of members, just like the organizational members for the ordering orgs. Each consortium also defines a `ChannelCreationPolicy` . This is a policy which is applied to authorize channel creation requests. Typically, this value will be set to an `ImplicitMetaPolicy` requiring that the new members of

the channel sign to authorize the channel creation. More details about channel creation follow later in this document.

Application channel configuration

Application configuration is for channels which are designed for application type transactions. It is defined as follows:

```
&ConfigGroup{
    Groups: map<string, *ConfigGroup> {
        "Application":&ConfigGroup{
            Groups:map<String, *ConfigGroup> {
                {{org_name}}:&ConfigGroup{
                    Values:map<string, *ConfigValue>{
                        "MSP":msp.MSPConfig,
                        "AnchorPeers":peer.AnchorPeers,
                    },
                },
            },
        },
    },
}
```

Just like with the `Orderer` section, each organization is encoded as a group. However, instead of only encoding the `MSP` identity information, each org additionally encodes a list of `AnchorPeers` . This list allows the peers of different organizations to contact each other for peer gossip networking.

The application channel encodes a copy of the orderer orgs and consensus options to allow for deterministic updating of these parameters, so the same `Orderer` section from the orderer system channel configuration is included. However from an application perspective this may be largely ignored.

Channel creation

When the orderer receives a `CONFIG_UPDATE` for a channel which does not exist, the orderer assumes that this must be a channel creation request and performs the following.

1. The orderer identifies the consortium which the channel creation request is to be performed for. It does this by looking at the `Consortium` value of the top level group.
2. The orderer verifies that the organizations included in the `Application` group are a subset of the organizations included in the corresponding consortium and that the `ApplicationGroup` is set to `version 1` .
3. The orderer verifies that if the consortium has members, that the new channel also has application members (creation consortiums and channels with no members is useful for testing only).
4. The orderer creates a template configuration by taking the `Orderer` group from the ordering system channel, and creating an `Application` group with the newly specified members and specifying its `mod_policy` to be the `ChannelCreationPolicy` as specified in the consortium config. Note that the policy is evaluated in the context of the new configuration, so a policy requiring `ALL` members, would require signatures from all the new channel members, not all the members of the consortium.
5. The orderer then applies the `CONFIG_UPDATE` as an update to this template configuration. Because the `CONFIG_UPDATE` applies modifications to the `Application` group (its `version` is `1`), the config code validates these updates against the `ChannelCreationPolicy` . If the channel creation contains any other modifications, such as to an individual org's anchor peers, the corresponding mod policy for the element will be invoked.

6. The new `CONFIG` transaction with the new channel config is wrapped and sent for ordering on the ordering system channel. After ordering, the channel is created.

CHAPTER 16

Channel Configuration (configtxgen)

This document describe the usage for the `configtxgen` utility for manipulating Hyperledger Fabric channel configuration.

For now, the tool is primarily focused on generating the genesis block for bootstrapping the orderer, but it is intended to be enhanced in the future for generating new channel configurations as well as reconfiguring existing channels.

Configuration Profiles

The configuration parameters supplied to the `configtxgen` tool are primarily provided by the `configtx.yaml` file. This file is located at `fabric/sampleconfig/configtx.yaml` in the fabric.git repository.

This configuration file is split primarily into three pieces.

1. The `Profiles` section. By default, this section includes some sample configurations which can be used for development or testing scenarios, and refer to crypto material present in the fabric.git tree. These profiles can make a good starting point for construction a real deployment profile. The `configtxgen` tool allows you to specify the profile it is operating under by passing the `-profile` flag. Profiles may explicitly declare all configuration, but usually inherit configuration from the defaults in (3) below.
2. The `Organizations` section. By default, this section includes a single reference to the sampleconfig MSP definition. For production deployments, the sample organization should be removed, and the MSP definitions of the network members should be referenced and defined instead. Each element in the `Organizations` section should be tagged with an anchor label such as `&orgName` which will allow the definition to be referenced in the `Profiles` sections.
3. The default sections. There are default sections for `Orderer` and `Application` configuration, these include attributes like `BatchTimeout` and are generally used as the base inherited values for the profiles.

This configuration file may be edited, or, individual properties may be overridden by setting environment variables, such as `CONFIGTX_ORDERER_ORDERERTYPE=kafka` . Note that the `Profiles` element and profile name do not need to be specified.

Bootstrapping the orderer

After creating a configuration profile as desired, simply invoke

```
configtxgen -profile <profile_name>
```

This will produce a `genesis.block` file in the current directory. You may optionally specify another filename by passing in the `-path` parameter, or, you may skip the writing of the file by passing the `dryRun` parameter if you simply wish to test parsing of the file.

Then, to utilize this genesis block, before starting the orderer, simply specify `ORDERER_GENERAL_GENESISMETHOD=file` and `ORDERER_GENERAL_GENESISFILE=$PWD/genesis.block` or modify the `orderer.yaml` file to encode these values.

Creating a channel

The tool can also output a channel creation tx by executing

```
configtxgen -profile <profile_name> -channelID <channel_name> -outputCreateChannelTx
↪<tx_filename>
```

This will output a marshaled `Envelope` message which may be sent to broadcast to create a channel.

Reviewing a configuration

In addition to creating configuration, the `configtxgen` tool is also capable of inspecting configuration.

It supports inspecting both configuration blocks, and configuration transactions. You may use the inspect flags `-inspectBlock` and `-inspectChannelCreateTx` respectively with the path to a file to inspect to output a human readable (JSON) representation of the configuration.

You may even wish to combine the inspection with generation. For example:

```
$ build/bin/configtxgen -channelID foo -outputBlock foo.block -inspectBlock foo.block
2017/03/01 21:24:24 Loading configuration
2017/03/01 21:24:24 Checking for configtx.yaml at:
2017/03/01 21:24:24 Checking for configtx.yaml at:
2017/03/01 21:24:24 Checking for configtx.yaml at: /home/yellickj/go/src/github.com/
↪hyperledger/fabric/common/configtx/tool
2017/03/01 21:24:24 map[orderer:map[BatchSize:map[MaxMessageCount:10 AbsoluteMaxBytes:
↪99 MB PreferredMaxBytes:512 KB] Kafka:map[Brokers:[127.0.0.1:9092]] Organizations:
↪<nil> OrdererType:solo Addresses:[127.0.0.1:7050] BatchTimeout:10s] application:
↪map[Organizations:<nil>] profiles:map[SampleInsecureSolo:map[Orderer:
↪map[BatchTimeout:10s BatchSize:map[MaxMessageCount:10 AbsoluteMaxBytes:99 MB␣
↪PreferredMaxBytes:512 KB] Kafka:map[Brokers:[127.0.0.1:9092]] Organizations:<nil>␣
↪OrdererType:solo Addresses:[127.0.0.1:7050]] Application:map[Organizations:<nil>]]␣
↪SampleInsecureKafka:map[Orderer:map[Addresses:[127.0.0.1:7050] BatchTimeout:10s␣
↪BatchSize:map[AbsoluteMaxBytes:99 MB PreferredMaxBytes:512 KB MaxMessageCount:10]␣
↪Kafka:map[Brokers:[127.0.0.1:9092]] Organizations:<nil> OrdererType:kafka]␣
↪Application:map[Organizations:<nil>]] SampleSingleMSPSolo:map[Orderer:
↪map[OrdererType:solo Addresses:[127.0.0.1:7050] BatchTimeout:10s BatchSize:
↪map[MaxMessageCount:10 AbsoluteMaxBytes:99 MB PreferredMaxBytes:512 KB] Kafka:
↪map[Brokers:[127.0.0.1:9092]] Organizations:[map[Name:SampleOrg ID:DEFAULT MSPDir:
↪msp BCCSP:map[Default:SW SW:map[Hash:SHA3 Security:256 FileKeyStore:map[KeyStore:
↪<nil>]]] AnchorPeers:[map[Host:127.0.0.1 Port:7051]]]]] Application:
↪map[Organizations:[map[Name:SampleOrg ID:DEFAULT MSPDir:msp BCCSP:map[Default:SW SW:
↪map[Hash:SHA3 Security:256 FileKeyStore:map[KeyStore:<nil>]]] AnchorPeers:[map[Port:
↪7051 Host:127.0.0.1]]]]]]] organizations:[map[Name:SampleOrg ID:DEFAULT MSPDir:msp␣
↪BCCSP:map[Default:SW SW:map[Hash:SHA3 Security:256 FileKeyStore:map[KeyStore:<nil>
↪]]] AnchorPeers:[map[Host:127.0.0.1 Port:7051]]]]]
2017/03/01 21:24:24 Generating genesis block
```

```
2017/03/01 21:24:24 Writing genesis block
2017/03/01 21:24:24 Inspecting block
2017/03/01 21:24:24 Parsing genesis block
Config for channel: foo
{
    "": {
        "Values": {},
        "Groups": {
            "/Channel": {
                "Values": {
                    "HashingAlgorithm": {
                        "Version": "0",
                        "ModPolicy": "",
                        "Value": {
                            "name": "SHA256"
                        }
                    },
                    "BlockDataHashingStructure": {
                        "Version": "0",
                        "ModPolicy": "",
                        "Value": {
                            "width": 4294967295
                        }
                    },
                    "OrdererAddresses": {
                        "Version": "0",
                        "ModPolicy": "",
                        "Value": {
                            "addresses": [
                                "127.0.0.1:7050"
                            ]
                        }
                    }
                },
                "Groups": {
                    "/Channel/Orderer": {
                        "Values": {
                            "ChainCreationPolicyNames": {
                                "Version": "0",
                                "ModPolicy": "",
                                "Value": {
                                    "names": [
                                        "AcceptAllPolicy"
                                    ]
                                }
                            },
                            "ConsensusType": {
                                "Version": "0",
                                "ModPolicy": "",
                                "Value": {
                                    "type": "solo"
                                }
                            },
                            "BatchSize": {
                                "Version": "0",
                                "ModPolicy": "",
                                "Value": {
                                    "maxMessageCount": 10,
```

```
                                    "absoluteMaxBytes": 103809024,
                                    "preferredMaxBytes": 524288
                                }
                            },
                            "BatchTimeout": {
                                "Version": "0",
                                "ModPolicy": "",
                                "Value": {
                                    "timeout": "10s"
                                }
                            },
                            "IngressPolicyNames": {
                                "Version": "0",
                                "ModPolicy": "",
                                "Value": {
                                    "names": [
                                        "AcceptAllPolicy"
                                    ]
                                }
                            },
                            "EgressPolicyNames": {
                                "Version": "0",
                                "ModPolicy": "",
                                "Value": {
                                    "names": [
                                        "AcceptAllPolicy"
                                    ]
                                }
                            }
                        },
                        "Groups": {}
                    },
                    "/Channel/Application": {
                        "Values": {},
                        "Groups": {}
                    }
                }
            }
        }
    }
}
```

CHAPTER 17

Reconfiguring with configtxlator

Overview

The `configtxlator` tool was created to support reconfiguration independent of SDKs. Channel configuration is stored as a transaction in configuration blocks of a channel and may be manipulated directly, such as in the bdd behave tests. However, at the time of this writing, no SDK natively supports manipulating the configuration directly, so the `configtxlator` tool is designed to provide an API which consumers of any SDK may interact with to assist with configuration updates.

The tool name is a portmanteau of *configtx* and *translator* and is intended to convey that the tool simply converts between different equivalent data representations. It does not generate configuration. It does not submit or retrieve configuration. It does not modify configuration itself, it simply provides some bijective operations between different views of the configtx format.

The standard usage is expected to be:

1. SDK retrieves latest config
2. `configtxlator` produces human readable version of config
3. User or application edits the config
4. `configtxlator` is used to compute config update representation of changes to the config
5. SDK submits signs and submits config

The `configtxlator` tool exposes a truly stateless REST API for interacting with configuration elements. These REST components support converting the native configuration format to/from a human readable JSON representation, as well as computing configuration updates based on the difference between two configurations.

Because the `configtxlator` service deliberately does not contain any crypto material, or otherwise secret information, it does not include any authorization or access control. The anticipated typical deployment would be to operate as a sandboxed container, locally with the application, so that there is a dedicated `configtxlator` process for each consumer of it.

Running the configtxlator

The `configtxlator` tool can be downloaded with the other Hyperledger Fabric platform-specific binaries. Please see download-platform-specific-binaries for details.

The tool may be configured to listen on a different port and you may also specify the hostname using the `--port` and `--hostname` flags. To explore the complete set of commands and flags, run `configtxlator --help`.

The binary will start an http server listening on the designated port and is now ready to process request.

To start the `configtxlator` server:

```
configtxlator start
2017-06-21 18:16:58.248 HKT [configtxlator] startServer -> INFO 001 Serving HTTP␣
↪requests on 0.0.0.0:7059
```

Proto translation

For extensibility, and because certain fields must be signed over, many proto fields are stored as bytes. This makes the natural proto to JSON translation using the `jsonpb` package ineffective for producing a human readable version of the protobufs. Instead, the `configtxlator` exposes a REST component to do a more sophisticated translation.

To convert a proto to its human readable JSON equivalent, simply post the binary proto to the rest target `http://$SERVER:$PORT/protolator/decode/<message.Name>` , where `<message.Name>` is the fully qualified proto name of the message.

For instance, to decode a configuration block saved as `configuration_block.pb` , run the command:

```
curl -X POST --data-binary @configuration_block.pb http://127.0.0.1:7059/protolator/
↪decode/common.Block
```

To convert the human readable JSON version of the proto message, simply post the JSON version to `http://$SERVER:$PORT/protolator/encode/<message.Name` , where `<message.Name>` is again the fully qualified proto name of the message.

For instance, to re-encode the block saved as `configuration_block.json` , run the command:

```
curl -X POST --data-binary @configuration_block.json http://127.0.0.1:7059/protolator/
↪encode/common.Block
```

Any of the configuration related protos, including `common.Block` , `common.Envelope` , `common.ConfigEnvelope` , `common.ConfigUpdateEnvelope` , `common.Config` , and `common.ConfigUpdate` are valid targets for these URLs. In the future, other proto decoding types may be added, such as for endorser transactions.

Config update computation

Given two different configurations, it is possible to compute the config update which transitions between them. Simply POST the two `common.Config` proto encoded configurations as `multipart/formdata` , with the original as field `original` and the updated as field `updated` , to `http://$SERVER:$PORT/configtxlator/compute/update-from-configs` .

For example, given the original config as the file `original_config.pb` and the updated config as the file `updated_config.pb` for the channel `desiredchannel` :

```
curl -X POST -F channel=desiredchannel -F original=@original_config.pb -F␣
↪updated=@updated_config.pb http://127.0.0.1:7059/configtxlator/compute/update-from-
↪configs
```

Bootstraping example

First start the `configtxlator` :

```
$ configtxlator start
2017-05-31 12:57:22.499 EDT [configtxlator] main -> INFO 001 Serving HTTP requests on␣
↪port: 7059
```

First, produce a genesis block for the ordering system channel:

```
$ configtxgen -outputBlock genesis_block.pb
2017-05-31 14:15:16.634 EDT [common/configtx/tool] main -> INFO 001 Loading␣
↪configuration
2017-05-31 14:15:16.646 EDT [common/configtx/tool] doOutputBlock -> INFO 002␣
↪Generating genesis block
2017-05-31 14:15:16.646 EDT [common/configtx/tool] doOutputBlock -> INFO 003 Writing␣
↪genesis block
```

Decode the genesis block into a human editable form:

```
curl -X POST --data-binary @genesis_block.pb http://127.0.0.1:7059/protolator/decode/
↪common.Block > genesis_block.json
```

Edit the `genesis_block.json` file in your favorite JSON editor, or manipulate it programatically. Here we use the JSON CLI tool `jq` . For simplicity, we are editing the batch size for the channel, because it is a single numeric field. However, any edits, including policy and MSP edits may be made here.

First, let's establish an environment variable to hold the string that defines the path to a property in the json:

```
export MAXBATCHSIZEPATH=".data.data[0].payload.data.config.channel_group.groups.
↪Orderer.values.BatchSize.value.max_message_count"
```

Next, let's display the value of that property:

```
jq "$MAXBATCHSIZEPATH" genesis_block.json
10
```

Now, let's set the new batch size, and display the new value:

> jq "$MAXBATCHSIZEPATH = 20" genesis_block.json > updated_genesis_block.json jq "$MAXBATCHSIZEPATH" updated_genesis_block.json 20

The genesis block is now ready to be re-encoded into the native proto form to be used for bootstrapping:

```
curl -X POST --data-binary @updated_genesis_block.json http://127.0.0.1:7059/
↪protolator/encode/common.Block > updated_genesis_block.pb
```

The `updated_genesis_block.pb` file may now be used as the genesis block for bootstrapping an ordering system channel.

Reconfiguration example

In another terminal window, start the orderer using the default options, including the provisional bootstrapper which will create a `testchainid` ordering system channel.

```
ORDERER_GENERAL_LOGLEVEL=debug orderer
```

Reconfiguring a channel can be performed in a very similar way to modifying a genesis config.

First, fetch the config_block proto:

```
$ peer channel fetch config config_block.pb -o 127.0.0.1:7050 -c testchainid
2017-05-31 15:11:37.617 EDT [msp] getMspConfig -> INFO 001 intermediate certs folder␣
↪not found at [/home/yellickj/go/src/github.com/hyperledger/fabric/sampleconfig/msp/
↪intermediatecerts]. Skipping.: [stat /home/yellickj/go/src/github.com/hyperledger/
↪fabric/sampleconfig/msp/intermediatecerts: no such file or directory]
2017-05-31 15:11:37.617 EDT [msp] getMspConfig -> INFO 002 crls folder not found at [/
↪home/yellickj/go/src/github.com/hyperledger/fabric/sampleconfig/msp/
↪intermediatecerts]. Skipping.: [stat /home/yellickj/go/src/github.com/hyperledger/
↪fabric/sampleconfig/msp/crls: no such file or directory]
Received block:  1
Received block:  1
2017-05-31 15:11:37.635 EDT [main] main -> INFO 003 Exiting.....
```

Next, send the config block to the `configtxlator` service for decoding:

```
curl -X POST --data-binary @config_block.pb http://127.0.0.1:7059/protolator/decode/
↪common.Block > config_block.json
```

Extract the config section from the block:

```
jq .data.data[0].payload.data.config config_block.json > config.json
```

Edit the config, saving it as a new `updated_config.json` . Here, we set the batch size to 30.

```
jq ".channel_group.groups.Orderer.values.BatchSize.value.max_message_count = 30"␣
↪config.json  > updated_config.json
```

Re-encode both the original config, and the updated config into proto:

```
curl -X POST --data-binary @config.json http://127.0.0.1:7059/protolator/encode/
↪common.Config > config.pb
```

```
curl -X POST --data-binary @updated_config.json http://127.0.0.1:7059/protolator/
↪encode/common.Config > updated_config.pb
```

Now, with both configs properly encoded, send them to the *configtxlator* service to compute the config update which transitions between the two.

```
curl -X POST -F original=@config.pb -F updated=@updated_config.pb http://127.0.0.1:
↪7059/configtxlator/compute/update-from-configs -F channel=testchainid > config_
↪update.pb
```

At this point, the computed config update is now prepared. Traditionally, an SDK would be used to sign and wrap this message. However, in the interest of using only the peer cli, the *configtxlator* can also be used for this task.

First, we decode the ConfigUpdate so that we may work with it as text:

```
$ curl -X POST --data-binary @config_update.pb http://127.0.0.1:7059/protolator/
↪decode/common.ConfigUpdate > config_update.json
```

Then, we wrap it in an envelope message:

```
echo '{"payload":{"header":{"channel_header":{"channel_id":"testchainid", "type":2}},
↪"data":{"config_update":'$(cat config_update.json)'}}}' > config_update_as_envelope.
↪json
```

Next, convert it back into the proto form of a full fledged config transaction:

```
curl -X POST --data-binary @config_update_as_envelope.json http://127.0.0.1:7059/
↪protolator/encode/common.Envelope > config_update_as_envelope.pb
```

Finally, submit the config update transaction to ordering to perform a config update.

```
peer channel update -f config_update_as_envelope.pb -c testchainid -o 127.0.0.1:7050
```

Adding an organization

First start the `configtxlator` :

```
$ configtxlator start
2017-05-31 12:57:22.499 EDT [configtxlator] main -> INFO 001 Serving HTTP requests on␣
↪port: 7059
```

Start the orderer using the `SampleDevModeSolo` profile option.

```
ORDERER_GENERAL_LOGLEVEL=debug ORDERER_GENERAL_GENESISPROFILE=SampleDevModeSolo␣
↪orderer
```

The process to add an organization then follows exactly like the batch size example. However, instead of setting the batch size, a new org is defined at the application level. Adding an organization is slightly more involved because we must first create a channel, then modify its membership set.

CHAPTER 18

Endorsement policies

Endorsement policies are used to instruct a peer on how to decide whether a transaction is properly endorsed. When a peer receives a transaction, it invokes the VSCC (Validation System Chaincode) associated with the transaction's Chaincode as part of the transaction validation flow to determine the validity of the transaction. Recall that a transaction contains one or more endorsement from as many endorsing peers. VSCC is tasked to make the following determinations: - all endorsements are valid (i.e. they are valid signatures from valid certificates over the expected message) - there is an appropriate number of endorsements - endorsements come from the expected source(s)

Endorsement policies are a way of specifying the second and third points.

Endorsement policy design

Endorsement policies have two main components: - a principal - a threshold gate

A principal `P` identifies the entity whose signature is expected.

A threshold gate `T` takes two inputs: an integer `t` (the threshold) and a list of `n` principals or gates; this gate essentially captures the expectation that out of those `n` principals or gates, `t` are requested to be satisfied.

For example: - `T(2,'A','B','C')` requests a signature from any 2 principals out of 'A', 'B' or 'C'; - `T(1,'A',T(2,'B','C'))` requests either one signature from principal `A` or 1 signature from `B` and `C` each.

Endorsement policy syntax in the CLI

In the CLI, a simple language is used to express policies in terms of boolean expressions over principals.

A principal is described in terms of the MSP that is tasked to validate the identity of the signer and of the role that the signer has within that MSP. Currently, two roles are supported: **member** and **admin**. Principals are described as `MSP.ROLE`, where `MSP` is the MSP ID that is required, and `ROLE` is either one of the two strings `member` and `admin`. Examples of valid principals are `'Org0.admin'` (any administrator of the `Org0` MSP) or `'Org1.member'` (any member of the `Org1` MSP).

The syntax of the language is:

```
EXPR(E[,E...])
```

where `EXPR` is either `AND` or `OR`, representing the two boolean expressions and `E` is either a principal (with the syntax described above) or another nested call to `EXPR`.

For example: - `AND('Org1.member','Org2.member','Org3.member')` requests 1 signature from each of the three principals - `OR('Org1.member','Org2.member')` requests 1 signature from either one of the two

principals - `OR('Org1.member',AND('Org2.member','Org3.member'))` requests 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.

Specifying endorsement policies for a chaincode

Using this language, a chaincode deployer can request that the endorsements for a chaincode be validated against the specified policy. NOTE - the default policy requires one signature from a member of the `DEFAULT` MSP). This is used if a policy is not specified in the CLI.

The policy can be specified at deploy time using the `-P` switch, followed by the policy.

For example:

```
peer chaincode deploy -C testchainid -n mycc -p github.com/hyperledger/fabric/
↪examples/chaincode/go/chaincode_example02 -c '{"Args":["init","a","100","b","200"]}
↪' -P "AND('Org1.member', 'Org2.member')"
```

This command deploys chaincode `mycc` on chain `testchainid` with the policy `AND('Org1.member','Org2.member')`.

Future enhancements

In this section we list future enhancements for endorsement policies: - alongside the existing way of identifying principals by their relationship with an MSP, we plan to identify principals in terms of the *Organization Unit (OU)* expected in their certificates; this is useful to express policies where we request signatures from any identity displaying a valid certificate with an OU matching the one requested in the definition of the principal. - instead of the syntax `AND(.,.)` we plan to move to a more intuitive syntax `. AND .` - we plan to expose generalized threshold gates in the language as well alongside `AND` (which is the special `n` -out-of-`n` gate) and `OR` (which is the special `1` -out-of-`n` gate)

CHAPTER 19

Error handling

General Overview

The Hyperledger Fabric error handling framework can be found in the source repository under **common/errors**. It defines a new type of error, CallStackError, to use in place of the standard error type provided by Go.

A CallStackError consists of the following:

- Component code - a name for the general area of the code that is generating the error. Component codes should consist of three uppercase letters. Numerics and special characters are not allowed. A set of component codes is defined in common/errors/codes.go
- Reason code - a short code to help identify the reason the error occurred. Reason codes should consist of three numeric values. Letters and special characters are not allowed. A set of reason codes is defined in common/error/codes.go
- Error code - the component code and reason code separated by a colon, e.g. MSP:404
- Error message - the text that describes the error. This is the same as the input provided to `fmt.Errorf()` and `Errors.New()` . If an error has been wrapped into the current error, its message will be appended.
- Callstack - the callstack at the time the error is created. If an error has been wrapped into the current error, its error message and callstack will be appended to retain the context of the wrapped error.

The CallStackError interface exposes the following functions:

- Error() - returns the error message with callstack appended
- Message() - returns the error message (without callstack appended)
- GetComponentCode() - returns the 3-character component code
- GetReasonCode() - returns the 3-digit reason code
- GetErrorCode() - returns the error code, which is "component:reason"
- GetStack() - returns just the callstack
- WrapError(error) - wraps the provided error into the CallStackError

Usage Instructions

The new error handling framework should be used in place of all calls to `fmt.Errorf()` or `Errors.new()` . Using this framework will provide error codes to check against as well as the option to generate a callstack that will be appended to the error message.

Using the framework is simple and will only require an easy tweak to your code.

First, you'll need to import **github.com/hyperledger/fabric/common/errors** into any file that uses this framework.

Let's take the following as an example from core/chaincode/chaincode_support.go:

```
err = fmt.Errorf("Error starting container: %s", err)
```

For this error, we will simply call the constructor for Error and pass a component code, reason code, followed by the error message. At the end, we then call the `WrapError()` function, passing along the error itself.

```
fmt.Errorf("Error starting container: %s", err)
```

becomes

```
errors.ErrorWithCallstack("CHA", "505", "Error starting container").WrapError(err)
```

You could also just leave the message as is without any problems:

```
errors.ErrorWithCallstack("CHA", "505", "Error starting container: %s", err)
```

With this usage you will be able to format the error message from the previous error into the new error, but will lose the ability to print the callstack (if the wrapped error is a CallStackError).

A second example to highlight a scenario that involves formatting directives for parameters other than errors, while still wrapping an error, is as follows:

```
fmt.Errorf("failed to get deployment payload %s - %s", canName, err)
```

becomes

```
errors.ErrorWithCallstack("CHA", "506", "Failed to get deployment payload %s",␣
↪canName).WrapError(err)
```

Displaying error messages

Once the error has been created using the framework, displaying the error message is as simple as:

```
logger.Errorf(err)
```

or

```
fmt.Println(err)
```

or

```
fmt.Printf("%s\n", err)
```

An example from peer/common/common.go:

```
errors.ErrorWithCallstack("PER", "404", "Error trying to connect to local peer").
↪WrapError(err)
```

would display the error message:

```
PER:404 - Error trying to connect to local peer
Caused by: grpc: timed out when dialing
```

Note: The callstacks have not been displayed for this example for the sake of brevity.

General guidelines for error handling in Hyperledger Fabric

- If it is some sort of best effort thing you are doing, you should log the error and ignore it.
- If you are servicing a user request, you should log the error and return it.
- If the error comes from elsewhere, you have the choice to wrap the error or not. Typically, it's best to not wrap the error and simply return it as is. However, for certain cases where a utility function is called, wrapping the error with a new component and reason code can help an end user understand where the error is really occurring without inspecting the callstack.
- A panic should be handled within the same layer by throwing an internal error code/start a recovery process and should not be allowed to propagate to other packages.

CHAPTER 20

Logging Control

Overview

Logging in the `peer` application and in the `shim` interface to chaincodes is programmed using facilities provided by the `github.com/op/go-logging` package. This package supports

- Logging control based on the severity of the message
- Logging control based on the software *module* generating the message
- Different pretty-printing options based on the severity of the message

All logs are currently directed to `stderr`, and the pretty-printing is currently fixed. However global and module-level control of logging by severity is provided for both users and developers. There are currently no formalized rules for the types of information provided at each severity level, however when submitting bug reports the developers may want to see full logs down to the DEBUG level.

In pretty-printed logs the logging level is indicated both by color and by a 4-character code, e.g, "ERRO" for ERROR, "DEBU" for DEBUG, etc. In the logging context a *module* is an arbitrary name (string) given by developers to groups of related messages. In the pretty-printed example below, the logging modules "peer", "rest" and "main" are generating logs.

```
16:47:09.634 [peer] GetLocalAddress -> INFO 033 Auto detected peer address: 9.3.158.
↪178:7051
16:47:09.635 [rest] StartOpenchainRESTServer -> INFO 035 Initializing the REST␣
↪service...
16:47:09.635 [main] serve -> INFO 036 Starting peer with id=name:"vp1" , network␣
↪id=dev, address=9.3.158.178:7051, discovery.rootnode=, validator=true
```

An arbitrary number of logging modules can be created at runtime, therefore there is no "master list" of modules, and logging control constructs can not check whether logging modules actually do or will exist. Also note that the logging module system does not understand hierarchy or wildcarding: You may see module names like "foo/bar" in the code, but the logging system only sees a flat string. It doesn't understand that "foo/bar" is related to "foo" in any way, or that "foo/*" might indicate all "submodules" of foo.

peer

The logging level of the `peer` command can be controlled from the command line for each invocation using the `--logging-level` flag, for example

```
peer node start --logging-level=debug
```

The default logging level for each individual `peer` subcommand can also be set in the core.yaml file. For example the key `logging.node` sets the default level for the `node` subcommmand. Comments in the file also explain how the logging level can be overridden in various ways by using environment varaibles.

Logging severity levels are specified using case-insensitive strings chosen from

```
CRITICAL | ERROR | WARNING | NOTICE | INFO | DEBUG
```

The full logging level specification for the `peer` is of the form

```
[<module>[,<module>...]=]<level>[:[<module>[,<module>...]=]<level>...]
```

A logging level by itself is taken as the overall default. Otherwise, overrides for individual or groups of modules can be specified using the

```
<module>[,<module>...]=<level>
```

syntax. Examples of specifications (valid for all of `--logging-level` , environment variable and core.yaml settings):

```
info                                        - Set default to INFO
warning:main,db=debug:chaincode=info        - Default WARNING; Override for␣
↪main,db,chaincode
chaincode=info:main=debug:db=debug:warning - Same as above
```

Go chaincodes

The standard mechanism to log within a chaincode application is to integrate with the logging transport exposed to each chaincode instance via the peer. The chaincode `shim` package provides APIs that allow a chaincode to create and manage logging objects whose logs will be formatted and interleaved consistently with the `shim` logs.

As independently executed programs, user-provided chaincodes may technically also produce output on stdout/stderr. While naturally useful for "devmode", these channels are normally disabled on a production network to mitigate abuse from broken or malicious code. However, it is possible to enable this output even for peer-managed containers (e.g. "netmode") on a per-peer basis via the CORE_VM_DOCKER_ATTACHSTDOUT=true configuration option.

Once enabled, each chaincode will receive its own logging channel keyed by its container-id. Any output written to either stdout or stderr will be integrated with the peer's log on a per-line basis. It is not recommended to enable this for production.

API

`NewLogger(name string) *ChaincodeLogger` - Create a logging object for use by a chaincode

`(c *ChaincodeLogger) SetLevel(level LoggingLevel)` - Set the logging level of the logger

`(c *ChaincodeLogger) IsEnabledFor(level LoggingLevel) bool` - Return true if logs will be generated at the given level

`LogLevel(levelString string) (LoggingLevel,error)` - Convert a string to a `LoggingLevel`

A `LoggingLevel` is a member of the enumeration

```
LogDebug, LogInfo, LogNotice, LogWarning, LogError, LogCritical
```

which can be used directly, or generated by passing a case-insensitive version of the strings

```
DEBUG, INFO, NOTICE, WARNING, ERROR, CRITICAL
```

to the `LogLevel` API.

Formatted logging at various severity levels is provided by the functions

```
(c *ChaincodeLogger) Debug(args ...interface{})
(c *ChaincodeLogger) Info(args ...interface{})
(c *ChaincodeLogger) Notice(args ...interface{})
(c *ChaincodeLogger) Warning(args ...interface{})
(c *ChaincodeLogger) Error(args ...interface{})
(c *ChaincodeLogger) Critical(args ...interface{})

(c *ChaincodeLogger) Debugf(format string, args ...interface{})
(c *ChaincodeLogger) Infof(format string, args ...interface{})
(c *ChaincodeLogger) Noticef(format string, args ...interface{})
(c *ChaincodeLogger) Warningf(format string, args ...interface{})
(c *ChaincodeLogger) Errorf(format string, args ...interface{})
(c *ChaincodeLogger) Criticalf(format string, args ...interface{})
```

The `f` forms of the logging APIs provide for precise control over the formatting of the logs. The non-`f` forms of the APIs currently insert a space between the printed representations of the arguments, and arbitrarily choose the formats to use.

In the current implementation, the logs produced by the `shim` and a `ChaincodeLogger` are timestamped, marked with the logger *name* and severity level, and written to `stderr` . Note that logging level control is currently based on the *name* provided when the `ChaincodeLogger` is created. To avoid ambiguities, all `ChaincodeLogger` should be given unique names other than "shim". The logger *name* will appear in all log messages created by the logger. The `shim` logs as "shim".

Go language chaincodes can also control the logging level of the chaincode `shim` interface through the `SetLoggingLevel` API.

`SetLoggingLevel(LoggingLevel level)` - Control the logging level of the shim

The default logging level for the shim is `LogDebug` .

Below is a simple example of how a chaincode might create a private logging object logging at the `LogInfo` level, and also control the amount of logging provided by the `shim` based on an environment variable.

```
var logger = shim.NewLogger("myChaincode")

func main() {

    logger.SetLevel(shim.LogInfo)

    logLevel, _ := shim.LogLevel(os.Getenv("SHIM_LOGGING_LEVEL"))
    shim.SetLoggingLevel(logLevel)
    ...
}
```

CHAPTER 21

Architecture Explained

The Hyperledger Fabric architecture delivers the following advantages:

- **Chaincode trust flexibility.** The architecture separates *trust assumptions* for chaincodes (blockchain applications) from trust assumptions for ordering. In other words, the ordering service may be provided by one set of nodes (orderers) and tolerate some of them to fail or misbehave, and the endorsers may be different for each chaincode.
- **Scalability.** As the endorser nodes responsible for particular chaincode are orthogonal to the orderers, the system may *scale* better than if these functions were done by the same nodes. In particular, this results when different chaincodes specify disjoint endorsers, which introduces a partitioning of chaincodes between endorsers and allows parallel chaincode execution (endorsement). Besides, chaincode execution, which can potentially be costly, is removed from the critical path of the ordering service.
- **Confidentiality.** The architecture facilitates deployment of chaincodes that have *confidentiality* requirements with respect to the content and state updates of its transactions.
- **Consensus modularity.** The architecture is *modular* and allows pluggable consensus (i.e., ordering service) implementations.

Part I: Elements of the architecture relevant to Hyperledger Fabric v1

1. System architecture
2. Basic workflow of transaction endorsement
3. Endorsement policies

   Part II: Post-v1 elements of the architecture

4. Ledger checkpointing (pruning)

1. System architecture

The blockchain is a distributed system consisting of many nodes that communicate with each other. The blockchain runs programs called chaincode, holds state and ledger data, and executes transactions. The chaincode is the central element as transactions are operations invoked on the chaincode. Transactions have to be "endorsed" and only endorsed transactions may be committed and have an effect on the state. There may exist one or more special chaincodes for management functions and parameters, collectively called *system chaincodes*.

1.1. Transactions

Transactions may be of two types:

- *Deploy transactions* create new chaincode and take a program as parameter. When a deploy transaction executes successfully, the chaincode has been installed "on" the blockchain.
- *Invoke transactions* perform an operation in the context of previously deployed chaincode. An invoke transaction refers to a chaincode and to one of its provided functions. When successful, the chaincode executes the specified function - which may involve modifying the corresponding state, and returning an output.

As described later, deploy transactions are special cases of invoke transactions, where a deploy transaction that creates new chaincode, corresponds to an invoke transaction on a system chaincode.

Remark: *This document currently assumes that a transaction either creates new chaincode or invokes an operation provided by *one* already deployed chaincode. This document does not yet describe: a) optimizations for query (read-only) transactions (included in v1), b) support for cross-chaincode transactions (post-v1 feature).**

1.2. Blockchain datastructures

1.2.1. State

The latest state of the blockchain (or, simply, *state*) is modeled as a versioned key/value store (KVS), where keys are names and values are arbitrary blobs. These entries are manipulated by the chaincodes (applications) running on the blockchain through `put` and `get` KVS-operations. The state is stored persistently and updates to the state are logged. Notice that versioned KVS is adopted as state model, an implementation may use actual KVSs, but also RDBMSs or any other solution.

More formally, state `s` is modeled as an element of a mapping `K -> (V X N)`, where:

- `K` is a set of keys
- `V` is a set of values
- `N` is an infinite ordered set of version numbers. Injective function `next: N -> N` takes an element of `N` and returns the next version number.

Both `V` and `N` contain a special element `\bot`, which is in case of `N` the lowest element. Initially all keys are mapped to `(\bot,\bot)`. For `s(k)=(v,ver)` we denote `v` by `s(k).value`, and `ver` by `s(k).version`.

KVS operations are modeled as follows:

- `put(k,v)`, for `k\in K` and `v\in V`, takes the blockchain state `s` and changes it to `s'` such that `s'(k)=(v,next(s(k).version))` with `s'(k')=s(k')` for all `k'!=k`.
- `get(k)` returns `s(k)`.

State is maintained by peers, but not by orderers and clients.

State partitioning. Keys in the KVS can be recognized from their name to belong to a particular chaincode, in the sense that only transaction of a certain chaincode may modify the keys belonging to this chaincode. In principle, any chaincode can read the keys belonging to other chaincodes. *Support for cross-chaincode transactions, that modify the state belonging to two or more chaincodes is a post-v1 feature.*

1.2.2 Ledger

Ledger provides a verifiable history of all successful state changes (we talk about *valid* transactions) and unsuccessful attempts to change state (we talk about *invalid* transactions), occurring during the operation of the system.

Ledger is constructed by the ordering service (see Sec 1.3.3) as a totally ordered hashchain of *blocks* of (valid or invalid) transactions. The hashchain imposes the total order of blocks in a ledger and each block contains an array of totally ordered transactions. This imposes total order across all transactions.

Ledger is kept at all peers and, optionally, at a subset of orderers. In the context of an orderer we refer to the Ledger as to `OrdererLedger` , whereas in the context of a peer we refer to the ledger as to `PeerLedger` . `PeerLedger` differs from the `OrdererLedger` in that peers locally maintain a bitmask that tells apart valid transactions from invalid ones (see Section XX for more details).

Peers may prune `PeerLedger` as described in Section XX (post-v1 feature). Orderers maintain `OrdererLedger` for fault-tolerance and availability (of the `PeerLedger`) and may decide to prune it at anytime, provided that properties of the ordering service (see Sec. 1.3.3) are maintained.

The ledger allows peers to replay the history of all transactions and to reconstruct the state. Therefore, state as described in Sec 1.2.1 is an optional datastructure.

1.3. Nodes

Nodes are the communication entities of the blockchain. A "node" is only a logical function in the sense that multiple nodes of different types can run on the same physical server. What counts is how nodes are grouped in "trust domains" and associated to logical entities that control them.

There are three types of nodes:

1. **Client** or **submitting-client**: a client that submits an actual transaction-invocation to the endorsers, and broadcasts transaction-proposals to the ordering service.
2. **Peer**: a node that commits transactions and maintains the state and a copy of the ledger (see Sec, 1.2). Besides, peers can have a special **endorser** role.
3. **Ordering-service-node** or **orderer**: a node running the communication service that implements a delivery guarantee, such as atomic or total order broadcast.

The types of nodes are explained next in more detail.

1.3.1. Client

The client represents the entity that acts on behalf of an end-user. It must connect to a peer for communicating with the blockchain. The client may connect to any peer of its choice. Clients create and thereby invoke transactions.

As detailed in Section 2, clients communicate with both peers and the ordering service.

1.3.2. Peer

A peer receives ordered state updates in the form of *blocks* from the ordering service and maintain the state and the ledger.

Peers can additionally take up a special role of an **endorsing peer**, or an **endorser**. The special function of an *endorsing peer* occurs with respect to a particular chaincode and consists in *endorsing* a transaction before it is committed. Every chaincode may specify an *endorsement policy* that may refer to a set of endorsing peers. The policy defines the necessary and sufficient conditions for a valid transaction endorsement (typically a set of endorsers' signatures), as described later in Sections 2 and 3. In the special case of deploy transactions that install new chaincode the (deployment) endorsement policy is specified as an endorsement policy of the system chaincode.

1.3.3. Ordering service nodes (Orderers)

The *orderers* form the *ordering service*, i.e., a communication fabric that provides delivery guarantees. The ordering service can be implemented in different ways: ranging from a centralized service (used e.g., in development and testing) to distributed protocols that target different network and node fault models.

Ordering service provides a shared *communication channel* to clients and peers, offering a broadcast service for messages containing transactions. Clients connect to the channel and may broadcast messages on the channel which are then delivered to all peers. The channel supports *atomic* delivery of all messages, that is, message communication with total-order delivery and (implementation specific) reliability. In other words, the channel outputs the same messages to all connected peers and outputs them to all peers in the same logical order. This atomic communication guarantee is also called *total-order broadcast*, *atomic broadcast*, or *consensus* in the context of distributed systems. The communicated messages are the candidate transactions for inclusion in the blockchain state.

Partitioning (ordering service channels). Ordering service may support multiple *channels* similar to the *topics* of a publish/subscribe (pub/sub) messaging system. Clients can connects to a given channel and can then send messages and obtain the messages that arrive. Channels can be thought of as partitions - clients connecting to one channel are unaware of the existence of other channels, but clients may connect to multiple channels. Even though some ordering service implementations included with Hyperledger Fabric support multiple channels, for simplicity of presentation, in the rest of this document, we assume ordering service consists of a single channel/topic.

Ordering service API. Peers connect to the channel provided by the ordering service, via the interface provided by the ordering service. The ordering service API consists of two basic operations (more generally *asynchronous events*):

TODO add the part of the API for fetching particular blocks under client/peer specified sequence numbers.

- `broadcast(blob)` : a client calls this to broadcast an arbitrary message `blob` for dissemination over the channel. This is also called `request(blob)` in the BFT context, when sending a request to a service.
- `deliver(seqno,prevhash,blob)` : the ordering service calls this on the peer to deliver the message `blob` with the specified non-negative integer sequence number (`seqno`) and hash of the most recently delivered blob (`prevhash`). In other words, it is an output event from the ordering service. `deliver()` is also sometimes called `notify()` in pub-sub systems or `commit()` in BFT systems.

Ledger and block formation. The ledger (see also Sec. 1.2.2) contains all data output by the ordering service. In a nutshell, it is a sequence of `deliver(seqno,prevhash,blob)` events, which form a hash chain according to the computation of `prevhash` described before.

Most of the time, for efficiency reasons, instead of outputting individual transactions (blobs), the ordering service will group (batch) the blobs and output *blocks* within a single `deliver` event. In this case, the ordering service must impose and convey a deterministic ordering of the blobs within each block. The number of blobs in a block may be chosen dynamically by an ordering service implementation.

In the following, for ease of presentation, we define ordering service properties (rest of this subsection) and explain the workflow of transaction endorsement (Section 2) assuming one blob per `deliver` event. These are easily extended to blocks, assuming that a `deliver` event for a block corresponds to a sequence of individual `deliver` events for each blob within a block, according to the above mentioned deterministic ordering of blobs within a blocs.

Ordering service properties

The guarantees of the ordering service (or atomic-broadcast channel) stipulate what happens to a broadcasted message and what relations exist among delivered messages. These guarantees are as follows:

1. **Safety (consistency guarantees)**: As long as peers are connected for sufficiently long periods of time to the channel (they can disconnect or crash, but will restart and reconnect), they will see an *identical* series of delivered `(seqno,prevhash,blob)` messages. This means the outputs (`deliver()` events) occur in the *same order* on all peers and according to sequence number and carry *identical content* (`blob` and `prevhash`) for the same sequence number. Note this is only a *logical order*, and a `deliver(seqno,prevhash,blob)` on one peer is not required to occur in any real-time relation to `deliver(seqno,prevhash,blob)` that outputs the same message at another peer. Put differently, given a particular `seqno` , *no* two correct peers deliver *different* `prevhash` or `blob` values. Moreover, no value `blob` is delivered unless some client (peer) actually called `broadcast(blob)` and, preferably, every broadcasted blob is only delivered *once*.

   Furthermore, the `deliver()` event contains the cryptographic hash of the data in the previous `deliver()` event (`prevhash`). When the ordering service implements atomic broadcast guarantees, `prevhash` is the cryptographic hash of the parameters from the `deliver()` event with sequence number `seqno-1` . This

establishes a hash chain across `deliver()` events, which is used to help verify the integrity of the ordering service output, as discussed in Sections 4 and 5 later. In the special case of the first `deliver()` event, `prevhash` has a default value.

2. **Liveness (delivery guarantee)**: Liveness guarantees of the ordering service are specified by a ordering service implementation. The exact guarantees may depend on the network and node fault model.

   In principle, if the submitting client does not fail, the ordering service should guarantee that every correct peer that connects to the ordering service eventually delivers every submitted transaction.

To summarize, the ordering service ensures the following properties:

- *Agreement.* For any two events at correct peers `deliver(seqno,prevhash0,blob0)` and `deliver(seqno,prevhash1,blob1)` with the same `seqno` , `prevhash0==prevhash1` and `blob0==blob1` ;
- *Hashchain integrity.* For any two events at correct peers `deliver(seqno-1,prevhash0,blob0)` and `deliver(seqno,prevhash,blob)` , `prevhash = HASH(seqno-1||prevhash0||blob0)` .
- *No skipping*. If an ordering service outputs `deliver(seqno,prevhash,blob)` at a correct peer *p*, such that `seqno>0` , then *p* already delivered an event `deliver(seqno-1,prevhash0,blob0)` .
- *No creation*. Any event `deliver(seqno,prevhash,blob)` at a correct peer must be preceded by a `broadcast(blob)` event at some (possibly distinct) peer;
- *No duplication (optional, yet desirable).* For any two events `broadcast(blob)` and `broadcast(blob')` , when two events `deliver(seqno0,prevhash0,blob)` and `deliver(seqno1,prevhash1,blob')` occur at correct peers and `blob == blob'` , then `seqno0==seqno1` and `prevhash0==prevhash1` .
- *Liveness*. If a correct client invokes an event `broadcast(blob)` then every correct peer "eventually" issues an event `deliver(*,*,blob)` , where `*` denotes an arbitrary value.

2. Basic workflow of transaction endorsement

In the following we outline the high-level request flow for a transaction.

Remark: *Notice that the following protocol *does not* assume that all transactions are deterministic, i.e., it allows for non-deterministic transactions.**

2.1. The client creates a transaction and sends it to endorsing peers of its choice

To invoke a transaction, the client sends a `PROPOSE` message to a set of endorsing peers of its choice (possibly not at the same time - see Sections 2.1.2. and 2.3.). The set of endorsing peers for a given `chaincodeID` is made available to client via peer, which in turn knows the set of endorsing peers from endorsement policy (see Section 3). For example, the transaction could be sent to *all* endorsers of a given `chaincodeID` . That said, some endorsers could be offline, others may object and choose not to endorse the transaction. The submitting client tries to satisfy the policy expression with the endorsers available.

In the following, we first detail `PROPOSE` message format and then discuss possible patterns of interaction between submitting client and endorsers.

2.1.1. `PROPOSE` message format

The format of a `PROPOSE` message is `<PROPOSE,tx,[anchor]>` , where `tx` is a mandatory and `anchor` optional argument explained in the following.

- tx=<clientID,chaincodeID,txPayload,timestamp,clientSig> , where
  - clientID is an ID of the submitting client,
  - chaincodeID refers to the chaincode to which the transaction pertains,
  - txPayload is the payload containing the submitted transaction itself,
  - timestamp is a monotonically increasing (for every new transaction) integer maintained by the client,
  - clientSig is signature of a client on other fields of tx .

  The details of txPayload will differ between invoke transactions and deploy transactions (i.e., invoke transactions referring to a deploy-specific system chaincode). For an **invoke transaction**, txPayload would consist of two fields
  - txPayload = <operation,metadata> , where
    - operation denotes the chaincode operation (function) and arguments,
    - metadata denotes attributes related to the invocation.

  For a **deploy transaction**, txPayload would consist of three fields
  - txPayload = <source,metadata,policies> , where
    - source denotes the source code of the chaincode,
    - metadata denotes attributes related to the chaincode and application,
    - policies contains policies related to the chaincode that are accessible to all peers, such as the endorsement policy. Note that endorsement policies are not supplied with txPayload in a deploy transaction, but txPayload of a deploy contains endorsement policy ID and its parameters (see Section 3).
- anchor contains *read version dependencies*, or more specifically, key-version pairs (i.e., anchor is a subset of KxN), that binds or "anchors" the PROPOSE request to specified versions of keys in a KVS (see Section 1.2.). If the client specifies the anchor argument, an endorser endorses a transaction only upon *read* version numbers of corresponding keys in its local KVS match anchor (see Section 2.2. for more details).

Cryptographic hash of tx is used by all nodes as a unique transaction identifier tid (i.e., tid=HASH(tx)). The client stores tid in memory and waits for responses from endorsing peers.

2.1.2. Message patterns

The client decides on the sequence of interaction with endorsers. For example, a client would typically send <PROPOSE,tx> (i.e., without the anchor argument) to a single endorser, which would then produce the version dependencies (anchor) which the client can later on use as an argument of its PROPOSE message to other endorsers. As another example, the client could directly send <PROPOSE,tx> (without anchor) to all endorsers of its choice. Different patterns of communication are possible and client is free to decide on those (see also Section 2.3.).

2.2. The endorsing peer simulates a transaction and produces an endorsement signature

On reception of a <PROPOSE,tx,[anchor]> message from a client, the endorsing peer epID first verifies the client's signature clientSig and then simulates a transaction. If the client specifies anchor then endorsing peer simulates the transactions only upon read version numbers (i.e., readset as defined below) of corresponding keys in its local KVS match those version numbers specified by anchor .

Simulating a transaction involves endorsing peer tentatively *executing* a transaction (`txPayload`), by invoking the chaincode to which the transaction refers (`chaincodeID`) and the copy of the state that the endorsing peer locally holds.

As a result of the execution, the endorsing peer computes *read version dependencies* (`readset`) and *state updates* (`writeset`), also called *MVCC+postimage info* in DB language.

Recall that the state consists of key/value (k/v) pairs. All k/v entries are versioned, that is, every entry contains ordered version information, which is incremented every time when the value stored under a key is updated. The peer that interprets the transaction records all k/v pairs accessed by the chaincode, either for reading or for writing, but the peer does not yet update its state. More specifically:

- Given state `s` before an endorsing peer executes a transaction, for every key `k` read by the transaction, pair `(k,s(k).version)` is added to `readset`.
- Additionally, for every key `k` modified by the transaction to the new value `v'`, pair `(k,v')` is added to `writeset`. Alternatively, `v'` could be the delta of the new value to previous value (`s(k).value`).

If a client specifies `anchor` in the `PROPOSE` message then client specified `anchor` must equal `readset` produced by endorsing peer when simulating the transaction.

Then, the peer forwards internally `tran-proposal` (and possibly `tx`) to the part of its (peer's) logic that endorses a transaction, referred to as **endorsing logic**. By default, endorsing logic at a peer accepts the `tran-proposal` and simply signs the `tran-proposal`. However, endorsing logic may interpret arbitrary functionality, to, e.g., interact with legacy systems with `tran-proposal` and `tx` as inputs to reach the decision whether to endorse a transaction or not.

If endorsing logic decides to endorse a transaction, it sends `<TRANSACTION-ENDORSED,tid,tran-proposal,epSig>` message to the submitting client(`tx.clientID`), where:

- `tran-proposal := (epID,tid,chaincodeID,txContentBlob,readset,writeset)`,

  where `txContentBlob` is chaincode/transaction specific information. The intention is to have `txContentBlob` used as some representation of `tx` (e.g., `txContentBlob=tx.txPayload`).

- `epSig` is the endorsing peer's signature on `tran-proposal`

Else, in case the endorsing logic refuses to endorse the transaction, an endorser *may* send a message `(TRANSACTION-INVALID,tid,REJECTED)` to the submitting client.

Notice that an endorser does not change its state in this step, the updates produced by transaction simulation in the context of endorsement do not affect the state!

2.3. The submitting client collects an endorsement for a transaction and broadcasts it through ordering service

The submitting client waits until it receives "enough" messages and signatures on `(TRANSACTION-ENDORSED,tid,*,*)` statements to conclude that the transaction proposal is endorsed. As discussed in Section 2.1.2., this may involve one or more round-trips of interaction with endorsers.

The exact number of "enough" depend on the chaincode endorsement policy (see also Section 3). If the endorsement policy is satisfied, the transaction has been *endorsed*; note that it is not yet committed. The collection of signed `TRANSACTION-ENDORSED` messages from endorsing peers which establish that a transaction is endorsed is called an *endorsement* and denoted by `endorsement`.

If the submitting client does not manage to collect an endorsement for a transaction proposal, it abandons this transaction with an option to retry later.

For transaction with a valid endorsement, we now start using the ordering service. The submitting client invokes ordering service using the `broadcast(blob)`, where `blob=endorsement`. If the client does not have capability

of invoking ordering service directly, it may proxy its broadcast through some peer of its choice. Such a peer must be trusted by the client not to remove any message from the `endorsement` or otherwise the transaction may be deemed invalid. Notice that, however, a proxy peer may not fabricate a valid `endorsement` .

2.4. The ordering service delivers a transactions to the peers

When an event `deliver(seqno,prevhash,blob)` occurs and a peer has applied all state updates for blobs with sequence number lower than `seqno` , a peer does the following:

- It checks that the `blob.endorsement` is valid according to the policy of the chaincode (`blob.tran-proposal.chaincodeID`) to which it refers.
- In a typical case, it also verifies that the dependencies (`blob.endorsement.tran-proposal.readset`) have not been violated meanwhile. In more complex use cases, `tran-proposal` fields in endorsement may differ and in this case endorsement policy (Section 3) specifies how the state evolves.

Verification of dependencies can be implemented in different ways, according to a consistency property or "isolation guarantee" that is chosen for the state updates. **Serializability** is a default isolation guarantee, unless chaincode endorsement policy specifies a different one. Serializability can be provided by requiring the version associated with *every* key in the `readset` to be equal to that key's version in the state, and rejecting transactions that do not satisfy this requirement.

- If all these checks pass, the transaction is deemed *valid* or *committed*. In this case, the peer marks the transaction with 1 in the bitmask of the `PeerLedger` , applies `blob.endorsement.tran-proposal.writeset` to blockchain state (if `tran-proposals` are the same, otherwise endorsement policy logic defines the function that takes `blob.endorsement`).
- If the endorsement policy verification of `blob.endorsement` fails, the transaction is invalid and the peer marks the transaction with 0 in the bitmask of the `PeerLedger` . It is important to note that invalid transactions do not change the state.

Note that this is sufficient to have all (correct) peers have the same state after processing a deliver event (block) with a given sequence number. Namely, by the guarantees of the ordering service, all correct peers will receive an identical sequence of `deliver(seqno,prevhash,blob)` events. As the evaluation of the endorsement policy and evaluation of version dependencies in `readset` are deterministic, all correct peers will also come to the same conclusion whether a transaction contained in a blob is valid. Hence, all peers commit and apply the same sequence of transactions and update their state in the same way.

Fig. 21.1: Illustration of the transaction flow (common-case path).

Figure 1. Illustration of one possible transaction flow (common-case path).

3. Endorsement policies

3.1. Endorsement policy specification

An **endorsement policy**, is a condition on what *endorses* a transaction. Blockchain peers have a pre-specified set of endorsement policies, which are referenced by a `deploy` transaction that installs specific chaincode. Endorsement policies can be parametrized, and these parameters can be specified by a `deploy` transaction.

To guarantee blockchain and security properties, the set of endorsement policies **should be a set of proven policies** with limited set of functions in order to ensure bounded execution time (termination), determinism, performance and security guarantees.

Dynamic addition of endorsement policies (e.g., by `deploy` transaction on chaincode deploy time) is very sensitive in terms of bounded policy evaluation time (termination), determinism, performance and security guarantees. Therefore, dynamic addition of endorsement policies is not allowed, but can be supported in future.

3.2. Transaction evaluation against endorsement policy

A transaction is declared valid only if it has been endorsed according to the policy. An invoke transaction for a chaincode will first have to obtain an *endorsement* that satisfies the chaincode's policy or it will not be committed. This takes place through the interaction between the submitting client and endorsing peers as explained in Section 2.

Formally the endorsement policy is a predicate on the endorsement, and potentially further state that evaluates to TRUE or FALSE. For deploy transactions the endorsement is obtained according to a system-wide policy (for example, from the system chaincode).

An endorsement policy predicate refers to certain variables. Potentially it may refer to:

1. keys or identities relating to the chaincode (found in the metadata of the chaincode), for example, a set of endorsers;
2. further metadata of the chaincode;
3. elements of the `endorsement` and `endorsement.tran-proposal` ;
4. and potentially more.

The above list is ordered by increasing expressiveness and complexity, that is, it will be relatively simple to support policies that only refer to keys and identities of nodes.

The evaluation of an endorsement policy predicate must be deterministic. An endorsement shall be evaluated locally by every peer such that a peer does *not* need to interact with other peers, yet all correct peers evaluate the endorsement policy in the same way.

3.3. Example endorsement policies

The predicate may contain logical expressions and evaluates to TRUE or FALSE. Typically the condition will use digital signatures on the transaction invocation issued by endorsing peers for the chaincode.

Suppose the chaincode specifies the endorser set `E = {Alice,Bob,Charlie,Dave,Eve,Frank,George}` . Some example policies:

- A valid signature from on the same `tran-proposal` from all members of E.
- A valid signature from any single member of E.
- Valid signatures on the same `tran-proposal` from endorsing peers according to the condition `(Alice OR Bob) AND (any two of: Charlie,Dave,Eve,Frank,George)` .
- Valid signatures on the same `tran-proposal` by any 5 out of the 7 endorsers. (More generally, for chaincode with `n > 3f` endorsers, valid signatures by any `2f+1` out of the `n` endorsers, or by any group of *more* than `(n+f)/2` endorsers.)
- Suppose there is an assignment of "stake" or "weights" to the endorsers, like `{Alice=49,Bob=15,Charlie=15,Dave=10,Eve=7,Frank=3,George=1}` , where the total stake is 100: The policy requires valid signatures from a set that has a majority of the stake (i.e., a group with combined stake strictly more than 50), such as `{Alice,X}` with any `X` different from George, or `{everyone together except Alice}` . And so on.
- The assignment of stake in the previous example condition could be static (fixed in the metadata of the chaincode) or dynamic (e.g., dependent on the state of the chaincode and be modified during the execution).

- Valid signatures from (Alice OR Bob) on `tran-proposal1` and valid signatures from `(any two of: Charlie,Dave,Eve,Frank,George)` on `tran-proposal2`, where `tran-proposal1` and `tran-proposal2` differ only in their endorsing peers and state updates.

How useful these policies are will depend on the application, on the desired resilience of the solution against failures or misbehavior of endorsers, and on various other properties.

4 (post-v1). Validated ledger and `PeerLedger` checkpointing (pruning)

4.1. Validated ledger (VLedger)

To maintain the abstraction of a ledger that contains only valid and committed transactions (that appears in Bitcoin, for example), peers may, in addition to state and Ledger, maintain the *Validated Ledger (or VLedger)*. This is a hash chain derived from the ledger by filtering out invalid transactions.

The construction of the VLedger blocks (called here *vBlocks*) proceeds as follows. As the `PeerLedger` blocks may contain invalid transactions (i.e., transactions with invalid endorsement or with invalid version dependencies), such transactions are filtered out by peers before a transaction from a block becomes added to a vBlock. Every peer does this by itself (e.g., by using the bitmask associated with `PeerLedger`). A vBlock is defined as a block without the invalid transactions, that have been filtered out. Such vBlocks are inherently dynamic in size and may be empty. An illustration of vBlock construction is given in the figure below.

Figure 2. Illustration of validated ledger block (vBlock) formation from ledger (`PeerLedger`) blocks.

vBlocks are chained together to a hash chain by every peer. More specifically, every block of a validated ledger contains:

- The hash of the previous vBlock.
- vBlock number.
- An ordered list of all valid transactions committed by the peers since the last vBlock was computed (i.e., list of valid transactions in a corresponding block).
- The hash of the corresponding block (in `PeerLedger`) from which the current vBlock is derived.

All this information is concatenated and hashed by a peer, producing the hash of the vBlock in the validated ledger.

4.2. `PeerLedger` Checkpointing

The ledger contains invalid transactions, which may not necessarily be recorded forever. However, peers cannot simply discard `PeerLedger` blocks and thereby prune `PeerLedger` once they establish the corresponding vBlocks. Namely, in this case, if a new peer joins the network, other peers could not transfer the discarded blocks (pertaining to `PeerLedger`) to the joining peer, nor convince the joining peer of the validity of their vBlocks.

To facilitate pruning of the `PeerLedger`, this document describes a *checkpointing* mechanism. This mechanism establishes the validity of the vBlocks across the peer network and allows checkpointed vBlocks to replace the discarded `PeerLedger` blocks. This, in turn, reduces storage space, as there is no need to store invalid transactions. It also reduces the work to reconstruct the state for new peers that join the network (as they do not need to establish validity of individual transactions when reconstructing the state by replaying `PeerLedger`, but may simply replay the state updates contained in the validated ledger).

4.2.1. Checkpointing protocol

Checkpointing is performed periodically by the peers every *CHK* blocks, where *CHK* is a configurable parameter. To initiate a checkpoint, the peers broadcast (e.g., gossip) to other peers message `<CHECKPOINT,blocknohash,blockno,stateHash,peerSig>` , where `blockno` is the current block-number and `blocknohash` is its respective hash, `stateHash` is the hash of the latest state (produced by e.g., a Merkle hash) upon validation of block `blockno` and `peerSig` is peer's signature on `(CHECKPOINT,blocknohash,blockno,stateHash)` , referring to the validated ledger.

A peer collects `CHECKPOINT` messages until it obtains enough correctly signed messages with matching `blockno` , `blocknohash` and `stateHash` to establish a *valid checkpoint* (see Section 4.2.2.).

Upon establishing a valid checkpoint for block number `blockno` with `blocknohash` , a peer:

- if `blockno>latestValidCheckpoint.blockno` , then a peer assigns `latestValidCheckpoint=(blocknohash,blockno)` ,
- stores the set of respective peer signatures that constitute a valid checkpoint into the set `latestValidCheckpointProof` ,
- stores the state corresponding to `stateHash` to `latestValidCheckpointedState` ,
- (optionally) prunes its `PeerLedger` up to block number `blockno` (inclusive).

4.2.2. Valid checkpoints

Clearly, the checkpointing protocol raises the following questions: *When can a peer prune its ''PeerLedger''? How many ''CHECKPOINT'' messages are "sufficiently many"?*. This is defined by a *checkpoint validity policy*, with (at least) two possible approaches, which may also be combined:

- *Local (peer-specific) checkpoint validity policy (LCVP).* A local policy at a given peer *p* may specify a set of peers which peer *p* trusts and whose `CHECKPOINT` messages are sufficient to establish a valid checkpoint. For example, LCVP at peer *Alice* may define that *Alice* needs to receive `CHECKPOINT` message from Bob, or from *both Charlie* and *Dave*.
- *Global checkpoint validity policy (GCVP).* A checkpoint validity policy may be specified globally. This is similar to a local peer policy, except that it is stipulated at the system (blockchain) granularity, rather than peer granularity. For instance, GCVP may specify that:
  - each peer may trust a checkpoint if confirmed by *11* different peers.
  - in a specific deployment in which every orderer is collocated with a peer in the same machine (i.e., trust domain) and where up to *f* orderers may be (Byzantine) faulty, each peer may trust a checkpoint if confirmed by *f+1* different peers collocated with orderers.

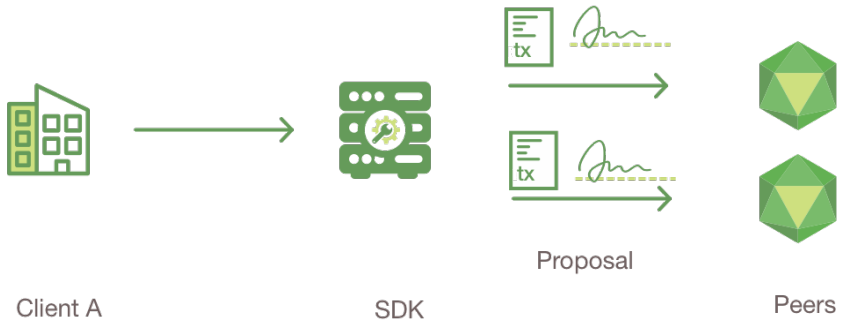
Transaction Flow

This document outlines the transactional mechanics that take place during a standard asset exchange. The scenario includes two clients, A and B, who are buying and selling radishes. They each have a peer on the network through which they send their transactions and interact with the ledger.

Assumptions

This flow assumes that a channel is set up and running. The application user has registered and enrolled with the organization's certificate authority (CA) and received back necessary cryptographic material, which is used to authenticate to the network.

The chaincode (containing a set of key value pairs representing the initial state of the radish market) is installed on the peers and instantiated on the channel. The chaincode contains logic defining a set of transaction instructions and the agreed upon price for a radish. An endorsement policy has also been set for this chaincode, stating that both `peerA` and `peerB` must endorse any transaction.

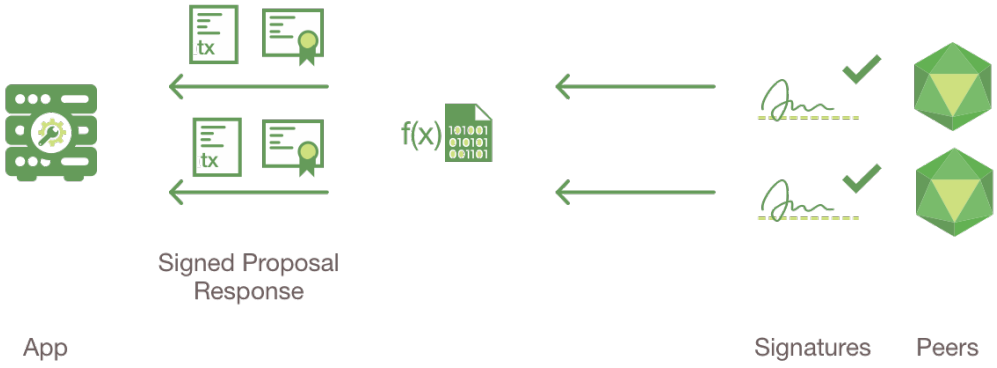


1. **Client A initiates a transaction**

What's happening? - Client A is sending a request to purchase radishes. The request targets `peerA` and `peerB` , who are respectively representative of Client A and Client B. The endorsement policy states that both peers must endorse

any transaction, therefore the request goes to `peerA` and `peerB`.

Next, the transaction proposal is constructed. An application leveraging a supported SDK (Node, Java, Python) utilizes one of the available API's which generates a transaction proposal. The proposal is a request to invoke a chaincode function so that data can be read and/or written to the ledger (i.e. write new key value pairs for the assets). The SDK serves as a shim to package the transaction proposal into the properly architected format (protocol buffer over gRPC) and takes the user's cryptographic credentials to produce a unique signature for this transaction proposal.



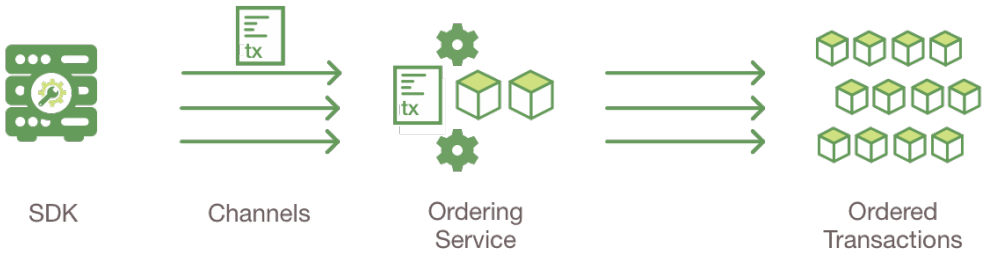
2. **Endorsing peers verify signature & execute the transaction**

The endorsing peers verify (1) that the transaction proposal is well formed, (2) it has not been submitted already in the past (replay-attack protection), (3) the signature is valid (using MSP), and (4) that the submitter (Client A, in the example) is properly authorized to perform the proposed operation on that channel (namely, each endorsing peer ensures that the submitter satisfies the channel's *Writers* policy). The endorsing peers take the transaction proposal inputs as arguments to the invoked chaincode's function. The chaincode is then executed against the current state database to produce transaction results including a response value, read set, and write set. No updates are made to the ledger at this point. The set of these values, along with the endorsing peer's signature and a YES/NO endorsement statement is passed back as a "proposal response" to the SDK which parses the payload for the application to consume.

*{The MSP is a peer component that allows them to verify transaction requests arriving from clients and to sign transaction results(endorsements). The *Writing* policy is defined at channel creation time, and determines which user is entitled to submit a transaction to that channel.}**

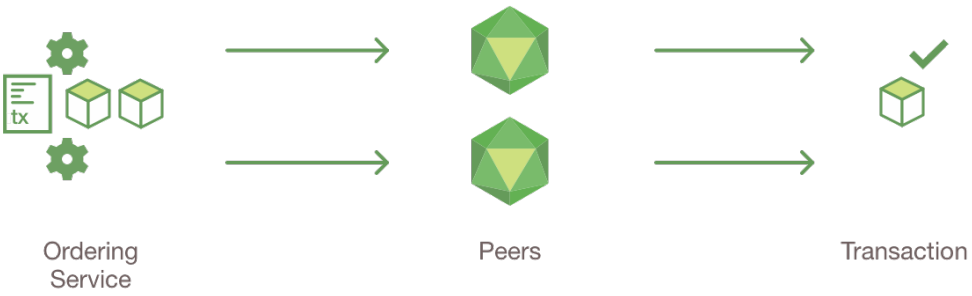
3. **Proposal responses are inspected**

The application verifies the endorsing peer signatures and compares the proposal responses (link to glossary term which will contain a representation of the payload) to determine if the proposal responses are the same and if the specified endorsement policy has been fulfilled (i.e. did peerA and peerB both endorse). The architecture is such that even if an application chooses not to inspect responses or otherwise forwards an unendorsed transaction, the policy will still be enforced by peers and upheld at the commit validation phase.



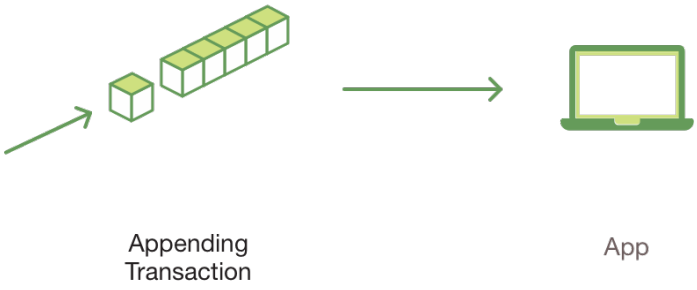
4. **Client assembles endorsements into a transaction**

The application "broadcasts" the transaction proposal and response within a "transaction message" to the Ordering Service. The transaction will contain the read/write sets, the endorsing peers signatures and the Channel ID. The Ordering Service does not need to inspect the entire content of a transaction in order to perform its operation, it simply receives transactions from all channels in the network, orders them chronologically by channel, and creates blocks of transactions per channel.



5. **Transaction is validated and committed**

The blocks of transactions are "delivered" to all peers on the channel. The transactions within the block are validated to ensure endorsement policy is fulfilled and to ensure that there have been no changes to ledger state for read set variables since the read set was generated by the transaction execution. Transactions in the block are tagged as being valid or invalid.



6. **Ledger updated**

Each peer appends the block to the channel's chain, and for each valid transaction the write sets are committed to current state database. An event is emitted, to notify the client application that the transaction (invocation) has been immutably appended to the chain, as well as notification of whether the transaction was validated or invalidated.

Note: See the swimlane diagram to better understand the server side flow and the protobuffers.

CHAPTER 23

Hyperledger Fabric SDKs

Hyperledger Fabric intends to offer a number of SDKs for a wide variety of programming languages. The first two delivered are the Node.js and Java SDKs. We hope to provide Python and Go SDKs soon after the 1.0.0 release.

- Hyperledger Fabric Node SDK documentation.
- Hyperledger Fabric Java SDK documentation.

CHAPTER 24

Bringing up a Kafka-based Ordering Service

Caveat emptor

This document assumes that the reader generally knows how to set up a Kafka cluster and a ZooKeeper ensemble. The purpose of this guide is to identify the steps you need to take so as to have a set of Hyperledger Fabric ordering service nodes (OSNs) use your Kafka cluster and provide an ordering service to your blockchain network.

Big picture

Each channel maps to a separate single-partition topic in Kafka. When an OSN receives transactions via the `Broadcast` RPC, it checks to make sure that the broadcasting client has permissions to write on the channel, then relays (i.e. produces) those transactions to the appropriate partition in Kafka. This partition is also consumed by the OSN which groups the received transactions into blocks locally, persists them in its local ledger, and serves them to receiving clients via the `Deliver` RPC. For low-level details, refer to the document that describes how we came to this design – Figure 8 is a schematic representation of the process described above.

Steps

Let `K` and `Z` be the number of nodes in the Kafka cluster and the ZooKeeper ensemble respectively:

i. At a minimum, `K` should be set to 4. (As we will explain in Step 4 below, this is the minimum number of nodes necessary in order to exhibit crash fault tolerance, i.e. with 4 brokers, you can have 1 broker go down, all channels will continue to be writeable and readable, and new channels can be created.)

ii. `Z` will either be 3, 5, or 7. It has to be an odd number to avoid split-brain scenarios, and larger than 1 in order to avoid single point of failures. Anything beyond 7 ZooKeeper servers is considered an overkill.

Proceed as follows:

1. Orderers: **Encode the Kafka-related information in the network's genesis block.** If you are using `configtxgen` , edit `configtx.yaml` – or pick a preset profile for the system channel's genesis block – so that:

    1. `Orderer.OrdererType` is set to `kafka` .

    b. `Orderer.Kafka.Brokers` contains the address of *at least two* of the Kafka brokers in your cluster in `IP:port` notation. The list does not need to be exhaustive. (These are your seed brokers.)

2. Orderers: **Set the maximum block size.** Each block will have at most *Orderer.AbsoluteMaxBytes* bytes (not including headers), a value that you can set in `configtx.yaml`. Let the value you pick here be `A` and make note of it – it will affect how you configure your Kafka brokers in Step 4.

3. Orderers: **Create the genesis block.** Use `configtxgen`. The settings you picked in Steps 1 and 2 above are system-wide settings, i.e. they apply across the network for all the OSNs. Make note of the genesis block's location.

4. Kafka cluster: **Configure your Kafka brokers appropriately.** Ensure that every Kafka broker has these keys configured:

a. `unclean.leader.election.enable = false` – Data consistency is key in a blockchain environment. We cannot have a channel leader chosen outside of the in-sync replica set, or we run the risk of overwriting the offsets that the previous leader produced, and –as a result– rewrite the blockchain that the orderers produce.

b. `min.insync.replicas = M` – Where you pick a value `M` such that 1 < M < N (see `default.replication.factor` below). Data is considered committed when it is written to at least `M` replicas (which are then considered in-sync and belong to the in-sync replica set, or ISR). In any other case, the write operation returns an error. Then:

i. If up to N-M replicas – out of the `N` that the channel data is written to – become unavailable, operations proceed normally. ii. If more replicas become unavailable, Kafka cannot maintain an ISR set of `M`, so it stops accepting writes. Reads work without issues. The channel becomes writeable again when `M` replicas get in-sync.

c. `default.replication.factor = N` – Where you pick a value `N` such that N < K. A replication factor of `N` means that each channel will have its data replicated to `N` brokers. These are the candidates for the ISR set of a channel. As we noted in the `min.insync.replicas` section above, not all of these brokers have to be available all the time. `N` should be set *strictly smaller* to `K` because channel creations cannot go forward if less than `N` brokers are up. So if you set N = K, a single broker going down means that no new channels can be created on the blockchain network – the crash fault tolerance of the ordering service is non-existent.

d. `message.max.bytes` and `replica.fetch.max.bytes` should be set to a value larger than `A`, the value you picked in `Orderer.AbsoluteMaxBytes` in Step 2 above. Add some buffer to account for headers – 1 MiB is more than enough. The following condition applies:

```
Orderer.AbsoluteMaxBytes < replica.fetch.max.bytes <= message.max.bytes
```

(For completeness, we note that `message.max.bytes` should be strictly smaller to `socket.request.max.bytes` which is set by default to 100 MiB. If you wish to have blocks larger than 100 MiB you will need to edit the hard-coded value in `brokerConfig.Producer.MaxMessageBytes` in `fabric/orderer/kafka/config.go` and rebuild the binary from source. This is not advisable.)

e. `log.retention.ms = -1`. Until the ordering service adds support for pruning of the Kafka logs, you should disable time-based retention and prevent segments from expiring. (Size-based retention – see `log.retention.bytes` – is disabled by default in Kafka at the time of this writing, so there's no need to set it explicitly.)

Based on what we've described above, the minimum allowed values for `M` and `N` are 2 and 3 respectively. This configuration allows for the creation of new channels to go forward, and for all channels to continue to be writeable.

5. Orderers: **Point each OSN to the genesis block.** Edit `General.GenesisFile` in `orderer.yaml` so that it points to the genesis block created in Step 3 above. (While at it, ensure all other keys in that YAML file are set appropriately.)

6. Orderers: **Adjust polling intervals and timeouts.** (Optional step.)

a. The `Kafka.Retry` section in the `orderer.yaml` file allows you to adjust the frequency of the metadata/producer/consumer requests, as well as the socket timeouts. (These are all settings you would expect to see in a Kafka producer or consumer.)

b. Additionally, when a new channel is created, or when an existing channel is reloaded (in case of a just-restarted orderer), the orderer interacts with the Kafka cluster in the following ways:

a. It creates a Kafka producer (writer) for the Kafka partition that corresponds to the channel.

b. It uses that producer to post a no-op `CONNECT` message to that partition.

(a) It creates a Kafka consumer (reader) for that partition.

If any of these steps fail, you can adjust the frequency with which they are repeated. Specifically they will be re-attempted every `Kafka.Retry.ShortInterval` for a total of `Kafka.Retry.ShortTotal`, and then every `Kafka.Retry.LongInterval` for a total of `Kafka.Retry.LongTotal` until they succeed. Note that the orderer will be unable to write to or read from a channel until all of the steps above have been completed successfully.

7. **Set up the OSNs and Kafka cluster so that they communicate over SSL.** (Optional step, but highly recommended.) Refer to the Confluent guide for the Kafka cluster side of the equation, and set the keys under `Kafka.TLS` in `orderer.yaml` on every OSN accordingly.

8. **Bring up the nodes in the following order: ZooKeeper ensemble, Kafka cluster, ordering service nodes.**

Additional considerations

1. **Preferred message size.** In Step 2 above (see *Steps* section) you can also set the preferred size of blocks by setting the `Orderer.Batchsize.PreferredMaxBytes` key. Kafka offers higher throughput when dealing with relatively small messages; aim for a value no bigger than 1 MiB.

2. **Using environment variables to override settings.** When using the sample Kafka and Zookeeper Docker images provided with Hyperledger Fabric (see `images/kafka` and `images/zookeeper` respectively), you can override a Kafka broker or a ZooKeeper server's settings by using environment variables. Replace the dots of the configuration key with underscores – e.g. `KAFKA_UNCLEAN_LEADER_ELECTION_ENABLE=false` will allow you to override the default value of `unclean.leader.election.enable`. The same applies to the OSNs for their *local* configuration, i.e. what can be set in `orderer.yaml`. For example `ORDERER_KAFKA_RETRY_SHORTINTERVAL=1s` allows you to override the default value for `Orderer.Kafka.Retry.ShortInterval`.

Supported Kafka versions and upgrading

Supported Kafka versions for v1 are `0.9` and `0.10`. (Hyperledger Fabric uses the sarama client library and vendors a version of it that supports Kafka 0.9 and 0.10.)

Out of the box the Kafka version defaults to `0.9.0.1`. The sample Kafka image provided by Hyperledger Fabric matches this default version. If you are not using the sample Kafka image provided by Hyperledger Fabric, ensure that you specify your Kafka cluster's Kafka version using the `Kafka.Version` key in `orderer.yaml`.

The current supported Kafka versions are:

- `Version: 0.9.0.1`
- `Version: 0.10.0.0`
- `Version: 0.10.0.1`

- `Version: 0.10.1.0`

Debugging

Set `General.LogLevel` to `DEBUG` and `Kafka.Verbose` in `orderer.yaml` to `true`.

Example

Sample Docker Compose configuration files inline with the recommended settings above can be found under the `fabric/bddtests` directory. Look for `dc-orderer-kafka-base.yml` and `dc-orderer-kafka.yml`.

CHAPTER 25

Channels

A Hyperledger Fabric **channel** is a private "subnet" of communication between two or more specific network members, for the purpose of conducting private and confidential transactions. A channel is defined by members (organizations), anchor peers per member, the shared ledger, chaincode application(s) and the ordering service node(s). Each transaction on the network is executed on a channel, where each party must be authenticated and authorized to transact on that channel. Each peer that joins a channel, has its own identity given by a membership services provider (MSP), which authenticates each peer to its channel peers and services.

To create a new channel, the client SDK calls configuration system chaincode and references properties such as **anchor peer**s, and members (organizations). This request creates a **genesis block** for the channel ledger, which stores configuration information about the channel policies, members and anchor peers. When adding a new member to an existing channel, either this genesis block, or if applicable, a more recent reconfiguration block, is shared with the new member.

Note: See the *Channel Configuration (configtx)* section for more more details on the properties and proto structures of config transactions.

The election of a **leading peer** for each member on a channel determines which peer communicates with the ordering service on behalf of the member. If no leader is identified, an algorithm can be used to identify the leader. The consensus service orders transactions and delivers them, in a block, to each leading peer, which then distributes the block to its member peers, and across the channel, using the **gossip** protocol.

Although any one anchor peer can belong to multiple channels, and therefore maintain multiple ledgers, no ledger data can pass from one channel to another. This separation of ledgers, by channel, is defined and implemented by configuration chaincode, the identity membership service and the gossip data dissemination protocol. The dissemination of data, which includes information on transactions, ledger state and channel membership, is restricted to peers with verifiable membership on the channel. This isolation of peers and ledger data, by channel, allows network members that require private and confidential transactions to coexist with business competitors and other restricted members, on the same blockchain network.

CHAPTER 26

Ledger

The ledger is the sequenced, tamper-resistant record of all state transitions. State transitions are a result of chaincode invocations ('transactions') submitted by participating parties. Each transaction results in a set of asset key-value pairs that are committed to the ledger as creates, updates, or deletes.

The ledger is comprised of a blockchain ('chain') to store the immutable, sequenced record in blocks, as well as a state database to maintain current state. There is one ledger per channel. Each peer maintains a copy of the ledger for each channel of which they are a member.

Chain

The chain is a transaction log, structured as hash-linked blocks, where each block contains a sequence of N transactions. The block header includes a hash of the block's transactions, as well as a hash of the prior block's header. In this way, all transactions on the ledger are sequenced and cryptographically linked together. In other words, it is not possible to tamper with the ledger data, without breaking the hash links. The hash of the latest block represents every transaction that has come before, making it possible to ensure that all peers are in a consistent and trusted state.

The chain is stored on the peer file system (either local or attached storage), efficiently supporting the append-only nature of the blockchain workload.

State Database

The ledger's current state data represents the latest values for all keys ever included in the chain transaction log. Since current state represents all latest key values known to the channel, it is sometimes referred to as World State.

Chaincode invocations execute transactions against the current state data. To make these chaincode interactions extremely efficient, the latest values of all keys are stored in a state database. The state database is simply an indexed view into the chain's transaction log, it can therefore be regenerated from the chain at any time. The state database will automatically get recovered (or generated if needed) upon peer startup, before transactions are accepted.

Transaction Flow

At a high level, the transaction flow consists of a transaction proposal sent by an application client to specific endorsing peers. The endorsing peers verify the client signature, and execute a chaincode function to simulate the transaction. The output is the chaincode results, a set of key/value versions that were read in the chaincode (read set), and the set of keys/values that were written in chaincode (write set). The proposal response gets sent back to the client along with an endorsement signature.

The client assembles the endorsements into a transaction payload and broadcasts it to an ordering service. The ordering service delivers ordered transactions as blocks to all peers on a channel.

Before committal, peers will validate the transactions. First, they will check the endorsement policy to ensure that the correct allotment of the specified peers have signed the results, and they will authenticate the signatures against the transaction payload.

Secondly, peers will perform a versioning check against the transaction read set, to ensure data integrity and protect against threats such as double-spending. Hyperledger Fabric has concurrency control whereby transactions execute in parallel (by endorsers) to increase throughput, and upon commit (by all peers) each transaction is verified to ensure that no other transaction has modified data it has read. In other words, it ensures that the data that was read during chaincode execution has not changed since execution (endorsement) time, and therefore the execution results are still valid and can be committed to the ledger state database. If the data that was read has been changed by another transaction, then the transaction in the block is marked as invalid and is not applied to the ledger state database. The client application is alerted, and can handle the error or retry as appropriate.

See the *Transaction Flow* and *Read-Write set semantics* topics for a deeper dive on transaction structure, concurrency control, and the state DB.

State Database options

State database options include LevelDB and CouchDB (beta). LevelDB is the default key/value state database embedded in the peer process. CouchDB is an optional alternative external state database. Like the LevelDB key/value store, CouchDB can store any binary data that is modeled in chaincode (CouchDB attachment functionality is used internally for non-JSON binary data). But as a JSON document store, CouchDB additionally enables rich query against the chaincode data, when chaincode values (e.g. assets) are modeled as JSON data.

Both LevelDB and CouchDB support core chaincode operations such as getting and setting a key (asset), and querying based on keys. Keys can be queried by range, and composite keys can be modeled to enable equivalence queries against multiple parameters. For example a composite key of (owner,asset_id) can be used to query all assets owned by a certain entity. These key-based queries can be used for read-only queries against the ledger, as well as in transactions that update the ledger.

If you model assets as JSON and use CouchDB, you can also perform complex rich queries against the chaincode data values, using the CouchDB JSON query language within chaincode. These types of queries are excellent for understanding what is on the ledger. Proposal responses for these types of queries are typically useful to the client application, but are not typically submitted as transactions to the ordering service. In fact, there is no guarantee the result set is stable between chaincode execution and commit time for rich queries, and therefore rich queries are not appropriate for use in update transactions, unless your application can guarantee the result set is stable between chaincode execution time and commit time, or can handle potential changes in subsequent transactions. For example, if you perform a rich query for all assets owned by Alice and transfer them to Bob, a new asset may be assigned to Alice by another transaction between chaincode execution time and commit time, and you would miss this 'phantom' item.

CouchDB runs as a separate database process alongside the peer, therefore there are additional considerations in terms of setup, management, and operations. You may consider starting with the default embedded LevelDB, and move to CouchDB if you require the additional complex rich queries. It is a good practice to model chaincode asset data as JSON, so that you have the option to perform complex rich queries if needed in the future.

To enable CouchDB as the state database, configure the /fabric/sampleconfig/core.yaml `stateDatabase` section.

CHAPTER 27

Read-Write set semantics

This documents discusses the details of the current implementation about the semantics of read-write sets.

Transaction simulation and read-write set

During simulation of a transaction at an `endorser` , a read-write set is prepared for the transaction. The `read set` contains a list of unique keys and their committed versions that the transaction reads during simulation. The `write set` contains a list of unique keys (though there can be overlap with the keys present in the read set) and their new values that the transaction writes. A delete marker is set (in the place of new value) for the key if the update performed by the transaction is to delete the key.

Further, if the transaction writes a value multiple times for a key, only the last written value is retained. Also, if a transaction reads a value for a key, the value in the committed state is returned even if the transaction has updated the value for the key before issuing the read. In another words, Read-your-writes semantics are not supported.

As noted earlier, the versions of the keys are recorded only in the read set; the write set just contains the list of unique keys and their latest values set by the transaction.

There could be various schemes for implementing versions. The minimal requirement for a versioning scheme is to produce non-repeating identifiers for a given key. For instance, using monotonically increasing numbers for versions can be one such scheme. In the current implementation, we use a blockchain height based versioning scheme in which the height of the committing transaction is used as the latest version for all the keys modified by the transaction. In this scheme, the height of a transaction is represented by a tuple (txNumber is the height of the transaction within the block). This scheme has many advantages over the incremental number scheme - primarily, it enables other components such as statedb, transaction simulation and validation for making efficient design choices.

Following is an illustration of an example read-write set prepared by simulation of a hypothetical transaction. For the sake of simplicity, in the illustrations, we use the incremental numbers for representing the versions.

```
<TxReadWriteSet>
  <NsReadWriteSet name="chaincode1">
    <read-set>
      <read key="K1", version="1">
      <read key="K2", version="1">
    </read-set>
    <write-set>
      <write key="K1", value="V1"
      <write key="K3", value="V2"
      <write key="K4", isDelete="true"
    </write-set>
  </NsReadWriteSet>
<TxReadWriteSet>
```

Additionally, if the transaction performs a range query during simulation, the range query as well as its results will be added to the read-write set as `query-info` .

Transaction validation and updating world state using read-write set

A `committer` uses the read set portion of the read-write set for checking the validity of a transaction and the write set portion of the read-write set for updating the versions and the values of the affected keys.

In the validation phase, a transaction is considered `valid` if the version of each key present in the read set of the transaction matches the version for the same key in the world state - assuming all the preceding `valid` transactions (including the preceding transactions in the same block) are committed (*committed-state*). An additional validation is performed if the read-write set also contains one or more query-info.

This additional validation should ensure that no key has been inserted/deleted/updated in the super range (i.e., union of the ranges) of the results captured in the query-info(s). In other words, if we re-execute any of the range queries (that the transaction performed during simulation) during validation on the committed-state, it should yield the same results that were observed by the transaction at the time of simulation. This check ensures that if a transaction observes phantom items during commit, the transaction should be marked as invalid. Note that the this phantom protection is limited to range queries (i.e., `GetStateByRange` function in the chaincode) and not yet implemented for other queries (i.e., `GetQueryResult` function in the chaincode). Other queries are at risk of phantoms, and should therefore only be used in read-only transactions that are not submitted to ordering, unless the application can guarantee the stability of the result set between simulation and validation/commit time.

If a transaction passes the validity check, the committer uses the write set for updating the world state. In the update phase, for each key present in the write set, the value in the world state for the same key is set to the value as specified in the write set. Further, the version of the key in the world state is changed to reflect the latest version.

Example simulation and validation

This section helps with understanding the semantics through an example scenario. For the purpose of this example, the presence of a key, `k` , in the world state is represented by a tuple `(k,ver,val)` where `ver` is the latest version of the key `k` having `val` as its value.

Now, consider a set of five transactions `T1,T2,T3,T4,and T5` , all simulated on the same snapshot of the world state. The following snippet shows the snapshot of the world state against which the transactions are simulated and the sequence of read and write activities performed by each of these transactions.

```
World state: (k1,1,v1), (k2,1,v2), (k3,1,v3), (k4,1,v4), (k5,1,v5)
T1 -> Write(k1, v1'), Write(k2, v2')
T2 -> Read(k1), Write(k3, v3')
T3 -> Write(k2, v2'')
T4 -> Write(k2, v2'''), read(k2)
T5 -> Write(k6, v6'), read(k5)
```

Now, assume that these transactions are ordered in the sequence of T1,..,T5 (could be contained in a single block or different blocks)

1. `T1` passes validation because it does not perform any read. Further, the tuple of keys `k1` and `k2` in the world state are updated to `(k1,2,v1'),(k2,2,v2')`
2. `T2` fails validation because it reads a key, `k1` , which was modified by a preceding transaction - `T1`

3. `T3` passes the validation because it does not perform a read. Further the tuple of the key, `k2` , in the world state is updated to `(k2,3,v2'')`
4. `T4` fails the validation because it reads a key, `k2` , which was modified by a preceding transaction `T1`
5. `T5` passes validation because it reads a key, `k5,` which was not modified by any of the preceding transactions

Note: Transactions with multiple read-write sets are not yet supported.

CHAPTER 28

Gossip data dissemination protocol

Hyperledger Fabric optimizes blockchain network performance, security and scalability by dividing workload across transaction execution (endorsing and committing) peers and transaction ordering nodes. This decoupling of network operations requires a secure, reliable and scalable data dissemination protocol to ensure data integrity and consistency. To meet these requirements, Hyperledger Fabric implements a **gossip data dissemination protocol**.

Gossip protocol

Peers leverage gossip to broadcast ledger and channel data in a scalable fashion. Gossip messaging is continuous, and each peer on a channel is constantly receiving current and consistent ledger data, from multiple peers. Each gossiped message is signed, thereby allowing Byzantine participants sending faked messages to be easily identified and the distribution of the message(s) to unwanted targets to be prevented. Peers affected by delays, network partitions or other causations resulting in missed blocks, will eventually be synced up to the current ledger state by contacting peers in possession of these missing blocks.

The gossip-based data dissemination protocol performs three primary functions on a Hyperledger Fabric network:

1. Manages peer discovery and channel membership, by continually identifying available member peers, and eventually detecting peers that have gone offline.
2. Disseminates ledger data across all peers on a channel. Any peer with data that is out of sync with the rest of the channel identifies the missing blocks and syncs itself by copying the correct data.
3. Bring newly connected peers up to speed by allowing peer-to-peer state transfer update of ledger data.

Gossip-based broadcasting operates by peers receiving messages from other peers on the channel, and then forwarding these messages to a number of randomly-selected peers on the channel, where this number is a configurable constant. Peers can also exercise a pull mechanism, rather than waiting for delivery of a message. This cycle repeats, with the result of channel membership, ledger and state information continually being kept current and in sync. For dissemination of new blocks, the **leader** peer on the channel pulls the data from the ordering service and initiates gossip dissemination to peers.

Gossip messaging

Online peers indicate their availability by continually broadcasting "alive" messages, with each containing the **public key infrastructure (PKI)** ID and the signature of the sender over the message. Peers maintain channel membership by collecting these alive messages; if no peer receives an alive message from a specific peer, this "dead" peer is eventually purged from channel membership. Because "alive" messages are cryptographically signed, malicious peers can never impersonate other peers, as they lack a signing key authorized by a root certificate authority (CA).

In addition to the automatic forwarding of received messages, a state reconciliation process synchronizes **world state** across peers on each channel. Each peer continually pulls blocks from other peers on the channel, in order to repair its own state if discrepancies are identified. Because fixed connectivity is not required to maintain gossip-based data dissemination, the process reliably provides data consistency and integrity to the shared ledger, including tolerance for node crashes.

Because channels are segregated, peers on one channel cannot message or share information on any other channel. Though any peer can belong to multiple channels, partitioned messaging prevents blocks from being disseminated to peers that are not in the channel by applying message routing policies based on peers' channel subscriptions.

Notes:

1. Security of point-to-point messages are handled by the peer TLS layer, and do not require signatures. Peers are authenticated by their certificates, which are assigned by a CA. Although TLS certs are also used, it is the peer certificates that are authenticated in the gossip layer. Ledger blocks are signed by the ordering service, and then delivered to the leader peers on a channel. 2. Authentication is governed by the membership service provider for the peer. When the peer connects to the channel for the first time, the TLS session binds with the membership identity. This essentially authenticates each peer to the connecting peer, with respect to membership in the network and channel.

CHAPTER 29

Hyperledger Fabric FAQ

Endorsement

Endorsement architecture:

17. How many peers in the network need to endorse a transaction?

A. The number of peers required to endorse a transaction is driven by the endorsement policy that is specified at chaincode deployment time.

17. Does an application client need to connect to all peers?

A. Clients only need to connect to as many peers as are required by the endorsement policy for the chaincode.

Security & Access Control

Data Privacy and Access Control:

17. How do I ensure data privacy?

A. There are various aspects to data privacy. First, you can segregate your network into channels, where each channel represents a subset of participants that are authorized to see the data for the chaincodes that are deployed to that channel. Second, within a channel you can restrict the input data to chaincode to the set of endorsers only, by using visibility settings. The visibility setting will determine whether input and output chaincode data is included in the submitted transaction, versus just output data. Third, you can hash or encrypt the data before calling chaincode. If you hash the data then you will need to provide a means to share the source data. If you encrypt the data then you will need to provide a means to share the decryption keys. Fourth, you can restrict data access to certain roles in your organization, by building access control into the chaincode logic. Fifth, ledger data at rest can be encrypted via file system encryption on the peer, and data in-transit is encrypted via TLS.

17. Do the orderers see the transaction data?

A. No, the orderers only order transactions, they do not open the transactions. If you do not want the data to go through the orderers at all, and you are only concerned about the input data, then you can use visibility settings. The visibility setting will determine whether input and output chaincode data is included in the submitted transaction, versus just output data. Therefore, the input data can be private to the endorsers only. If you do not want the orderers to see chaincode output, then you can hash or encrypt the data before calling chaincode. If you hash the data then you will need to provide a meansto share the source data. If you encrypt the data then you will need to provide a means to share the decryption keys.

Application-side Programming Model

Transaction execution result:

17. How do application clients know the outcome of a transaction?

A. The transaction simulation results are returned to the client by the endorser in the proposal response. If there are multiple endorsers, the client can check that the responses are all the same, and submit the results and endorsements for ordering and commitment. Ultimately the committing peers will validate or invalidate the transaction, and the client becomes aware of the outcome via an event, that the SDK makes available to the application client.

Ledger queries:

17. How do I query the ledger data?

A. Within chaincode you can query based on keys. Keys can be queried by range, and composite keys can be modeled to enable equivalence queries against multiple parameters. For example a composite key of (owner,asset_id) can be used to query all assets owned by a certain entity. These key-based queries can be used for read-only queries against the ledger, as well as in transactions that update the ledger.

If you model asset data as JSON in chaincode and use CouchDB as the state database, you can also perform complex rich queries against the chaincode data values, using the CouchDB JSON query language within chaincode. The application client can perform read-only queries, but these responses are not typically submitted as part of transactions to the ordering service.

17. How do I query the historical data to understand data provenance?

A. The chaincode API `GetHistoryForKey()` will return history of values for a key.

Q. How to guarantee the query result is correct, especially when the peer being queried may be recovering and catching up on block processing?

A. The client can query multiple peers, compare their block heights, compare their query results, and favor the peers at the higher block heights.

Chaincode (Smart Contracts and Digital Assets)

17. Does Hyperledger Fabric support smart contract logic?

A. Yes. We call this feature *Chaincode*. It is our interpretation of the smart contract method/algorithm, with additional features.

A chaincode is programmatic code deployed on the network, where it is executed and validated by chain validators together during the consensus process. Developers can use chaincodes to develop business contracts, asset definitions, and collectively-managed decentralized applications.

17. How do I create a business contract?

A. There are generally two ways to develop business contracts: the first way is to code individual contracts into standalone instances of chaincode; the second way, and probably the more efficient way, is to use chaincode to create decentralized applications that manage the life cycle of one or multiple types of business contracts, and let end users instantiate instances of contracts within these applications.

17. How do I create assets?

A. Users can use chaincode (for business rules) and membership service (for digital tokens) to design assets, as well as the logic that manages them.

There are two popular approaches to defining assets in most blockchain solutions: the stateless UTXO model, where account balances are encoded into past transaction records; and the account model, where account balances are kept in state storage space on the ledger.

Each approach carries its own benefits and drawbacks. This blockchain technology does not advocate either one over the other. Instead, one of our first requirements was to ensure that both approaches can be easily implemented.

17. Which languages are supported for writing chaincode?

A. Chaincode can be written in any programming language and executed in containers. The first fully supported chaincode language is Golang.

Support for additional languages and the development of a templating language have been discussed, and more details will be released in the near future.

It is also possible to build Hyperledger Fabric applications using Hyperledger Composer.

17. Does the Hyperledger Fabric have native currency?

A. No. However, if you really need a native currency for your chain network, you can develop your own native currency with chaincode. One common attribute of native currency is that some amount will get transacted (the chaincode defining that currency will get called) every time a transaction is processed on its chain.

CHAPTER 30

Contributions Welcome!

We welcome contributions to Hyperledger in many forms, and there's always plenty to do!

First things first, please review the Hyperledger Code of Conduct before participating. It is important that we keep things civil.

Install prerequisites

Before we begin, if you haven't already done so, you may wish to check that you have all the *prerequisites* installed on the platform(s) on which you'll be developing blockchain applications and/or operating Hyperledger Fabric.

Getting a Linux Foundation account

In order to participate in the development of the Hyperledger Fabric project, you will need a *Linux Foundation account*. You will need to use your LF ID to access to all the Hyperledger community development tools, including Gerrit, Jira and the Wiki (for editing, only).

Setting up your SSH key

For Gerrit, before you can submit any change set for review, you will need to register your public SSH key. Login to Gerrit with your *LFID*, and click on your name in the upper right-hand corner of your browser window and then click 'Settings'. In the left-hand margin, you should see a link for 'SSH Public Keys'. Copy-n-paste your public SSH key into the window and press 'Add'.

Getting help

If you are looking for something to work on, or need some expert assistance in debugging a problem or working out a fix to an issue, our community is always eager to help. We hang out on Chat, IRC (#hyperledger on freenode.net) and the mailing lists. Most of us don't bite :grin: and will be glad to help. The only silly question is the one you don't ask. Questions are in fact a great way to help improve the project as they highlight where our documentation could be clearer.

Requirements and Use Cases

We have a Requirements WG that is documenting use cases and from those use cases deriving requirements. If you are interested in contributing to this effort, please feel free to join the discussion in chat.

Reporting bugs

If you are a user and you find a bug, please submit an issue using JIRA. Please try to provide sufficient information for someone else to reproduce the issue. One of the project's maintainers should respond to your issue within 24 hours. If not, please bump the issue with a comment and request that it be reviewed. You can also post to the `#fabric-maintainers` channel in chat.

Fixing issues and working stories

Review the issues list and find something that interests you. You could also check the "help-wanted" list. It is wise to start with something relatively straight forward and achievable, and that no one is already assigned. If no one is assigned, then assign the issue to yourself. Please be considerate and rescind the assignment if you cannot finish in a reasonable time, or add a comment saying that you are still actively working the issue if you need a little more time.

Making Feature/Enhancement Proposals

Review JIRA. to be sure that there isn't already an open (or recently closed) proposal for the same function. If there isn't, to make a proposal we recommend that you open a JIRA Epic, Story or Improvement, whichever seems to best fit the circumstance and link or inline a "one pager" of the proposal that states what the feature would do and, if possible, how it might be implemented. It would help also to make a case for why the feature should be added, such as identifying specific use case(s) for which the feature is needed and a case for what the benefit would be should the feature be implemented. Once the JIRA issue is created, and the "one pager" either attached, inlined in the description field, or a link to a publicly accessible document is added to the description, send an introductory email to the hyperledger-fabric@lists.hyperledger.org mailing list linking the JIRA issue, and soliciting feedback.

Discussion of the proposed feature should be conducted in the JIRA issue itself, so that we have a consistent pattern within our community as to where to find design discussion.

Getting the support of three or more of the Hyperledger Fabric maintainers for the new feature will greatly enhance the probability that the feature's related CRs will be merged.

Working with a local clone and Gerrit

We are using Gerrit to manage code contributions. If you are unfamiliar, please review this *document* before proceeding.

After you have familiarized yourself with `Gerrit` , and maybe played around with the `lf-sandbox` project, you should be ready to set up your local development *environment*.

Next, try *building the project* in your local development environment to ensure that everything is set up correctly.

The *Logging Control* document describes how to tweak the logging levels of various components within Hyperledger Fabric. Finally, every source file needs to include a license header: modified to include a copyright statement for the principle author(s).

What makes a good change request?

- One change at a time. Not five, not three, not ten. One and only one. Why? Because it limits the blast area of the change. If we have a regression, it is much easier to identify the culprit commit than if we have some composite change that impacts more of the code.
- Include a link to the JIRA story for the change. Why? Because a) we want to track our velocity to better judge what we think we can deliver and when and b) because we can justify the change more effectively. In many cases, there should be some discussion around a proposed change and we want to link back to that from the change itself.
- Include unit and integration tests (or changes to existing tests) with every change. This does not mean just happy path testing, either. It also means negative testing of any defensive code that it correctly catches input errors. When you write code, you are responsible to test it and provide the tests that demonstrate that your change does what it claims. Why? Because without this we have no clue whether our current code base actually works.
- Unit tests should have NO external dependencies. You should be able to run unit tests in place with `go test` or equivalent for the language. Any test that requires some external dependency (e.g. needs to be scripted to run another component) needs appropriate mocking. Anything else is not unit testing, it is integration testing by definition. Why? Because many open source developers do Test Driven Development. They place a watch on the directory that invokes the tests automagically as the code is changed. This is far more efficient than having to run a whole build between code changes. See this definition of unit testing for a good set of criteria to keep in mind for writing effective unit tests.
- Minimize the lines of code per CR. Why? Maintainers have day jobs, too. If you send a 1,000 or 2,000 LOC change, how long do you think it takes to review all of that code? Keep your changes to < 200-300 LOC, if possible. If you have a larger change, decompose it into multiple independent changess. If you are adding a bunch of new functions to fulfill the requirements of a new capability, add them separately with their tests, and then write the code that uses them to deliver the capability. Of course, there are always exceptions. If you add a small change and then add 300 LOC of tests, you will be forgiven;-) If you need to make a change that has broad impact or a bunch of generated code (protobufs, etc.). Again, there can be exceptions.

  Note: large change requests, e.g. those with more than 300 LOC are more likely than not going to receive a -2, and you'll be asked to refactor the change to conform with this guidance.
- Do not stack change requests (e.g. submit a CR from the same local branch as your previous CR) unless they are related. This will minimize merge conflicts and allow changes to be merged more quickly. If you stack requests your subsequent requests may be held up because of review comments in the preceding requests.
- Write a meaningful commit message. Include a meaningful 50 (or less) character title, followed by a blank line, followed by a more comprehensive description of the change. Each change MUST include the JIRA identifier corresponding to the change (e.g. [FAB-1234]). This can be in the title but should also be in the body of the commit message.

  Note that Gerrit will automatically create a hyperlink to the JIRA item.

e.g.

```
[FAB-1234] fix foobar() panic

Fix [FAB-1234] added a check to ensure that when foobar(foo string) is called,
that there is a non-empty string argument.
```

Finally, be responsive. Don't let a change request fester with review comments such that it gets to a point that it requires a rebase. It only further delays getting it merged and adds more work for you - to remediate the merge conflicts.

Communication

We use RocketChat for communication and Google Hangouts™ for screen sharing between developers. Our development planning and prioritization is done in JIRA, and we take longer running discussions/decisions to the mailing list.

Maintainers

The project's *maintainers* are responsible for reviewing and merging all patches submitted for review and they guide the over-all technical direction of the project within the guidelines established by the Hyperledger Technical Steering Committee (TSC).

Becoming a maintainer

This project is managed under an open governance model as described in our charter. Projects or sub-projects will be lead by a set of maintainers. New sub-projects can designate an initial set of maintainers that will be approved by the top-level project's existing maintainers when the project is first approved. The project's maintainers will, from time-to-time, consider adding or removing a maintainer. An existing maintainer can submit a change set to the *MAINTAINERS.rst* file. If there are less than eight maintainers, a majority of the existing maintainers on that project are required to merge the change set. If there are more than eight existing maintainers, then if five or more of the maintainers concur with the proposal, the change set is then merged and the individual is added to (or alternatively, removed from) the maintainers group. explicit resignation, some infraction of the code of conduct or consistently demonstrating poor judgement.

Legal stuff

Note: Each source file must include a license header for the Apache Software License 2.0. See the template of the license header.

We have tried to make it as easy as possible to make contributions. This applies to how we handle the legal aspects of contribution. We use the same approach—the Developer's Certificate of Origin 1.1 (DCO)—that the Linux® Kernel community uses to manage code contributions.

We simply ask that when submitting a patch for review, the developer must include a sign-off statement in the commit message.

Here is an example Signed-off-by line, which indicates that the submitter accepts the DCO:

```
Signed-off-by: John Doe <john.doe@hisdomain.com>
```

You can include this automatically when you commit a change to your local git repository using `git commit -s`.

CHAPTER 31

Maintainers

Name	Gerrit	GitHub	RocketChat	email
Artem Barger	c0rwin	c0rwin	c0rwin	bartem@il.ibm.com
Binh Nguyen	binhn	binhn	binhn	binhn@us.ibm.com
Chris Ferris	ChristopherFerris	christo4ferris	cbf	chris.ferris@gmail.com
Dave Enyeart	denyeart	denyeart	dave.enyeart	enyeart@us.ibm.com
Gabor Hosszu	hgabre	gabre	hgabor	gabor@digitalasset.com
Gari Singh	mastersingh24	mastersingh24	garisingh	gari.r.singh@gmail.com
Greg Haskins	greg.haskins	ghaskins	ghaskins	gregory.haskins@gmail.com
Jason Yellick	jyellick	jyellick	jyellick	jyellick@us.ibm.com
Jim Zhang	jimthematrix	jimthematrix	jzhang	jim_the_matrix@hotmail.com
Jonathan Levi	JonathanLevi	JonathanLevi	JonathanLevi	jonathan@hacera.com
Keith Smith	smithbk	smithbk	smithbk	bksmith@us.ibm.com
Kostas Christidis	kchristidis	kchristidis	kostas	kostas@gmail.com
Manish Sethi	manish-sethi	manish-sethi	manish-sethi	manish.sethi@gmail.com
Sheehan Anderson	sheehan	srderson	sheehan	sranderson@gmail.com
Srinivasan Muralidharan	muralisr	muralisrini	muralisr	muralisr@us.ibm.com
Tamas Blummer	TamasBlummer	tamasblummer	tamas	tamas@digitalasset.com
Yacov Manevich	yacovm	yacovm	yacovm	yacovm@il.ibm.com
Yaoguo Jiang	jiangyaoguo	jiangyaoguo	jiangyaoguo	jiangyaoguo@gmail.com

CHAPTER 32

Using Jira to understand current work items

This document has been created to give further insight into the work in progress towards the hyperledger/fabric v1 architecture based off the community roadmap. The requirements for the roadmap are being tracked in Jira.

It was determined to organize in sprints to better track and show a prioritized order of items to be implemented based on feedback received. We've done this via boards. To see these boards and the priorities click on **Boards -> Manage Boards**:

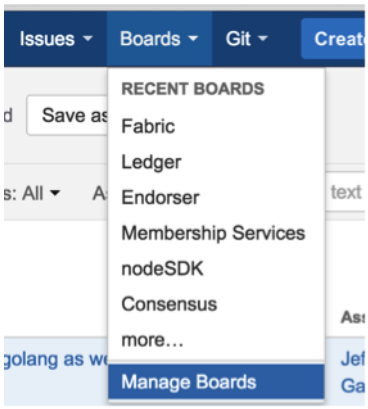


Fig. 32.1: Jira boards

Now on the left side of the screen click on **All boards**:

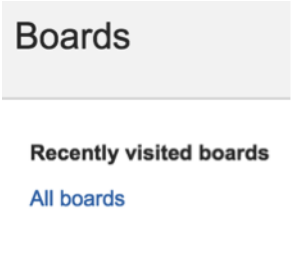


Fig. 32.2: Jira boards

On this page you will see all the public (and restricted) boards that have been created. If you want to see the items with current sprint focus, click on the boards where the column labeled **Visibility** is **All Users** and the column **Board type** is labeled **Scrum**. For example the **Board Name** Consensus:

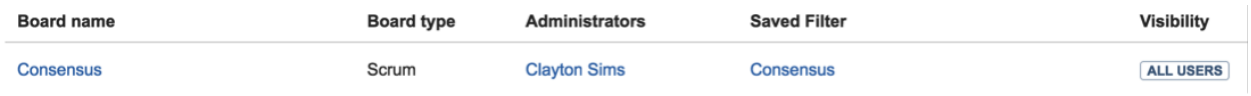


Fig. 32.3: Jira boards

When you click on Consensus under **Board name** you will be directed to a page that contains the following columns:

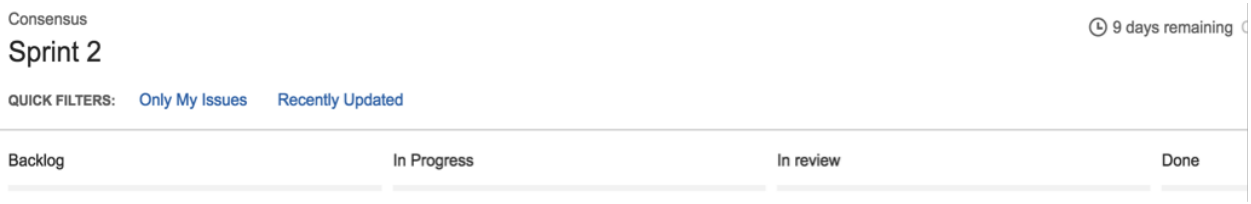


Fig. 32.4: Jira boards

The meanings to these columns are as follows:

- Backlog – list of items slated for the current sprint (sprints are defined in 2 week iterations), but are not currently in progress
- In progress – are items currently being worked by someone in the community.
- In Review – waiting to be reviewed and merged in Gerritt
- Done – merged and complete in the sprint.

If you want to see all items in the backlog for a given feature set click on the stacked rows on the left navigation of the screen:

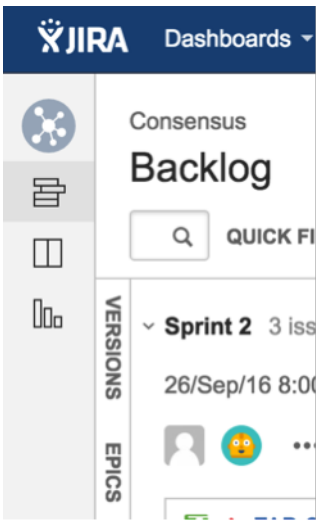


Fig. 32.5: Jira boards

This shows you items slated for the current sprint at the top, and all items in the backlog at the bottom. Items are listed in priority order.

If there is an item you are interested in working on, want more information or have questions, or if there is an item that you feel needs to be in higher priority, please add comments directly to the Jira item. All feedback and help is very much appreciated.

CHAPTER 33

Setting up the development environment

Overview

Prior to the v1.0.0 release, the development environment utilized Vagrant running an Ubuntu image, which in turn launched Docker containers as a means of ensuring a consistent experience for developers who might be working with varying platforms, such as macOS, Windows, Linux, or whatever. Advances in Docker have enabled native support on the most popular development platforms: macOS and Windows. Hence, we have reworked our build to take full advantage of these advances. While we still maintain a Vagrant based approach that can be used for older versions of macOS and Windows that Docker does not support, we strongly encourage that the non-Vagrant development setup be used.

Note that while the Vagrant-based development setup could not be used in a cloud context, the Docker-based build does support cloud platforms such as AWS, Azure, Google and IBM to name a few. Please follow the instructions for Ubuntu builds, below.

Prerequisites

- Git client
- Go - 1.7 or later (for releases before v1.0, 1.6 or later)
- For macOS, Xcode must be installed
- Docker - 1.12 or later
- Docker Compose - 1.8.1 or later
- Pip
- (macOS) you may need to install gnutar, as macOS comes with bsdtar as the default, but the build uses some gnutar flags. You can use Homebrew to install it as follows:

```
brew install gnu-tar --with-default-names
```

- (only if using Vagrant) - Vagrant - 1.7.4 or later
- (only if using Vagrant) - VirtualBox - 5.0 or later
- BIOS Enabled Virtualization - Varies based on hardware
- Note: The BIOS Enabled Virtualization may be within the CPU or Security settings of the BIOS

pip, behave and docker-compose

```
pip install --upgrade pip
pip install behave nose docker-compose
pip install -I flask==0.10.1 python-dateutil==2.2 pytz==2014.3 pyyaml==3.10␣
↪couchdb==1.0 flask-cors==2.0.1 requests==2.4.3 pyOpenSSL==16.2.0 pysha3==1.0b1␣
↪grpcio==1.0.4

#PIP packages required for some behave tests
pip install urllib3 ndg-httpsclient pyasn1 ecdsa python-slugify grpcio-tools jinja2␣
↪b3j0f.aop six
```

Steps

Set your GOPATH

Make sure you have properly setup your Host's GOPATH environment variable. This allows for both building within the Host and the VM.

In case you installed Go into a different location from the standard one your Go distribution assumes, make sure that you also set GOROOT environment variable.

Note to Windows users

If you are running Windows, before running any `git clone` commands, run the following command.

```
git config --get core.autocrlf
```

If `core.autocrlf` is set to `true` , you must set it to `false` by running

```
git config --global core.autocrlf false
```

If you continue with `core.autocrlf` set to `true` , the `vagrant up` command will fail with the error:

```
./setup.sh: /bin/bash^M: bad interpreter: No such file or directory
```

Cloning the Hyperledger Fabric source

Since Hyperledger Fabric is written in `Go` , you'll need to clone the source repository to your $GOPATH/src directory. If your $GOPATH has multiple path components, then you will want to use the first one. There's a little bit of setup needed:

```
cd $GOPATH/src
mkdir -p github.com/hyperledger
cd github.com/hyperledger
```

Recall that we are using `Gerrit` for source control, which has its own internal git repositories. Hence, we will need to clone from *Gerrit*. For brevity, the command is as follows:

```
git clone ssh://LFID@gerrit.hyperledger.org:29418/fabric && scp -p -P 29418␣
↪LFID@gerrit.hyperledger.org:hooks/commit-msg fabric/.git/hooks/
```

Note: Of course, you would want to replace `LFID` with your own *Linux Foundation ID*.

Bootstrapping the VM using Vagrant

If you are planning on using the Vagrant developer environment, the following steps apply. **Again, we recommend against its use except for developers that are limited to older versions of macOS and Windows that are not supported by Docker for Mac or Windows.**

```
cd $GOPATH/src/github.com/hyperledger/fabric/devenv
vagrant up
```

Go get coffee... this will take a few minutes. Once complete, you should be able to `ssh` into the Vagrant VM just created.

```
vagrant ssh
```

Once inside the VM, you can find the source under `$GOPATH/src/github.com/hyperledger/fabric`. It is also mounted as `/hyperledger`.

Building Hyperledger Fabric

Once you have all the dependencies installed, and have cloned the repository, you can proceed to *build and test* Hyperledger Fabric.

Notes

NOTE: Any time you change any of the files in your local fabric directory (under `$GOPATH/src/github.com/hyperledger/fabric`), the update will be instantly available within the VM fabric directory.

NOTE: If you intend to run the development environment behind an HTTP Proxy, you need to configure the guest so that the provisioning process may complete. You can achieve this via the *vagrant-proxyconf* plugin. Install with `vagrant plugin install vagrant-proxyconf` and then set the VAGRANT_HTTP_PROXY and VAGRANT_HTTPS_PROXY environment variables *before* you execute `vagrant up`. More details are available here: https://github.com/tmatilai/vagrant-proxyconf/

NOTE: The first time you run this command it may take quite a while to complete (it could take 30 minutes or more depending on your environment) and at times it may look like it's not doing anything. As long you don't get any error messages just leave it alone, it's all good, it's just cranking.

NOTE to Windows 10 Users: There is a known problem with vagrant on Windows 10 (see mitchellh/vagrant#6754). If the `vagrant up` command fails it may be because you do not have the Microsoft Visual C++ Redistributable package installed. You can download the missing package at the following address: http://www.microsoft.com/en-us/download/details.aspx?id=8328

Building Hyperledger Fabric

The following instructions assume that you have already set up your *development environment*.

To build Hyperledger Fabric:

```
cd $GOPATH/src/github.com/hyperledger/fabric
make dist-clean all
```

Running the unit tests

Use the following sequence to run all unit tests

```
cd $GOPATH/src/github.com/hyperledger/fabric
make unit-test
```

To run a subset of tests, set the TEST_PKGS environment variable. Specify a list of packages (separated by space), for example:

```
export TEST_PKGS="github.com/hyperledger/fabric/core/ledger/..."
make unit-test
```

To run a specific test use the `-run RE` flag where RE is a regular expression that matches the test case name. To run tests with verbose output use the `-v` flag. For example, to run the `TestGetFoo` test case, change to the directory containing the `foo_test.go` and call/excecute

```
go test -v -run=TestGetFoo
```

Running Node.js Unit Tests

You must also run the Node.js unit tests to insure that the Node.js client SDK is not broken by your changes. To run the Node.js unit tests, follow the instructions here.

Running Behave BDD Tests

Note: currently, the behave tests must be run from within in the Vagrant environment. See the *development environment* setup instructions if you have not already set up your Vagrant environment.

Behave tests will setup networks of peers with different security and consensus configurations and verify that transactions run properly. To run these tests

```
cd $GOPATH/src/github.com/hyperledger/fabric
make behave
```

Some of the Behave tests run inside Docker containers. If a test fails and you want to have the logs from the Docker containers, run the tests with this option:

```
cd $GOPATH/src/github.com/hyperledger/fabric/bddtests
behave -D logs=Y
```

CHAPTER 35

Building outside of Vagrant

It is possible to build the project and run peers outside of Vagrant. Generally speaking, one has to 'translate' the vagrant setup file to the platform of your choice.

Building on Z

To make building on Z easier and faster, this script is provided (which is similar to the setup file provided for vagrant). This script has been tested only on RHEL 7.2 and has some assumptions one might want to re-visit (firewall settings, development as root user, etc.). It is however sufficient for development in a personally-assigned VM instance.

To get started, from a freshly installed OS:

```
sudo su
yum install git
mkdir -p $HOME/git/src/github.com/hyperledger
cd $HOME/git/src/github.com/hyperledger
git clone http://gerrit.hyperledger.org/r/fabric
source fabric/devenv/setupRHELonZ.sh
```

From this point, you can proceed as described above for the Vagrant development environment.

```
cd $GOPATH/src/github.com/hyperledger/fabric
make peer unit-test behave
```

Building on Power Platform

Development and build on Power (ppc64le) systems is done outside of vagrant as outlined *here*. For ease of setting up the dev environment on Ubuntu, invoke this script as root. This script has been validated on Ubuntu 16.04 and assumes certain things (like, development system has OS repositories in place, firewall setting etc) and in general can be improvised further.

To get started on Power server installed with Ubuntu, first ensure you have properly setup your Host's GOPATH environment variable. Then, execute the following commands to build the fabric code:

```
mkdir -p $GOPATH/src/github.com/hyperledger
cd $GOPATH/src/github.com/hyperledger
git clone http://gerrit.hyperledger.org/r/fabric
sudo ./fabric/devenv/setupUbuntuOnPPC64le.sh
```

```
cd $GOPATH/src/github.com/hyperledger/fabric
make dist-clean all
```

CHAPTER 36

Configuration

Configuration utilizes the viper and cobra libraries.

There is a **core.yaml** file that contains the configuration for the peer process. Many of the configuration settings can be overridden on the command line by setting ENV variables that match the configuration setting, but by prefixing with *'CORE_'*. For example, logging level manipulation through the environment is shown below:

```
CORE_PEER_LOGGING_LEVEL=CRITICAL peer
```

CHAPTER 37

Logging

Logging utilizes the go-logging library.

The available log levels in order of increasing verbosity are: *CRITICAL | ERROR | WARNING | NOTICE | INFO | DEBUG*

See the logging-control document for instructions on tweaking the level of log messages to output when running the various Hyperledger Fabric components.

CHAPTER 38

Requesting a Linux Foundation Account

Contributions to the Hyperledger Fabric code base require a Linux Foundation account. Follow the steps below to create a Linux Foundation account.

Creating a Linux Foundation ID

1. Go to the Linux Foundation ID website.
2. Select the option `I need to create a Linux Foundation ID.`
3. Fill out the form that appears:
4. Open your email account and look for a message with the subject line: "Validate your Linux Foundation ID email".
5. Open the received URL to validate your email address.
6. Verify the browser displays the message `You have successfully validated your e-mail address.`
7. Access `Gerrit` by selecting `Sign In`:
8. Use your Linux Foundation ID to Sign In:

Configuring Gerrit to Use SSH

Gerrit uses SSH to interact with your Git client. A SSH private key needs to be generated on the development machine with a matching public key on the Gerrit server.

If you already have a SSH key-pair, skip this section.

As an example, we provide the steps to generate the SSH key-pair on a Linux environment. Follow the equivalent steps on your OS.

1. Create a key-pair, enter:

```
ssh-keygen -t rsa -C "John Doe john.doe@example.com"
```

Note: This will ask you for a password to protect the private key as it generates a unique key. Please keep this password private, and DO NOT enter a blank password.

The generated key-pair is found in: `~/.ssh/id_rsa` and `~/.ssh/id_rsa.pub`.

1. Add the private key in the `id_rsa` file in your key ring, e.g.:

```
ssh-add ~/.ssh/id_rsa
```

Once the key-pair has been generated, the public key must be added to Gerrit.

Follow these steps to add your public key `id_rsa.pub` to the Gerrit account:

1. Go to Gerrit.
2. Click on your account name in the upper right corner.
3. From the pop-up menu, select `Settings` .
4. On the left side menu, click on `SSH Public Keys` .
5. Paste the contents of your public key `~/.ssh/id_rsa.pub` and click `Add key` .

Note: The `id_rsa.pub` file can be opened with any text editor. Ensure that all the contents of the file are selected, copied and pasted into the `Add SSH key` window in Gerrit.

Note: The ssh key generation instructions operate on the assumtion that you are using the default naming. It is possible to generate multiple ssh Keys and to name the resulting files differently. See the ssh-keygen documentation for details on how to do that. Once you have generated non-default keys, you need to configure ssh to use the correct key for Gerrit. In that case, you need to create a `~/.ssh/config` file modeled after the one below.

```
host gerrit.hyperledger.org
 HostName gerrit.hyperledger.org
 IdentityFile ~/.ssh/id_rsa_hyperledger_gerrit
 User <LFID>
```

where is your Linux Foundation ID and the value of IdentityFile is the name of the public key file you generated.

Warning: Potential Security Risk! Do not copy your private key `~/.ssh/id_rsa` Use only the public `~/.ssh/id_rsa.pub` .

Checking Out the Source Code

1. Ensure that SSH has been set up properly. See `Configuring Gerrit to Use SSH` for details.
2. Clone the repository with your Linux Foundation ID ():

```
git clone ssh://<LFID>@gerrit.hyperledger.org:29418/fabric fabric
```

You have successfully checked out a copy of the source code to your local machine.

CHAPTER 39

Working with Gerrit

Follow these instructions to collaborate on Hyperledger Fabric through the Gerrit review system.

Please be sure that you are subscribed to the mailing list and of course, you can reach out on chat if you need help.

Gerrit assigns the following roles to users:

- **Submitters**: May submit changes for consideration, review other code changes, and make recommendations for acceptance or rejection by voting +1 or -1, respectively.
- **Maintainers**: May approve or reject changes based upon feedback from reviewers voting +2 or -2, respectively.
- **Builders**: (e.g. Jenkins) May use the build automation infrastructure to verify the change.

Maintainers should be familiar with the *review process*. However, anyone is welcome to (and encouraged!) review changes, and hence may find that document of value.

Git-review

There's a **very** useful tool for working with Gerrit called git-review. This command-line tool can automate most of the ensuing sections for you. Of course, reading the information below is also highly recommended so that you understand what's going on behind the scenes.

Sandbox project

We have created a sandbox project to allow developers to familiarize themselves with Gerrit and our workflows. Please do feel free to use this project to experiment with the commands and tools, below.

Getting deeper into Gerrit

A comprehensive walk-through of Gerrit is beyond the scope of this document. There are plenty of resources available on the Internet. A good summary can be found here. We have also provided a set of *Best Practices* that you may find helpful.

Working with a local clone of the repository

To work on something, whether a new feature or a bugfix:

1. Open the Gerrit Projects page
2. Select the project you wish to work on.
3. Open a terminal window and clone the project locally using the `Clone with git hook` URL. Be sure that `ssh` is also selected, as this will make authentication much simpler:

```
git clone ssh://LFID@gerrit.hyperledger.org:29418/fabric && scp -p -P 29418␣
↪LFID@gerrit.hyperledger.org:hooks/commit-msg fabric/.git/hooks/
```

Note: if you are cloning the fabric project repository, you will want to clone it to the `$GOPATH/src/github.com/hyperledger` directory so that it will build, and so that you can use it with the Vagrant *development environment*.

4. Create a descriptively-named branch off of your cloned repository

```
cd fabric
git checkout -b issue-nnnn
```

5. Commit your code. For an in-depth discussion of creating an effective commit, please read *this document on submitting changes*.

```
git commit -s -a
```

Then input precise and readable commit msg and submit.

6. Any code changes that affect documentation should be accompanied by corresponding changes (or additions) to the documentation and tests. This will ensure that if the merged PR is reversed, all traces of the change will be reversed as well.

Submitting a Change

Currently, Gerrit is the only method to submit a change for review.

Note: Please review the *guidelines* for making and submitting a change.

Use git review

Note: if you prefer, you can use the *git-review* tool instead of the following. e.g.

Add the following section to `.git/config`, and replace `<USERNAME>` with your gerrit id.

```
[remote "gerrit"]
    url = ssh://<USERNAME>@gerrit.hyperledger.org:29418/fabric.git
    fetch = +refs/heads/*:refs/remotes/gerrit/*
```

Then submit your change with `git review`.

```
$ cd <your code dir>
$ git review
```

When you update your patch, you can commit with `git commit --amend`, and then repeat the `git review` command.

Not Use git review

See the *directions for building the source code*.

When a change is ready for submission, Gerrit requires that the change be pushed to a special branch. The name of this special branch contains a reference to the final branch where the code should reside, once accepted.

For the Hyperledger Fabric repository, the special branch is called `refs/for/master` .

To push the current local development branch to the gerrit server, open a terminal window at the root of your cloned repository:

```
cd <your clone dir>
git push origin HEAD:refs/for/master
```

If the command executes correctly, the output should look similar to this:

```
Counting objects: 3, done.
Writing objects: 100% (3/3), 306 bytes | 0 bytes/s, done.
Total 3 (delta 0), reused 0 (delta 0)
remote: Processing changes: new: 1, refs: 1, done
remote:
remote: New Changes:
remote:   https://gerrit.hyperledger.org/r/6 Test commit
remote:
To ssh://LFID@gerrit.hyperledger.org:29418/fabric
* [new branch]      HEAD -> refs/for/master
```

The gerrit server generates a link where the change can be tracked.

Adding reviewers

Optionally, you can add reviewers to your change.

To specify a list of reviewers via the command line, add `%r=reviewer@project.org` to your push command. For example:

```
git push origin HEAD:refs/for/master%r=rev1@email.com,r=rev2@notemail.com
```

Alternatively, you can auto-configure GIT to add a set of reviewers if your commits will have the same reviewers all at the time.

To add a list of default reviewers, open the :file:`.git/config` file in the project directory and add the following line in the `[ branch "master" ]` section:

```
[branch "master"] #.... push =
HEAD:refs/for/master%r=rev1@email.com,r=rev2@notemail.com`
```

Make sure to use actual email addresses instead of the `@email.com and @notemail.com` addressses. Don't forget to replace `origin` with your git remote name.

Reviewing Using Gerrit

- **Add**: This button allows the change submitter to manually add names of people who should review a change; start typing a name and the system will auto-complete based on the list of people registered and with access to

the system. They will be notified by email that you are requesting their input.

- **Abandon**: This button is available to the submitter only; it allows a committer to abandon a change and remove it from the merge queue.
- **Change-ID**: This ID is generated by Gerrit (or system). It becomes useful when the review process determines that your commit(s) have to be amended. You may submit a new version; and if the same Change-ID header (and value) are present, Gerrit will remember it and present it as another version of the same change.
- **Status**: Currently, the example change is in review status, as indicated by "Needs Verified" in the upper-left corner. The list of Reviewers will all emit their opinion, voting +1 if they agree to the merge, -1 if they disagree. Gerrit users with a Maintainer role can agree to the merge or refuse it by voting +2 or -2 respectively.

Notifications are sent to the email address in your commit message's Signed-off-by line. Visit your Gerrit dashboard, to check the progress of your requests.

The history tab in Gerrit will show you the in-line comments and the author of the review.

Viewing Pending Changes

Find all pending changes by clicking on the `All --> Changes` link in the upper-left corner, or open this link.

If you collaborate in multiple projects, you may wish to limit searching to the specific branch through the search bar in the upper-right side.

Add the filter *project:fabric* to limit the visible changes to only those from Hyperledger Fabric.

List all current changes you submitted, or list just those changes in need of your input by clicking on `My --> Changes` or open this link

CHAPTER 40

Submitting a Change to Gerrit

Carefully review the following before submitting a change. These guidelines apply to developers that are new to open source, as well as to experienced open source developers.

Change Requirements

This section contains guidelines for submitting code changes for review. For more information on how to submit a change using Gerrit, please see *Gerrit*.

Changes are submitted as Git commits. Each commit must contain:

- a short and descriptive subject line that is 72 characters or fewer, followed by a blank line.
- a change description with your logic or reasoning for the changes, followed by a blank line
- a Signed-off-by line, followed by a colon (Signed-off-by:)
- a Change-Id identifier line, followed by a colon (Change-Id:). Gerrit won't accept patches without this identifier.

A commit with the above details is considered well-formed.

All changes and topics sent to Gerrit must be well-formed. Informationally, `commit messages` must include:

- **what** the change does,
- **why** you chose that approach, and
- **how** you know it works – for example, which tests you ran.

Commits must *build cleanly* when applied in top of each other, thus avoiding breaking bisectability. Each commit must address a single identifiable issue and must be logically self-contained.

For example: One commit fixes whitespace issues, another renames a function and a third one changes the code's functionality. An example commit file is illustrated below in detail:

```
A short description of your change with no period at the end

You can add more details here in several paragraphs, but please keep each line
width less than 80 characters. A bug fix should include the issue number.

Fix Issue # 7050.

Change-Id: IF7b6ac513b2eca5f2bab9728ebd8b7e504d3cebe1
Signed-off-by: Your Name <commit-sender@email.address>
```

Each commit must contain the following line at the bottom of the commit message:

```
Signed-off-by: Your Name <your@email.address>
```

The name in the Signed-off-by line and your email must match the change authorship information. Make sure your :file:`.git/config` is set up correctly. Always submit the full set of changes via Gerrit.

When a change is included in the set to enable other changes, but it will not be part of the final set, please let the reviewers know this.

CHAPTER 41

Reviewing a Change

1. Click on a link for incoming or outgoing review.
2. The details of the change and its current status are loaded:

- **Status:** Displays the current status of the change. In the example below, the status reads: Needs Verified.
- **Reply:** Click on this button after reviewing to add a final review message and a score, -1, 0 or +1.
- **Patch Sets:** If multiple revisions of a patch exist, this button enables navigation among revisions to see the changes. By default, the most recent revision is presented.
- **Download:** This button brings up another window with multiple options to download or checkout the current changeset. The button on the right copies the line to your clipboard. You can easily paste it into your git interface to work with the patch as you prefer.

Underneath the commit information, the files that have been changed by this patch are displayed.

3. Click on a filename to review it. Select the code base to differentiate against. The default is `Base` and it will generally be what is needed.
4. The review page presents the changes made to the file. At the top of the review, the presentation shows some general navigation options. Navigate through the patch set using the arrows on the top right corner. It is possible to go to the previous or next file in the set or to return to the main change screen. Click on the yellow sticky pad to add comments to the whole file.

The focus of the page is on the comparison window. The changes made are presented in green on the right versus the base version on the left. Double click to highlight the text within the actual change to provide feedback on a specific section of the code. Press *c* once the code is highlighted to add comments to that section.

5. After adding the comment, it is saved as a *Draft*.
6. Once you have reviewed all files and provided feedback, click the *green up arrow* at the top right to return to the main change page. Click the `Reply` button, write some final comments, and submit your score for the patch set. Click `Post` to submit the review of each reviewed file, as well as your final comment and score. Gerrit sends an email to the change-submitter and all listed reviewers. Finally, it logs the review for future reference. All individual comments are saved as *Draft* until the `Post` button is clicked.

CHAPTER 42

Gerrit Recommended Practices

This document presents some best practices to help you use Gerrit more effectively. The intent is to show how content can be submitted easily. Use the recommended practices to reduce your troubleshooting time and improve participation in the community.

Browsing the Git Tree

Visit Gerrit then select `Projects --> List --> SELECT-PROJECT --> Branches` . Select the branch that interests you, click on `gitweb` located on the right-hand side. Now, `gitweb` loads your selection on the Git web interface and redirects appropriately.

Watching a Project

Visit Gerrit, then select `Settings` , located on the top right corner. Select `Watched Projects` and then add any projects that interest you.

Commit Messages

Gerrit follows the Git commit message format. Ensure the headers are at the bottom and don't contain blank lines between one another. The following example shows the format and content expected in a commit message:

Brief (no more than 50 chars) one line description.

Elaborate summary of the changes made referencing why (motivation), what was changed and how it was tested. Note also any changes to documentation made to remain consistent with the code changes, wrapping text at 72 chars/line.

Jira: FAB-100
Change-Id: LONGHEXHASH
Signed-off-by: Your Name your.email@example.org
AnotherExampleHeader: An Example of another Value

The Gerrit server provides a precommit hook to autogenerate the Change-Id which is one time use.

Recommended reading: How to Write a Git Commit Message

Avoid Pushing Untested Work to a Gerrit Server

To avoid pushing untested work to Gerrit.

Check your work at least three times before pushing your change to Gerrit. Be mindful of what information you are publishing.

Keeping Track of Changes

- Set Gerrit to send you emails:
- Gerrit will add you to the email distribution list for a change if a developer adds you as a reviewer, or if you comment on a specific Patch Set.
- Opening a change in Gerrit's review interface is a quick way to follow that change.
- Watch projects in the Gerrit projects section at `Gerrit` , select at least *New Changes, New Patch Sets, All Comments* and *Submitted Changes*.

Always track the projects you are working on; also see the feedback/comments mailing list to learn and help others ramp up.

Topic branches

Topic branches are temporary branches that you push to commit a set of logically-grouped dependent commits:

To push changes from `REMOTE/master` tree to Gerrit for being reviewed as a topic in **TopicName** use the following command as an example:

$ git push REMOTE HEAD:refs/for/master/TopicName

The topic will show up in the review :abbr:`UI` and in the `Open Changes List` . Topic branches will disappear from the master tree when its content is merged.

Creating a Cover Letter for a Topic

You may decide whether or not you'd like the cover letter to appear in the history.

1. To make a cover letter that appears in the history, use this command:

```
git commit --allow-empty
```

Edit the commit message, this message then becomes the cover letter. The command used doesn't change any files in the source tree.

2. To make a cover letter that doesn't appear in the history follow these steps:

- Put the empty commit at the end of your commits list so it can be ignored without having to rebase.
- Now add your commits

```
git commit ...
git commit ...
git commit ...
```

- Finally, push the commits to a topic branch. The following command is an example:

```
git push REMOTE HEAD:refs/for/master/TopicName
```

If you already have commits but you want to set a cover letter, create an empty commit for the cover letter and move the commit so it becomes the last commit on the list. Use the following command as an example:

```
git rebase -i HEAD~#Commits
```

Be careful to uncomment the commit before moving it. `#Commits` is the sum of the commits plus your new cover letter.

Finding Available Topics

```
$ ssh -p 29418 gerrit.hyperledger.org gerrit query \ status:open project:fabric␣
↪branch:master \
| grep topic: | sort -u
```

- gerrit.hyperledger.org Is the current URL where the project is hosted.
- *status* Indicates the topic's current status: open , merged, abandoned, draft, merge conflict.
- *project* Refers to the current name of the project, in this case fabric.
- *branch* The topic is searched at this branch.
- *topic* The name of an specific topic, leave it blank to include them all.
- *sort* Sorts the found topics, in this case by update (-u).

Downloading or Checking Out a Change

In the review UI, on the top right corner, the **Download** link provides a list of commands and hyperlinks to checkout or download diffs or files.

We recommend the use of the *git review* plugin. The steps to install git review are beyond the scope of this document. Refer to the git review documentation for the installation process.

To check out a specific change using Git, the following command usually works:

```
git review -d CHANGEID
```

If you don't have Git-review installed, the following commands will do the same thing:

```
git fetch REMOTE refs/changes/NN/CHANGEIDNN/VERSION \ && git checkout FETCH_HEAD
```

For example, for the 4th version of change 2464, NN is the first two digits (24):

```
git fetch REMOTE refs/changes/24/2464/4 \ && git checkout FETCH_HEAD
```

Using Draft Branches

You can use draft branches to add specific reviewers before you publishing your change. The Draft Branches are pushed to `refs/drafts/master/TopicName`

The next command ensures a local branch is created:

```
git checkout -b BRANCHNAME
```

The next command pushes your change to the drafts branch under **TopicName**:

```
git push REMOTE HEAD:refs/drafts/master/TopicName
```

Using Sandbox Branches

You can create your own branches to develop features. The branches are pushed to the `refs/sandbox/USERNAME/BRANCHNAME` location.

These commands ensure the branch is created in Gerrit's server.

```
git checkout -b sandbox/USERNAME/BRANCHNAME
git push --set-upstream REMOTE HEAD:refs/heads/sandbox/USERNAME/BRANCHNAME
```

Usually, the process to create content is:

- develop the code,
- break the information into small commits,
- submit changes,
- apply feedback,
- rebase.

The next command pushes forcibly without review:

```
git push REMOTE sandbox/USERNAME/BRANCHNAME
```

You can also push forcibly with review:

```
git push REMOTE HEAD:ref/for/sandbox/USERNAME/BRANCHNAME
```

Updating the Version of a Change

During the review process, you might be asked to update your change. It is possible to submit multiple versions of the same change. Each version of the change is called a patch set.

Always maintain the **Change-Id** that was assigned. For example, there is a list of commits, **c0...c7**, which were submitted as a topic branch:

```
git log REMOTE/master..master

c0
...
c7

git push REMOTE HEAD:refs/for/master/SOMETOPIC
```

After you get reviewers' feedback, there are changes in **c3** and **c4** that must be fixed. If the fix requires rebasing, rebasing changes the commit Ids, see the rebasing section for more information. However, you must keep the same Change-Id and push the changes again:

```
git push REMOTE HEAD:refs/for/master/SOMETOPIC
```

This new push creates a patches revision, your local history is then cleared. However you can still access the history of your changes in Gerrit on the `review UI` section, for each change.

It is also permitted to add more commits when pushing new versions.

Rebasing

Rebasing is usually the last step before pushing changes to Gerrit; this allows you to make the necessary *Change-Ids*. The *Change-Ids* must be kept the same.

- **squash:** mixes two or more commits into a single one.
- **reword:** changes the commit message.
- **edit:** changes the commit content.
- **reorder:** allows you to interchange the order of the commits.
- **rebase:** stacks the commits on top of the master.

Rebasing During a Pull

Before pushing a rebase to your master, ensure that the history has a consecutive order.

For example, your `REMOTE/master` has the list of commits from **a0** to **a4**; Then, your changes **c0...c7** are on top of **a4**; thus:

```
git log --oneline REMOTE/master..master

a0
a1
a2
a3
a4
c0
c1
...
c7
```

If `REMOTE/master` receives commits **a5**, **a6** and **a7**. Pull with a rebase as follows:

```
git pull --rebase REMOTE master
```

This pulls **a5-a7** and re-apply **c0-c7** on top of them:

```
$ git log --oneline REMOTE/master..master
a0
...
a7
c0
```

```
c1
...
c7
```

Getting Better Logs from Git

Use these commands to change the configuration of Git in order to produce better logs:

```
git config log.abbrevCommit true
```

The command above sets the log to abbreviate the commits' hash.

```
git config log.abbrev 5
```

The command above sets the abbreviation length to the last 5 characters of the hash.

```
git config format.pretty oneline
```

The command above avoids the insertion of an unnecessary line before the Author line.

To make these configuration changes specifically for the current Git user, you must add the path option `--global` to `config` as follows:

CHAPTER 43

Testing

Unit test

See *building Hyperledger Fabric* for unit testing instructions.

See Unit test coverage reports

To see coverage for a package and all sub-packages, execute the test with the `-cover` switch:

```
go test ./... -cover
```

To see exactly which lines are not covered for a package, generate an html report with source code annotated by coverage:

```
go test -coverprofile=coverage.out
go tool cover -html=coverage.out -o coverage.html
```

System test

[WIP] ...coming soon

This topic is intended to contain recommended test scenarios, as well as current performance numbers against a variety of configurations.

CHAPTER 44

Coding guidelines

Coding Golang

We code in Go™ and strictly follow the best practices and will not accept any deviations. You must run the following tools against your Go code and fix all errors and warnings: - golint - go vet - goimports

CHAPTER 45

Generating gRPC code

If you modify any `.proto` files, run the following command to generate/update the respective `.pb.go` files.

```
cd $GOPATH/src/github.com/hyperledger/fabric
make protos
```

CHAPTER 46

Adding or updating Go packages

Hyperledger Fabric uses Govendor for package management. This means that all required packages reside in the `$GOPATH/src/github.com/hyperledger/fabric/vendor` folder. Go will use packages in this folder instead of the GOPATH when the `go install` or `go build` commands are executed. To manage the packages in the `vendor` folder, we use Govendor, which is installed in the Vagrant environment. The following commands can be used for package management:

```
# Add external packages.
govendor add +external

# Add a specific package.
govendor add github.com/kardianos/osext

# Update vendor packages.
govendor update +vendor

# Revert back to normal GOPATH packages.
govendor remove +vendor

# List package.
govendor list
```

Needs Review

CHAPTER 47

Glossary

Terminology is important, so that all Hyperledger Fabric users and developers agree on what we mean by each specific term. What is chaincode, for example. The documentation will reference the glossary as needed, but feel free to read the entire thing in one sitting if you like; it's pretty enlightening!

Anchor Peer

A peer node on a channel that all other peers can discover and communicate with. Each *Member* on a channel has an anchor peer (or multiple anchor peers to prevent single point of failure), allowing for peers belonging to different Members to discover all existing peers on a channel.

Block

An ordered set of transactions that is cryptographically linked to the preceding block(s) on a channel.

Chain

The ledger's chain is a transaction log structured as hash-linked blocks of transactions. Peers receive blocks of transactions from the ordering service, mark the block's transactions as valid or invalid based on endorsement policies and concurrency violations, and append the block to the hash chain on the peer's file system.

Chaincode

Chaincode is software, running on a ledger, to encode assets and the transaction instructions (business logic) for modifying the assets.

Channel

A channel is a private blockchain overlay which allows for data isolation and confidentiality. A channel-specific ledger is shared across the peers in the channel, and transacting parties must be properly authenticated to a channel in order to interact with it. Channels are defined by a *Configuration-Block*.

Commitment

Each *Peer* on a channel validates ordered blocks of transactions and then commits (writes/appends) the blocks to its replica of the channel *Ledger*. Peers also mark each transaction in each block as valid or invalid.

Concurrency Control Version Check

Concurrency Control Version Check is a method of keeping state in sync across peers on a channel. Peers execute transactions in parallel, and before commitment to the ledger, peers check that the data read at execution time has not changed. If the data read for the transaction has changed between execution time and commitment time, then a Concurrency Control Version Check violation has occurred, and the transaction is marked as invalid on the ledger and values are not updated in the state database.

Configuration Block

Contains the configuration data defining members and policies for a system chain (ordering service) or channel. Any configuration modifications to a channel or overall network (e.g. a member leaving or joining) will result in a new configuration block being appended to the appropriate chain. This block will contain the contents of the genesis block, plus the delta.

Consensus

A broader term overarching the entire transactional flow, which serves to generate an agreement on the order and to confirm the correctness of the set of transactions constituting a block.

Current State

The current state of the ledger represents the latest values for all keys ever included in its chain transaction log. Peers commit the latest values to ledger current state for each valid transaction included in a processed block. Since current state represents all latest key values known to the channel, it is sometimes referred to as World State. Chaincode executes transaction proposals against current state data.

Dynamic Membership

Hyperledger Fabric supports the addition/removal of members, peers, and ordering service nodes, without compromising the operationality of the overall network. Dynamic membership is critical when business relationships adjust and entities need to be added/removed for various reasons.

Endorsement

Refers to the process where specific peer nodes execute a transaction and return a `YES/NO` response to the client application that generated the transaction proposal. Chaincode applications have corresponding endorsement policies, in which the endorsing peers are specified.

Endorsement policy

Defines the peer nodes on a channel that must execute transactions attached to a specific chaincode application, and the required combination of responses (endorsements). A policy could require that a transaction be endorsed by a minimum number of endorsing peers, a minimum percentage of endorsing peers, or by all endorsing peers that are assigned to a specific chaincode application. Policies can be curated based on the application and the desired level of resilience against misbehavior (deliberate or not) by the endorsing peers. A distinct endorsement policy for install and instantiate transactions is also required.

Hyperledger Fabric CA

Hyperledger Fabric CA is the default Certificate Authority component, which issues PKI-based certificates to network member organizations and their users. The CA issues one root certificate (rootCert) to each member and one enrollment certificate (ECert) to each authorized user.

Genesis Block

The configuration block that initializes a blockchain network or channel, and also serves as the first block on a chain.

Gossip Protocol

The gossip data dissemination protocol performs three functions: 1) manages peer discovery and channel membership; 2) disseminates ledger data across all peers on the channel; 3) syncs ledger state across all peers on the channel. Refer to the *Gossip* topic for more details.

Initialize

A method to initialize a chaincode application.

Install

The process of placing a chaincode on a peer's file system.

Instantiate

The process of starting a chaincode container.

Invoke

Used to call chaincode functions. Invocations are captured as transaction proposals, which then pass through a modular flow of endorsement, ordering, validation, committal. The structure of invoke is a function and an array of arguments.

Leading Peer

Each *Member* can own multiple peers on each channel that it subscribes to. One of these peers is serves as the leading peer for the channel, in order to communicate with the network ordering service on behalf of the member. The ordering service "delivers" blocks to the leading peer(s) on a channel, who then distribute them to other peers within the same member cluster.

Ledger

A ledger is a channel's chain and current state data which is maintained by each peer on the channel.

Member

A legally separate entity that owns a unique root certificate for the network. Network components such as peer nodes and application clients will be linked to a member.

Membership Service Provider

The Membership Service Provider (MSP) refers to an abstract component of the system that provides credentials to clients, and peers for them to participate in a Hyperledger Fabric network. Clients use these credentials to authenticate their transactions, and peers use these credentials to authenticate transaction processing results (endorsements). While strongly connected to the transaction processing components of the systems, this interface aims to have membership services components defined, in such a way that alternate implementations of this can be smoothly plugged in without modifying the core of transaction processing components of the system.

Membership Services

Membership Services authenticates, authorizes, and manages identities on a permissioned blockchain network. The membership services code that runs in peers and orderers both authenticates and authorizes blockchain operations. It is a PKI-based implementation of the Membership Services Provider (MSP) abstraction.

Ordering Service

A defined collective of nodes that orders transactions into a block. The ordering service exists independent of the peer processes and orders transactions on a first-come-first-serve basis for all channel's on the network. The ordering service is designed to support pluggable implementations beyond the out-of-the-box SOLO and Kafka varieties. The ordering service is a common binding for the overall network; it contains the cryptographic identity material tied to each *Member*.

Peer

A network entity that maintains a ledger and runs chaincode containers in order to perform read/write operations to the ledger. Peers are owned and maintained by members.

Policy

There are policies for endorsement, validation, block committal, chaincode management and network/channel management.

Proposal

A request for endorsement that is aimed at specific peers on a channel. Each proposal is either an instantiate or an invoke (read/write) request.

Query

A query requests the value of a key(s) against the current state.

Software Development Kit (SDK)

The Hyperledger Fabric client SDK provides a structured environment of libraries for developers to write and test chaincode applications. The SDK is fully configurable and extensible through a standard interface. Components, including cryptographic algorithms for signatures, logging frameworks and state stores, are easily swapped in and out of the SDK. The SDK provides APIs for transaction processing, membership services, node traversal and event handling. The SDK comes in multiple flavors: Node.js, Java. and Python.

State Database

Current state data is stored in a state database for efficient reads and queries from chaincode. These databases include levelDB and couchDB.

System Chain

Contains a configuration block defining the network at a system level. The system chain lives within the ordering service, and similar to a channel, has an initial configuration containing information such as: MSP information, policies, and configuration details. Any change to the overall network (e.g. a new org joining or a new ordering node being added) will result in a new configuration block being added to the system chain.

The system chain can be thought of as the common binding for a channel or group of channels. For instance, a collection of financial institutions may form a consortium (represented through the system chain), and then proceed to create channels relative to their aligned and varying business agendas.

Transaction

An invoke or instantiate operation. Invokes are requests to read/write data from the ledger. Instantiate is a request to start a chaincode container on a peer.

CHAPTER 48

Release Notes

v1.0.0 July 11, 2017

Bug fixes, documentation and test coverage improvements, UX improvements based on user feedback and changes to address a variety of static scan findings (removal of unused code, static security scanning, spelling, linting and more).

Known Vulnerabilities none

Resolved Vulnerabilities https://jira.hyperledger.org/browse/FAB-5207

Known Issues & Workarounds The fabric-ccenv image which is used to build chaincode, currently includes the github.com/hyperledger/fabric/core/chaincode/shim ("shim") package. This is convenient, as it provides the ability to package chaincode without the need to include the "shim". However, this may cause issues in future releases (and/or when trying to use packages which are included by the "shim").

In order to avoid any issues, users are advised to manually vendor the "shim" package with their chaincode prior to using the peer CLI for packaging and/or for installing chaincode.

Please refer to https://jira.hyperledger.org/browse/FAB-5177 for more details, and kindly be aware that given the above, we may end up changing the fabric-ccenv in the future.

Change Log

v1.0.0-rc1 June 23, 2017

Bug fixes, documentation and test coverage improvements, UX improvements based on user feedback and changes to address a variety of static scan findings (unused code, static security scanning, spelling, linting and more).

Known Vulnerabilities none

Resolved Vulnerabilities https://jira.hyperledger.org/browse/FAB-4856 https://jira.hyperledger.org/browse/FAB-4848 https://jira.hyperledger.org/browse/FAB-4751 https://jira.hyperledger.org/browse/FAB-4626 https://jira.hyperledger.org/browse/FAB-4567 https://jira.hyperledger.org/browse/FAB-3715

Known Issues & Workarounds none

Change Log

v1.0.0-beta June 8, 2017

Bug fixes, documentation and test coverage improvements, UX improvements based on user feedback and changes to address a variety of static scan findings (unused code, static security scanning, spelling, linting and more).

Upgraded to latest version (a precursor to 1.4.0) of gRPC-go and implemented keep-alive feature for improved resiliency.

Added a new tool *configtxlator* to enable users to translate the contents of a channel configuration transaction into a human readable form.

Known Vulnerabilities

none

Resolved Vulnerabilities

none

Known Issues & Workarounds

BCCSP content in the configtx.yaml has been removed. This change will cause a panic when running *configtxgen* tool with a configtx.yaml file that includes the removed BCCSP content.

Java Chaincode support has been disabled until post 1.0.0 as it is not yet fully mature. It may be re-enabled for experimentation by cloning the hyperledger/fabric repository, reversing this commit and building your own fork.

Change Log

v1.0.0-alpha2

The second alpha release of the v1.0.0 Hyperledger Fabric. The code is now feature complete. From now until the v1.0.0 release, the community is focused on documentation improvements, testing, hardening, bug fixing and tooling. We will be releasing successive release candidates periodically as the release firms up.

Change Log

v1.0.0-alpha March 16, 2017

The first alpha release of the v1.0.0 Hyperledger Fabric. The code is being made available to developers to begin exploring the v1.0 architecture.

Change Log

v0.6-preview September 16, 2016

A developer preview release of the Hyperledger Fabric intended to exercise the release logistics and stabilize a set of capabilities for developers to try out. This will be the last release under the original architecture. All subsequent releases will deliver on the v1.0 architecture.

Change Log

v0.5-developer-preview June 17, 2016

A developer preview release of the Hyperledger Fabric intended to exercise the release logistics and stabilize a set of capabilities for developers to try out.

Key features:

Permissioned blockchain with immediate finality Chaincode (aka smart contract) execution environments Docker container (user chaincode) In-process with peer (system chaincode) Pluggable consensus with PBFT, NOOPS (development mode), SIEVE (prototype) Event framework supports pre-defined and custom events Client SDK (Node.js), basic REST APIs and CLIs Known Key Bugs and work in progress

- 1895 - Client SDK interfaces may crash if wrong parameter specified
- 1901 - Slow response after a few hours of stress testing
- 1911 - Missing peer event listener on the client SDK
- 889 - The attributes in the TCert are not encrypted. This work is still on-going

CHAPTER 49

Still Have Questions?

We try to maintain a comprehensive set of documentation for various audiences. However, we realize that often there are questions that remain unanswered. For any technical questions relating to Hyperledger Fabric not answered here, please use StackOverflow. Another approach to getting your questions answered to send an email to the mailing list (hyperledger-fabric@lists.hyperledger.org), or ask your questions on RocketChat (an alternative to Slack) on the #fabric or #fabric-questions channel.

CHAPTER 50

Status

Hyperledger Fabric is in the *Active* state. For more information on the history of this project see our wiki page. Information on what *Active* entails can be found in the Hyperledger Project Lifecycle document.