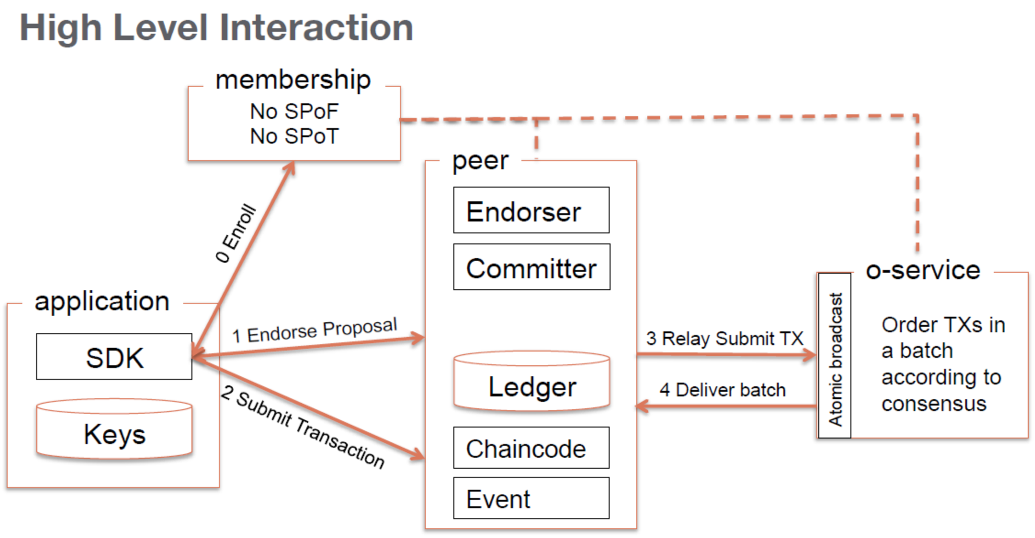
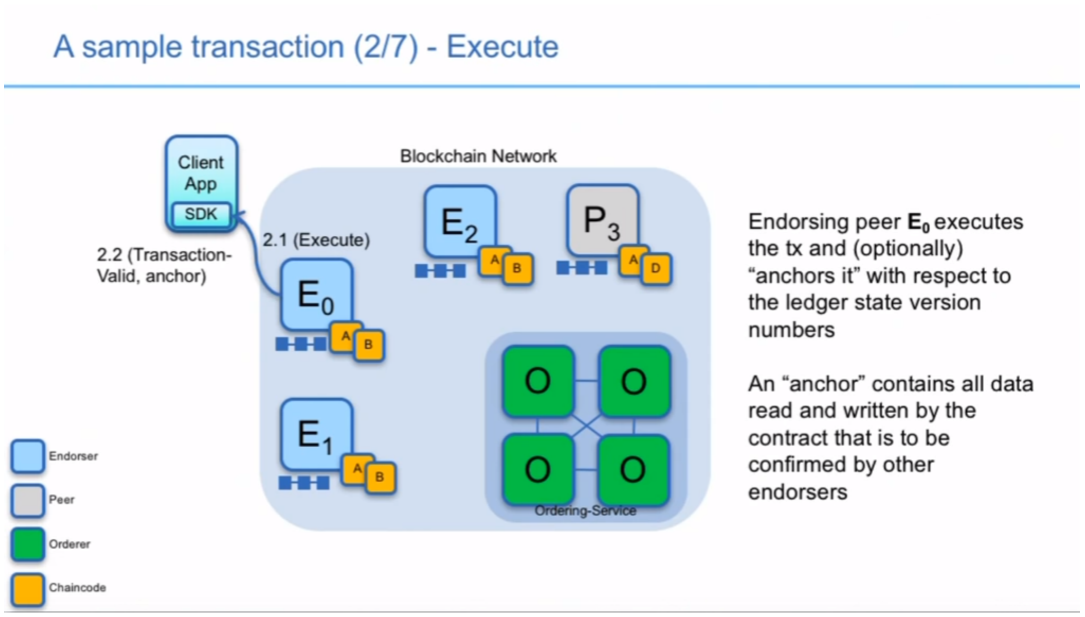
GT Nexus BlockChain Project Report
8/11/2017

BlockChain Terminology





Endorsing peer E_0 executes the tx and (optionally) “anchors it” with respect to the ledger state version numbers

An “anchor” contains all data read and written by the contract that is to be confirmed by other endorsers

Member

The members on Fabric network. Each member(organization) holds a list of peers and may subscribe to different channels.

Peer

A peer is a node(machine) on Fabric network. A peer can be a committer which sends the transaction proposals or it can be an endorser which endorse the transaction proposals. After collecting the endorsed proposals and verified the transaction, a peer will send this verified transaction to orderer. A peer receives the blocks sent by orderer and maintain blockchain/ledger.

Orderer

An orderer orders the transactions sent from the peers, aggregating the transactions into one block and sent the block/batch copies back to all the peers by channel definition. We can have multiple orderers run as an ordering service. In case of multiple orderers a consensus algorithm (like PFBT) is used to agree on the transaction order.

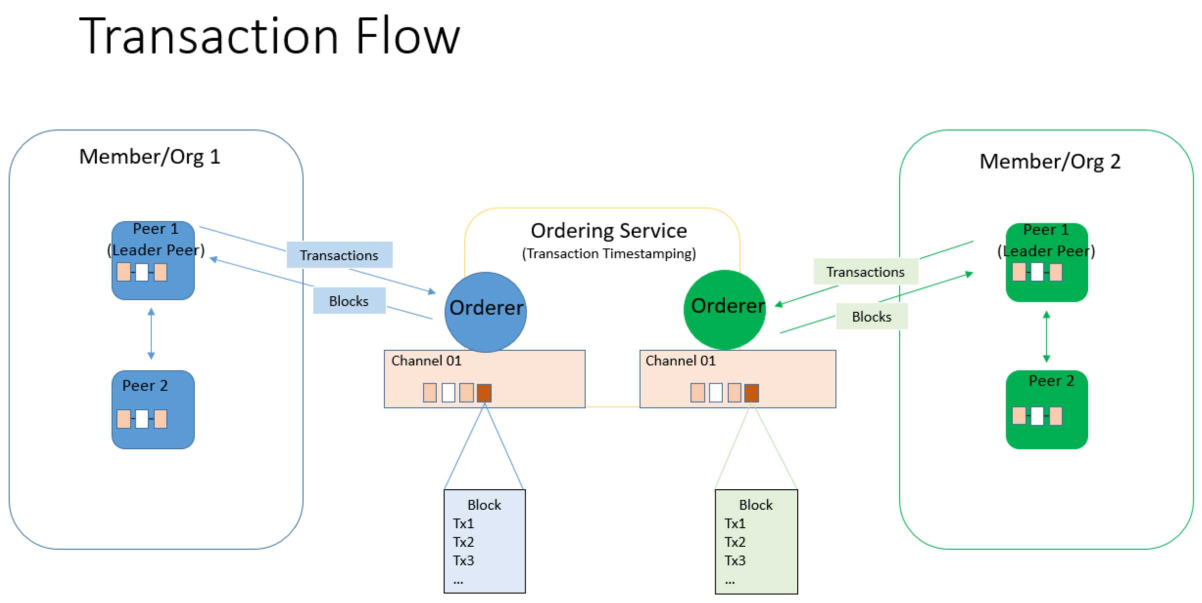
EventHub

Listen to the events on channel

User

An application user can use SDK to send the request to peers. A user may have roles like admin or user.

Channels



A Hyperledger Fabric **channel** is a private “subnet” of communication between two or more specific network members, for the purpose of conducting private and confidential transactions. A channel is defined by members (organizations), anchor peers per member, the shared ledger, chaincode application(s) and the ordering service node(s). Each transaction on the network is executed on a channel, where each party must be authenticated and authorized to transact on that channel. Each peer that joins a channel, has its own identity given by a membership services provider (MSP), which authenticates each peer to its channel peers and services.

Channel genesis blocks(on orderers) stores the policy of configuration, saying e.g. the majority of members need to approve for updating the channel configuration.

To create a channel, you need to send transaction to a system chaincode. To update the channel, you will send an updated genesis block. You will have the signing party who has a privilege to create channel sign the transaction and send it to orderer.

Transaction

There are system level transactions which call system chaincodes. And there are channel level transactions which call the normal chaincodes. In Hyperledger document, sometimes they have “tx” stand for transaction.
To know more about transaction flow: http://hyperledger-fabric.readthedocs.io/en/latest/txflow.html

Chaincode

Chaincode is a program that implements a prescribed interface. Chaincode runs in a secured Docker container isolated from the endorsing peer process. Chaincode initializes and manages ledger state through transactions submitted by applications. We can install different chaincodes on peers for the channel. A chaincode typically handles business logic agreed to by members of the network, so it may be considered as a “smart contract”.

Each chaincode may be associated with an endorsement and validation system chaincode (ESCC, VSCC)
– ESCC decides how to endorse a proposal (including simulation and app specifics)
– VSCC decides transaction validity (including correctness of endorsements)

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

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

The current list of system chaincodes:

LSCC Lifecycle system chaincode handles lifecycle requests described above.
CSCC Configuration system chaincode handles channel configuration on the peer side.
QSCC Query system chaincode provides ledger query APIs such as getting blocks and transactions.
ESCC Endorsement system chaincode handles endorsement by signing the transaction proposal response.
VSCC Validation system chaincode handles the transaction validation, including checking endorsement policy and multi-versioning concurrency control.

Constructing Chaincode

Chaincode has two required imports; one for the shim and one for the peer, and a class that will function as the Chaincode class from the shim. This class is often empty and is passed in the main method to the shim as a Chaincode. The new Chaincode class requires 2 functions; an init function and an invoke function.

Init will be called once at the beginning, when the chaincode is created, and is used to declare any necessary information that must be present from the beginning

Any other function will have to be called through the **invoke** function, which takes the call and separates the arguments into function and arguments. For example, for query, the API would have to call invoke with two parameters; query and a name of an object. In invoke, it will check the first parameter and if it matches any other function in the chaincode, will pass the rest of the arguments into that class.

Each function has a return type of pb.Response, which comes from the peer protobuf, allowing for the API to get a readable response. Returns are in the form of shim.Success(payload) or shim.Error(error message), where any field that needs to returned is in the format of a byte array and passed inside the Success or Error.

The ledger is a key value store, where the key is a string and the value is a byte array. To write to this ledger, stub.PutState will be called with the parameters of key and value, and to read to the ledger, there is stub.GetState with parameter of a string key and returns the byte array value.

In golang, json.Marshal can be used to convert data into a byte array and json.Unmarshal can be used to convert this byte array back into readable format, but unmarshal isn't used too often because the data returned will often be of the byte array type.

Chaincode will be installed on the peers, and is currently just being installed on every peer, creating their own docker containers. Instantiation will occur once per channel and will be replicated throughout the chaincode containers. An important thing to note is that a call to ./fabric.sh up call will **NOT** recreate chaincode containers, so if any modification is done to the chaincode ./fabric.sh restart must be called instead.

To debug the chaincode, all print lines will show up in the docker container for that respective chaincode. First, call docker ps to get the list of all the containers, and find the chaincode container you're looking for (eg dev-peer1.gtn.example.com-mycc_go-1). Then call docker logs dev-peer1.gtn.example.com-mycc_go-1 to see all the print statements and errors.

To know more about chaincode:
http://hyperledger-fabric.readthedocs.io/en/latest/chaincode.html
http://hyperledger-fabric.readthedocs.io/en/latest/chaincode4noah.html?highlight=system%20chaincode

Hyperledger API walkthrough

1.Construct a channel

To create a channel, the sdk take a channelConfiguration file (channel_name.tx) generated by using the tool of configtx. This file contains the predefined channel information such as the memberships(MSPs), Consortium, Readers and Writers.

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*.

To subscribe to a channel, a Peer's certificate must be signed by 1 of the members authorized to the channel. The members authorized to the channel are encoded in a configuration transaction on the channel, starting with the genesis block. That is, the genesis block of every channel contains a configuration transaction.

By using SDK API, a Peer can be instructed to subscribe to existing channels. Access control on whom may join a channel is performed by the Orderers with the information given during channel creation or reconfiguration thereafter.

2. Install chaincode on a channel

Create an install chaincode proposal request providing the information of chaincodeID, chaincode file location, and chaincode version. Send the proposals to systemChannel and then the systemChannel will it send to all the peers on the channel. Note that only users with admin role privileges can install and instantiate chain code. MSP determines if someone has the admin role by doing a strict byte comparison with certificates found in the admincerts directory. For chaincode install, this is the local MSP and for chaincode instantiate, it is the channel MSP in the config block.
https://jira.hyperledger.org/browse/FAB-3752

3. Initiate chaincode

Every chaincode program must implement the Chaincode interface whose methods are called in response to received transactions. In particular the Init method is called when a chaincode receives an instantiate or upgrade transaction so that the chaincode may perform any necessary initialization, including initialization of application state. When initiating chaincodes, a chaincode deployer can specify that endorsements for a chaincode be validated against a specified endorsement policy. So different chaincode can have different endorsement policy by mapping with the chaincodeID.

4. Run the chaincode

A user can send proposals to a channel such as calling the method of invoke in chaincode. After getting the verified proposals, the chaincode on each peer will execute the program by the arguments passed in. For example, if we pass String[] args { "query", key} into the invoke chaincode, it will execute a query for the data with the given key stored on the ledger on the peer. Note that each peer has chaincode installed and each peer maintains it’s ledger under channel consensus. The orderer plays the role of maintaining the consensus of channel.

Working Report

Things we have done

- **Configurations:** Set up configurations for our Network of Network business case. The setting is for 3 orgs on one channel. Please refer to the section of CONFIGURATIONS in **README.md**

- **Chaincode for onboarding trading partners:** Implemented our chaincode interface in go language. In myCC.go file, we have defined our Init() and Invoke() methods, and also defined the data structure of each trading partner we will put into the ledger. In the generic method of invoke(), we have implemented functions of “add”, “addMember”, “query”, “getHistory”, “queryVerified”, “queryByRange”,“delete”, and “modify”.

- **Hyperledger API:** Tried to understand java-sdk by reading the sample test of End2EndIT and the codes in java-sdk. We have made our Hyperledger API for developers to develop an application easily. We made generic methods for different stages from constructing a new channel, installing chaincode to run the channel. In the End2EndIT test, it only has one org running on one channel. We have figured out how to bring three orgs on one channel. And we also made the API methods compatible with our customized chaincode(myCC.go).

- **Application UI**: Implemented the UI for the application. We used dropwizard for creating a simple web server that would be able to make calls to our Hyperledger API. The web pages themselves were created using HTML and JQuery, formatting was done using Bootstrap. Users log in as one of the three orgs and now have the option to add and query trading partners and connections. There is an additional “Other organization” section in the login screen for partners of the blockchain members. These other organizations can query the data but are not allowed to add a new partner.

- **Query Proposal:** We learned that unlike other methods in invoke(), a query proposal doesn’t need endorsement process. A user can send the query proposal to only the peers from the user’s org and obtains the data from ledger. The sdk differentiates the behaviors of query() and other methods like add()/edit()/remove() by the type of proposal it sends. So it doesn't matter that we have query() as one of the function in invoke() in myCC.go. The query proposal skips the endorsement process due to its proposal type (queryProposalRequest).

- **Transaction Proposal:** We tested a few things on Hyperledger and it turned out that the SDK doesn't help send transaction proposal requests to the right endorsing peers. It only checks the number of signatures for this tx defined in endorsement policy. That's why we are sending the proposal to all the peers on channel for now. We wonder if there's a method in SDK that help to connect to as many peers as are required by the endorsement policy for the chaincode.

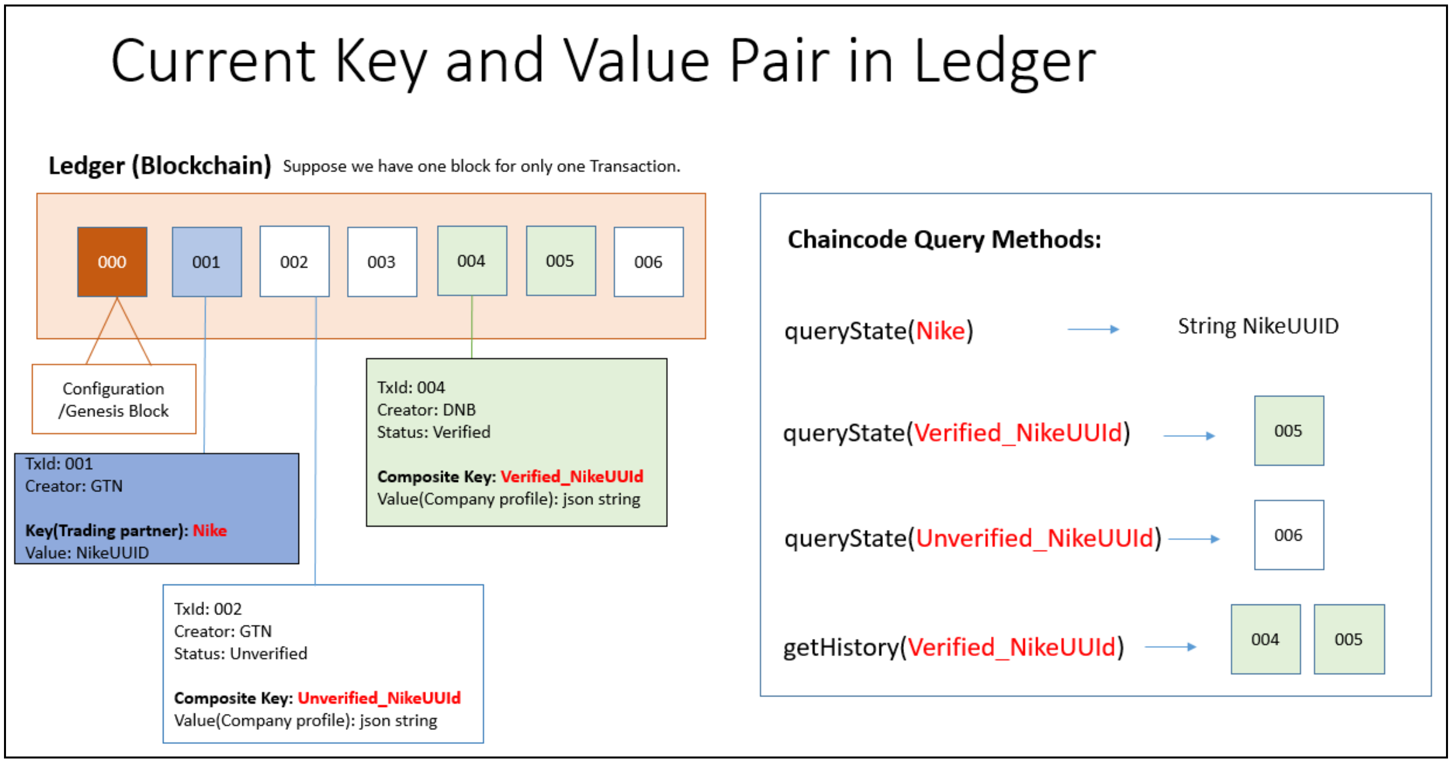
- **Implement getHistory(key**): We implemented the method of getting the transaction history of a given key in our chaincode.go(myCC.go). Hyperledger provides a chaincode method of getHistoryForKey(key string) documented in interfaces.go. It returns a history of key values across time (HistoryQueryIteratorInterface, error). By using the HistoryQueryIteratorInterface, we can access TxId, Value, Timestamp, state of IsDelete of each transaction in chronological order.

- **BlockListener**: We created a class of NetworkBlockListener which implements BlockListener in java-sdk. We used channel.registerBlockListener() in our java application for setting up a blockListener to receive blockevents whenever an eventHub on channel receives a new blockevent. Fabric committing peers provides an event stream to publish events to registered listeners. As of v1.0, the only events that get published are Block events. A Block event gets published whenever the committing peer adds a validated block to the ledger. In NetworkBlockListener, we implemented the method for reading block information and provide output. The next step would be trying to initiate a transaction based on the events we read in current block.

- **Chaincode for verifying input data:** Currently, after the channel and chaincode have been created, each user is registered in the ledger by their certificates and roles. The two roles are Network Provider (ntp) and Data Oracle (oracle). In our scenario, GT Nexus and Elemica are Network Providers because they are entering data into the ledger and Dun and Bradstreet is an oracle because they are the ones who are verifying data. Any future transactions will now check the user context of the transaction to see who is the creator. If the creator is a NTP, then the data they enter is unverified, and only data entered by an Oracle can be considered verified. All unverified data is stored as a separate key so oracles can quickly search through them to find which data they need to check and verify.

- **Chaincode for Connections:** In the connectionCC.go file, we have methods similar to that of the myCC.go, with an empty init function, and add and query in the invoke function. Adding is slightly different where all the keys are now composite keys with both of the connections placed in the key so it would be easier to search. Query now will also return all the connections with the key searched instead of only one result.

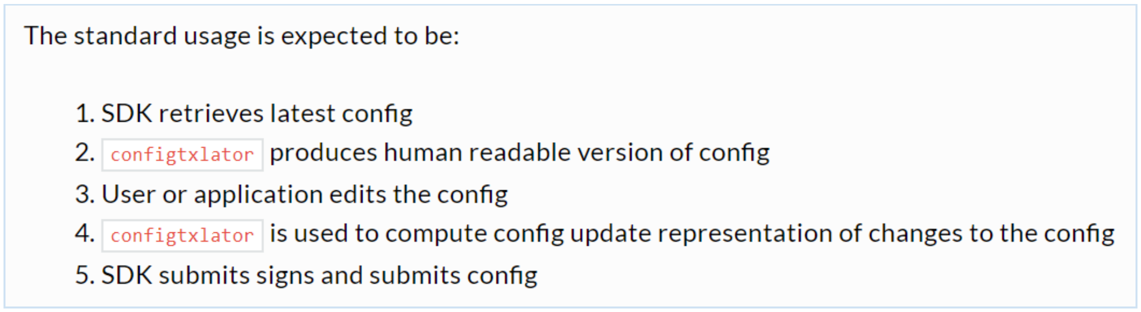
- **Data Storage Model:**


Current Key and Value Pair in Ledger
Ledger (Blockchain) Suppose we have one block for only one Transaction.
000
001
002
003
004
005
006
Configuration /Genesis Block
TxId: 001
Creator: GTN
Key(Trading partner): Nike
Value: NikeUUID
TxId: 002
Creator: GTN
Status: Unverified
Composite Key: Unverified_NikeUUId
Value(Company profile): json string
TxId: 004
Creator: DNB
Status: Verified
Composite Key: Verified_NikeUUId
Value(Company profile): json string
Chaincode Query Methods:
queryState(Nike)
String NikeUUID
queryState(Verified_NikeUUId)
005
queryState(Unverified_NikeUUId)
006
getHistory(Verified_NikeUUId)
004
005

When a new partner is added to the ledger, a UUID (universal unique identification) string is generated and assigned to this partner. Depending on the role of the creator, a composite key of VerifiedUUID or UnverifiedUUID is created and the trading partner is stored as the value for that key. Each trading partner will have a metadata class with their UUID in the key (metadataUUID) which will contain the name of the class for the unverified data. When a query command comes in, the ledger searches for the UUID of this name and then looks only for a verified version of this partner. Currently, only oracles are allowed to look at the unverified data and they have an option to view all of the unverified data in the ledger. This call with search the composite keys for those which have a prefix of Unverified and return their data in a large json array. Get History will return all the changes to the verified version of the key that is entered.

Things under testing/studying

- **Updating channel configuration to bring new orgs onto channel.**



The standard usage is expected to be:

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

We have tried using the tool of configtxlator to provide a write_set (steps 2 to 4). We found that there is no method in the current SDK that supports retrieving the latest config from a channel. We expect java-sdk will support this feature in the future (see Jira issues below) and will keep following up with it.

After consulting with a Hyperledger-Fabric developer *@jeffgarratt* at Hyperledger developer discussion channel, we were informed that in step 5, the submitter of the TX would have to have current write rights on the channel, and the signers of the TX envelope would have to be based upon the mod_policy of the application group, which commonly is ALL. Meaning a meta policy that represents the signature of the channel config admins from each organization currently in the channel. Refer Update Channel Documentation

Reference of how to use configtxlator:
http://hyperledger-fabric.readthedocs.io/en/latest/configtxlator.html
Jira issue- No means to get channel config bytes for update:
https://jira.hyperledger.org/browse/FAB-5368
Jira issue- Missing channel upgrade method:
https://jira.hyperledger.org/browse/FAB-5408

- **Revising the endorsement process**
Endorsement currently works as in when a peer executes a transaction and it does not throw an error, it is considered endorsed and the peer will sign this transaction. For a business scenario, we would like to be able to check the data

before we decide we endorse it, for example if we accidently put “Beaverton” as a zip code, the system would note that this not of a format which is accurate and not endorse this transaction.

- **Setting up the Fabric network with peers on different machines**
  Early attempts were to continue using the docker containers and to move on to using Docker Swarm, which would allow docker containers on different hosts to talk to each other. However, docker swarm is not compatible with our version of docker, and does not understand the “extends” keyword of our docker compose files.

- **Checking errors from the chaincode**
  Currently, when an error is thrown from the chaincode, it often has a string with helpful debugging advice. However, we are only getting the payload of the chaincode and that does not include the payload of error messages so we currently are not checking the errors from the UI and instead have to check console or docker containers for these error messages. In an ideal scenario, we can have the error messages being sent back to the UI to provide a useful notice to the user.

- **Importing golibs on the chaincode peers**
  Currently our version of creating a uuid is using a math/rand to generate a string of length 16 where each character is a random number between 0-9. An optimization would be eventually to use an actually golib for generating a UUID. One of the issues with our current docker container is that it doesn’t see the gopath of the localhost so it doesnt have the libraries for the UUID libraries.
  https://www.youtube.com/watch?v=-mlUaJbFHcM

Questions to be followed up

- How can we do a more complicated endorsement process with our business case requirements?
    - We have created an endorsement system through chaincode, where after every query, the payload would invoke another chaincode, which could be specified per organization. This second chaincode would look at the data and determine if this data should be approved or rejected.
    - However this system would still be inside the network. Ideally, we'd like it to be endorsed by an outside party, maybe even a human user

- We wonder if there's a method in sdk-java that helps to connect to as many peers as are required by the endorsement policy for the chaincode? (So we don't have to always send the transaction proposal request to all the peers on channel)
- As of now, we currently need to constantly recreate peers and restart the network anytime we make a change or if the network goes down. Is it possible to eventually have the database and docker containers to persist when the network goes down so we can avoid having to do fabric.sh up every iteration?

Resources

Hyperledger Developer Discussion channel

Hyperledger fabric-adk-java

Hyperledger Fabric online document

Hyperledger chaincode.go

Godoc for chaincode shim