
hyperledger-fabricdocs Documentation

Release master

hyperledger

Apr 09, 2017

1	Getting Started	3
1.1	Prerequisites	3
1.2	All in one with docker images	4
1.3	Configuration Transaction Generator	6
1.4	Start the network	7
1.5	Manually execute the transactions	10
1.6	Manually generate images	13
1.7	Use the native binaries	14
1.8	Using CouchDB	16
1.9	A Note on Data Persistence	18
1.10	Troubleshooting	18
2	Overview	21
3	The Fabric Model	23
3.1	Assets	23
3.2	Chaincode	23
3.3	Ledger Features	23
3.4	Privacy through Channels	24
3.5	Security & Membership Services	24
3.6	Consensus	24
4	Use Cases	27
4.1	B2B Contract	27
4.2	Manufacturing Supply Chain	28
4.3	Asset Depository	28
4.4	One Trade, One Contract	29
4.5	Direct Communication	29
4.6	Separation of Asset Ownership and Custodian's Duties	30
4.7	Interoperability of Assets	30
5	Demos	31
5.1	Art Auction	31
5.2	Marbles	31
6	What is chaincode?	33
6.1	Chaincode interfaces	33
6.2	Dependencies	33
6.3	Chaincode APIs	34

6.4	Response	34
6.5	Command Line Interfaces	35
6.6	Chaincode Swimlanes	37
6.7	Deploy a chaincode	37
7	Videos	39
8	Best Practices	41
9	Channel Configuration (configtx)	43
9.1	Anatomy of a configuration	43
9.2	Configuration updates	45
9.3	Permitted configuration groups and values	46
9.4	Orderer system channel configuration	47
9.5	Application channel configuration	49
9.6	Channel creation	49
10	Configuring using the configtxgen tool	51
10.1	Building the tool	51
10.2	Configuration Profiles	51
10.3	Bootstrapping the orderer	52
10.4	Creating a channel	52
10.5	Reviewing a configuration	52
11	Logging Control	55
11.1	Overview	55
11.2	peer	55
11.3	Go chaincodes	56
12	Architecture Explained	59
12.1	1. System architecture	59
12.2	2. Basic workflow of transaction endorsement	63
12.3	3. Endorsement policies	66
12.4	4 (post-v1). Validated ledger and PeerLedger checkpointing (pruning)	68
13	Transaction Flow	71
14	Fabric CA User's Guide	75
14.1	Table of Contents	75
14.2	Overview	76
14.3	Getting Started	77
14.4	File Formats	80
14.5	Configuration Settings Precedence	84
14.6	A word on file paths	84
14.7	Fabric CA Server	84
14.8	Fabric CA Client	90
14.9	Appendix	94
15	Endorsement policies	97
15.1	Endorsement policy design	97
15.2	Endorsement policy syntax in the CLI	97
15.3	Specifying endorsement policies for a chaincode	98
15.4	Future enhancements	98
16	Node SDK	99

17	Ordering Service	101
18	Ledger	103
18.1	Chain	103
18.2	State Database	103
18.3	Transaction Flow	103
18.4	State Database options	104
19	Read-Write set semantics	105
19.1	Transaction simulation and read-write set	105
19.2	Transaction validation and updating world state using read-write set	106
19.3	Example simulation and validation	106
20	Gossip data dissemination protocol	109
20.1	Gossip protocol	109
20.2	Gossip messaging	109
21	Troubleshooting	111
22	V1 Architecture	113
22.1	Endorsement	113
22.2	Security & Access Control	113
22.3	Application-side Programming Model	114
23	Chaincode (Smart Contracts and Digital Assets)	115
24	Identity Management (Membership Service)	117
25	Glossary	119
25.1	Anchor Peer	119
25.2	Block	119
25.3	Chain	119
25.4	Chaincode	119
25.5	Channel	119
25.6	Commitment	120
25.7	Concurrency Control Version Check	120
25.8	Configuration Block	120
25.9	Consensus	120
25.10	Current State	120
25.11	Dynamic Membership	120
25.12	Endorsement	120
25.13	Endorsement policy	121
25.14	Genesis Block	121
25.15	Gossip Protocol	121
25.16	Initialize	121
25.17	Install	121
25.18	Instantiate	121
25.19	Invoke	121
25.20	Leading Peer	121
25.21	Ledger	122
25.22	Member	122
25.23	Membership Service Provider	122
25.24	Membership Services	122
25.25	Ordering Service	122
25.26	Peer	122

25.27 Policy	123
25.28 Proposal	123
25.29 Query	123
25.30 Software Development Kit (SDK)	123
25.31 State Database	123
25.32 System Chain	123
25.33 Transaction	123
26 Contributions Welcome!	127
26.1 Getting a Linux Foundation account	127
26.2 Getting help	127
26.3 Requirements and Use Cases	127
26.4 Reporting bugs	128
26.5 Fixing issues and working stories	128
26.6 Working with a local clone and Gerrit	128
26.7 What makes a good change request?	128
26.8 Coding guidelines	129
26.9 Communication	129
26.10 Maintainers	129
26.11 Legal stuff	130
27 Maintainers	131
28 Using Jira to understand current work items	133
29 Setting up the development environment	135
29.1 Overview	135
29.2 Prerequisites	135
29.3 pip, behave and docker-compose	136
29.4 Steps	136
29.5 Building the fabric	137
29.6 Notes	137
30 Building the fabric	139
30.1 Running the unit tests	139
30.2 Running Node.js Unit Tests	139
30.3 Running Behave BDD Tests	139
31 Building outside of Vagrant	141
31.1 Building on Z	141
31.2 Building on Power Platform	141
32 Configuration	143
33 Logging	145
34 Testing	147
35 Coding guidelines	149
35.1 Coding Golang	149
36 Generating gRPC code	151
37 Adding or updating Go packages	153
38 Still Have Questions?	155

39	Quality	157
40	Status	159
41	License	161

Hyperledger Fabric is a social innovation that is about to free innovators in startups, enterprises and government to transform and radically reduce the cost of working together across organizations. By the end of this section, you should have the essential understanding of Fabric you need to start *knitting* together a great business network.

Fabric is a network of networks, like the Internet itself. An application can use one or more networks, each managing different *Assets*, Agreements and Transactions between different sets of *Member* nodes. In Fabric, the Ordering Service is the foundation of each network. The founder of a network selects an Ordering Service (or creates a new one) and passes in a config file with the rules (usually called Policies) that govern it. Examples of these rules include setting/defining which Members can join the network, how Members can be added or removed, and configuration details like block size. While it is possible for one company to set and control these rules as a “dictator,” typically these rules will also include policies that make changing the rules a matter of consensus among the members of the network. Fabric also requires some level of “endorsement” in order to transact. Check out the power and intricacy of *Endorsement policies* , which are used across the Fabric landscape - from a consortium’s network configuration to a simple read operation.

We mentioned that the Ordering Service (OS) is the foundation of the network, and you’re probably thinking, “It must do something beyond just ordering.” Well you’re right! All members and entities in the network will be tied to a higher level certificate authority, and this authority is defined within the configuration of the Ordering Service. As a result, the OS can verify and authenticate transactions arriving from any corner of the network. The OS plays a central and critical role in the functionality and integrity of the network, and skeptics might fear too much centralization of power and responsibility. After all, that’s a principal feature of shared ledger technology - to decentralize the control and provide a foundation of trust with entities who you CAN’T wholeheartedly trust. Well let’s assuage that fear. The OS is agnostic to transaction details; it simply orders on a first-come-first-serve basis and returns blocks to their corresponding channels. Perhaps more importantly though, control of the ordering service can be shared and co-administered by the participating members in the network. OR, if even that solution is untenable, then the OS can be hosted and maintained by a trusted third-party. Fabric is built upon a modular and pluggable architecture, so the only real decision for business networks is how to configure an OS to meet their requirements.

(This notion of the OS as a pluggable component also opens the door to exciting opportunities for innovative teams and individuals. Currently there are only a few OS orchestrations - Solo and Kafka. However, other options such as Intel’s PoET or certain BFT flavors could be powerful supplementaries to Fabric, and help solve challenging use cases.)

To participate in the Network, each Organization maintains a runtime called a *Peer*, which will allow an application to participate in transactions, interact with the Ordering Service, and maintain a set of ledgers. Notice we said a set of ledgers. One of Fabric’s key innovations is the ability to run multiple *Channel* s on each network. This is how a network can conduct both highly confidential bilateral transactions and multilateral, or even public, transactions in the same solution without everyone having a copy of every transaction or run the code in every agreement.

Watch how Fabric is [Building a Blockchain for Business](#) .

If you’re still reading, you clearly have some knowledge and an interest in distributed ledger technology, AND you probably think a key piece is missing. Where is consensus in all of this? Well, it’s embedded in the entire life cycle of a transaction. Transactions come into the network, and the submitting client’s identity is verified and consented upon. Transactions then get executed and endorsed, and these endorsements are consented upon. Transactions get ordered, and the validity of this order is consented upon. Finally, transactions get committed to a shared ledger, and each transaction’s subsequent impact on the state of the involved asset(s) is consented upon. Consensus isn’t pigeonholed into one module or one function. It lives and exists throughout the entire DNA of Fabric. Fabric is built with security at the forefront, not as an afterthought. Members and participating entities operate with known identities, and no action on the network circumvents the sign/verify/authenticate mandate. Requirements such as security, privacy and confidentiality are paramount in some manner to nearly all business dealings, and they, like consensus, are stitched into the very essence of Fabric.

So what problem do you want to solve? What assets are at stake? Who are the players? What levels of security and encryption do you need? Fabric is designed to provide an answer and solution to this challenging collective of questions and beyond. Just like fabric - in the literal sense of the word - is used in everything from airplane seats to bespoke suits, solutions built on Hyperledger Fabric can range from diamond provenance to equities trading. Explore

the documentation and see how you can leverage Fabric to craft a PoC for your own business network.

Note: This build of the docs is from the “master” branch

Getting Started

The getting started scenario provisions a sample Fabric network consisting of two organizations, each maintaining two peers, and a “solo” ordering service. The required crypto material (x509 certs) for the network entities has been pre-generated and is baked into the appropriate directories and configuration files. You do not need to modify any of these certificates. The `examples/e2e_cli` folder contains the docker compose files and supporting scripts that you will use to create and test the sample network.

This section also demonstrates usage of a configuration generation tool, `configtxgen`, to generate the network’s configuration. Upon conclusion of this section, you will have a fully functional transactional network. Let’s get going...

Prerequisites

Complete the following to install the Fabric source code and build the `configtxgen` tool:

- Follow the steps for setting up a *development environment* and ensure that you have properly set the `$GOPATH` environment variable. This process will load the various software dependencies onto your machine.
- Clone the Fabric code base.

```
git clone https://github.com/hyperledger/fabric.git
```

- Build the `configtxgen` tool.

If you are running Linux, open a terminal and execute the following from your `fabric` directory:

```
cd $GOPATH/src/github.com/hyperledger/fabric
make configtxgen
# if you see an error stating - 'ltdl.h' file not found
sudo apt install libtool libltdl-dev
# then run the make again
make configtxgen
```

If you are running OSX, first install `Xcode` version 8 or above. Next, open a terminal and execute the following from your `fabric` directory:

```
# install Homebrew
/usr/bin/ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/
↪master/install)"
# add gnu-tar
brew install gnu-tar --with-default-names
# add libtool
```

```
brew install libtool
# make the configtxgen
make configtxgen
```

A successful build will result in the following output:

```
build/bin/configtxgen
CGO_CFLAGS=" " GOBIN=/Users/johndoe/work/src/github.com/hyperledger/fabric/build/bin_
↳go install -ldflags "-X github.com/hyperledger/fabric/common/metadata.Version=1.0.0-
↳snapshot-8d3275f -X github.com/hyperledger/fabric/common /metadata.BaseVersion=0.3.
↳0 -X github.com/hyperledger/fabric/common/metadata.BaseDockerLabel=org.hyperledger.
↳fabric" github.com/hyperledger/fabric/common/configtx/tool/configtxgen
Binary available as build/bin/configtxgen``
```

The executable is placed in the build/bin/configtxgen directory of the Fabric source tree.

All in one with docker images

In order to expedite the process, we provide a script that performs all the heavy lifting. This script will generate the configuration artifacts, spin up a local network, and drive the chaincode tests. Navigate to the examples/e2e_cli directory.

First, pull the images from Docker Hub for your Fabric network:

```
# make the script an executable
chmod +x download-dockerimages.sh
# run the script
./download-dockerimages.sh
```

This process will take a few minutes...

You should see the exact output in your terminal upon completion of the script:

```
==> List out hyperledger docker images
hyperledger/fabric-ca          latest          35311d8617b4    7 days ago    ↳
↳ 240 MB
hyperledger/fabric-ca          x86_64-1.0.0-alpha 35311d8617b4    7 days ago    ↳
↳ 240 MB
hyperledger/fabric-couchdb     latest         f3ce31e25872    7 days ago    ↳
↳ 1.51 GB
hyperledger/fabric-couchdb     x86_64-1.0.0-alpha f3ce31e25872    7 days ago    ↳
↳ 1.51 GB
hyperledger/fabric-kafka       latest         589dad0b93fc    7 days ago    ↳
↳ 1.3 GB
hyperledger/fabric-kafka       x86_64-1.0.0-alpha 589dad0b93fc    7 days ago    ↳
↳ 1.3 GB
hyperledger/fabric-zookeeper   latest         9a51f5be29c1    7 days ago    ↳
↳ 1.31 GB
hyperledger/fabric-zookeeper   x86_64-1.0.0-alpha 9a51f5be29c1    7 days ago    ↳
↳ 1.31 GB
hyperledger/fabric-orderer     latest         5685fd77ab7c    7 days ago    ↳
↳ 182 MB
hyperledger/fabric-orderer     x86_64-1.0.0-alpha 5685fd77ab7c    7 days ago    ↳
↳ 182 MB
hyperledger/fabric-peer        latest         784c5d41ac1d    7 days ago    ↳
↳ 184 MB
```

hyperledger/fabric-peer	x86_64-1.0.0-alpha	784c5d41ac1d	7 days ago	↵
↵ 184 MB				
hyperledger/fabric-javaenv	latest	a08f85d8f0a9	7 days ago	↵
↵ 1.42 GB				
hyperledger/fabric-javaenv	x86_64-1.0.0-alpha	a08f85d8f0a9	7 days ago	↵
↵ 1.42 GB				
hyperledger/fabric-ccenv	latest	91792014b61f	7 days ago	↵
↵ 1.29 GB				
hyperledger/fabric-ccenv	x86_64-1.0.0-alpha	91792014b61f	7 days ago	↵
↵ 1.29 GB				

Now run the all-in-one script:

```
./network_setup.sh up <channel-ID>
```

If you choose not to pass the `channel-ID` parameter, then your channel name will default to `mychannel`. In your terminal you will see the chaincode logs for the various commands being executed within the script.

When the script completes successfully, you should see the following message in your terminal:

```
===== Query on PEER3 on channel 'mychannel' is successful ↵
↵=====

===== All GOOD, End-2-End execution completed =====
```

At this point your network is up and running and the tests have completed successfully. Continue through this document for more advanced network operations.

Clean up

Shut down your network:

```
# make sure you're in the e2e_cli directory
docker rm -f $(docker ps -aq)
```

Next, execute a `docker images` command in your terminal to view the **chaincode** images. They will look similar to the following:

REPOSITORY	TAG	IMAGE ID	CREATED	↵
↵ SIZE				
dev-peer3-mycc-1.0	latest	13f6c8b042c6	5 minutes ago	↵
↵ 176 MB				
dev-peer0-mycc-1.0	latest	e27456b2bd92	5 minutes ago	↵
↵ 176 MB				
dev-peer2-mycc-1.0	latest	111098a7c98c	5 minutes ago	↵
↵ 176 MB				

Remove these images:

```
docker rmi <IMAGE ID> <IMAGE ID> <IMAGE ID>
```

For example:

```
docker rmi -f 13f e27 111
```

Finally, delete the config artifacts. Navigate to the `crypto/orderer` directory and remove `orderer.block` and `channel.tx`. You can rerun the all-in-one script or continue reading for a deeper dive on configuration transactions and chaincode commands.

Configuration Transaction Generator

The *configtxgen tool* is used to create two artifacts: Orderer **bootstrap block** and Fabric **channel configuration transaction**.

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 `configtx.yaml` contains the definitions for the sample network and presents the topology of the network components - two members (Org0 & Org1), each managing and maintaining two peers. It also points to the filesystem location where the cryptographic material for each network entity is stored. This directory, `crypto`, contains the admin certs, ca certs, signing certs, and private key for each entity.

For ease of use, we provide a script - `generateCfgTx.sh` - that orchestrates the process of running `configtxgen`. The script will output our two configuration artifacts - `orderer.block` and `channel.tx`. If you ran the all-in-one script then these artifacts have already been created. Navigate to the `crypto/orderer` directory and ensure they have been deleted.

Run the `generateCfgTx.sh` shell script

Make sure you are in the `e2e_cli` directory:

```
cd $GOPATH/src/github.com/hyperledger/fabric/examples/e2e_cli
```

The `generateCfgTx.sh` script takes an optional `<channel-ID>` argument. If none is provided, then a channel will be generated with a default channel-ID of `mychannel`.

```
# as mentioned above, the <channel-ID> parm is optional
./generateCfgTx.sh <channel-ID>
```

After you run the shell script, you should see an output in your terminal similar to the following:

```
2017/02/28 17:01:52 Generating new channel configtx
2017/02/28 17:01:52 Creating no-op MSP instance
2017/02/28 17:01:52 Obtaining default signing identity
2017/02/28 17:01:52 Creating no-op signing identity instance
2017/02/28 17:01:52 Serializing identity
2017/02/28 17:01:52 signing message
2017/02/28 17:01:52 signing message
2017/02/28 17:01:52 Writing new channel tx
```

The script generates two files - `orderer.block` and `channel.tx` and outputs them into the `crypto/orderer` directory.

`orderer.block` is the genesis block for the ordering service. `channel.tx` contains the configuration information for the new channel. As mentioned earlier, both are derived from `configtx.yaml` and contain data such as crypto material and network endpoint information.

Note: You also have the option to manually exercise the embedded commands within the `generateCfgTx.sh` script. Open the script and inspect the syntax for the two commands. If you do elect to pursue this route, you

must replace the default `configtx.yaml` in the fabric source tree. Navigate to the `common/configtx/tool` directory and replace the `configtx.yaml` file with the supplied `yaml` file in the `e2e_cli` directory. Then return to the `fabric` directory to execute the commands (you will run these manual commands from `fabric`, NOT from `e2e_cli`). Be sure to remove any existing artifacts from previous runs of the `generateCfgTrx.sh` script before commencing.

Start the network

We will use `docker-compose` to launch our network with the images that we pulled earlier. If you have not yet pulled the Fabric images, return to the **All in one** section and follow the instructions to retrieve the images.

Embedded within the `docker-compose` file is a script, `script.sh`, which joins the peers to a channel and sends read/write requests to the peers. As a result, you are able to see the transaction flow without manually submitting the commands. Skip down to the **Manually execute the transactions** section if you don't want to leverage the script.

Make sure you are in the `e2e_cli` directory. Then use `docker-compose` to spawn the network entities and kick off the embedded script.

```
CHANNEL_NAME=<channel-id> docker-compose up -d
```

If you created a unique channel name, be sure to pass in that parameter. Otherwise, pass in the default `mychannel` string. For example:

```
CHANNEL_NAME=mychannel docker-compose up -d
```

Wait, 30 seconds. Behind the scenes, there are transactions being sent to the peers. Execute a `docker ps` to view your active containers. You should see an output identical to the following:

```
vagrant@hyperledger-devenv:v0.3.0-4eec836:/opt/gopath/src/github.com/hyperledger/
↳ fabric/examples/e2e_cli$ docker ps
```

CONTAINER ID	IMAGE	COMMAND	CREATED
45e3e114f7a2	dev-peer3-mycc-1.0	"chaincode -peer.a..."	4 seconds
5970f740ad2b	dev-peer0-mycc-1.0	"chaincode -peer.a..."	24 seconds
b84808d66e99	dev-peer2-mycc-1.0	"chaincode -peer.a..."	48 seconds
16d7d94c8773	hyperledger/fabric-peer	"peer node start -..."	About a
3561a99e35e6	hyperledger/fabric-peer	"peer node start -..."	About a
0baad3047d92	hyperledger/fabric-peer	"peer node start -..."	About a
1216896b7b4f	hyperledger/fabric-peer	"peer node start -..."	About a
155ff8747b4d	hyperledger/fabric-orderer	"orderer"	About a

What happened behind the scenes?

- A script - `script.sh` - is baked inside the CLI container. The script drives the `createChannel` command against the default `mychannel` name. The `createChannel` command uses the `channel.tx` artifact created previously with the `configtxgen` tool.
- The output of `createChannel` is a genesis block - `mychannel.block` - which is stored on the file system.
- The `joinChannel` command is exercised for all four peers who will pass in the genesis block - `mychannel.block`.
- Now we have a channel consisting of four peers, and two organizations.
- `PEER0` and `PEER3` belong to `Org0`; `PEER1` and `PEER2` belong to `Org1`
- Recall that these relationships are defined in the `configtx.yaml`
- A chaincode - **chaincode_example02** - is installed on `PEER0` and `PEER2`
- The chaincode is then “instantiated” on `PEER2`. Instantiate simply refers to starting the container and initializing 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-peer2-mycc-1.0` starting. Notice that this container is specific to `PEER2`.
- The instantiation also passes in an argument for the endorsement policy. The policy is defined as `-P "OR ('Org0MSP.member', 'Org1MSP.member')"`, meaning that any transaction must be endorsed by a peer tied to `Org0` or `Org1`.
- A query against the value of “a” is issued to `PEER0`. The chaincode was previously installed on `PEER0`, so this will start another container by the name of `dev-peer0-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` to move “10” from “a” to “b”
- The chaincode is installed on `PEER3`
- A query is sent to `PEER3` for the value of “a”. This starts a third chaincode container by the name of `dev-peer3-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 a read/write operation 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 current fabric state. This includes those peers that do not have chaincode installed on them (like `Peer3` in the above example). Finally, the chaincode is accessible after it is installed (like `Peer3` in the above example) because it already has 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:

```
2017-02-28 04:31:20.841 UTC [logging] InitFromViper -> DEBU 001 Setting default_
↳ logging level to DEBUG for command 'chaincode'
2017-02-28 04:31:20.842 UTC [msp] GetLocalMSP -> DEBU 002 Returning existing local MSP
2017-02-28 04:31:20.842 UTC [msp] GetDefaultSigningIdentity -> DEBU 003 Obtaining_
↳ default signing identity
2017-02-28 04:31:20.843 UTC [msp] Sign -> DEBU 004 Sign: plaintext:_
↳ 0A8F050A59080322096D796368616E6E...6D7963631A0A0A0571756572790A0161
2017-02-28 04:31:20.843 UTC [msp] Sign -> DEBU 005 Sign: digest:_
↳ 52F1A41B7B0B08CF3FC94D9D7E916AC4C01C54399E71BC81D551B97F5619AB54
Query Result: 90
2017-02-28 04:31:30.425 UTC [main] main -> INFO 006 Exiting.....
===== Query on chaincode on PEER3 on channel 'mychannel' is_
↳ successful =====
===== All GOOD, End-2-End execution completed =====
```

You also have the option of viewing the logs in real time. You will need two terminals for this. First, kill your docker containers:

```
docker rm -f $(docker ps -aq)
```

In the first terminal launch your docker-compose script:

```
# add the appropriate CHANNEL_NAME parm
CHANNEL_NAME=<channel-id> docker-compose up -d
```

In your second terminal view the logs:

```
docker logs -f cli
```

This will show you the live output for the transactions being driven by script.sh.

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-peer2-mycc-1.0
04:30:45.947 [BCCSP_FACTORY] DEBU : Initialize BCCSP [SW]
ex02 Init
Aval = 100, Bval = 200

$ docker logs dev-peer0-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-peer3-mycc-1.0
04:31:30.420 [BCCSP_FACTORY] DEBU : Initialize BCCSP [SW]
```

```
ex02 Invoke
Query Response: {"Name": "a", "Amount": "90"}
```

Manually execute the transactions

The following section caters towards a more advanced chaincode developer. It involves wide usage of global environment variables and requires exact syntax in order for commands to work properly. Fully-functional sample commands are provided, however it is still recommended that you have a fundamental understanding of Fabric before continuing with this section.

From your current working directory, kill your containers:

```
docker rm -f $(docker ps -aq)
```

Next, execute a `docker images` command in your terminal to view the **chaincode** images. They will look similar to the following:

REPOSITORY	TAG	IMAGE ID	CREATED
dev-peer3-mycc-1.0	latest	13f6c8b042c6	5 minutes ago
dev-peer0-mycc-1.0	latest	e27456b2bd92	5 minutes ago
dev-peer2-mycc-1.0	latest	111098a7c98c	5 minutes ago

Remove these images:

```
.. code:: bash

    docker rmi <IMAGE ID> <IMAGE ID> <IMAGE ID>
```

For example:

```
.. code:: bash

    docker rmi -f 13f e27 111
```

Ensure you have the configuration artifacts. If you deleted them, run the shell script again:

```
./generateCfgTrx.sh <channel-ID>
```

Or manually generate the artifacts using the commands within the script.

Modify the docker-compose file

Open the docker-compose file and comment out the command to run `script.sh`. Navigate down to the `cli` image and place a `#` to the left of the command. For example:

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

Save the file. Now restart your network:

```
# make sure you are in the e2e_cli directory where you docker-compose script resides
# add the appropriate CHANNEL_NAME parm
CHANNEL_NAME=<channel-id> docker-compose up -d
```

Command syntax

Refer to the create and join commands in the `script.sh`. The file is located in the `scripts` directory.

For the following cli commands against `PEER0` to work, you need to set the values for the four global environment variables, given below. Please make sure to override the values accordingly when calling commands against other peers and the orderer.

```
# Environment variables for PEER0
CORE_PEER_MSPCONFIGPATH=$GOPATH/src/github.com/hyperledger/fabric/peer/crypto/peer/
↪peer0/localMspConfig
CORE_PEER_ADDRESS=peer0:7051
CORE_PEER_LOCALMSPID="Org0MSP"
CORE_PEER_TLS_ROOTCERT_FILE=$GOPATH/src/github.com/hyperledger/fabric/peer/crypto/
↪peer/peer0/localMspConfig/cacerts/peerOrg0.pem
```

These environment variables for each peer are defined in the supplied docker-compose file.

Create channel

Exec into the cli container:

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

If successful you should see the following:

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

Specify your channel name with the `-c` flag. Specify your 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.

```
# the channel.tx and orderer.block are mounted in the crypto/orderer directory within
↪your cli container
# as a result, we pass the full path for the file
peer channel create -o orderer0:7050 -c mychannel -f crypto/orderer/channel.tx --tls
↪$CORE_PEER_TLS_ENABLED --cafile $GOPATH/src/github.com/hyperledger/fabric/peer/
↪crypto/orderer/localMspConfig/cacerts/ordererOrg0.pem
```

Since the `channel create` command runs against the orderer, we need to override the four environment variables set before. So the above command in its entirety would be:

```
CORE_PEER_MSPCONFIGPATH=$GOPATH/src/github.com/hyperledger/fabric/peer/crypto/orderer/
↪localMspConfig CORE_PEER_LOCALMSPID="OrdererMSP" peer channel create -o orderer0:
↪7050 -c mychannel -f crypto/orderer/channel.tx --tls $CORE_PEER_TLS_ENABLED --
↪cafile $GOPATH/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/
↪cacerts/ordererOrg0.pem
```

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 for targeting a peer other than `PEER0`.

Join channel

Join specific peers to the channel

```
# By default, this joins PEER0 only
# the mychannel.block is also mounted in the crypto/orderer directory
peer channel join -b mychannel.block
```

This full command in its entirety would be:

```
CORE_PEER_MSPCONFIGPATH=$GOPATH/src/github.com/hyperledger/fabric/peer/crypto/peer/
↪peer0/localMspConfig CORE_PEER_ADDRESS=peer0:7051 CORE_PEER_LOCALMSPID="Org0MSP"
↪CORE_PEER_TLS_ROOTCERT_FILE=$GOPATH/src/github.com/hyperledger/fabric/peer/crypto/
↪peer/peer0/localMspConfig/cacerts/peerOrg0.pem peer channel join -b mychannel.block
```

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

Install chaincode onto a remote peer

Install the sample go code onto one of the four peer nodes

```
# remember to preface this command with the global environment variables for the
↪appropriate peer
peer chaincode install -n mycc -v 1.0 -p github.com/hyperledger/fabric/examples/
↪chaincode/go/chaincode_example02
```

Instantiate chaincode and define the endorsement policy

Instantiate the chaincode on a peer. This will launch a chaincode container for the targeted peer and set the endorsement policy for the chaincode. In this snippet, we define the policy as requiring an endorsement from one peer node that is a part of either Org0 or Org1. The command is:

```
# remember to preface this command with the global environment variables for the
↪appropriate peer
# remember to pass in the correct string for the -C argument. The default is
↪mychannel
peer chaincode instantiate -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile
↪$GOPATH/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/
↪cacerts/ordererOrg0.pem -C mychannel -n mycc -v 1.0 -p github.com/hyperledger/
↪fabric/examples/chaincode/go/chaincode_example02 -c '{"Args":["init","a","100","b
↪","200"]}]' -P "OR ('Org0MSP.member','Org1MSP.member')"
```

See the *endorsement policies* <endorsement-policies> documentation for more details on policy implementation.

Invoke chaincode

```
# remember to preface this command with the global environment variables for the
↪appropriate peer
peer chaincode invoke -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile $GOPATH/
↪src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/cacerts/
↪ordererOrg0.pem -C mychannel -n mycc -c '{"Args":["invoke","a","b","10"]}'
```

NOTE: Make sure to wait a few seconds for the operation to complete.

Query chaincode

```
# remember to preface this command with the global environment variables for the
↪appropriate peer
peer chaincode query -C mychannel -n mycc -c '{"Args":["query","a"]}'
```

The result of the above command should be as below:

```
Query Result: 90
```

Manually generate images

Fabric developers can elect to create the images against the latest iteration of the code base. This is a useful method for testing new features that have not yet been baked into the published images.

- Make the peer and orderer images.

```
# make sure you are in the fabric directory
# if you are unable to generate the images natively, you may need to be in a vagrant
↪environment
make peer-docker orderer-docker
```

Execute a `docker images` command in your terminal. If the images compiled successfully, you should see an output similar to the following:

```
vagrant@hyperledger-devenv:v0.3.0-4eec836:/opt/gopath/src/github.com/hyperledger/
↪fabric$ docker images
```

REPOSITORY	TAG	IMAGE ID	
↪CREATED			
hyperledger/fabric-orderer	latest	264e45897bfb	10
↪minutes ago			
hyperledger/fabric-orderer	x86_64-0.7.0-snapshot-a0d032b	264e45897bfb	10
↪minutes ago			
hyperledger/fabric-peer	latest	b3d44cff07c6	10
↪minutes ago			
hyperledger/fabric-peer	x86_64-0.7.0-snapshot-a0d032b	b3d44cff07c6	10
↪minutes ago			
hyperledger/fabric-javaenv	latest	6e2a2adb998a	10
↪minutes ago			
hyperledger/fabric-javaenv	x86_64-0.7.0-snapshot-a0d032b	6e2a2adb998a	10
↪minutes ago			
hyperledger/fabric-ccenv	latest	0ce0e7dc043f	12
↪minutes ago			
hyperledger/fabric-ccenv	x86_64-0.7.0-snapshot-a0d032b	0ce0e7dc043f	12
↪minutes ago			
hyperledger/fabric-baseimage	x86_64-0.3.0	f4751a503f02	4
↪weeks ago			
hyperledger/fabric-baseos	x86_64-0.3.0	c3a4cf3b3350	4
↪weeks ago			

Use the native binaries

Similar to the previous two sections, this is catered towards advanced developers with a working understanding of the Fabric codebase.

Open your vagrant environment:

```
cd $GOPATH/src/github.com/hyperledger/fabric/devenv
```

```
# you may have to first start your VM with vagrant up
vagrant ssh
```

From the `fabric` directory issue the following commands to build the peer and orderer executables:

```
make clean
make native
```

You will also need the `ccenv` image. From the `fabric` directory:

```
make peer-docker
```

Next, open two more terminals and start your vagrant environment in each. You should now have a total of three terminals, all within vagrant.

Before starting, make sure to clear your ledger folder `/var/hyperledger/`. You will want to do this after each run to avoid errors and duplication.

```
rm -rf /var/hyperledger/*
```

Vagrant window 1

Use the `configtxgen` tool to create the orderer genesis block:

```
configtxgen -profile SampleSingleMSPSolo -outputBlock orderer.block
```

Vagrant window 2

Start the orderer with the genesis block you just generated:

```
ORDERER_GENERAL_GENESISMETHOD=file ORDERER_GENERAL_GENESISFILE=./orderer.block orderer
```

Vagrant window 1

Create the channel configuration transaction:

```
configtxgen -profile SampleSingleMSPSolo -outputCreateChannelTx channel.tx -channelID
↪<channel-ID>
```

This will generate a `channel.tx` file in your current directory

Vagrant window 3

Start the peer in “chainless” mode

```
peer node start --peer-defaultchain=false
```

Note: Use Vagrant window 1 for the remainder of commands

Create channel

Ask peer to create a channel with the configuration parameters in `channel.tx`

```
peer channel create -o 127.0.0.1:7050 -c mychannel -f channel.tx
```

This will return a channel genesis block - `mychannel.block` - in your current directory.

Join channel

Ask peer to join the channel by passing in the channel genesis block:

```
peer channel join -b mychannel.block
```

Install

Install chaincode on the peer:

```
peer chaincode install -o 127.0.0.1:7050 -n mycc -v 1.0 -p github.com/hyperledger/
↳ fabric/examples/chaincode/go/chaincode_example02
```

Make sure the chaincode is in the filesystem:

```
ls /var/hyperledger/production/chaincodes
```

You should see `mycc.1.0`

Instantiate

Instantiate the chaincode:

```
peer chaincode instantiate -o 127.0.0.1:7050 -C mychannel -n mycc -v 1.0 -p github.
↳ com/hyperledger/fabric/examples/chaincode/go/chaincode_example02 -c '{"Args":["init
↳ ", "a", "100", "b", "200"]}'
```

Check your active containers:

```
docker ps
```

If the chaincode container started successfully, you should see:

CONTAINER ID	IMAGE	COMMAND	CREATED
↳ STATUS	PORTS	NAMES	
bd9c6bda7560	dev-jdoe-mycc-1.0	"chaincode -peer.a..."	5 seconds ago
↳ Up 5 seconds		dev-jdoe-mycc-1.0	

Invoke

Issue an invoke to move “10” from “a” to “b”:

```
peer chaincode invoke -o 127.0.0.1:7050 -C mychannel -n mycc -c '{"Args":["invoke", "a
↳ ", "b", "10"]}'
```

Wait a few seconds for the operation to complete

Query

Query for the value of “a”:

```
# this should return 90
peer chaincode query -o 127.0.0.1:7050 -C mychannel -n mycc -c '{"Args":["query","a"]}'
```

Don’t forget to clear ledger folder /var/hyperledger/ after each run!

```
rm -rf /var/hyperledger/*
```

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 procedure in the **Prerequisites** section, and additionally perform the following two steps to enable the CouchDB containers and associate each peer container with a CouchDB container:

- Make the CouchDB image.

```
# make sure you are in the fabric directory
make couchdb
```

- Open the `fabric/examples/e2e_cli/docker-compose.yaml` and un-comment all commented statements relating to CouchDB containers and peer container use of CouchDB. These instructions are also outlined in the same `docker-compose.yaml` file. Search the file for ‘couchdb’ (case insensitive) references.

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 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 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.

Install, instantiate, invoke, and query **marbles02** chaincode by following the same general steps outlined above for **chaincode_example02** in the **Manually execute transactions** section. After the **Join channel** step, use the following commands to interact with the **marbles02** chaincode:

- Install and instantiate the chaincode on `PEER0` :


```
peer chaincode install -o orderer0:7050 -n marbles -v 1.0 -p github.com/hyperledger/
↪fabric/examples/chaincode/go/marbles02
peer chaincode instantiate -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile /
↪opt/gopath/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/
↪cacerts/ordererOrg0.pem -C mychannel -n marbles -v 1.0 -p github.com/hyperledger/
↪fabric/examples/chaincode/go/marbles02 -c '{"Args":["init"]}' -P "OR ('Org0MSP.
↪member', 'Org1MSP.member') "
```

- Create some marbles and move them around:

```
peer chaincode invoke -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile /opt/
↪gopath/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/cacerts/
↪ordererOrg0.pem -C mychannel -n marbles -c '{"Args":["initMarble","marble1","blue",
↪"35","tom"]}'
peer chaincode invoke -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile /opt/
↪gopath/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/cacerts/
↪ordererOrg0.pem -C mychannel -n marbles -c '{"Args":["initMarble","marble2","red",
↪"50","tom"]}'
peer chaincode invoke -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile /opt/
↪gopath/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/cacerts/
↪ordererOrg0.pem -C mychannel -n marbles -c '{"Args":["initMarble","marble3","blue",
↪"70","tom"]}'
peer chaincode invoke -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile /opt/
↪gopath/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/cacerts/
↪ordererOrg0.pem -C mychannel -n marbles -c '{"Args":["transferMarble","marble2",
↪"jerry"]}'
peer chaincode invoke -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile /opt/
↪gopath/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/cacerts/
↪ordererOrg0.pem -C mychannel -n marbles -c '{"Args":["transferMarblesBasedOnColor",
↪"blue","jerry"]}'
peer chaincode invoke -o orderer0:7050 --tls $CORE_PEER_TLS_ENABLED --cafile /opt/
↪gopath/src/github.com/hyperledger/fabric/peer/crypto/orderer/localMspConfig/cacerts/
↪ordererOrg0.pem -C mychannel -n marbles -c '{"Args":["delete","marble1"]}'
```

- If you chose to activate port mapping, you can now view the state database through the CouchDB web interface (Fauxton) by opening a browser and navigating to one of the two URLs below.

For containers running in a vagrant environment:

`http://localhost:15984/_utils`

For non-vagrant environment, use the port address that was mapped in CouchDB container specification:

`http://localhost:5984/_utils`

You should see a database named `mychannel` and the documents inside it.

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

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

You should see the details of `marble2`:

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

Retrieve the history of `marble1`:

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

You should see the transactions on marble1 :

```
Query Result: [{"TxId":
  ↳ "1c3d3caf124c89f91a4c0f353723ac736c58155325f02890adebaa15e16e6464", "Value":{
  ↳ "docType":"marble", "name":"marble1", "color":"blue", "size":35, "owner":"tom"}}, {"TxId
  ↳ ":"755d55c281889eaeef405586f9e25d71d36eb3d35420af833a20a2f53a3eefd", "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 mychannel -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}}]
```

Query by field owner where the value is jerry :

```
peer chaincode query -C mychannel -n marbles -c '{"Args":["queryMarbles", "{\\"selector\
  ↳ \": {\\"owner\\":\\"jerry\\"}"}"]}'
```

The output should display:

```
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.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

- Ensure you clear the file system after each run
- If you see docker errors, remove your images and start from scratch.

```
make clean
make peer-docker orderer-docker
```

- 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-peer0-mycc-1.0 or dev-peer1-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}')
```

- To cleanup the network, use the down option:

```
./network_setup.sh down
```

Overview

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.

This section provides a high-level overview of key Fabric concepts:

- *Assets*
- *Chaincode*
- *Ledger Features*
- *Privacy through Channels*
- *Security & Membership Services*
- *Consensus*

Needs Review

The Fabric Model

Assets

Assets can range from the tangible (real estate and hardware) to the intangible (contracts and intellectual property). You can easily define Assets in client-side javascript and use them in your Fabric application using the included [Fabric Composer](#) tool.

Fabric supports the ability to exchange assets using unspent transaction outputs as the inputs for subsequent transactions. Assets (and asset registries) live in Fabric as a collection of key-value pairs, with state changes recorded as transactions on a [Channel](#) ledger. Fabric allows for any asset to be represented in binary or JSON format.

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 :ref:`MSP’s allowing 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

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. Fabric even solves scenarios that want to bridge the gap between total transparency and privacy. Chaincode gets 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 SHA0-256, etc. 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 Fabric, coupled with the existence and capabilities of channels, helps address scenarios where privacy and confidentiality are paramount concerns.

See the Fabric CA section to better understand cryptographic implementations, and the sign, verify, authenticate approach used in 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.

Use Cases

B2B Contract

Business contracts can be codified to allow two or more parties to automate contractual agreements in a trusted way. Although information on blockchain is naturally “public”, B2B contracts may require privacy control to protect sensitive business information from being disclosed to outside parties that also have access to the ledger.

While confidential agreements are a key business case, there are many scenarios where contracts can and should be easily discoverable by all parties on a ledger. For example, a ledger used to create offers (asks) seeking bids, by definition, requires access without restriction. This type of contract may need to be standardized so that bidders can easily find them, effectively creating an electronic trading platform with smart contracts (aka chaincode).

Persona

- Contract participant – Contract counter parties
- Third party participant – A third party stakeholder guaranteeing the integrity of the contract.

Key Components

- Multi-sig contract activation - When a contract is first deployed by one of the counter parties, it will be in the pending activation state. To activate a contract, signatures from other counterparties and/or third party participants are required.
- Multi-sig contract execution - Some contracts will require one of many signatures to execute. For example, in trade finance, a payment instruction can only be executed if either the recipient or an authorized third party (e.g. UPS) confirms the shipment of the good.
- Discoverability - If a contract is a business offer seeking bids, it must be easily searchable. In addition, such contracts must have the built-in intelligence to evaluate, select and honor bids.
- Atomicity of contract execution - Atomicity of the contract is needed to guarantee that asset transfers can only occur when payment is received (Delivery vs. Payment). If any step in the execution process fails, the entire transaction must be rolled back.
- Contract to chain-code communication - Contracts must be able to communicate with chaincodes that are deployed on the same ledger.
- Longer Duration contract - Timer is required to support B2B contracts that have long execution windows.
- Reuseable contracts - Often-used contracts can be standardized for reuse.

- Auditable contractual agreement - Any contract can be made auditable to third parties.
- Contract life-cycle management - B2B contracts are unique and cannot always be standardized. An efficient contract management system is needed to enhance the scalability of the ledger network.
- Validation access – Only nodes with validation rights are allowed to validate transactions of a B2B contract.
- View access – B2B contracts may include confidential information, so only accounts with predefined access rights are allowed to view and interrogate them.

Manufacturing Supply Chain

Final assemblers, such as automobile manufacturers, can create a supply chain network managed by its peers and suppliers so that a final assembler can better manage its suppliers and be more responsive to events that would require vehicle recalls (possibly triggered by faulty parts provided by a supplier). The blockchain fabric must provide a standard protocol to allow every participant on a supply chain network to input and track numbered parts that are produced and used on a specific vehicle.

Why is this specific example an abstract use case? Because while all blockchain cases store immutable information, and some add the need for transfer of assets between parties, this case emphasizes the need to provide deep searchability backwards through as many as 5-10 transaction layers. This backwards search capability is the core of establishing provenance of any manufactured good that is made up of other component goods and supplies.

Persona

- Final Assembler – The business entity that performs the final assembly of a product.
- Part supplier – Supplier of parts. Suppliers can also be assemblers by assembling parts that they receive from their sub-suppliers, and then sending their finished product to the final (root) assembler.

Key Components

- Payment upon delivery of goods - Integration with off-chain payment systems is required, so that payment instructions can be sent when parts are received.
- Third party Audit - All supplied parts must be auditable by third parties. For example, regulators might need to track the total number of parts supplied by a specific supplier, for tax accounting purposes.
- Obfuscation of shipments - Balances must be obfuscated so that no supplier can deduce the business activities of any other supplier.
- Obfuscation of market size - Total balances must be obfuscated so that part suppliers cannot deduce their own market share to use as leverage when negotiating contractual terms.
- Validation Access – Only nodes with validation rights are allowed to validate transactions (shipment of parts).
- View access – Only accounts with view access rights are allowed to interrogate balances of shipped parts and available parts.

Asset Depository

Assets such as financial securities must be able to be dematerialized on a blockchain network so that all stakeholders of an asset type will have direct access to that asset, allowing them to initiate trades and acquire information on an asset without going through layers of intermediaries. Trades should be settled in near real time and all stakeholders

must be able to access asset information in near real time. A stakeholder should be able to add business rules on any given asset type, as one example of using automation logic to further reduce operating costs.

Persona

- Investor – Beneficial and legal owner of an asset.
- Issuer – Business entity that issued the asset which is now dematerialized on the ledger network.
- Custodian – Hired by investors to manage their assets, and offer other value-add services on top of the assets being managed.
- Securities Depository – Depository of dematerialized assets.

Key Components

- Asset to cash - Integration with off-chain payment systems is necessary so that issuers can make payments to and receive payments from investors.
- Reference Rate - Some types of assets (such as floating rate notes) may have attributes linked to external data (such as reference rate), and such information must be fed into the ledger network.
- Asset Timer - Many types of financial assets have predefined life spans and are required to make periodic payments to their owners, so a timer is required to automate the operation management of these assets.
- Asset Auditor - Asset transactions must be made auditable to third parties. For example, regulators may want to audit transactions and movements of assets to measure market risks.
- Obfuscation of account balances - Individual account balances must be obfuscated so that no one can deduce the exact amount that an investor owns.
- Validation Access – Only nodes with validation rights are allowed to validate transactions that update the balances of an asset type (this could be restricted to CSD and/or the issuer).
- View access – Only accounts with view access rights are allowed to interrogate the chaincode that defines an asset type. If an asset represents shares of publicly traded companies, then the view access right must be granted to every entity on the network.

One Trade, One Contract

From the time that a trade is captured by the front office until the trade is finally settled, only one contract that specifies the trade will be created and used by all participants. The middle office will enrich the same electronic contract submitted by the front office, and that same contract will then be used by counter parties to confirm and affirm the trade. Finally, securities depository will settle the trade by executing the trading instructions specified on the contract. When dealing with bulk trades, the original contract can be broken down into sub-contracts that are always linked to the original parent contract.

Direct Communication

Company A announces its intention to raise 2 Billion USD by way of rights issue. Because this is a voluntary action, Company A needs to ensure that complete details of the offer are sent to shareholders in real time, regardless of how many intermediaries are involved in the process (such as receiving/paying agents, CSD, ICSD, local/global custodian banks, asset management firms, etc). Once a shareholder has made a decision, that decision will also be processed and

settled (including the new issuance of shares) in real time. If a shareholder sold its rights to a third party, the securities depository must be able to record the new shares under the name of their new rightful owner.

Separation of Asset Ownership and Custodian's Duties

Assets should always be owned by their actual owners, and asset owners must be able to allow third-party professionals to manage their assets without having to pass legal ownership of assets to third parties (such as nominee or street name entities). If issuers need to send messages or payments to asset owners (for example, listed share holders), issuers send them directly to asset owners. Third-party asset managers and/or custodians can always buy, sell, and lend assets on behalf of their owners. Under this arrangement, asset custodians can focus on providing value-add services to shareowners, without worrying about asset ownership duties such as managing and redirecting payments from issuers to shareowners.

Interoperability of Assets

If an organization requires 20,000 units of asset B, but instead owns 10,000 units of asset A, it needs a way to exchange asset A for asset B. Though the current market might not offer enough liquidity to fulfill this trade quickly, there might be plenty of liquidity available between asset A and asset C, and also between asset C and asset B. Instead of settling for market limits on direct trading (A for B) in this case, a chain network connects buyers with “buried” sellers, finds the best match (which could be buried under several layers of assets), and executes the transaction.

Demos

Art Auction

[WIP] ...coming soon

Shows the provenance, attestation, and ownership of a piece of artwork and the ensuing interaction of the various stakeholders. Not yet stable with v1 codebase.

Learn more about the components [here](#)

Learn more about the client-side application [here](#)

Marbles

[WIP] ...coming soon

The marbles chaincode application demonstrates the ability to create assets (marbles) with unique attributes - size, color, owner, etc... and trade these assets with fellow participants in a blockchain network. It is not yet stable with v1 codebase.

Learn more about the marbles chaincode and client-side application [here](#)

What is chaincode?

[WIP]

coming soon ... end-to-end examples of chaincode demonstrating the available APIs.

Chaincode is a piece of code that is written in one of the supported languages such as Go or Java. It is installed and instantiated through an SDK or CLI onto a network of Hyperledger Fabric peer nodes, enabling interaction with that network's shared ledger.

There are three aspects to chaincode development:

- Chaincode Interfaces
- APIs
- Chaincode Responses

Chaincode interfaces

A chaincode implements the Chaincode Interface that supports two methods:

- `Init`
- `Invoke`

Init()

Init is called when you first deploy your chaincode. As the name implies, this function is used to do any initialization your chaincode needs.

Invoke()

Invoke is called when you want to call chaincode functions to do real work (i.e. read and write to the ledger). Invocations are captured as transactions, which get grouped into blocks on the chain. When you need to update or query the ledger, you do so by invoking your chaincode.

Dependencies

The import statement lists a few dependencies for the chaincode to compile successfully.

- `fmt` – contains `Println` for debugging/logging.
- `errors` – standard go error format.
- `shim` – contains the definitions for the chaincode interface and the chaincode stub, which are required to interact with the ledger.

Chaincode APIs

When the `Init` or `Invoke` function of a chaincode is called, the fabric passes the `shim.ChaincodeStubInterface` parameter and the chaincode returns a `pb.Response`. This stub can be used to call APIs to access to the ledger services, transaction context, or to invoke other chaincodes.

The current APIs are defined in the `shim` package, and can be generated with the following command:

```
godoc github.com/hyperledger/fabric/core/chaincode/shim
```

However, it also includes functions from `chaincode.pb.go` (protobuf functions) that are not intended as public APIs. The best practice is to look at the function definitions in `chaincode.go` and the `examples` directory.

Response

The chaincode response comes in the form of a protobuf.

```
message Response {  
  
    // A status code that should follow the HTTP status codes.  
    int32 status = 1;  
  
    // A message associated with the response code.  
    string message = 2;  
  
    // A payload that can be used to include metadata with this response.  
    bytes payload = 3;  
  
}
```

The chaincode will also return events. Message events and chaincode events.

```
messageEvent {  
  
    oneof Event {  
  
        //Register consumer sent event  
        Register register = 1;  
  
        //producer events common.  
        Block block = 2;  
        ChaincodeEvent chaincodeEvent = 3;  
        Rejection rejection = 4;  
  
        //Unregister consumer sent events  
        Unregister unregister = 5;  
  
    }
```

```
}
```

```
messageChaincodeEvent {
    string chaincodeID = 1;
    string txID = 2;
    string eventName = 3;
    bytes payload = 4;
}
```

Once developed and deployed, there are two ways to interact with the chaincode - through an SDK or the CLI. The steps for CLI are described below. For SDK interaction, refer to the [balance transfer](#) samples. **Note:** This SDK interaction is covered in the **Getting Started** section.

Command Line Interfaces

To view the currently available CLI commands, execute the following:

```
# this assumes that you have correctly set the GOPATH variable and cloned the Fabric_
↪codebase into that path
cd /opt/gopath/src/github.com/hyperledger/fabric
build /bin/peer
```

You will see output similar to the example below. (**NOTE:** rootcommand below is hardcoded in main.go. Currently, the build will create a *peer* executable file).

```
Usage:
    peer [flags]
    peer [command]

Available Commands:
    version      Print fabric peer version.
    node         node specific commands.
    channel      channel specific commands.
    chaincode    chaincode specific commands.
    logging      logging specific commands

Flags:
    --logging-level string: Default logging level and overrides, see core.yaml for_
↪full syntax
    --test.coverprofile string: Done (default "coverage.cov")
    -v, --version: Display current version of fabric peer server
    Use "peer [command] --help" for more information about a command.
```

The `peer` command supports several subcommands and flags, as shown above. To facilitate its use in scripted applications, the `peer` command always produces a non-zero return code in the event of command failure. Upon success, many of the subcommands produce a result on stdout as shown in the table below:

Command

stdout result in the event of success

version

String form of peer.version defined in core.yaml

node start

N/A

node status

String form of StatusCode

node stop

String form of StatusCode

chaincode deploy

The chaincode container name (hash) required for subsequent chaincode invoke and chaincode query commands

chaincode invoke

The transaction ID (UUID)

chaincode query

By default, the query result is formatted as a printable

channel create

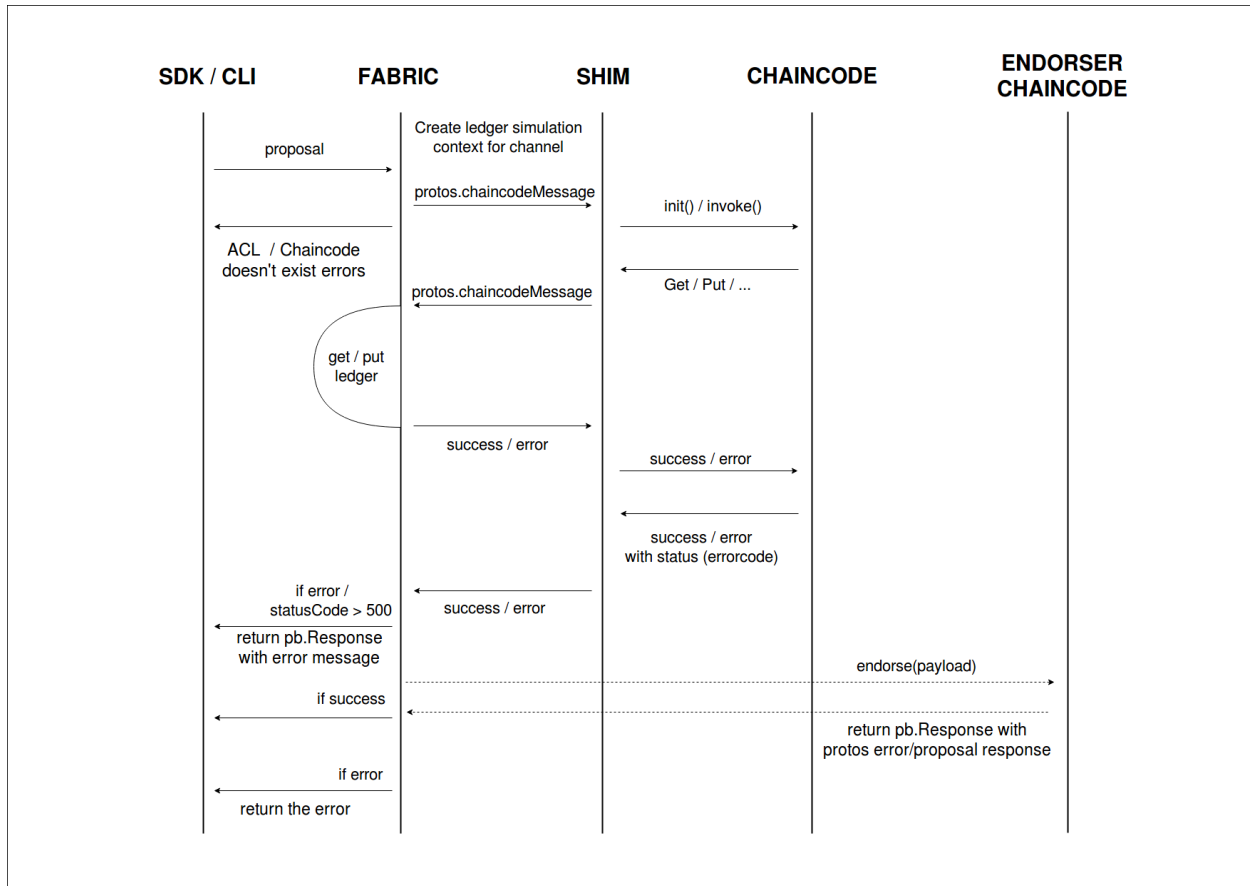
Create a chain

channel join

Adds a peer to the chain

Command line options support writing this value as raw bytes (-r, -raw) or formatted as the hexadecimal representation of the raw bytes (-x, -hex). If the query response is empty then nothing is output.

Chaincode Swimlanes



Deploy a chaincode

[WIP] - the CLI commands need to be refactored based on the new deployment model. Channel Create and Channel Join will remain the same.

Videos

Refer to the Hyperledger Fabric library on [youtube](#). The collection contains developers demonstrating various v1 features and components such as: ledger, channels, gossip, SDK, chaincode, MSP, and more...

Best Practices

Coming soon...

Intended to contain best practices and configurations for MSP, networks, ordering service, channels, ACL, stress, policies, chaincode development, functions, etc...

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, consider an example hierarchical arrangement of “`ConfigGroup`”s (expressed for clarity in golang notation).

```
// Assume the 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 go lang 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)
  Application (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.

Configuring using the configtxgen tool

This document describe the usage for the `configtxgen` utility for manipulating 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.

Building the tool

Building the tool is as simple as `make configtxgen`. This will create a `configtxgen` binary at `build/bin/configtxgen` which is included in the Vagrant development environment path by default.

Configuration Profiles

The configuration parameters supplied to the `configtxgen` tool are primarily provided by the `configtx.yaml` file. This file is located at `fabric/common/configtx/tool/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> -outputCreateChannelTx <output.txname>
```

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/sampleconfig 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/sampleconfig 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/sampleconfig 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": {}
}
}
}
}
```

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` subcommand. Comments in the file also explain how the logging level can be overridden in various ways by using environment variables.

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 `SetLogLevel` API.

`SetLogLevel(LogLevel 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.SetLogLevel(logLevel)
    ...
}
```

Architecture Explained

The v1 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 $K \rightarrow (V \times N)$, where:

- K is a set of keys
- V is a set of values
- N is an infinite ordered set of version numbers. Injective function $\text{next}: N \rightarrow N$ takes an element of N and returns the next version number.

Both V and N contain a special element $\text{\textbackslash bot}$, which is in case of N the lowest element. Initially all keys are mapped to $(\text{\textbackslash bot}, \text{\textbackslash bot})$. For $s(k) = (v, \text{ver})$ 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 $s'(k) = (v, \text{next}(s(k).version))$ with $s'(k') = s(k')$ for all $k' \neq k$.
- `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 connect 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 v1 will 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 block.

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. 12.1: 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 $E = \{\text{Alice}, \text{Bob}, \text{Charlie}, \text{Dave}, \text{Eve}, \text{Frank}, \text{George}\}$. 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 $(\text{Alice OR Bob}) \text{ AND } (\text{any two of: Charlie, Dave, Eve, Frank, George})$.
- 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 $\{\text{Alice}=49, \text{Bob}=15, \text{Charlie}=15, \text{Dave}=10, \text{Eve}=7, \text{Frank}=3, \text{George}=1\}$, 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 $\{\text{Alice}, X\}$ with any X different from George, or $\{\text{everyone together except Alice}\}$. 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

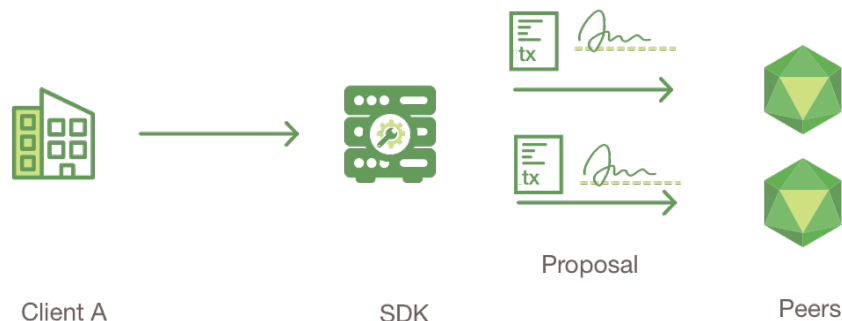
This document outlines the transactional mechanics that take place during a standard asset exchange. The scenario includes two clients, A and B, who are buying and selling radishes. They each have a peer on the network through which they send their transactions and interact with the ledger.



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.

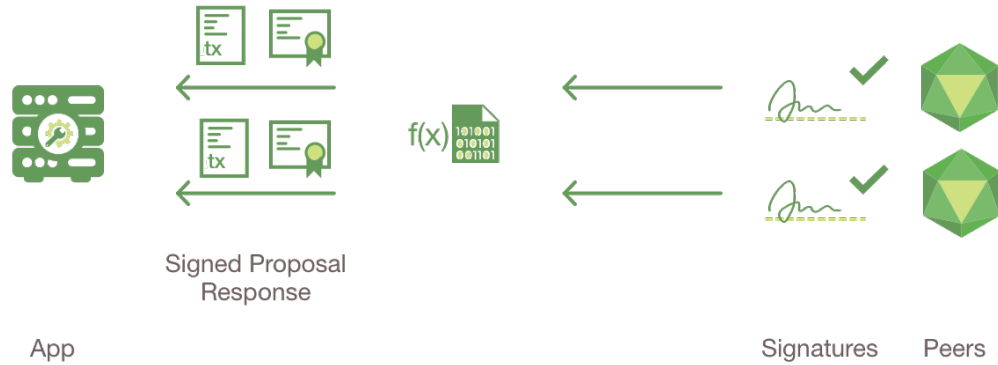


1. Client A initiates a transaction

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

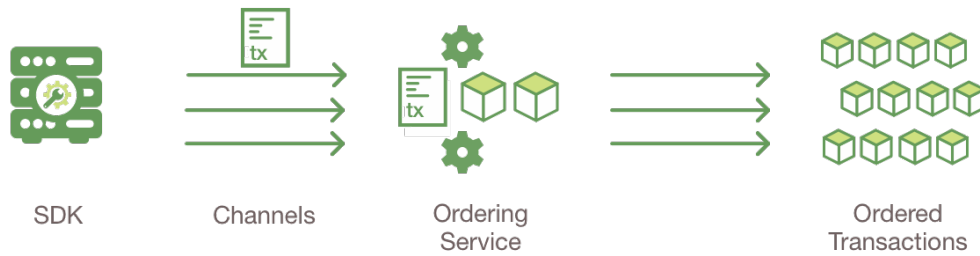
The endorsing peers verify the signature (using MSP) and determine if the submitter is properly authorized to perform the proposed operation (using the channel's ACL). The endorsing peers take the transaction proposal arguments as inputs and execute them against the current state database to produce 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 local process running on the peers which allows them to verify transaction requests arriving from clients and to sign transaction results(endorsements). The ACL (Access Control List) is defined at channel creation time, and determines which peers and end users are permitted to perform certain actions.}



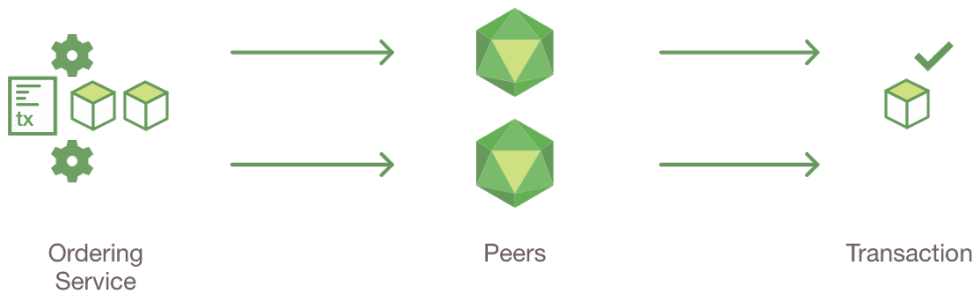
3. Proposal responses are inspected

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.



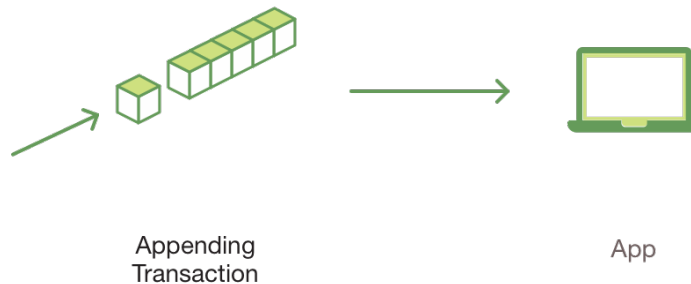
4. Client assembles endorsements into a transaction

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 read the transaction details, 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 [Chaincode Swimlanes](#) diagram to better understand the server side flow and the protobufs.

Fabric CA User's Guide

Fabric CA is a Certificate Authority for Hyperledger Fabric.

It provides features such as:

- 1) registration of identities, or connects to LDAP as the user registry;
- 2) issuance of Enrollment Certificates (ECerts);
- 3) issuance of Transaction Certificates (TCerts), providing both anonymity and unlinkability when transacting on a Hyperledger Fabric blockchain;
- 4) certificate renewal and revocation.

Fabric CA consists of both a server and a client component as described later in this document.

For developers interested in contributing to Fabric CA, see the [Fabric CA repository](#) for more information.

Table of Contents

1. *Overview*
2. *Getting Started*
 - (a) *Prerequisites*
 - (b) *Install*
 - (c) *Explore the Fabric CA CLI*
3. *File Formats*
 - (a) *Fabric CA server's configuration file format*
 - (b) *Fabric CA client's configuration file format*
4. *Configuration Settings Precedence*
5. *Fabric CA Server*
 - (a) *Initializing the server*
 - (b) *Starting the server*
 - (c) *Configuring the database*
 - (d) *Configuring LDAP*

(e) *Setting up a cluster*

6. Fabric CA Client

(a) *Enrolling the bootstrap user*

(b) *Registering a new identity*

(c) *Enrolling a peer identity*

(d) *Reenrolling an identity*

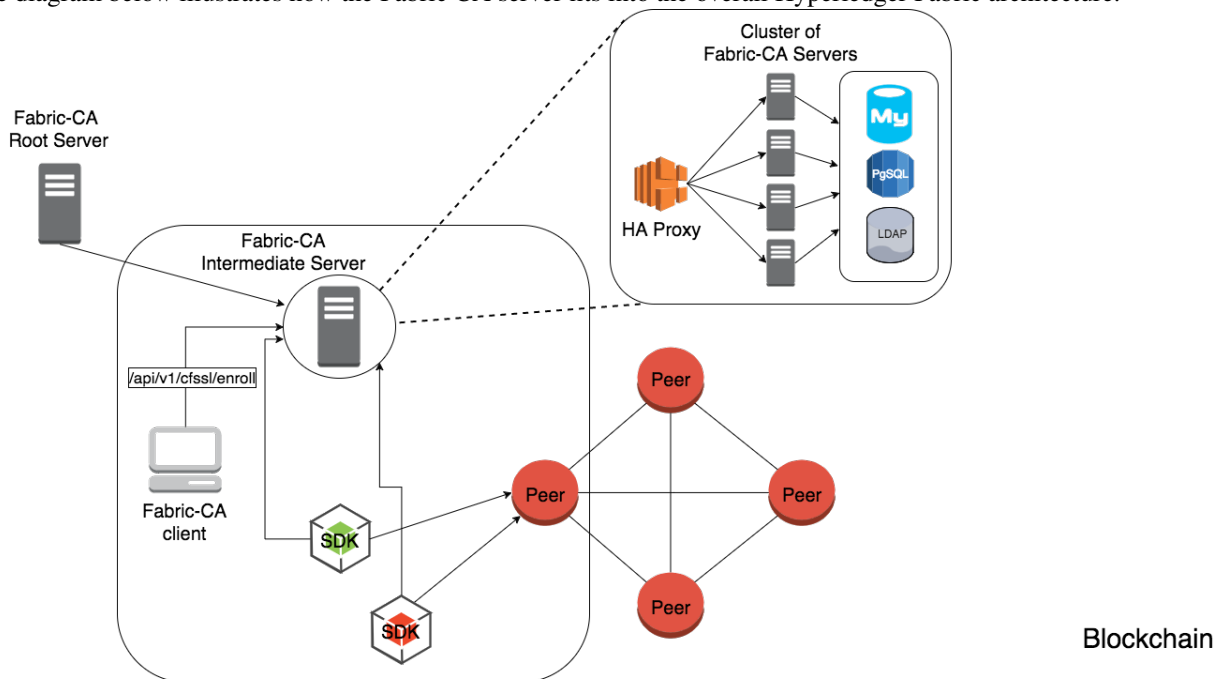
(e) *Revoking a certificate or identity*

(f) *Enabling TLS*

7. Appendix

Overview

The diagram below illustrates how the Fabric CA server fits into the overall Hyperledger Fabric architecture.



Text

There are two ways of interacting with a Fabric CA server: via the Fabric CA client or through one of the Fabric SDKs. All communication to the Fabric CA server is via REST APIs. See [fabric-ca/swagger/swagger-fabric-ca.json](#) for the swagger documentation for these REST APIs.

The Fabric CA client or SDK may connect to a server in a cluster of Fabric CA servers. This is illustrated in the top right section of the diagram. The client routes to an HA Proxy endpoint which load balances traffic to one of the fabric-ca-server cluster members. All Fabric CA servers in a cluster share the same database for keeping track of users and certificates. If LDAP is configured, the user information is kept in LDAP rather than the database.

Getting Started

Prerequisites

- Go 1.7+ installation or later
- **GOPATH** environment variable is set correctly
- libtool and libtdhl-dev packages are installed

The following installs the libtool dependencies.

```
# sudo apt install libtool libltdl-dev
```

For more information on libtool, see <https://www.gnu.org/software/libtool>.

For more information on libtdhl-dev, see https://www.gnu.org/software/libtool/manual/html_node/Using-libltdl.html.

Install

The following installs both the *fabric-ca-server* and *fabric-ca-client* commands.

```
# go get -u github.com/hyperledger/fabric-ca/cmd/...
```

Start Server Natively

The following starts the *fabric-ca-server* with default settings.

```
# fabric-ca-server start -b admin:adminpw
```

The *-b* option provides the enrollment ID and secret for a bootstrap administrator. A default configuration file named *fabric-ca-server-config.yaml* is created in the local directory which can be customized.

Start Server via Docker

You can build and start the server via docker-compose as shown below.

```
# cd $GOPATH/src/github.com/hyperledger/fabric-ca
# make docker
# cd docker/server
# docker-compose up -d
```

The hyperledger/fabric-ca docker image contains both the *fabric-ca-server* and the *fabric-ca-client*.

Explore the Fabric CA CLI

This section simply provides the usage messages for the Fabric CA server and client for convenience. Additional usage information is provided in following sections.

The following shows the Fabric CA server usage message.

Hyperledger Fabric Certificate Authority Server

Usage:

```
fabric-ca-server [command]
```

Available Commands:

```
init      Initialize the fabric-ca server
start     Start the fabric-ca server
```

Flags:

```
--address string      Listening address of fabric-ca-server
↪(default "0.0.0.0")
-b, --boot string     The user:pass for bootstrap admin which is
↪required to build default config file
--ca.certfile string   PEM-encoded CA certificate file (default "ca-
↪cert.pem")
--ca.keyfile string     PEM-encoded CA key file (default "ca-key.pem")
-c, --config string    Configuration file (default "fabric-ca-server-
↪config.yaml")
--csr.cn string        The common name field of the certificate
↪signing request to a parent fabric-ca-server
--csr.serialnumber string The serial number in a certificate signing
↪request to a parent fabric-ca-server
--db.datasource string  Data source which is database specific
↪(default "fabric-ca-server.db")
--db.tls.certfiles string PEM-encoded comma separated list of trusted
↪certificate files (e.g. root1.pem, root2.pem)
--db.tls.client.certfile string PEM-encoded certificate file when mutual
↪authentication is enabled
--db.tls.client.keyfile string PEM-encoded key file when mutual
↪authentication is enabled
--db.tls.enabled       Enable TLS for client connection
--db.type string       Type of database; one of: sqlite3, postgres,
↪mysql (default "sqlite3")
-d, --debug           Enable debug level logging
--ldap.enabled        Enable the LDAP client for authentication and
↪attributes
--ldap.groupfilter string The LDAP group filter for a single
↪affiliation group (default "(memberUid=%s)")
--ldap.url string      LDAP client URL of form ldap://adminDN:
↪adminPassword@host[:port]/base
--ldap.userfilter string The LDAP user filter to use when searching
↪for users (default "(uid=%s)")
-p, --port int        Listening port of fabric-ca-server (default
↪7054)
--registry.maxenrollments int Maximum number of enrollments; valid if LDAP
↪not enabled
--tls.certfile string  PEM-encoded TLS certificate file for server's
↪listening port (default "ca-cert.pem")
--tls.enabled         Enable TLS on the listening port
--tls.keyfile string   PEM-encoded TLS key for server's listening
↪port (default "ca-key.pem")
-u, --url string       URL of the parent fabric-ca-server
```

Use "fabric-ca-server [command] --help" for more information about a command.

The following shows the Fabric CA client usage message:

```
# fabric-ca-client
Hyperledger Fabric Certificate Authority Client

Usage:
  fabric-ca-client [command]

Available Commands:
  enroll      Enroll user
  getcacert   Get CA certificate chain
  reenroll    Reenroll user
  register    Register user
  revoke      Revoke user

Flags:
  -c, --config string          Configuration file (default "$HOME/.fabric-ca-
    ↪client/fabric-ca-client-config.yaml")
  --csr.cn string              The common name field of the certificate signing_
    ↪request to a parent fabric-ca-server
  --csr.serialnumber string    The serial number in a certificate signing_
    ↪request to a parent fabric-ca-server
  -d, --debug                  Enable debug level logging
  --enrollment.hosts string    Comma-separated host list
  --enrollment.label string    Label to use in HSM operations
  --enrollment.profile string  Name of the signing profile to use in issuing_
    ↪the certificate
  --id.affiliation string       The identity's affiliation
  --id.attr string              Attributes associated with this identity (e.g._
    ↪hf.Revoker=true)
  --id.maxenrollments int      The maximum number of times the secret can be_
    ↪reused to enroll
  --id.name string              Unique name of the identity
  --id.secret string            The enrollment secret for the identity being_
    ↪registered
  --id.type string              Type of identity being registered (e.g. 'peer,_
    ↪app, user')
  -M, --mspdir string           Membership Service Provider directory (default
    ↪"msp")
  -m, --myhost string           Hostname to include in the certificate signing_
    ↪request during enrollment (default "$HOSTNAME")
  --tls.certfiles string        PEM-encoded comma separated list of trusted_
    ↪certificate files (e.g. root1.pem, root2.pem)
  --tls.client.certfile string  PEM-encoded certificate file when mutual_
    ↪authentication is enabled
  --tls.client.keyfile string   PEM-encoded key file when mutual authentication_
    ↪is enabled
  --tls.enabled                 Enable TLS for client connection
  -u, --url string              URL of fabric-ca-server (default "http://
    ↪localhost:7054")

Use "fabric-ca-client [command] --help" for more information about a command.
```

Back to Top

File Formats

Fabric CA server's configuration file format

A configuration file can be provided to the server using the `-c` or `--config` option. If the config option is used and the specified file doesn't exist, a default configuration file (like the one shown below) will be created in the specified location. However, if no config option was used, it will be created in the server's home directory (see *Fabric CA Server* section more info).

```
# Server's listening port (default: 7054)
port: 7054

# Enables debug logging (default: false)
debug: false

#####
# TLS section for the server's listening port
#####
tls:
  # Enable TLS (default: false)
  enabled: false
  certfile: ca-cert.pem
  keyfile: ca-key.pem

#####
# The CA section contains the key and certificate files used when
# issuing enrollment certificates (ECerts) and transaction
# certificates (TCerts).
#####
ca:
  # Certificate file (default: ca-cert.pem)
  certfile: ca-cert.pem
  # Key file (default: ca-key.pem)
  keyfile: ca-key.pem

#####
# The registry section controls how the fabric-ca-server does two things:
# 1) authenticates enrollment requests which contain a username and password
#    (also known as an enrollment ID and secret).
# 2) once authenticated, retrieves the identity's attribute names and
#    values which the fabric-ca-server optionally puts into TCerts
#    which it issues for transacting on the Hyperledger Fabric blockchain.
#    These attributes are useful for making access control decisions in
#    chaincode.
# There are two main configuration options:
# 1) The fabric-ca-server is the registry
# 2) An LDAP server is the registry, in which case the fabric-ca-server
#    calls the LDAP server to perform these tasks.
#####
registry:
  # Maximum number of times a password/secret can be reused for enrollment
  # (default: 0, which means there is no limit)
  maxEnrollments: 0

  # Contains user information which is used when LDAP is disabled
  identities:
    - name: <<<ADMIN>>>
```



```

    pass: <<<ADMINPW>>>
    type: client
    affiliation: ""
    attrs:
        hf.Registrar.Roles: "client,user,peer,validator,auditor,ca"
        hf.Registrar.DelegateRoles: "client,user,validator,auditor"
        hf.Revoker: true
        hf.IntermediateCA: true

#####
# Database section
# Supported types are: "sqlite3", "postgres", and "mysql".
# The datasource value depends on the type.
# If the type is "sqlite3", the datasource value is a file name to use
# as the database store. Since "sqlite3" is an embedded database, it
# may not be used if you want to run the fabric-ca-server in a cluster.
# To run the fabric-ca-server in a cluster, you must choose "postgres"
# or "mysql".
#####
db:
    type: sqlite3
    datasource: fabric-ca-server.db
    tls:
        enabled: false
        certfiles: db-server-cert.pem
        client:
            certfile: db-client-cert.pem
            keyfile: db-client-key.pem

#####
# LDAP section
# If LDAP is enabled, the fabric-ca-server calls LDAP to:
# 1) authenticate enrollment ID and secret (i.e. username and password)
#    for enrollment requests
# 2) To retrieve identity attributes
#####
ldap:
    # Enables or disables the LDAP client (default: false)
    enabled: false
    # The URL of the LDAP server
    url: ldap://<adminDN>:<adminPassword>@<host>:<port>/<base>
    tls:
        certfiles: ldap-server-cert.pem
        client:
            certfile: ldap-client-cert.pem
            keyfile: ldap-client-key.pem

#####
# Affiliation section
#####
affiliations:
    org1:
        - department1
        - department2
    org2:
        - department1

#####

```

```

# Signing section
#####
signing:
  profiles:
    ca:
      usage:
        - cert sign
      expiry: 8000h
      caconstraint:
        isca: true
  default:
    usage:
      - cert sign
    expiry: 8000h

#####
# Certificate Signing Request section for generating the CA certificate
#####
csr:
  cn: fabric-ca-server
  names:
    - C: US
      ST: "North Carolina"
      L:
      O: Hyperledger
      OU: Fabric
  hosts:
    - <<<MYHOST>>>
  ca:
    pathlen:
    pathlenzero:
    expiry:

#####
# Crypto section configures the crypto primitives used for all
#####
crypto:
  software:
    hash_family: SHA2
    security_level: 256
    ephemeral: false
    key_store_dir: keys

```

Fabric CA client's configuration file format

A configuration file can be provided to the client using the `-c` or `--config` option. If the config option is used and the specified file doesn't exist, a default configuration file (like the one shown below) will be created in the specified location. However, if no config option was used, it will be created in the client's home directory (see [Fabric CA Client](#) section more info).

```

#####
# Client Configuration
#####

# URL of the fabric-ca-server (default: http://localhost:7054)
URL: http://localhost:7054

```

```

# Membership Service Provider (MSP) directory
# When the client is used to enroll a peer or an orderer, this field must be
# set to the MSP directory of the peer/orderer
MSPDir:

#####
#   TLS section for secure socket connection
#####
tls:
  # Enable TLS (default: false)
  enabled: false
  certfiles:  # Comma Separated (e.g. root.pem, root2.pem)
  client:
    certfile:
    keyfile:

#####
#   Certificate Signing Request section for generating the CSR for
#   an enrollment certificate (ECert)
#####
csr:
  cn: <<<ENROLLMENT_ID>>>
  names:
    - C: US
      ST: "North Carolina"
      L:
      O: Hyperledger
      OU: Fabric
  hosts:
    - <<<MYHOST>>>
  ca:
    pathlen:
    pathlenzero:
    expiry:

#####
#   Registration section used to register a new user with fabric-ca server
#####
id:
  name:
  type:
  affiliation:
  attributes:
    - name:
      value:

#####
#   Enrollment section used to enroll a user with fabric-ca server
#####
enrollment:
  hosts:
  profile:
  label:

```

[Back to Top](#)

Configuration Settings Precedence

The Fabric CA provides 3 ways to configure settings on the fabric-ca-server and fabric-ca-client. The precedence order is:

1. CLI flags
2. Environment variables
3. Configuration file

In the remainder of this document, we refer to making changes to configuration files. However, configuration file changes can be overridden through environment variables or CLI flags.

For example, if we have the following in the client configuration file:

```
tls:
  # Enable TLS (default: false)
  enabled: false

  # TLS for the client's listening port (default: false)
  certfiles: # Comma Separated (e.g. root.pem, root2.pem)
  client:
    certfile: cert.pem
    keyfile:
```

The following environment variable may be used to override the `cert.pem` setting in the configuration file:

```
export FABRIC_CA_CLIENT_TLS_CLIENT_CERTFILE=cert2.pem
```

If we wanted to override both the environment variable and configuration file, we can use a command line flag.

```
fabric-ca-client enroll --tls.client.certfile cert3.pem
```

The same approach applies to fabric-ca-server, except instead of using `FABRIC_CA_CLIENT` as the prefix to environment variables, `FABRIC_CA_SERVER` is used.

A word on file paths

All the properties in the Fabric CA server and client configuration file, that specify file names support both relative and absolute paths. Relative paths are relative to the config directory, where the configuration file is located. For example, if the config directory is `~/config` and the `tls` section is as shown below, the Fabric CA server or client will look for the `root.pem` file in the `~/config` directory, `cert.pem` file in the `~/config/certs` directory and the `key.pem` file in the `/abs/path` directory

```
tls:
  enabled: true
  certfiles: root.pem
  client:
    certfile: certs/cert.pem
    keyfile: /abs/path/key.pem
```

Fabric CA Server

This section describes the Fabric CA server.

You may initialize the Fabric CA server before starting it if you prefer. This provides an opportunity for you to generate a default configuration file but to review and customize its settings before starting it.

The fabric-ca-server's home directory is determined as follows:

- if the `FABRIC_CA_SERVER_HOME` environment variable is set, use its value;
- otherwise, if `FABRIC_CA_HOME` environment variable is set, use its value;
- otherwise, if the `CA_CFG_PATH` environment variable is set, use its value;
- otherwise, use current working directory.

For the remainder of this server section, we assume that you have set the `FABRIC_CA_HOME` environment variable to `$HOME/fabric-ca/server`.

The instructions below assume that the server configuration file exists in the server's home directory.

Initializing the server

Initialize the Fabric CA server as follows:

```
# fabric-ca-server init -b admin:adminpw
```

The `-b` (bootstrap user) option is required for initialization. At least one bootstrap user is required to start the fabric-ca-server. The server configuration file contains a Certificate Signing Request (CSR) section that can be configured. The following is a sample CSR.

If you are going to connect to the fabric-ca-server remotely over TLS, replace “localhost” in the CSR section below with the hostname where you will be running your fabric-ca-server.

```
cn: localhost
key:
  algo: ecdsa
  size: 256
names:
  - C: US
    ST: "North Carolina"
    L:
    O: Hyperledger
    OU: Fabric
```

All of the fields above pertain to the X.509 signing key and certificate which is generated by the `fabric-ca-server init`. This corresponds to the `ca.certfile` and `ca.keyfile` files in the server's configuration file. The fields are as follows:

- **cn** is the Common Name
- **key** specifies the algorithm and key size as described below
- **O** is the organization name
- **OU** is the organizational unit
- **L** is the location or city
- **ST** is the state
- **C** is the country

If custom values for the CSR are required, you may customize the configuration file, delete the files specified by the `ca.certfile` and `ca.keyfile` configuration items, and then run the `fabric-ca-server init -b admin:adminpw` command again.

The `fabric-ca-server init` command generates a self-signed CA certificate unless the `-u <parent-fabric-ca-server-URL>` option is specified. If the `-u` is specified, the server's CA certificate is signed by the parent fabric-ca-server. The `fabric-ca-server init` command also generates a default configuration file named **`fabric-ca-server-config.yaml`** in the server's home directory.

Algorithms and key sizes

The CSR can be customized to generate X.509 certificates and keys that support both RSA and Elliptic Curve (ECDSA). The following setting is an example of the implementation of Elliptic Curve Digital Signature Algorithm (ECDSA) with curve `prime256v1` and signature algorithm `ecdsa-with-SHA256`:

```
key:
  algo: ecdsa
  size: 256
```

The choice of algorithm and key size are based on security needs.

Elliptic Curve (ECDSA) offers the following key size options:

size	ASN1 OID	Signature Algorithm
256	prime256v1	ecdsa-with-SHA256
384	secp384r1	ecdsa-with-SHA384
521	secp521r1	ecdsa-with-SHA512

RSA offers the following key size options:

size	Modulus (bits)	Signature Algorithm
2048	2048	sha256WithRSAEncryption
4096	4096	sha512WithRSAEncryption

Starting the server

Start the Fabric CA server as follows:

```
# fabric-ca-server start -b <admin>:<adminpw>
```

If the server has not been previously initialized, it will initialize itself as it starts for the first time. During this initialization, the server will generate the `ca-cert.pem` and `ca-key.pem` files if they don't yet exist and will also create a default configuration file if it does not exist. See the *Initialize the Fabric CA server* section.

Unless the fabric-ca-server is configured to use LDAP, it must be configured with at least one pre-registered bootstrap user to enable you to register and enroll other identities. The `-b` option specifies the name and password for a bootstrap user.

A different configuration file may be specified with the `-c` option as shown below.

```
# fabric-ca-server start -c <path-to-config-file> -b <admin>:<adminpw>
```

To cause the fabric-ca-server to listen on `https` rather than `http`, set `tls.enabled` to `true`.

To limit the number of times that the same secret (or password) can be used for enrollment, set the `registry.maxEnrollments` in the configuration file to the appropriate value. If you set the value to 1, the fabric-ca server allows passwords to only be used once for a particular enrollment ID. If you set the value to 0, the fabric-ca-server places no limit on the number of times that a secret can be reused for enrollment. The default value is 0.

The fabric-ca-server should now be listening on port 7054.

You may skip to the [Fabric CA Client](#) section if you do not want to configure the fabric-ca-server to run in a cluster or to use LDAP.

Configuring the database

This section describes how to configure the fabric-ca-server to connect to Postgres or MySQL databases. The default database is SQLite and the default database file is `fabric-ca-server.db` in the Fabric CA server's home directory.

If you don't care about running the fabric-ca-server in a cluster, you may skip this section; otherwise, you must configure either Postgres or MySQL as described below.

Postgres

The following sample may be added to the server's configuration file in order to connect to a Postgres database. Be sure to customize the various values appropriately.

```
db:
  type: postgres
  datasource: host=localhost port=5432 user=Username password=Password dbname=fabric-
  ↪ca-server sslmode=verify-full
```

Specifying `sslmode` configures the type of SSL authentication. Valid values for `sslmode` are:

Mode	Description
dis-able	No SSL
re-quire	Always SSL (skip verification)
verify-ca	Always SSL (verify that the certificate presented by the server was signed by a trusted CA)
verify-full	Same as verify-ca AND verify that the certificate presented by the server was signed by a trusted CA and the server host name matches the one in the certificate

If you would like to use TLS, then the `db.tls` section in the fabric-ca-server configuration file must be specified. If SSL client authentication is enabled on the Postgres server, then the client certificate and key file must also be specified in the `db.tls.client` section. The following is an example of the `db.tls` section:

```
db:
  ...
  tls:
    enabled: true
    certfiles: db-server-cert.pem
    client:
```

```
certfile: db-client-cert.pem
keyfile: db-client-key.pem
```

certfiles - Comma separated list of PEM-encoded trusted root certificate files.

certfile and **keyfile** - PEM-encoded certificate and key files that are used by the Fabric CA server to communicate securely with the Postgres server

MySQL

The following sample may be added to the fabric-ca-server config file in order to connect to a MySQL database. Be sure to customize the various values appropriately.

```
db:
  type: mysql
  datasource: root:rootpw@tcp(localhost:3306)/fabric-ca?parseTime=true&tls=custom
```

If connecting over TLS to the MySQL server, the `db.tls.client` section is also required as described in the **Postgres** section above.

Configuring LDAP

The fabric-ca-server can be configured to read from an LDAP server.

In particular, the fabric-ca-server may connect to an LDAP server to do the following:

- authenticate a user prior to enrollment
- retrieve a user's attribute values which are used for authorization.

Modify the LDAP section of the server's configuration file to configure the fabric-ca-server to connect to an LDAP server.

```
ldap:
  # Enables or disables the LDAP client (default: false)
  enabled: false
  # The URL of the LDAP server
  url: <scheme>://<adminDN>:<adminPassword>@<host>:<port>/<base>
  userfilter: filter
```

where:

- * `scheme` is one of *ldap* or *ldaps*;
- * `adminDN` is the distinguished name of the admin user;
- * `pass` is the password of the admin user;
- * `host` is the hostname or IP address of the LDAP server;
- * `port` is the optional port number, where default 389 for *ldap* and 636 for *ldaps*;
- * `base` is the optional root of the LDAP tree to use for searches;
- * `filter` is a filter to use when searching to convert a login user name to a distinguished name. For example, a value of `(uid=%s)` searches for LDAP entries with the value of a `uid` attribute whose value is the login user name. Similarly, `(email=%s)` may be used to login with an email address.

The following is a sample configuration section for the default settings for the OpenLDAP server whose docker image is at <https://github.com/osixia/docker-openldap>.

```
ldap:
  enabled: true
  url: ldap://cn=admin,dc=example,dc=org:admin@localhost:10389/dc=example,dc=org
  userfilter: (uid=%s)
```

See FABRIC_CA/scripts/run-ldap-tests for a script which starts an OpenLDAP docker image, configures it, runs the LDAP tests in FABRIC_CA/cli/server/ldap/ldap_test.go, and stops the OpenLDAP server.

When LDAP is configured, enrollment works as follows:

- The fabric-ca-client or client SDK sends an enrollment request with a basic authorization header.
- The fabric-ca-server receives the enrollment request, decodes the user name and password in the authorization header, looks up the DN (Distinguished Name) associated with the user name using the “userfilter” from the configuration file, and then attempts an LDAP bind with the user’s password. If the LDAP bind is successful, the enrollment processing is authorized and can proceed.

When LDAP is configured, attribute retrieval works as follows:

- A client SDK sends a request for a batch of tcerts **with one or more attributes** to the fabric-ca-server.
- The fabric-ca-server receives the tcert request and does as follows:
 - extracts the enrollment ID from the token in the authorization header (after validating the token);
 - does an LDAP search/query to the LDAP server, requesting all of the attribute names received in the tcert request;
 - the attribute values are placed in the tcert as normal.

Setting up a cluster

You may use any IP sprayer to load balance to a cluster of fabric-ca servers. This section provides an example of how to set up Haproxy to route to a fabric-ca-server cluster. Be sure to change hostname and port to reflect the settings of your fabric-ca servers.

haproxy.conf

```
global
  maxconn 4096
  daemon

defaults
  mode http
  maxconn 2000
  timeout connect 5000
  timeout client 50000
  timeout server 50000

listen http-in
  bind *:7054
  balance roundrobin
  server server1 hostname1:port
  server server2 hostname2:port
  server server3 hostname3:port
```

Node: If using TLS, need to use mode `tcp`.

[Back to Top](#)

Fabric CA Client

This section describes how to use the `fabric-ca-client` command.

The `fabric-ca-client`'s home directory is determined as follows:

- if the `FABRIC_CA_CLIENT_HOME` environment variable is set, use its value;
- otherwise, if the `FABRIC_CA_HOME` environment variable is set, use its value;
- otherwise, if the `CA_CFG_PATH` environment variable is set, use its value;
- otherwise, use `$HOME/.fabric-ca-client`.

The instructions below assume that the client configuration file exists in the client's home directory.

Enrolling the bootstrap user

First, if needed, customize the CSR (Certificate Signing Request) section in the client configuration file. Note that `csr.cn` field must be set to the ID of the bootstrap user. Default CSR values are shown below:

```
csr:
  cn: <<enrollment ID>>
  key:
    algo: ecdsa
    size: 256
  names:
    - C: US
      ST: North Carolina
      L:
      O: Hyperledger Fabric
      OU: Fabric CA
  hosts:
    - <<hostname of the fabric-ca-client>>
  ca:
    pathlen:
    pathlenzero:
    expiry:
```

See [CSR fields](#) for description of the fields.

Then run `fabric-ca-client enroll` command to enroll the user. For example, following command enrolls an user whose ID is **admin** and password is **adminpw** by calling `fabric-ca-server` that is running locally at 7054 port.

```
# export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
# fabric-ca-client enroll -u http://admin:adminpw@localhost:7054
```

The `enroll` command stores an enrollment certificate (ECert), corresponding private key and CA certificate chain PEM files in the subdirectories of the `fabric-ca-client`'s `msp` directory. You will see messages indicating where the PEM files are stored.

Registering a new identity

The user performing the register request must be currently enrolled, and must also have the proper authority to register the type of user being registered.

In particular, two authorization checks are made by the fabric-ca-server during registration as follows:

1. The invoker's identity must have the "hf.Registrar.Roles" attribute with a comma-separated list of values where one of the value equals the type of identity being registered; for example, if the invoker's identity has the "hf.Registrar.Roles" attribute with a value of "peer,app,user", the invoker can register identities of type peer, app, and user, but not orderer.
2. The affiliation of the invoker's identity must be equal to or a prefix of the affiliation of the identity being registered. For example, an invoker with an affiliation of "a.b" may register an identity with an affiliation of "a.b.c" but may not register an identity with an affiliation of "a.c".

The following command uses the **admin** user's credentials to register a new identity with an enrollment id of "admin2", a type of "user", an affiliation of "org1.department1", and an attribute named "hf.Revoker" with a value of "true".

```
# export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
# fabric-ca-client register --id.name admin2 --id.type user --id.affiliation org1.
↳department1 --id.attr hf.Revoker=true
```

The password, also known as the enrollment secret, is printed. This password is required to enroll the user. This allows an administrator to register an identity and to then give the enrollment ID and secret to someone else to enroll the identity.

You may set default values for any of the fields used in the register command by editing the client's configuration file. For example, suppose the configuration file contains the following:

```
id:
  name:
  type: user
  affiliation: org1.department1
  attributes:
    - name: hf.Revoker
      value: true
    - name: anotherAttrName
      value: anotherAttrValue
```

The following command would then register a new identity with an enrollment id of "admin3" which it takes from the command line, and the remainder is taken from the config file including a type of "user", an affiliation of "org1.department1", and two attributes: "hf.Revoker" with a value of "true" and "anotherAttrName" with a value of "anotherAttrValue".

```
# export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
# fabric-ca-client register --id.name admin3
```

To register a user with multiple attributes requires specifying all attribute names and values in the configuration file as shown above.

Next, let's register a peer identity which will be used to enroll the peer in the following section. The following command registers the **peer1** identity. Note that we choose to specify our own password (or secret) rather than letting the server generate one for us.

```
# export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
# fabric-ca-client register --id.name peer1 --id.type peer --id.affiliation org1.
↳department1 --id.secret peer1pw
```

Enrolling a Peer Identity

Now that you have successfully registered a peer identity, you may now enroll the peer given the enrollment ID and secret (i.e. the *password* from the previous section). This is similar to enrolling the bootstrap user except that we also demonstrate how to use the “-M” option to populate the Hyperledger Fabric MSP (Membership Service Provider) directory structure.

The following command enrolls `peer1`. Be sure to replace the value of the “-M” option with the path to your peer’s MSP directory which is the ‘`mspConfigPath`’ setting in the peer’s `core.yaml` file. You may also set the `FABRIC_CA_CLIENT_HOME` to the home directory of your peer.

```
# export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/peer1
# fabric-ca-client enroll -u http://peer1:peer1pw@localhost:7054 -M $FABRIC_CA_CLIENT_
↪HOME/msp
```

Enrolling an orderer is the same, except the path to the MSP directory is the ‘`LocalMSPDir`’ setting in your orderer’s `orderer.yaml` file.

Getting a CA certificate chain from another fabric-ca-server

In general, the `cacerts` directory of the MSP directory must contain the certificate authority chains of other certificate authorities, representing all of the roots of trust for the peer.

The `fabric-ca-client getcacerts` command is used to retrieve these certificate chains from other `fabric-ca-server` instances.

For example, the following will start a second `fabric-ca-server` on `localhost` listening on port `7055` with a name of “CA2”. This represents a completely separate root of trust and would be managed by a different member on the blockchain.

```
# export FABRIC_CA_SERVER_HOME=$HOME/ca2
# fabric-ca-server start -b admin:ca2pw -p 7055 -n CA2
```

The following command will install CA2’s certificate chain into `peer1`’s MSP directory.

```
# export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/peer1
# fabric-ca-client getcacert -u http://localhost:7055 -M $FABRIC_CA_CLIENT_HOME/msp
```

Reenrolling an Identity

Suppose your enrollment certificate is about to expire or has been compromised. You can issue the `reenroll` command to renew your enrollment certificate as follows.

```
# export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/peer1
# fabric-ca-client reenroll
```

Revoking a certificate or identity

In order to revoke a certificate or user, the calling identity must have the `hf.Revoker` attribute. The revoking identity can only revoke a certificate or user that has an affiliation that is equal to or prefixed by the revoking identity’s affiliation.

For example, a revoker with affiliation `bank.bank_1` can revoke user with `bank.bank1.dep1` but can’t revoke `bank.bank2`.

You may revoke a specific certificate by specifying its AKI (Authority Key Identifier) and its serial number as follows:

```
fabric-ca-client revoke -a xxx -s yyy -r <reason>
```

The following command disables a user's identity and also revokes all of the certificates associated with the identity. All future requests received by the fabric-ca-server from this identity will be rejected.

```
fabric-ca-client revoke -e <enrollment_id> -r <reason>
```

The following are the supported reasons for revoking that can be specified using `-r` flag.

Reasons:

- unspecified
- keycompromise
- cacompromise
- affiliationchange
- superseded
- cessationofoperation
- certificatehold
- removefromcrl
- privilegewithdrawn
- aacompromise

The bootstrap admin can revoke **peer1**'s identity as follows:

```
# export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
# fabric-ca-client revoke -e peer1
```

Enabling TLS

This section describes in more detail how to configure TLS for a fabric-ca-client.

The following sections may be configured in the `fabric-ca-client-config.yaml`.

```
tls:
  # Enable TLS (default: false)
  enabled: true
  certfiles: root.pem # Comma Separated (e.g. root.pem, root2.pem)
  client:
    certfile: tls_client-cert.pem
    keyfile: tls_client-key.pem
```

The **certfiles** option is the set of root certificates trusted by the client. This will typically just be the root fabric-ca-server's certificate found in the server's home directory in the **ca-cert.pem** file.

The **client** option is required only if mutual TLS is configured on the server.

[Back to Top](#)

Appendix

Postgres SSL Configuration

Basic instructions for configuring SSL on the Postgres server:

1. In postgresql.conf, uncomment SSL and set to “on” (SSL=on)
2. Place certificate and key files in the Postgres data directory.

Instructions for generating self-signed certificates for: <https://www.postgresql.org/docs/9.5/static/ssl-tcp.html>

Note: Self-signed certificates are for testing purposes and should not be used in a production environment

Postgres Server - Require Client Certificates

1. Place certificates of the certificate authorities (CAs) you trust in the file root.crt in the Postgres data directory
2. In postgresql.conf, set “ssl_ca_file” to point to the root cert of client (CA cert)
3. Set the clientcert parameter to 1 on the appropriate hostssl line(s) in pg_hba.conf.

For more details on configuring SSL on the Postgres server, please refer to the following Postgres documentation: <https://www.postgresql.org/docs/9.4/static/libpq-ssl.html>

MySQL SSL Configuration

On MySQL 5.7.X, certain modes affect whether the server permits ‘0000-00-00’ as a valid date. It might be necessary to relax the modes that MySQL server uses. We want to allow the server to be able to accept zero date values.

Please refer to the following MySQL documentation on different modes available and select the appropriate settings for the specific version of MySQL that is being used.

<https://dev.mysql.com/doc/refman/5.7/en/sql-mode.html>

Basic instructions for configuring SSL on MySQL server:

1. Open or create my.cnf file for the server. Add or un-comment the lines below in the [mysqld] section. These should point to the key and certificates for the server, and the root CA cert.

Instructions on creating server and client side certificates: <http://dev.mysql.com/doc/refman/5.7/en/creating-ssl-files-using-openssl.html>

```
[mysqld] ssl-ca=ca-cert.pem ssl-cert=server-cert.pem ssl-key=server-key.pem
```

Can run the following query to confirm SSL has been enabled.

```
mysql> SHOW GLOBAL VARIABLES LIKE 'have_%ssl';
```

Should see:

Variable_name	Value
have_openssl	YES
have_ssl	YES

2. After the server-side SSL configuration is finished, the next step is to create a user who has a privilege to access the MySQL server over SSL. For that, log in to the MySQL server, and type:

```
mysql> GRANT ALL PRIVILEGES ON . TO 'ssluser'@'%' IDENTIFIED BY 'password' REQUIRE SSL;  
mysql> FLUSH PRIVILEGES;
```

If you want to give a specific ip address from which the user will access the server change the ‘%’ to the specific ip address.

MySQL Server - Require Client Certificates

Options for secure connections are similar to those used on the server side.

- `ssl-ca` identifies the Certificate Authority (CA) certificate. This option, if used, must specify the same certificate used by the server.
- `ssl-cert` identifies MySQL server's certificate.
- `ssl-key` identifies MySQL server's private key.

Suppose that you want to connect using an account that has no special encryption requirements or was created using a `GRANT` statement that includes the `REQUIRE SSL` option. As a recommended set of secure-connection options, start the MySQL server with at least `--ssl-cert` and `--ssl-key`, and invoke the `fabric-ca-server` with `db.tls.certfiles` option set in the Fabric CA server configuration file.

To require that a client certificate also be specified, create the account using the `REQUIRE X509` option. Then the client must also specify proper client key and certificate files; otherwise, the MySQL server will reject the connection. To specify client key and certification files for the Fabric CA server, set `db.tls.certfiles`, `db.tls.client.certfile`, and the `db.tls.client.keyfile` configuration properties.

[*Back to Top*](#)

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)

Node SDK

[WIP] ...coming soon

In the meantime, refer to the [Hyperledger Fabric SDK design doc](#) for more details on the APIs and specifications.

OR

Refer to the [fabric-sdk-node](#) repository in the Hyperledger community. The README will take you through a simple setup to build HTML output for the API classes and methods.

Ordering Service

[WIP] ...coming soon

This topic will outline the role and functionalities of the ordering service, and explain its place in the broader network and in the lifecycle of a transaction. The v1 architecture has been designed such that the ordering service is the centralized point of trust in a decentralized network, but also such that the specific implementation of “ordering” (solo, kafka, BFT) becomes a pluggable component.

Refer to the design document on a [Kafka-based Ordering Service](#) for more information on the default v1 implementation.

Ledger

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.

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. The 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 the fabric does not 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/peer/core.yaml` `stateDatabase` section.

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 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, k_2 , in the world state is updated to $(k_2, 3, v_2 '')$
4. T4 fails the validation because it reads a key, k_2 , which was modified by a preceding transaction T1
5. T5 passes validation because it reads a key, k_5 , which was not modified by any of the preceding transactions

Note: Transactions with multiple read-write sets are not yet supported.

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, the 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 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 fabric membership identity. This essentially authenticates each peer to the connecting peer, with respect to membership in the network and channel.

Troubleshooting

[WIP] ...coming soon

This topic is intended to solve high level bugs and then direct users to more granular FAQ topics based on their errors.

V1 Architecture

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 a way to share the source data outside of fabric. If you encrypt the data then you will need a way to share the decryption keys outside of fabric. 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 a way to share the source data outside of fabric. If you encrypt the data then you will need a way to share the decryption keys outside of fabric.

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?

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)

- Does the fabric implementation support smart contract logic?

Yes. Chaincode is the fabric's 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.

- How do I create a business contract using the fabric?

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.

- How do I create assets using the fabric?

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 fabric does not advocate either one over the other. Instead, one of our first requirements was to ensure that both approaches can be easily implemented with tools available in the fabric.

- Which languages are supported for writing chaincode?

Chaincode can be written in any programming language and executed in containers inside the fabric context layer. We are also looking into developing a templating language (such as Apache Velocity) that can either get compiled into chaincode or have its interpreter embedded into a chaincode container.

The fabric's first fully supported chaincode language is Golang, and support for JavaScript and Java is planned for 2016. Support for additional languages and the development of a fabric-specific templating language have been discussed, and more details will be released in the near future.

- Does the fabric have native currency?

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.

Identity Management (Membership Service)

- What is unique about the fabric's Membership Service module?

One of the things that makes the Membership Service module stand out from the pack is our implementation of the latest advances in cryptography.

In addition to ensuring private, auditable transactions, our Membership Service module introduces the concept of enrollment and transaction certificates. This innovation ensures that only verified owners can create asset tokens, allowing an infinite number of transaction certificates to be issued through parent enrollment certificates while guaranteeing the private keys of asset tokens can be regenerated if lost.

Issuers also have the ability revoke transaction certificates or designate them to expire within a certain timeframe, allowing greater control over the asset tokens they have issued.

Like most other modules on Fabric, you can always replace the default module with another membership service option should the need arise.

- Does its Membership Service make Fabric a centralized

solution?

No. The only role of the Membership Service module is to issue digital certificates to validated entities that want to participate in the network. It does not execute transactions nor is it aware of how or when these certificates are used in any particular network.

However, because certificates are the way networks regulate and manage their users, the module serves a central regulatory and organizational role.

Needs Review

Glossary

Terminology is important, so that all Fabric users and developers agree on what we mean by each specific term. What is chaincode, for example. So we'll point you there, whenever you want to reassure yourself. Of course, 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 on a Fabric network, allowing 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

Fabric supports the addition/removal of members, peers, and ordering service nodes, without compromising the operability 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 deploy transactions, which install new chaincode, is also required.

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.

The `fabric-ca` component is an implementation of membership services to manage identities. In particular, it handles the issuance and revocation of enrollment certificates and transaction certificates.

An enrollment certificate is a long-term identity credential; a transaction certificate is a short-term identity credential which is both anonymous and un-linkable.

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 API uses protocol buffers over gRPC for transaction processing, membership services, node traversal and event handling applications to communicate across the fabric. 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.

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.

Key enhancements:

- 8de58ed - NodeSDK doc changes – FAB-146
- 62d866d - Add flow control to SYNC_STATE_SNAPSHOT
- 4d97069 - Adding TLS changes to SDK
- e9d3ac2 - Node-SDK: add support for fabric events(block, chaincode, transactional)
- 7ed9533 - Allow deploying Java chaincode from remote git repositories
- 4bf9b93 - Move Docker-Compose files into their own folder
- ce9fcdc - Print ChaincodeName when deploy with CLI
- 4fa1360 - Upgrade go protobuf from 3-beta to 3
- 4b13232 - Table implementation in java shim with example
- df741bc - Add support for dynamically registering a user with attributes
- 4203ea8 - Check for duplicates when adding peers to the chain
- 518f3c9 - Update docker openjdk image
- 47053cd - Add GetTxID function to Stub interface (FAB-306)
- ac182fa - Remove deprecated devops REST API
- ad4645d - Support hyperledger fabric build on ppc64le platform
- 21a4a8a - SDK now properly adding a peer with an invalid URL
- 1d8114f - Fix setting of watermark on restore from crash
- a98c59a - Upgrade go protobuf from 3-beta to 3
- 937039c - DEVENV: Provide strong feedback when provisioning fails
- d74b1c5 - Make pbft broadcast timeout configurable
- 97ed71f - Java shim/chaincode project reorg, separate java docker env
- a76dd3d - Start container with HostConfig was deprecated since v1.10 and removed since v1.12
- 8b63a26 - Add ability to unregister for events
- 3f5b2fa - Add automatic peer command detection
- 6daedfd - Re-enable sending of chaincode events
- b39c93a - Update Cobra and pflag vendor libraries
- dad7a9d - Reassign port numbers to 7050-7060 range

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

Contributions Welcome!

We welcome contributions to the Hyperledger Project in many forms, and there's always plenty to do!

First things first, please review the Hyperledger Project's [Code of Conduct](#) before participating. It is important that we keep things civil.

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.

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.

Logging control describes how to tweak the logging levels of various components within the 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 automatically as the code is changed. This is far more efficient than having to run a whole build between code changes.

- 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.
- 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. Be sure to 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.

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.

Coding guidelines

Be sure to check out the language-specific style guides before making any changes. This will ensure a smoother review.

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 Project's 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.md 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. A template of that header can be found [here](#).

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`.

Maintainers

Name	Gerrit	GitHub	Slack	email
Binh Nguyen	binhn	binhn	binhn	binhn@us.ibm.com
Chris Ferris	ChristopherFerris	christo4ferris	cbf	chris.ferris@gmail.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	jimthetmatrix	jimthetmatrix	jzhang	jim_the_matrix@hotmail.com
Jonathan Levi	JonathanLevi	JonathanLevi	JonathanLevi	jonathan@hacera.com
Sheehan Anderson	sheehan	srderon	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

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**:

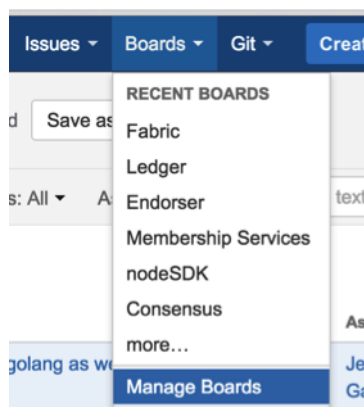


Fig. 28.1: Jira boards

Now on the left side of the screen click on **All boards**:

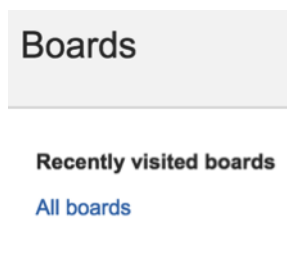


Fig. 28.2: Jira boards

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:

Board name	Board type	Administrators	Saved Filter	Visibility
Consensus	Scrum	Clayton Sims	Consensus	ALL USERS

Fig. 28.3: Jira boards

When you click on Consensus under **Board name** you will be directed to a page that contains the following columns:

Consensus

Sprint 2

QUICK FILTERS:

Only My Issues

Recently Updated

🕒 9 days remaining

Backlog

In Progress

In review

Done

Fig. 28.4: 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 Gerrit
- 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:

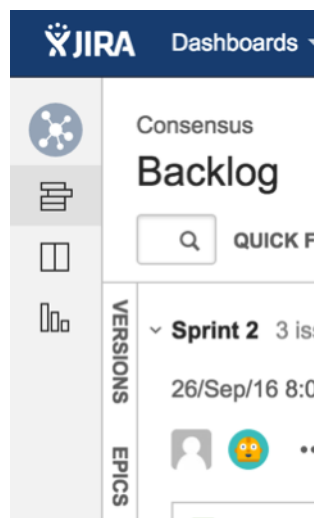


Fig. 28.5: Jira boards

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.

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.

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 Fabric project

Since the Fabric project is a Go project, you'll need to clone the Fabric repo 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.

Boostrapping 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 peer project under `$GOPATH/src/github.com/hyperledger/fabric`. It is also mounted as `/hyperledger`.

Building the fabric

Once you have all the dependencies installed, and have cloned the repository, you can proceed to build and test the 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 as 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](https://github.com/mitchellh/vagrant/issues/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 the fabric

The following instructions assume that you have already set up your development environment.

To build the 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 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/execute

```
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 devenv 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
```

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
```

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
```

Logging

Logging utilizes the [go-logging](#) library.

The available log levels in order of increasing verbosity are: *CRITICAL* | *ERROR* | *WARNING* | *NOTICE* | *INFO* | *DEBUG*

See [specific logging control](#) instructions when running the peer process.

Testing

[WIP] ...coming soon

This topic is intended to contain recommended test scenarios, as well as current performance numbers against a variety of configurations.

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](#)

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
```

Adding or updating Go packages

The Hyperledger Fabric Project uses Go 1.6 vendoring for package management. This means that all required packages reside in the `vendor` folder within the fabric project. 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
```

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 the Hyperledger Fabric project not answered in this documentation, please use [StackOverflow](#). If you need help finding things, please don't hesitate to send a note to the [mailing list](#), or ask on RocketChat (an alternative to Slack).

Quality

[WIP] ...coming soon

Status

This project is an *Active* Hyperledger project. For more information on the history of this project see the [Fabric wiki page](#). Information on what *Active* entails can be found in the [Hyperledger Project Lifecycle](#) document.

License

The Hyperledger Project uses the Apache License Version 2.0 software license.