POC REPORT: Distributed Ledger Technology Application for Renewable Battery Value Evaluation in the IoT

China unicom 中国联通

萬向集團 WANXIANG GROUP

Produced by China Unicom and Wanxiang Group
Supported by the GSMA

About China Unicom

China United Network Communications Group Co., Ltd. ("China Unicom") is the only Chinese telecom operator listed on the stock exchanges in New York, Hong Kong and Shanghai. It has been listed in Fortune 500 for ten consecutive years, and ranked the 273rd in 2018. China Unicom owns a modern communications network covering entire China and linking the world. It has been actively pushing forward broadband-based fixed and mobile network development, and providing comprehensive and high quality information and communications services to the wide users. China Unicom has officially released the brand logo for 5G - '5Gn'on April 23th 2019, focusing on the theme 'Grow into the Future'.

For more information, please visit the China Unicom official website at http://www.chinaunicom.cn.

About Wanxiang Group

Wanxiang Group was founded by Lu Guanqiu in 1969. At the beginning, it was only a small agricultural machinery Repair shop, with 50 years development, it is now an international diversification group with a revenue of over 100 billion and a profit of over 10 billion. Representing one of the leading enterprises in the industry, Wanxiang Group has its main business in automotive components manufacturing and sales. In 1999, Wanxiang Group began to set foot into the clean energy industry, including battery, electric vehicle, natural gas power generation, wind power generation industries and achieve great successs.

About GSMA

The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators with almost 400 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces the industry-leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

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Introduction

The GSMA IoT programme is mandated by a steering group of operators with the purpose of making the IoT more successful for the whole ecosystem. One of the tasks for the GSMA IoT programme for this year (2019-2020) is to identify the benefits and opportunities of combining blockchain or Distributed Ledger Technologies (DLT) in general. In this document, the name of Distributed Ledger Technologies is adopted with the Internet of Things (IoT) by launching related industrial blockchain Proof of Concepts (PoCs) to evaluate these technologies and their benefits. Under the GSMA IoT programme, China Unicom Network Technology Research Institute (CUNTRI) initiated a PoC together with Wanxiang Research Institute (WXRI), Wanxiang Blockchain and the GSMA in order to evaluate DLT application into IoT scenarios. The specific application scenario of the PoC is the application of DLT to the evaluation of the value of new energy batteries.

Blockchain and Distributed Ledger Technology is widely seen to be an important new platform capability to revolutionalise key processes, particularly where there is an involvement or interest from stakeholders from different organisations. Distributed Ledgers also add confidence to those processes by providing an immutability to the data stored, as well as a confidence regarding the authenticity of data by combining strong cryptographic techniques and strong methods of determining the consistency of a ledger replicated or distributed across multiple nodes. China Unicom, Wanxiang research institute and Wanxiang Blockchain have an ambition to partner with industrial businesses in China to help those businesses deploy blockchain / distributed ledger solutions.

This document describes the processes for establishing a blockchain / distributed ledger network working across multiple organisations. It can be used as a reference by those businesses wanting to establish a blockchain deployment, and also shows the experience that China Unicom and her partners can add to delivering a multi-organisation blockchain / distributed ledger network.

There are seven nodes provisioned in this PoC. Four nodes (including one ‘genesis node’) are set up by Wanxiang Research Institute. One node is set up by Wanxiang Blockchain. Two nodes are set up by CUNTRI.

Blockchain technology is provided by Wanxiang Blockchain. Application scenarios and business requirements are provided by Wanxiang Researc Institute. The overall technical scheme is jointly determined by Wanxiang Research Institute and China Unicom Network Technology Research Institute. The performance of PoC system was evaluated by Unicom Network Technology Research Institute. The GSMA provides necessary DLT technical advice and POC project management.

In this document, we summarise the experience obtained from the PoC, especially, describing how to build a ‘consortium’ blockchain and some of the problems encountered and learnings gathered.

PoC parties: China Unicom Network Research Institute, Wanxiang Research Institute, Shanghai Wanxiang Blockchain Inc., GSMA.

1. Main Findings of the PoC

1.1 DLT has the basic conditions for business operations

In the PoC, the process of creating a distributed ledger node is easy, including three steps:

1. Generating certificates;
2. Creating nodes;
3. Adding the node to the list of DLT (Distributed Ledger Technology) nodes while running the newly created node. The whole operation only takes about an hour.

With an hour deployment time taken, the DLT platform used by this PoC has the basic conditions for business operations. In order to have the service capability at the operator level, it is also needed to consider firewall settings, platform patching, monitoring, node network administration and so on, which are not covered by the PoC this time.

It should be noted that the precondition of implementing the above three steps is to prepare the deployment environment of DLT nodes in advance. Chapter 5 of this document gives an example of the actual deployment environment of a node in this PoC.

1.2 Network performance plays an important role for efficiency of node consensus

In the PoC, it is observed that some Nodes are seen to create blocks normally, but rarely participate in consensus. In order to express conveniently, we call the nodes that rarely participate in consensus as “blunt nodes” and the nodes with high probability of participating in consensus as “agile nodes”.

By comparing the parameters of deployment environment, it is found that under the condition that the node has absolute advantages in computing power and storage capacity, it is possible for the node to become a “blunt node” just because of the difference in network speed. Because before reaching consensus, there is a large amount of data need to interact between nodes, including transaction information, block synchronisation, consensus information and so on. Slow network speed means that nodes spend more time in the process of block synchronization, consensus and acquisition of new transaction information. The result of time-consuming is that the nodes are slow in processing and have little chance to participate in consensus, thus becoming “blunt nodes”.

In each consensus, the speed of reaching consensus between “Agile Nodes” is faster than that between “Agile Nodes” and “Slow Nodes”. If more than two-thirds of the nodes in a distributed accounting system are “Agile Nodes”, then “Agile Nodes” will reach consensus earlier than “Slow Nodes”. In this PoC, the network speed of the CUNTRI node is much lower than that of the WXRI node, so it seldom participates in the consensus and becomes a “blunt node” (only when one or some “agile node” goes down will the CUNTRI node have the opportunity to participate in the consensus).

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The configuration of the nodes of CUNTRI and WXRI is shown in table 1.

NODES	NETWORK SPEED	NETWORK SPEED COMPARISON	CPU	CPU COMPARISON	MEMORY	MEMORY COMPARISON	CONSENSUS EFFICIENCY
WXRI	40G/S	High	2 cores	low	8G	low	high
CUNTR	2MG/S	Low	4 cores	high	16G	high	low

Table 1 Configuration Parameters for some PoC nodes and related comparison

Based on this discovery, we have reason to believe that a high-quality DLT network needs reliable and high-performance network infrastructure support. China Unicom is willing to cooperate with the players of the DLT platform to help the development of the DLT business.

1.3. Beyond network connectivity potential service opportunities for operators

It is found that a large number of log files are generated during the running process of nodes, and can result in full disk storage. If local disk isn’t large enough and/or the number of transactions is high, local disk overflows occur.

In the PoC, the node adopted MPT (Merkle Paricia Trie) data structure and stored data locally through LevelDB. The LevelDB storage engine is limited by the local disk size. When the volume of business increases, the data is bloated, compounded by immutability of the blockchain. Most blockchain platforms in the industry face similar problems though using distributed databases / sharding can help. MPT enables lightweight clients and data traceability. In terms of performance, MPT State immutability has a natural disadvantage, the process ensures extreme provability and traceability, but makes some compromises on performance and scalability. So if MPT is adopted, it is suggested to clean up disk space regularly and delete dated logs in time.

To solve disk overflows, later the PoC uses AMDB (Advanced Mass Database). The data read and write requests do not go through MPT, but directly access the storage which can also be distributed across multiple MySQL database instances. Combined with the caching mechanism, the storage performance is greatly improved compared with the storage based on MPT.

Based on this observation, for operators, there may be a great market opportunity for them to cooperate with Block Chain Platform Providers to provide customers with services, including but not limited to, Block Chain Platform log file size monitoring, log file migration, as well as storage and network resources support.

2. Introduction on the Application Scenarios

"Renewable" (also "green" or electrically powered) energy vehicle is an important trend in recent years. People are paying more attention to the development of renewable energy vehicles. Environmental protection is a topic of growing interest as governments and individuals attach importance to environmental protection. China has a booming market for renewable energy vehicles, encouraged by national policy. The main parts and power batteries of new energy vehicles are in great demand (power batteries includes cells, modules, packages, and so on.). At the same time, battery production supply and demand for raw materials also means that there is an increasing use for related scrap material, which means battery recycling and reuse is an important topic on the agenda. It is estimated that about 100 million kilowatt hours of lithium batteries will enter the automobile market in the year 2025 alone, with cars equipped with an average of 20 kilowatt hours of batteries, and an estimated annual production exceeding five million cars in 2025 based on the current development rate of electric vehicles in China. It is therefore of great importance for enterprises to deal with the post-electric vehicle market, facilitating reasonable recycling and repurposing of 'retired' batteries removed from electric vehicles.

Currently the main cost of battery recycling or reuse is based on testing the performance of battery modules due to the unknown condition of the battery. Battery recycling / reuse enterprises need a lot of manpower, material resources, test equipment and financial resources to evaluate the residual value of battery modules. It has been learned that the main parameters to evaluate the reclamation or reuse value of the battery are the number of charges and discharges that the battery had been subject to at the time of leaving the factory and the number of charges and discharges that the battery has been subject to during the period from leaving the factory and entering the recycling/ reuse facility. Currently any records relating to charge / discharge cycles are stored by the battery manufacturers and new energy companies/charging pile companies. Because there is no authoritative and automated system to record the battery charge/discharge data there is a lack of trust in any records by battery recycling companies therefore the cost of handling 'retired' batteries is greater than it should be leading to a less efficient and effective reuse and recycling market. It is intended that through this Proof of Concept it is possible to demonstrate that trustworthy records can be maintained to provide independent proof of the authenticity of battery usage records, endorsed by the immutability of the DLT. It is convenient to use the authenticity of these two trusted parameters (i.e. battery charge/discharge data) to evaluate the reclamation or reuse value of the battery without passing the complex battery module performance test, thus reducing the cost of battery recycling.

3. Nodes Deployment in the PoC

3.1. Nodes of the PoC

In the PoC, a consortium blockchain is setup by 7 nodes, as shown in figure 1. Each node can participate in data consensus, accounting, data verification (for the data stored on the DLT) and other related activities based on consortium blockchain technology. WRI can verify the correctness of 'off-chain' battery charge/ state information based on the cryptographic hash data which is stored on the DLT.

The relationship between DLT platform and the business platform is shown in figure 2.

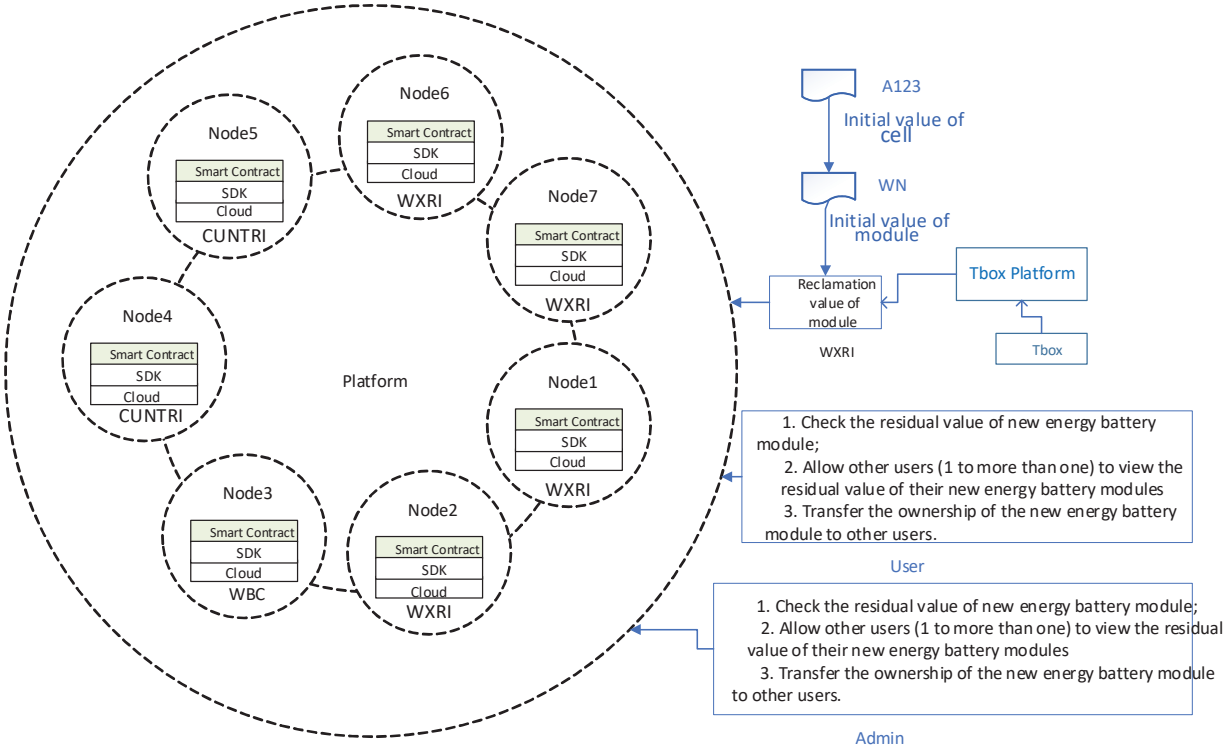

Figure 1 PoC nodes

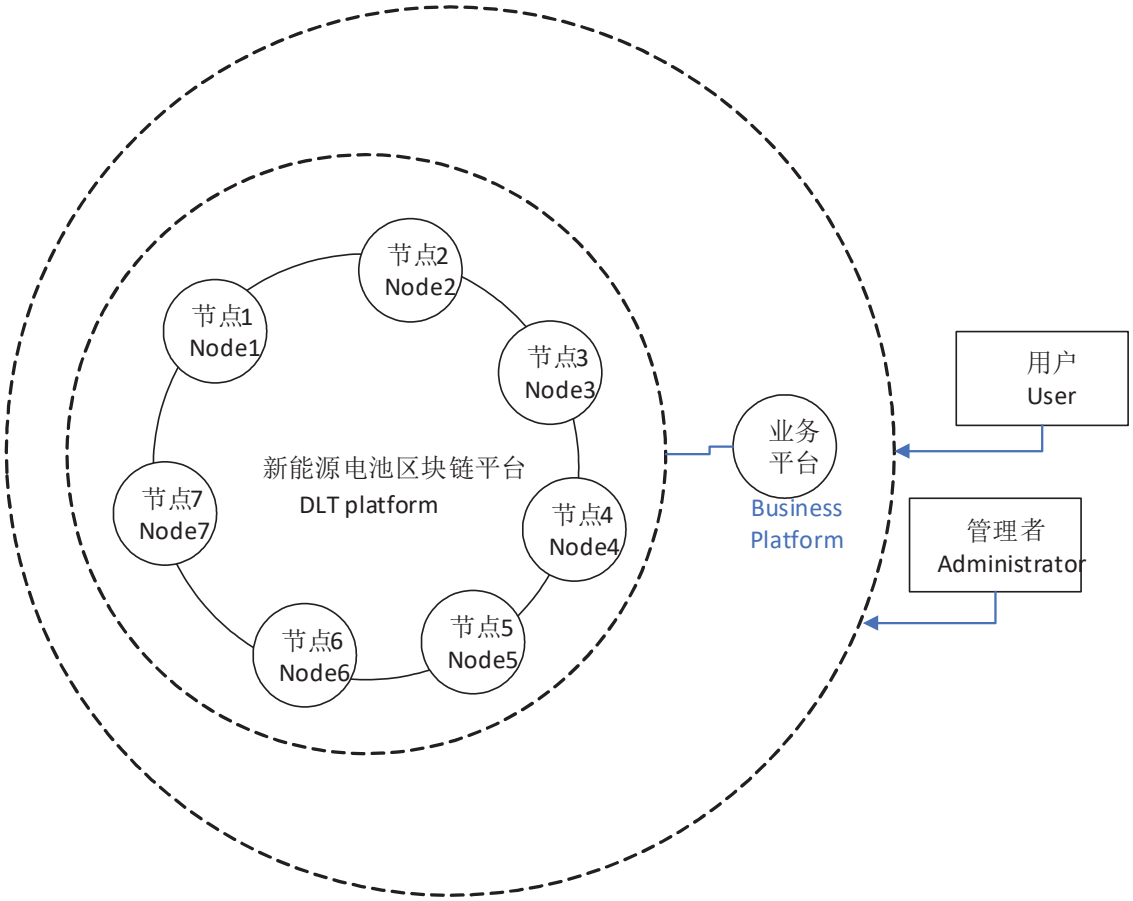

Figure 2 DLT platform and business platform

3.2. Node deployment flow

The proof of concept project uses DLT (Distributed Ledger Technology) to make enterprise data traceable and 'tamper resistant'. We have built a 'blockchain' based on an open-source framework to store 'check' information that can be used to verify externallystored information about battery modules deployed in electric vehicles. As this project is designed for use by private organisations each node of the chain usually has an entity organisation corresponding to it, it can only join and exit the network with specific authorisation, and each organisation can form an alliance with relevant interests to jointly maintain the healthy operation of the blockchain. Therefore, the type of blockchain built this time is a consortium blockchain. The blockchain is operated by three parties, namely Wanxiang Research Institute[5], China Unicom Network Technology Research Institute and Wanxiang Blockchain[6].

The open source framework supports both Raft and PBFT (Practical Byzantine Fault Tolerance[7]) consensus mechanisms, both of which enable consortium blockchains and PBFT has been used in this case study. As outlined above PBFT recommends that the total number of nodes n>=3f+1(where, f represents the number of potentially 'evil' nodes[8]).

[5] http://www.wanxiang.com.cn/en/index.php/service

[6] http://www.blockchainlabs.org/index_en.html

[7] See https://blockonomi.com/practical-byzantine-fault-tolerance/

[8] Being either nodes that might malfunction or which are under the control of malicious actors

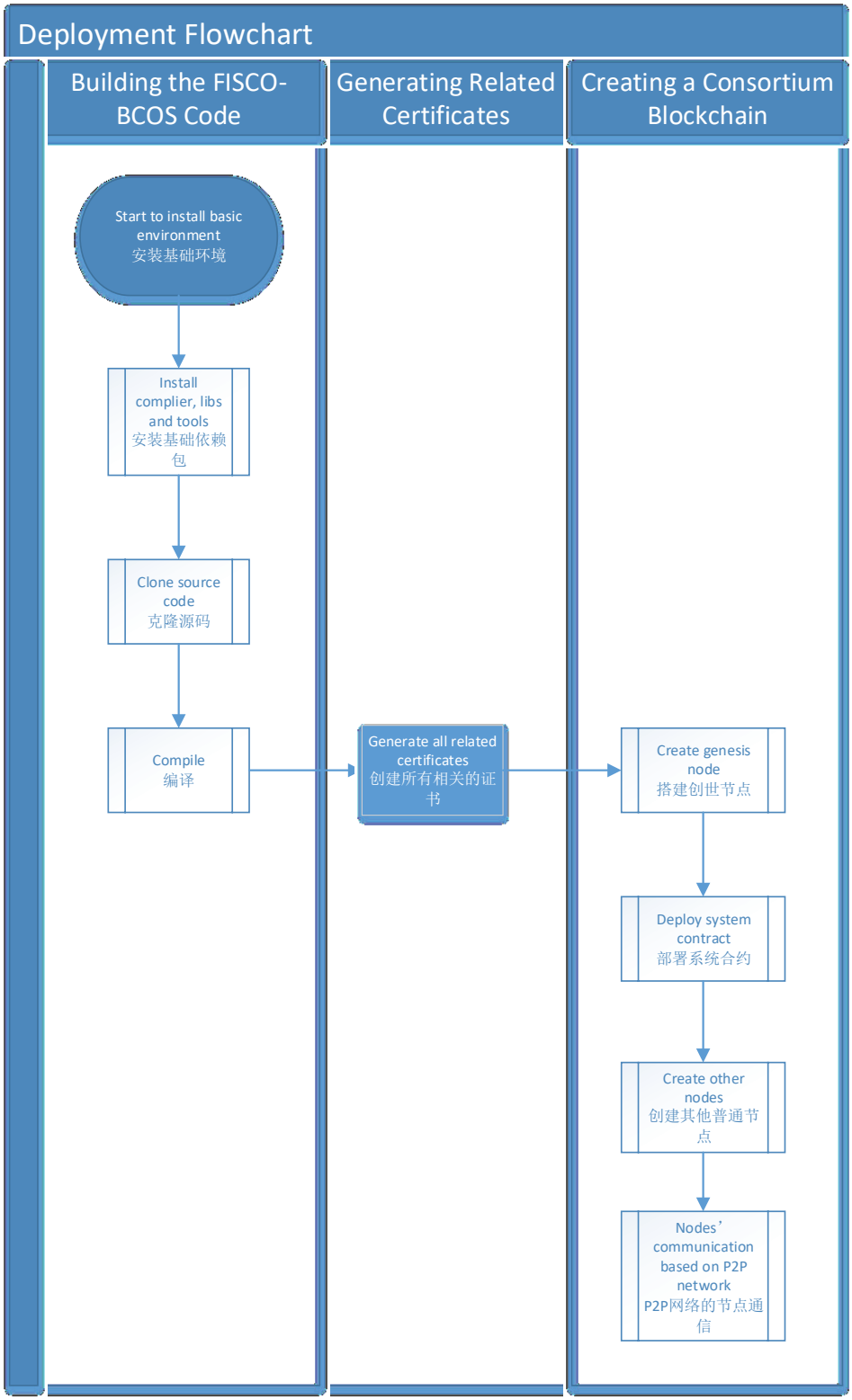

Figure 3 Deployment flowchat

4. Creating a Consortium Blockchain

4.1 Create Genesis Node

The first step in deploying a consortium blockchain is configuring and running a “genesis node”. As indicated above the genesis node maintains membership information about the other nodes forming the consortium. Provided there are more than two thirds of nodes behaving honestly the network can tolerate an outage of the genesis node.

The genesis node in this project is deployed by Wanxiang Research Institute, agreed through consultation of all sides.

4.2 Deploy System Contract

The system contract is an important feature of the PoC DLT platform. It is a group of built-in smart contracts. System contracts reach consensus by all members to control the running strategy of the chain. Adding or deleting nodes is achieved using an implicit node management contract and an institution certificate contract. The node management contract and institution certificate contract are two kinds of system contracts that serve to support the consortium model. Once deployed and enabled, generally, a system contract will not be changed. If you have to change or update a system contract, first it will be necessary to get approval from all the nodes in the network, then update the systemproxyaddress field in the config file, and restart.

4.3 Create Other Nodes

Nodes of a blockchain share the same genesis block file (genesis.json) and root certificate public key file (ca.crt). The process to deploy additional nodes is very similar to the process of deploying the original genesis node. The main difference is that for non genesis nodes there is no need to create/ modify genesis.json or the public key certiticate (ca.crt) generated by the genesis node.

China Unicom is responsible for deploying two nodes in this PoC.

4.3.1. Setup Node Environment

China Unicom chose to deploy blockchain nodes using Alibaba Cloud hosting. The two nodes built by China Unicom are located in the following two paths of Alibaba Cloud server ESC:

/China-Unicom-node0
/China-Unicom-node1

It is necessary to create three folders in each directory:

- ➔ the “data” folder holds the node certificate files, these are manually provisioned which need to be manually configured.
- ➔ the “log” folder holds logs which are generated by the system.
- ➔ the “keystore” folder to store accounts and keys which are generated by the system. Eg: New node’s directory is “/China-Unicom-node0”, and the command lines are as follow:

```
#Create directory structure
$ mkdir -p /China-Unicom-node0/
$ mkdir -p /China-Unicom-node0/data/ #store node files
$ mkdir -p /China-Unicom-node0/log/ #store logs
$ mkdir -p /China-Unicom-node0/keystore/ #store keys

#copy files from the genesis node
$ cd / directory of genesis node
$ cp genesis.json config.json log.conf start.sh stop.sh /China-Unicom-node0/
```

4.3.2. Start Up the Node

The operation of the node depends on the following files. Before starting, it is necessary to confirm that the files have been configured and installed correctly:

Certificate files /China-Unicom-node0/data ca.crt, agency.key, agency.crt, node.crt, node.key, node.private.

Configuration files /China-Unicom-node0/ genesis.json, config.json, log.conf.

Network files /China-Unicom-node0/data bootstrapnodes.json It is necessary to modify two parameters.:Genesis node’s IP and Peer-to-Peer port .

4.4. Peer-to-Peer Communication

Nodes can communicate with others after they have been configured for the peer to peer network access. In a Peer-to-Peer network there is a decentralized communications model in which each party has the same capabilities and any party can initiate a communication session. Therefore it is also important to configure any required firewall rules to permit access for external applications and peer to peer communications. Registration procedures are all the same for every nodes. Register genesis node first, then the other nodes. Make sure all the registered nodes have been started before registration.

Long lived TCP connections can be initiated and maintained automatically between blockchain nodes, and reconnection can be initiated automatically in case of system failure or network abnormality. The node certificate will be used for authentication when nodes establish connection and the chain certificate will demonstrate nodes are members of the same blockchain. The process for building connectivity between nodes is as shown in figure 4.

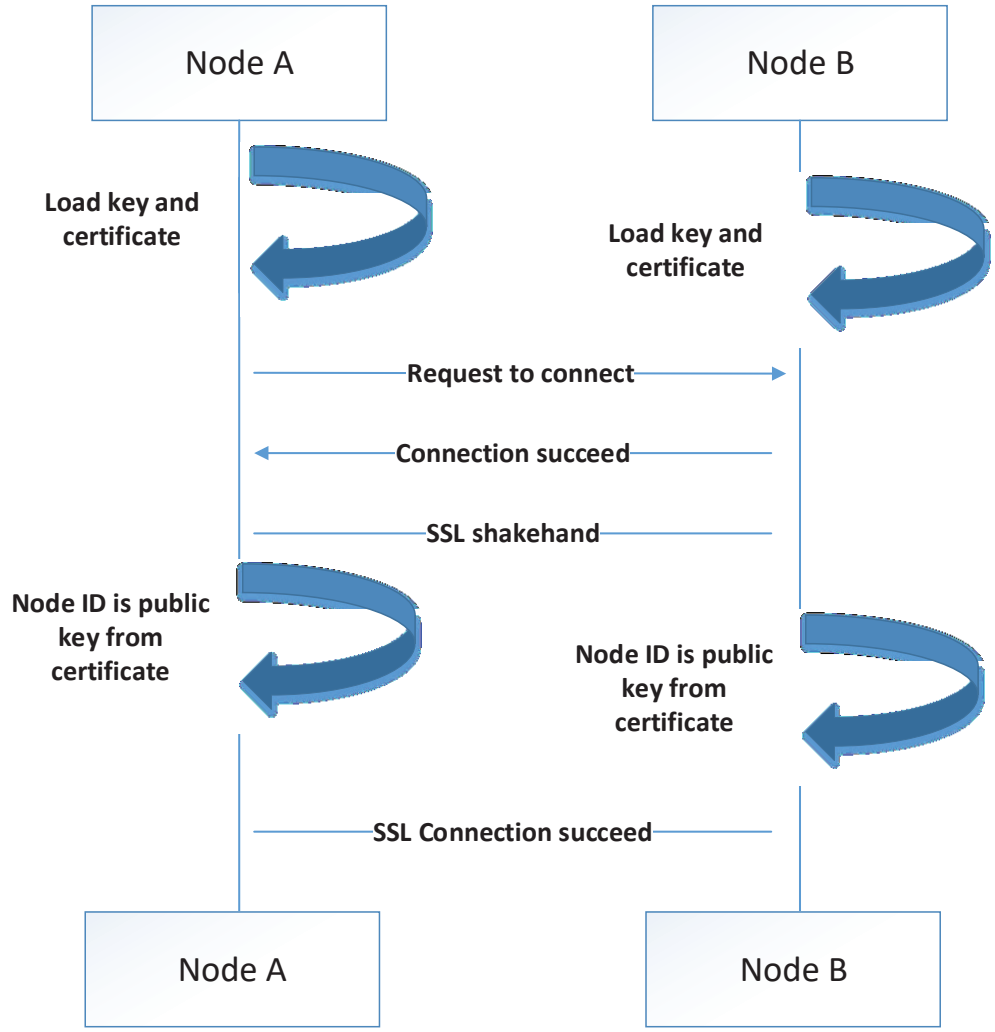

Figure 4 The process for building connectivity between nodes

Figure 5, below, shows a trace of the information about each node forming the whole consortium blockchain. Nodes 4 and 5 are two ordinary nodes built by China Unicom Network Research Institute.

```
[fbcos2@fbcos2 systemcontract]$ babel-node tool.js NodeAction all
{ HttpProvider: 'http://127.0.0.1:8545',
  Ouputpath: './output/',
  EncryptType: 0,
  privKey: 'bcec428d5205abe0f0cc8a734083908d9eb8563e31f943d760786edf42ad67dd',
  account: '0x64fa644d2a694681bd6addd6c5e36cccd8dcdde3' }
Soc File :NodeAction
Func :all
SystemProxy address 0x07536360c0fb65721d55339dde0528be9d97f886
NodeAction address 0x792b33395199425ae6cdf703439541a3e83cd32d
NodeIdsLength= 7
----------node 0---------
id=378549e87c36613902eef2a39cf2e6d00c66f4e9be50683c094bffed2f0a4729338a7f90533d6fcccf23a898b26cc560a724bcd38c8ca8d3
bcb461c2d427594b
name=wxr-nodedata-1
agency=POC
caHash=EA9CC68F8EF3E3E6
Idx=0
blocknumber=59
----------node 1---------
id=ca67bad9e742629ebcecffc4180d6f01de138532d45fe34dfacbaf54d97f6644d975a271a41e7f993a44347bea0f41f0c46c61b878e7c3fe
a27e72077fd97dd3
name=wxr-nodedata-2
agency=POC
caHash=EA9CC68F8EF3E3E7
Idx=1
blocknumber=60
----------node 2---------
id=b11adc7ace0db091c4f3fef6192892373e41b76f63164b093974daa2c36cd67610cfebb5d0ce0751079659037324fad5aca35f0951a16c48
9fb6371d2c11a7dc
name=wxr-nodedata-3
agency=POC
caHash=EA9CC68F8EF3E3EB
Idx=2
blocknumber=61
----------node 3---------
id=4878b6456c57fd647de48538e8c60e1acc75ffe78b424181018334852146ca10a1c58675a6746060c1b835005081a98550adb4d10026d7a5
2a2b27c167c2ad34
name=wxr-nodedata-4
agency=POC
caHash=EA9CC68F8EF3E3EC
Idx=3
blocknumber=62
----------node 4---------
id=b2e36d2ec19b6e33af055c07d48123efb39c471ad74ffbb42ba118eed160658499f32e5fc1fd2b48e951230c44ece38722636e7d16b51540
faa58480513403cc
name=China-Unicom-node1
agency=POC
caHash=EA9CC68F8EF3E3E9
Idx=4
blocknumber=63
----------node 5---------
id=86e98a8dd9d791684d885fac8fa32959b4f490e024871030744df3e928f4c46a4fdc5d54ef35d5f66d665732d5ec90870afe68514c957451
a9e40de4eec05b78
name=China-Unicom-node0
agency=POC
caHash=EA9CC68F8EF3E3EF
Idx=5
blocknumber=66
----------node 6---------
id=cb07a3c948b06b825d28984eef83fe50a55053cb9330c759f9e480574c5c9aec7a7e9cbc7004022e9c29ba670f33fd39c604d93fc277486a
f7c187ea8ac11775
name=WXBC
agency=POC
caHash=EA9CC68F8EF3E3F0
Idx=6
blocknumber=67
```

Figure 5 Node information on the whole block chain

4.5. Delete Nodes

Like adding a node, deleting a node also uses the node management contract within the system contract to unregister the node. If a check is subsequently made for the node registration, there will be no information about the cancelled node. The node has been removed from the network.

The DLT platform administrator controls the access mechanism of nodes by certificates. Only authorized nodes with valid certificates can communicate with other nodes. The DLT platform provides a tool for administrators, they can either register specified certificates to the revocation list of certificates to prevent specified nodes from accessing the DLT network, or nodes can be re-enlisted by removing specified certificates from the revocation list of certificates to permit those specified nodes to access the DLT network.

5. Actual Deployment Environment

There are multiple deployment environments used in the practice. The following table shows the configuration for one selected node of the PoC as an example to detail what our actual deployment environment is.

CONFIGURATION INFORMATION	
CPU	4 Cores
Memory	Optimized I/O
Type of instance	Ubuntu 14.04 64bit
Operation System	2Mbps
Network Bandwidth	51GiB
Data Disk Size	640GiB

Table 3 Actual Deployment Environment