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Model Checking the Reliability of Blockchain-based Edge Computing Network

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***Abstract*—In recent years, the development of blockchain and edge computing is very quickly. Compared with centralized cloud scenario, edge computing help to improve the efficiency of it. The end devices can undertake some of the work load to reduce the pressure of centralized cloud devices. Blockchain technology help to enhance the security of the whole network, and it is also an emerging technology. However, the reliability of blockchain-based edge computing network (BBECN) is still a challenge, few of the recent research focus on the reliability evaluation of it. To make up the research, in this paper, a continuous-time Markov chain (CTMC) model is proposed to calculate the reliability of BBECN. In this paper, 4 experiments are proposed to evaluate the influence of different influence factors and compare them. The research work of this paper will help to optimize the architecture design of BBECN .**

Keywords-edge computing;blockchain; cloud computing; CTMC;

I. INTRODUCTION

In the last few years, the the development of BBECN is very fast. Many governments gave policies to develop the 2 technologies. In China, the government also pay great attention to the 2 technologies. For edge computing, compared with centralized cloud scenario, edge computing help to improve the efficiency of it. The edge devices can undertake some of the work load to reduce the work load of centralized cloud devices.According to [1], edge computing can make the whole network works more efficiency. Now edge computing technology have been used in many areas, for example, healthcare[2], factories[3], smart home[4] and smart grid[5]. According to these use cases, edge computing has become a hot research topic now.

Blockchain technology help to enhance the security of the whole network[6], and it is also an emerging technology. Compared with centralized cloud scenarios, the security of blockchain network is much better and the data is well protected.Blockchain also have been used in many areas, for example, healthcare[7], factories[8], finance[9] and smart home[10].According to these use cases, blockchain also has become a hot research topic now.

Blockchain and edge computing has many advantages, however the reliability research of BBECN is still not enough.Some of the scholars focus on the efficiency of blockchain[11]. Some of them do research on the security of blockchain. The research works about the research evaluation of BBECN is not enough. If the reliability of the BBECN can be calculated before design, the design can be optimized and save the cost, this is very meaningful.

To make up this research, in this paper, CTMC model is proposed to calculate the reliability of BBECN. The consensus mechanism of blockchain network is Practical Byzantine Fault Tolerance (PBFT).In this paper, 4 experiments are proposed to evaluate the influence of different influence factors and compare them. The research work of this paper will help to optimize the architecture design of BBECN .

The paper will be organized below: in section 2, the architecture and the components of BBECN will be given. Section 3 will show the modeling process of BBECN. Section 4 will give the experiment results and the results will be analyzed. Then the optimize strategy will be given. Finally, the conclusion and further research will be introduced.

II. ARCHITECTURE OF BLOCKCHAIN -BASED EDGE COMPUTING NETWORK

In this chapter, the architecture of the BBECN will be introduced.The common architecture of blockchain-based edge computing network includes 3 components : end devices, edge devices and cloud devices. The functions of each component is shown below:

End devices: usability include IoT devices like sensors or wearable devices. the end devices can upload sensed data to the edge computing devices.Then wait for the command from edge devices and execute the commands.

Edge devices: the edge devices help to reduce the work load of centralized cloud server. A part of the data can be undertaken by the edge devices.

Cloud servers: for some important data , they should be uploaded to the cloud server, the cloud servers give command to the edge computing devices, then the edge devices pass the command to the end devices.

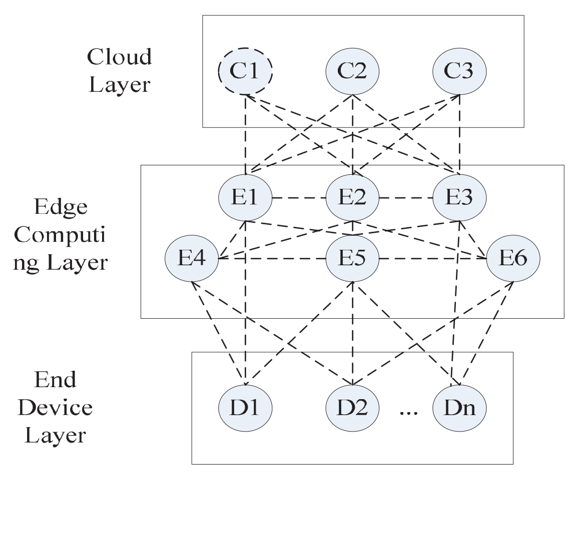

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Figure 1. Typical architecture of blockchain-based edge computing network

The typical architecture of BBECN is shown in Fig.1. The meaning of this architecture shown below:

- C1,C2 and C3 are cloud servers, they can deal with the data uploaded by edge computing layer.
- E1,E2 to E6 are 6 edge devices, also the 6 edge devices can communicate with each other for blockchain consensus mechanism. If the data need to be recorded by blockchain network, the communication is between each other is essential.
- D1 to Dn are end devices, for example , sensors and smart watches, the duty of them is upload data and receive commands.

For cloud computing layer, the workload make it should ensure enough workable devices. Due to cloud actually should deal with most part of data, so in this paper , we think 2 cloud devices should be workable in normal case. For edge computing layer, according to PBFT consensus mechanism, at least 2/3 nodes should be workable, so in this paper, the minimum limit is 4.

III. MODEL PROCESS

In this paper, a CTMC model is built to calculate the reliability of the BBECN. A model checker PRISM can be used to construct the CTMC model. The modeling process is illustrated as follows:

Cloud Layer Module: The initial value for cloud layer is 4 (means all cloud devices are available). If the cloud devices fails with a failure rate "lambda_cl", "cl" will minus 1 (means available cloud devices minus 1). The code for cloud layer is shown below:

```
cl : [ 0 . . 4 ] i n i t 4 ;
[ ] cl>0->cl*lambda_cl : ( cl' =cl-1) ;
```

Edge Computing Layer Module: The initial number of applicable edge devices is 2. If each edge devices fails with a failure rate "lambda_ed", "ed" then minus 1. The code for converter layer is shown below:

```
ed : [ 0 . . 6 ] i n i t 6 ;
[ ] ed>0 -> ed * lambda_ed  : ( ed ' = ed -1) ; // failure of single edge devices
```

End Device Layer Module: for the end devices, the devices are varible, what's more, the failure of these devices will not influence the whole network, so this layer will not be considered in this paper.

Failure Conditions: we need at least 2 cloud devices and 4 edge devices, so the failure conditions of this architecture is shown below:

```
formula down = ( cl<2) |( ed<4) ;
```

This is the most important part of code is show as previous. Then we can construct CTMC models in PRISM and evaluation the reliability of BBECN.

IV. EXPERIMENT RESULTS

4 experiments are designed in PRISM. The perimeters are shown in Table 1. "fcl" is the failure rate of cloud devices , "fed" is the failure rate of edge devices, "ncl" is the number of cloud devices, "ned" is the number of edge devices. "f" is the time period in experiments.

TABLE I. EXPERIMENT PERIMETERS

	fcl ($year^{-1}$)	fed ($year^{-1}$)	ncl	ned	t (years)
experiment 1	1/8	1/4	3,4,5,6	6	1,10
experiment 2	1/8,1/10,11/12,1/14	1/4	3	6	1,10
experiment 3	1/8	1/4	3	3,6,9,12	1,10
experiment 4	1/8	1/2,1/4,1/6,1/8	3	6	1,10

A. Experiment 1(influence of ncl)

In experiment 1, the influence of ncl is studied. Fig.2 shows the results.

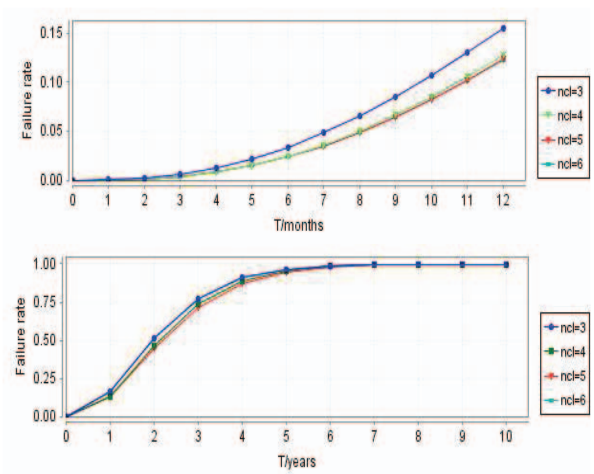
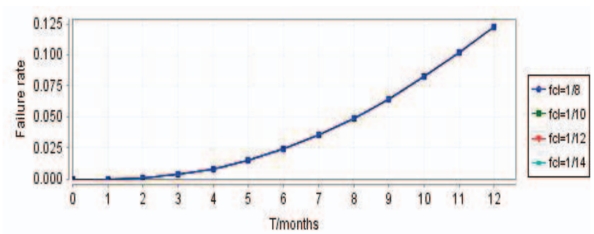


Figure 2. Influence of ncl

Finding 1: from Fig.2, we get to know that ncl influence the system failure rate slightly. The system failure rate is inversely proportional to ncl.

B. Experiment 2(influence of fcl)

In experiment 2, the influence of fcl is studied. Fig.3 shows the results.



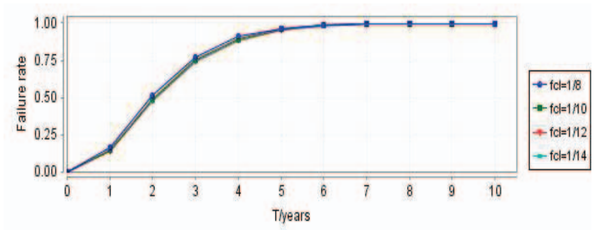


Figure 3. Influence of fcl

Finding 2: from Fig.3, we get to know that the influence of fcl is not obvious, for the first figure, the 4 lines almost coincide,this is because the performance and lifetime of cloud service is usually much better than edge devices.

C. *Experiment 3(influence of ned)*

In experiment 3, the influence of ned is studied. Fig.4 shows the results .

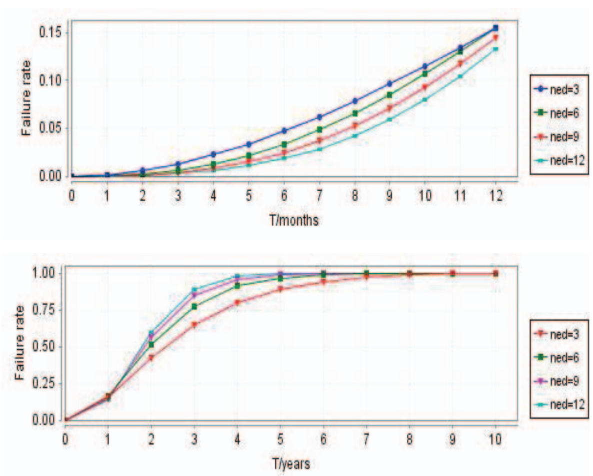


Figure 4. Influence of neg

Finding 3: from Fig.4, we can see that the influence of neg is obvious. Before 1 year, the system failure rate is inversely proportional to ned. However, after 1year, increase ned will increase the failure rate.

D. *Experiment 4(influence of fed)*

In experiment 3, the influence of ned is studied . Fig5 shows the results.

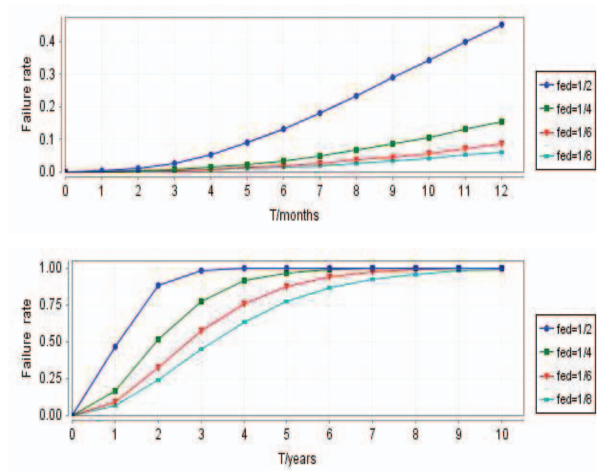


Figure 5. Influence of fed

Finding 4: from Fig.5, we can see that feg influence the system failure rate significantly. The failure rate is highly proportional to fed.

V. CONCLUSION

In this paper, a CTMC model is built to calculate the reliability of the BBECN. Different influence factors are analyzed.According to the experiment results, the most effective way is improve the reliability of edge devices. The number of edge devices is also influence a lot. The influence of cloud service is slight due to its better performance than edge devices.

But in this paper, the self-repairable devices is not considered. In further research, this part will be included, more complicated cases will be studied.

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