Model checking the Efficiency of Blockchain-based Edge Computing Network

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***Abstract*—In last 10 years, the development of cloud computing was very fast. Cloud computing enables the users to obtain remote computing resources and brings convenience to them. However, the increasing information exchange makes the efficiency of cloud computing becomes a problem. In order to solve the problem, edge computing emerged. For edge computing, the edge devices can deal with a part of work load. In this way, the work load of cloud can be reduced and the efficiency of the whole network can be.enhanced. For some edge computing networks, blockchain is used to increase the security and information transparency of the whole network. However, how to further optimize the efficiency of the blockchain-based network is still a challenge. In this paper, discrete-time Markov chain (DTMC) model is built to evaluate the efficiency of the blockchain-based network. The main influence factors for the efficiency of it will be find, and the strategies to improve the efficiency of it will be find.**

Keywords- cloud computing; edge computing ;blockchain; DTMC;

I. Introduction

In last 10 years, cloud computing has developed very fast and it has applications in many occasions like e-commerce, power system, IoT system and so on[1-3]. Cloud computing also brings more powerful computing resources to users.

However, the fast increasing information exchange makes the efficiency of cloud computing becomes a challenge. In order to solve the problem, the concept of edge computing appears. For edge servers in edge computing, they can deal with a part of work load and usually they are located near the user side. Thus, the efficiency of edge computing is better than cloud computing. In recent years, the application of edge computing is increasing.

In some edge computing network, blockchain is used to enhance the security and information transparency of the whole network [4]. The fist application of blockchain is bitcoin[5]. But many countries still do not want to encourage bitcoin trading. However, as the basic technology of bitcoin, blockchain began to get people ' s attention. Many areas use blockchain technology[6]. Many governments like Chinese government are also interested in developing blockchain technology to enhance the information security and transparency.

However, how to further improve the efficiency of blockchain based edge computing network become a challenge. Some researchers also did some research in this areas. In [7], an edge computing accelerator has been proposed to improve the efficiency of edge computing network. For blockchain network, there are also some researchers focus on improve the efficiency of it. According to [8], a coordinated satellite-terrestrial network is proposed to improve the efficiency of the blockchain network.

However, few of the researchers focus on collaborative cloud and edge computing for latency minimization. The research about how to evaluate the efficiency of the edge computing network is still not enough. If the efficiency of edge computing network can be evaluated, the influence factors for efficiency of edge computing can be find out to improve the design of edge computing. In order to solve the problem, we propose a Discrete-time Markov chain (DTMC) model to evaluate the efficiency of edge network by calculating the latency of the whole network. According to the experiment results, optimization strategies are given to enhance the efficiency of edge network.

The contribution of this paper is shown below:

- DTMC models are built to evaluate the efficiency of blockchain-based edge computing network.
- The influence factors (eg.the latency from edge devices to cloud) are evaluated in turn, the influence factor influence the efficiency most will be find out.
- According to the experiment results, the optimization strategies are given to enhance the efficiency of blockchain-based edge computing network.

The structure of this paper is shown as follows: section 2 gives the structure of blockchain-based edge computing, section 3 shows the basic knowledge of DCMC and the modeling process of blockchin-based cloud computing network. In section 4, the experiment results are illustrated and analyzed. Finally, the conclusion and further research are given.

II. The Structure of Blockchain-based Edge Network

A. The framework of SDPVES

The typical architecture of blockchain-based edge network usually has 3 layers: end device layer, edge computing layer and cloud layer. The functions of each layer is shown below:

End device layer: sensors, mobile phone or PC are included in this layer, they can send or receive data from edge servers.

Edge computing layer: edge servers are included in this layer, the edge servers are also blockchin nodes in blockchin network. The edge servers can deal with some simple task and reduce the work load of cloud servers, and reflect data to the end device layer. For some complicated task, the edge servers can reflect them to the cloud layer and wait for the reflect of cloud layer. The edge servers

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also help to build a blockchin network to enhance the security and information transparency of the whole network.

Cloud layer: deal with some complicated tasks and reflect the results to the edge computing layer.

The typical blockchin based edge computing network is shown in Figure 1.

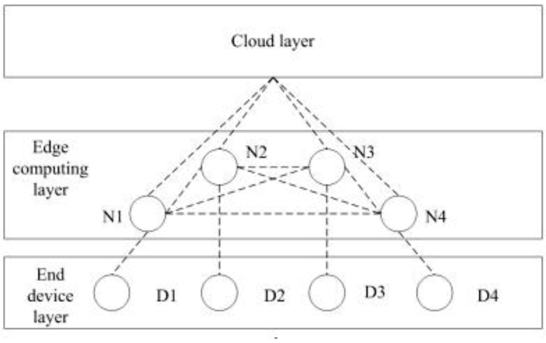

Figure 1. Architecture of blockchain-based edge computing network

In Figure 1, the meaning of each node is shown below:

- N1, N2,N3 and N4 are 4 edge servers, the edge servers can set up a blockchain network, so they can communicate with each other. They connect the cloud layer and end device layer.
- D1, D2,D3 and D4 are 4 end devices, the end devices can communicate with edge servers which is located near them.

For edge computing layer, a part of task should be connected to the blockchain network, so the consensus time should be considered. Another part of task can be deal with cloud server or edge server directly, so the consensus time is not needed. The process will be detailed illustrated in section 3.

III. Basic Knowledge about DTMC and The Modeling Process

A. DTMC

DTMC is a State-transition systems augmented with probabilities, DTMC has the following characters:

- States:set of states representing possible configurations of the system being modelled.
- Transitions: the transitions between states model evolution of system's state, and they occur in discrete time-steps .
- Probabilities:probabilities of making transitions between states are given by discrete probability distributions

Formally, a DTMC is a tuple (S, s_{init} ,P,L) where:

- S is a set of states ("state space")
- $s_{init} \in$ S is the initial state
- P : S × S → [0,1] is the transition probability matrix
- − L : is function labelling states with atomic propositions

According to the blockchain-based edge computing network, the state transition diagram for the DTMC model is shown in Figure 2.

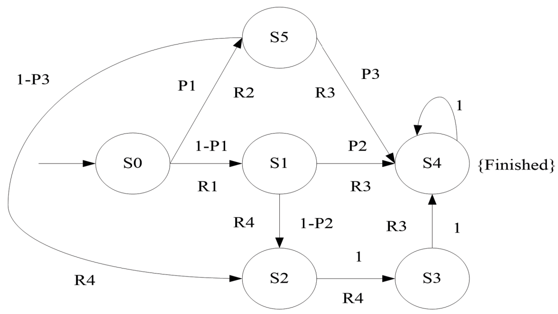

Figure 2. State transition diagram for the DTMC model

The parameters for Figure 2 are explained below:

- S0 is the initial state, end devices prepare to send messages to edge computing servers.
- S1 is the state that the messages come to edge computing servers, and the consensus time in blockchin network is not needed (means the messages are not necessary to be added to blockchin network)
- S2 is the state that the messages come to the cloud servers.
- S3 is the state that messages come to edge computing servers from cloud.
- S4 is the state that messages come to end device layer from edge computing layer.
- S5 is the state that the messages come to edge computing layer, but the consensus time in blockchain network is needed
- P1 is the probability that the consensus time in edge computing layer is needed. 1-P1 means the probability the consensus time is not needed.
- P2 is the probability that the messages can be dealt by edge computing servers.1-P2 means the probability messages should be dealt by cloud servers.
- P3 is the probability that the messages can be dealt by edge computing servers after consensus.1-P3 means the probability messages should be dealt by cloud servers .
- R1 stands for the latency between S0 and S1.
- R2 is the latency between S0 and S5.
- R3 is the latency between S1/S3/S5 and S4.
- R4 is the latency between S1/S5 and S2 or between S2 and S3.

B. Modelling Process

In this paper, DTMC is used to evaluate the efficiency of blockchain-based edge computing, the modeling process is show below.

Firstly, we can give values to P1, P2 and P3, in experiments, the value can be changed.

```
const double P1=0.1;
const double P2=0.2;
const double P3=0.2;
```

Secondly, the state transition can be modeled.

```
module edge
s : [0..6] init 0;
[] s=0 -> 1-P1: (s'=1) + P1: (s'=5);
[] s=1-> 1-P2 :(s'=2)+P2 :(s'=4);
[] s=4 -> (s'=4);
[] s=2 -> (s'=3);
[] s=3 -> (s'=4);
[] s=5 -> 1-P3 :(s'=2)+P3 :(s'=4);
endmodule
```

Finally, the latency between different states can be set in software PRISM by adjusting the rewards.

When the transition system reaches the last state S4, the whole process finishes. The average latency can be calculated.

We can set P1=P2=P3=0.1, R1=R3=2s,R2=4s, R4=3s, then we can use theory calculation method to verify the correctness of our DTMC model. The experiment result of DTMC model is shown in Figure 3. The result shows that the average latency is 9.6s.

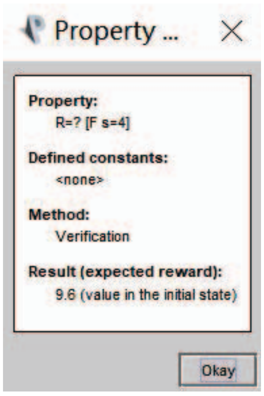

Figure 3. Average latency (by using DTMC model)

Then we use theory calculation method to calculate the average latency L:

$$L = R1(1-P1)+(R4+R4+R3)(1-P1)(1\text{-}P2)+R3(1-P1)P2+R$$
$$(R4+R4+R3)P1(1-P3)+R3P1P3 = 2\times0.9+8\times0.9\times0.9+2\times0$$
$$+4\times0.1+8\times0.1\times0.9+2\times0.1\times0.1 = 9.6$$

The result is same with previous one, so our DTMC model is verified to be correct.

IV. EXPERIMENT RESULTS

Before experiment, the parameters should be determined For each experiment. The parameters are shown in Table 1. In this paper, duo to the time limitation. Influence of P3 and R1 is not included in the experiments.

TABLE I. PARAMETERS

	P1	P2	P3	R1	R2	R3	R4
Experiment 1	0.05,0.1,0.15,0.2	0.2	0.2	2	4	2	3
Experiment 2	0.1	0.1,0.15 ,0.2,0.2 5,0.3	0.2	2	4	2	3
Experiment 3	0.1	0.2	0.2	2	3,4,5,6, 7	2	3
Experiment 4	0.1	0.2	0.2	2	4	1,2,3,4, 5	3
Experiment 5	0.1	0.2	0.2	2	4	2	2,3,4,5, 6

A. *Influence of P1*

For experiment 1, the experiment result is shown in Figure 4. Figure 4 reflects the influence of P1 about the efficiency of the blockchain-based edge computing network.

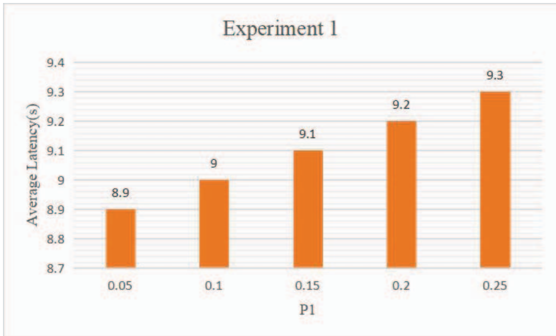

Figure 4. Experiment 1

Remark. Average latency is proportional to P1. However, the influence is not very obvious.

B. *Influence of P2*

For experiment 2, the experiment result is shown in Figure 5. Figure 5 reflects the influence of P2 about the efficiency of the blockchain-based edge computing network.

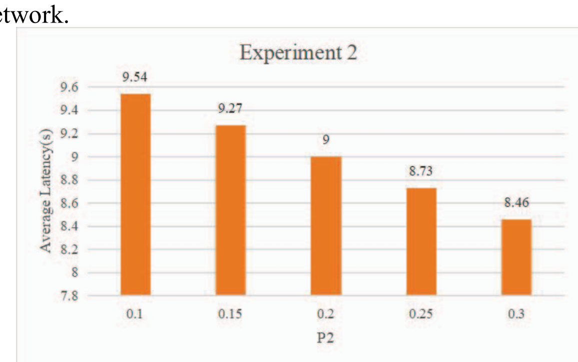

Figure 5. Experiment 2

Remark. Average latency is inversely proportional to P2. The impact of it is lager than P1.

C. Influence of R2

For experiment 3, the experiment result is shown in Figure 6. Figure 6 reflects the influence of R3 about the efficiency of the blockchain-based edge computing network.

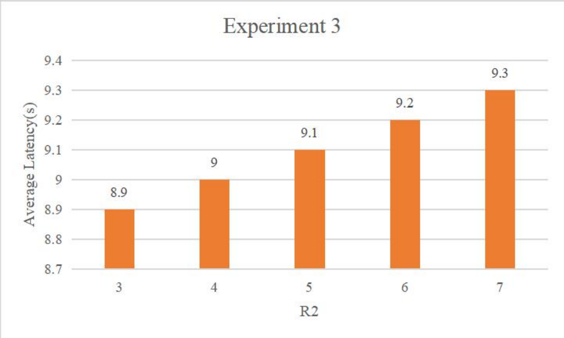

Figure 6. Experiment 3

Remark. Average latency is proportional to P1. However, the influence is not very obvious.

D. Influence of R3

For experiment 4, the experiment result is shown in Figure 7. Figure 7 reflects the influence of R3 about the efficiency of the blockchain-based edge computing network.

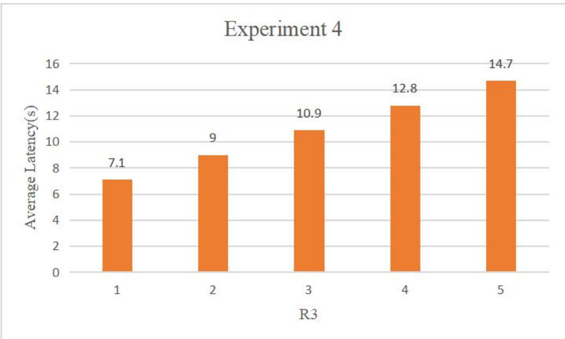

Figure 7. Experiment 4

Remark. Average latency is also proportional to R3. The impact of it is lager than R2.

E. Influence of R4

For experiment 5, the experiment result is shown in Figure 8. Figure 8 reflects the influence of R4 about the efficiency of the blockchain-based edge computing network.

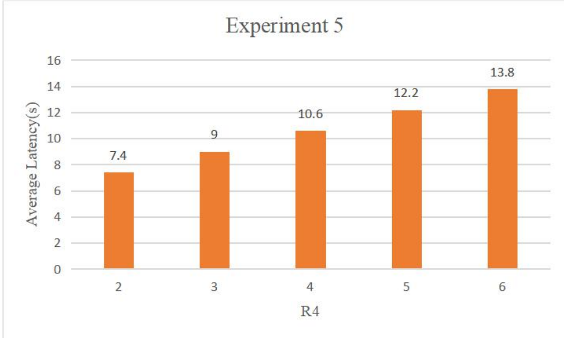

Figure 8. Experiment 5

Remark. Average latency is also proportional to R4. The impact of it is smaller than R2. For R2,R3 and R4, the impact of R3 is largest.

V. CONCLUSION

In this paper, a DTMC model is supposed to evaluate the efficiency of blockchain-based edge computing network. The experiment results are given for analyzing. For P1 and P2, the impact of P2 is larger. For R2,R3 and R4, the impact of R3 is largest. If we want to improve the efficiency of blockchain-based edge computing network, the service ability of edge computing server should be improved to reduce the probability the messages should be dealt by cloud. What's more, the latency between edge computing layer and end device layer should be reduced.

However, the modeling is not very complicated. In further research, I want to explore more complicated models to meet the evaluation need of real case. These will be included in further research.

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