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An Intelligent Judgment Platform Based on the Integration of Cloud Computing and Fog Computing

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Abstract. With the continuous advancement of law enforcement integration, the demand of court for joint case handling increases. Under the background, this paper proposes an intelligent judgment platform based on the integration of cloud computing and fog computing. The paper starts from the existing technology based on cloud computing, analyzes its shortcomings, and introduces fog computing, which has advantages such as low delay, easy to deal with, mobile and so on. And then it raises a comprehensive solution of integration of cloud computing and fog computing. Finally, it introduces the process of the integration of cloud computing and fog computing, the plan of user identity authentication in the platform in detail and the method of task assignment based on D-S evidence theory. And by establishing a system of the cloud, fog, and equipment, it achieves the goal of cloud controlling, fog processing, equipment performing.

Keywords: cloud computing, fog computing, identity authentication, D-S evidence theory

1 Introduction

At present, with the advancement of law enforcement integration in the courts, the number of cases that should be enforced outside is also increasing. For outside law enforcement, live audio and video data is particularly important for the execution of cases. The law enforcers need to send the scene image data back to the command center immediately. However, the basic functions such as audio recording, video recording and data transmission can hardly meet the demand of courts for commanding law enforcement, especially in some difficult cases requiring entrusted execution or coordinated execution. Therefore, a way of returning data efficiently will play an important role in solving such problems.

Under this goal, for the commonly used cloud computing, there are still some shortcomings such as high time delay and inconvenient for use at present. While fog computing has great advantages in these aspects and it can also be a good complement to the existing cloud computing methods. Therefore, an intelligent judgment platform based on the integration of cloud computing and fog computing will provide better technical support for the data sending during the outside law enforcement.

In this paper, it mainly includes four parts, system function, related work, key technologies, and future prospects. Among them, the system function part introduces the platform on the whole. The related work part introduces the advantages and disadvantages of cloud computing and fog computing, as well as the cloud and fog integration. The key technologies part introduces the process of cloud and fog integration and also introduces the process of user identity authentication during use. And the future prospects part analyzes the further optimization and improvement.

2 System Functions

This paper comes up with an intelligent judgment platform based on the integration of cloud computing and fog computing. The architecture of this platform is shown in Fig. 1. As can be seen from the figure, the platform has a three-layer structure, the top layer is the cloud layer, the middle layer is the fog layer,

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and the bottom layer is the handheld device layer. Among them, the main functions of the cloud layer are data storage, resource scheduling, data in-depth processing, data backup, and so on. The fog layer is mainly responsible for the interaction with the cloud layer and handheld device layer, and its functions include local data storage and data processing. And the main functions of handheld device layer are collecting data and uploading data.

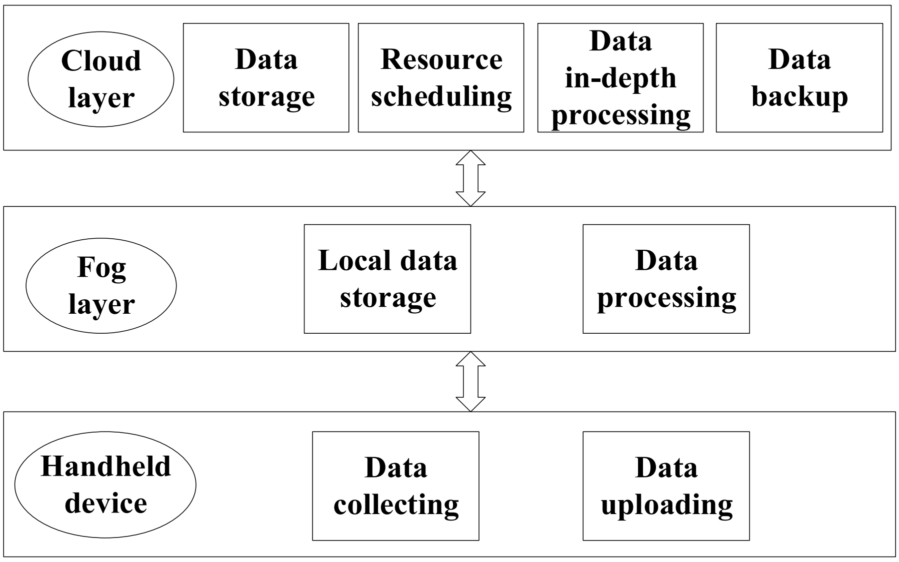

Fig. 1. The architecture of the platform integrated with cloud computing and fog computing

In addition, in order to ensure the integrity and effectiveness of the communication between various layers of the platform, a three-layer collaborative authentication method of cloud, fog and terminal is used in the process of identity authentication.

3 Related Work

The integrated cloud and fog computing is a new computing model based on cloud and fog computing. In this system, cloud computing and fog computing work together.

Among them, cloud computing is a centralized computing model. In the process of cloud computing, all data are transmitted to the cloud center through network for processing. Under the background of the wide application of big data now, cloud computing has been widely applied in different fields due to its convenience, expandability and accessibility. However, there are some problems in cloud computing. In some emerging fields, cloud computing has many inadaptation, which restricts the development and using of it. Some problems are introduced in [1] and [2]. The security threats of cloud computing, bandwidth problems, high system delay, and high energy consumption all restrict the further development and application of cloud computing.

To overcome the shortcomings of cloud computing, fog computing was first raised by Cisco in 2011. Fog computing is an extension of cloud computing and turns the centralized computing into distributed computing. Compared with cloud computing, it is closer to the edge of the network, which mainly relies on devices located at the edge of network for data storage, processing and other operations. Compared with the cloud servers, the performance of fog servers is not strong enough. However, due to the large number of fog devices, the fog devices can still meet various needs. The characteristics of fog computing is introduced in [3]. The main advantages of it are following. Distributed structure, lower transmission delay, being able to reduce the overload phenomenon of cloud server, lower energy consumption, and support for mobility.

In actual applications, cloud computing and fog computing usually work together. And it retains the computing power of cloud servers, meanwhile distributes the information processing to the edge of the network, and manages the transmission of data and the allocation of resources in the network.

At present, the integration of cloud and fog has been applied in Internet of Things (IoT), cloud service and other fields. A model of object-fog-cloud is raised in [4], and it analyzes the combined method of operation of fog terminal, cloud terminal and object terminal of Internet of things. Starting from the practical application, literature [5] introduces a three-layer joint processing model of cloud computing, fog computing and edge computing. A network architecture combined with Internet of things and cloud and fog computing is raised in [6], and with the use of cloud computing and fog computing, the traditional Internet of things architecture, the system can better adapt to the requirements. It designs an infrastructure architecture based on cloud computing and fog computing, and it proves the feasibility of this framework in the existing cloud computing products in [7]. It presents in progress e-health architecture using Internet of Things for data acquisition, fog for data pre-processing and short-term storage, and cloud for data processing, analyze and long-term storage in [8]. Fog computing is used for processing the data near to the edge of the network, and processing is done by distributed network nodes to minimize the application latency in [9], and the method shows significant decrease in both the application latency and energy consumption of fog-cloud. It introduces a study of the fog computing suitability assessment as a solution for the increasing demand of the IoT devices based on the energy consumption and the Quality of Service in [10]. It develops a cloud-fog computing architecture for information-centric Internet of Things applications with job classification and resource scheduling functions in [11], and the innovative scheduling mechanism optimize the dispatch of cloud and fog resources at minimum cost in a cloud-fog computing environment. It proposes a Unmanned Aerial Vehicle (UAV)-based Fog computing platform for the Internet of Things applications in [12], and it utilizes the advantages and features of both the Fog computing and UAVs to effectively support some IoT applications.

D-S evidence theory is a commonly used data fusion technology, and it is come up in the 1960s by Dempster and Shafer. It is a theory of dealing with the uncertainty. The core of D-S evidence theory is the fusion rule that it fuses multiple objects. And the objects can be the predictions of different people, the data of different sensors, and so on. Next is several basic concepts in the evidence theory. Frame of identification. It is the range of the event that we need to judge. Basic Probability Assignment. It is also called BPA. It is the probability of each event in the basic framework from each people or each sensor. And the sum of the probability from all of the people or sensor is 1. And the probability is called the mass function. Belief function. The belief function of an event is the sum of all the probability of the event's subsets, and it is used to show the degree of trust of the event. Plausibility function. The plausibility function of an event is the sum of all the probability of the condition that is intersected with it, and it is used to show the degree of trust of not denying the event.

The service selection is resolved with the distributed application of fuzzy inference or Dempster-Shafer theory of evidence in [13], and the selection strategy is also complemented by the adoption of a game theoretic approach for promoting truth-telling ones among service providers.

In this paper, an intelligent judgment platform based on the integration of cloud computing and fog computing is proposed. And with the method of the platform, the authentication is more reliable, and the task allocation is more reasonable.

4 Key Technologies

4.1 The Working Process of the Platform

As shown in Fig. 2, the platform described in this paper is divided into three layers, the cloud server layer, the fog server layer, and the terminal device layer [14].

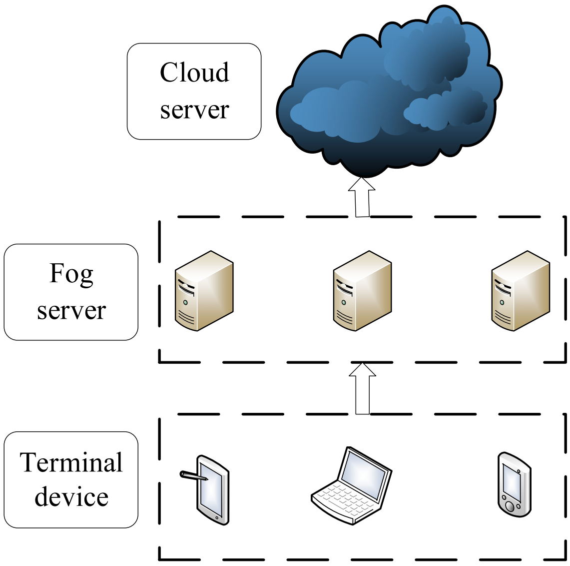

Fig. 2. The flow chart of the platform integrated with cloud computing and fog computing

By adding fog server layer between cloud and terminal devices, the whole network forms a platform integrates cloud computing and fog computing. In the platform, the advantages of cloud center and fog nodes complement each other, and realize the separation of node control and data processing, and thus reducing the complexity of the system. In addition, the fog nodes in the middle layer of the network work together with the cloud layer. Data collection and processing are carried out at the fog layer, and some important data results are uploaded to the cloud server for storage or further processing as required. And it can improve the data processing capacity of the whole system.

Among them, the cloud server layer is deployed in the court, which is the highest layer. And the main functions of it are storage of global data, further data processing of fog server, scheduling and unloading of resources, data backup, and so on.

The fog server layer is the core of fog computing, and it is deployed in the vehicle of law enforcers working outdoors. Each fog server can connect with each other, and every fog server is also connected to the cloud server.

In the process of going out to enforce the law, the data need to be sorted out and sent back to the command center after work. During the data collecting, data is collected by hand-held devices of the law enforcers first from the scene of the law enforcement. Then the law enforces connect the equipment with the fog equipment deployed on the law enforcement vehicles, and send the data to the fog server. After receiving the data, the fog server processes the data in advance by its own data processing ability, and it mainly processes the data with low complexity and low priority directly.

After the preliminary data processing of the fog server, the fog server sends relevant information to the cloud server according to the processing results. In the process of sending data from the fog server to the cloud server, the data sent is processed data, and it has greater significance than the data uploaded by the terminal device. For example, the fog server sends the analysis of the results of a set of data, rather than sending detailed values of this set of data to the cloud center continuously. Then the cloud server determines whether to further operation according to the analysis results sent by the fog server. Through this operation, the burden of cloud server is greatly reduced and the overload phenomenon is also avoided.

The cloud server receives the processing results from the fog server, and then further processes and gives corresponding instructions according to the information received. Next, the cloud server sends the information back to the fog server through the network, and then sends it to the handheld terminal device of the relevant enforcers. And the enforcers take the next step according to the instructions received.

At the same time, after the cloud center receives the processing results of the fog server, the processing results and some important data will be backed up and stored in the cloud center and recorded into the database.

4.2 Authentication of Fog Node

In the connection and communication process of terminal, fog nodes and cloud server, user identity authentication is a key part.

In the process of the user connecting to the fog node through the terminal device, and the fog node connecting to the cloud server, if only a simple terminal identity authentication is used, the platform can be easily attacked. An illegal device can pretend to be a terminal device to connect with a fog node, and if illegal authentication is successful, it can attack other devices in the network. Moreover, it can control the platform through further operating devices in the network, to steal or modify data, and it poses a serious threat to the data security of users and systems.

In addition, if the terminal device is directly authenticated with the cloud center, when there are a large number of devices connected with the platform at the same time, the cloud center will take a large number of resources for authentication, and it will also have a great impact on the performance of the device.

Therefore, in the platform, identity authentication at three levels will be an important way to protect the security of platform. This kind of distributed authentication method can also avoid the leakage of user information and the attack to cloud server [15].

Among the devices of the platform, there are three kinds of identity, terminal user, fog node user, and cloud center user. Among them, cloud center user has the highest authority, and can manage fog node users and monitor the equipment that authenticates through fog nodes. And it plays the role of monitoring, warning and forcing the illegal user out. Fog node is the key part of identity authentication. Through the preliminary authentication of users by fog node, some illegal users are filtered out to avoid a large number of identity authentication in the cloud center, so that the computing and storage capacity of the cloud center is efficiently used. In addition, each fog node can manage the terminal user to ensure the legal identity of the terminal user at the source, and it is the first guarantee of system identity authentication.

In the process of identity authentication, a combination of three levels of authentication is used. And users need to authenticate in terminal equipment, fog server and cloud server respectively, then they can start the communication from terminal to fog server and cloud server. This method guarantees the integrity and effectiveness of the communication and avoids information being stolen in the process [16].

The specific identity authentication process is as follows, and the flow chart is shown in Fig. 3.

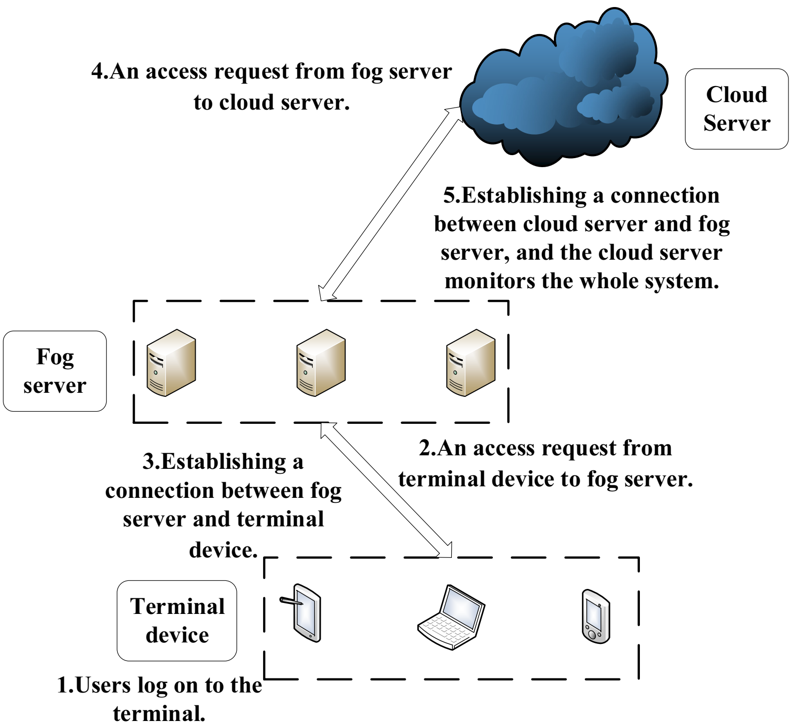

Fig. 3. The process of user identity authentication of the platform integrated with cloud computing and fog computing

(1) Law enforcer logs on to the terminal.

(2) The law enforcer sends an access request to a nearby fog server through the terminal device to a nearby fog server.

(3) Each fog server keeps a list of legitimate users that can be accessed, and determines whether the user is legitimate or not based on the comparison between the user who sent the request and users in the list. Then the corresponding fog server establishes a connection with the legitimate user terminal and they can send and receive data with each other now.

(4) After preliminary data processing, the fog node is ready to establish a connection with the cloud server according to the data type and needs. And then it sends an access request to the cloud server.

(5) The cloud server authenticates the fog node that sends the request, establishes connection with the fog node that has successfully authenticated, and then sends and receives data. Meanwhile, the cloud server monitors the devices connected to the fog node. By now, the cloud server can manage both the fog server and the terminal device.

4.3 Task Assignment Method Based on D-S evidence Theory

Usually, in the data transmission process of cloud computing, tasks can be decomposed and handled by each fog servers and cloud server respectively. In the scenario of this paper, since there is only one fog server around the user to transmit to the cloud server, and each task is a complete audio or video, there is no need to decompose it before transmission. Therefore, the collected data needs to be assigned tasks according to their own characteristics and the capabilities of servers.

In the process of data transmission, the factors affecting the transmission quality mainly include the resources consumed, the data transmission and processing time, and the processing capacity of the server. Therefore, it comprehensively considers the above factors and raises a task assignment method based on D-S evidence theory in this paper.

Among the above several factors, data transmission and processing time affect task allocation. And in order to maximize the efficiency, a method with less delay should be selected between cloud and fog computing. Among them, the main delay of fog computing is the delay of data processing by equipment, and the delay of cloud computing includes the delay of processing and data transmission from fog server to cloud server. Let the total delay of each mode is t_k (k=1 is cloud computing, k=2 is fog computing, the same below), then the proportion of the mode with larger delay should be smaller, that is, it is inversely proportional to the delay. So the assignment is $1/t_k$. And the normalized results are $\frac{t_2}{t_1+t_2}$, $\frac{t_1}{t_1+t_2}$ respectively.

Compared with fog servers, cloud servers have higher performance and consume more resources to process the same amount of data. Let the resources needed for each mode to transmit and process unit data be μ_k and the data size be L, then the values of the two modes are $L*\mu_k$. Normalize them, and the results are $\frac{\mu_1}{\mu_1+\mu_2}$ and $\frac{\mu_2}{\mu_1+\mu_2}$.

The handling capacity of the server itself determines the maximum amount of data it can handle. For the same data, the server with strong handling capacity has better processing effect, so we need to choose a way with better effect. Set the handling capacity of the server of each mode as C_k, and $C_k > L$, then the data processing degree of each mode is $\frac{C_k}{L}$. Normalize them, and the results are $\frac{C_1}{C_1+C_2}$ and $\frac{C_2}{C_1+C_2}$ respectively.

According to the above, we take the above three information as the basis for determining task assignment in this paper, and take the combination of them as the basic probability assignment. And the result of basic probability assignment is in Table 1.

Table 1. The probability of the evidence

The result of ask assignment	Transmission and processing time (1)	Resources con-sumed (2)	Resources consumed (2)
Cloud Computing (A)	$\frac{t_2}{t_1+t_2}$	$\frac{\mu_1}{\mu_1+\mu_2}$	$\frac{C_1}{C_1+C_2}$
Fog Computing (B)	$\frac{t_1}{t_1+t_2}$	$\frac{\mu_2}{\mu_1+\mu_2}$	$\frac{C_2}{C_1+C_2}$

And the processing of the data fusion is as follows.

$$\begin{aligned} K &= \sum_{A_1\cap A_2\cap A_3\neq\varnothing} m_1(A_1)*m_2(A_2)*m_3(A_3) \\ &= \frac{t_2}{t_1+t_2}*\frac{\mu_1}{\mu_1+\mu_2}*\frac{C_1}{C_1+C_2}+\frac{t_1}{t_1+t_2}*\frac{\mu_2}{\mu_1+\mu_2}*\frac{C_2}{C_1+C_2} \\ &= \frac{t_2*\mu_1*C_1+t_1*\mu_2*C_2}{(t_1+t_2)*(\mu_1+\mu_2)*(C_1+C_2)} \end{aligned} \quad \textbf{(1)}$$

Here K is the normalization coefficient.

$$\begin{aligned} m(A) &= m_1\oplus m_2\oplus m_3(A) \\ &= \frac{1}{K}\sum_{A_1\cap A_2\cap A_3=A} m_1(A_1)*m_2(A_2)*m_3(A_3) \\ &= \frac{t_2*\mu_1*C_1}{t_2*\mu_1*C_1+t_1*\mu_2*C_2} \end{aligned} \quad \textbf{(2)}$$

Here *m(A)* is the mass function of cloud computing.

$$\begin{aligned} m(B) &= m_1\oplus m_2\oplus m_3(B) \\ &= \frac{1}{K}\sum_{B_1\cap B_2\cap B_3=B} m_1(B_1)*m_2(B_2)*m_3(B_3) \\ &= \frac{t_1*\mu_2*C_2}{t_2*\mu_1*C_1+t_1*\mu_2*C_2} \end{aligned} \quad \textbf{(3)}$$

Here *m(B)* is the mass function of fog computing.

And then judge *m(A)* and *m(B)* to get the final result.

If

$$\begin{cases} m(A)-m(B)>\varepsilon_1 \\ m(\Theta)<\varepsilon_2 \\ m(A)>m(\Theta) \end{cases} \quad \textbf{(4)}$$

the information is processed through cloud computing. Otherwise, it is processed through fog computing. In the formula, $\varepsilon_1,\varepsilon_2$ is the threshold, and Θ is the uncertain set.

5 The Experimental Results

According to the task assignment method based on D-S evidence theory in the last part, in the experiment of this part, a cloud server and three fog servers with different performance indexes are selected for example to determine where to complete the task.

Here, for the convenience of calculation, each index of cloud server is taken as 1, and each index of other fog services is normalized. And we call them relative parameters. And the performance parameters of cloud server and three fog servers are shown in Table 2.

Table 2. The parameters of cloud server and fog servers

Server	Transmission and processing time (1)	Resources con-sumed (2)	Processing capacity (3)
Cloud Server	1	1	1
Fog Server A	0.2	2	0.5
Fog Server B	0.3	1.5	0.2
Fog Server C	0.2	1.5	0.3

According to the indicators of the above several servers, the task assignment algorithm based on the evidence theory was simulated and verified in Matlab.

According to the parameters of each fog server in table 1, the parameter matrix of fog server is established in Matlab, as shown in Fig. 4.

```
fog =

    0.3000    2.0000    0.4000
    0.4000    1.5000    0.3000
    0.2000    1.8000    0.1000
```

Fig. 4. The parameter matrix of fog servers

The simulation results are shown in Fig. 5.

```
>> i=1;select
The task is handled in the fog server.
>> i=2;select
The task is handled in the fog server.
>> i=3;select
The task is handled in the cloud server.
```

Fig. 5. The simulation results

And the values of mass function *mA*, *mB*, and the normalized coefficient *K* in every calculation are shown in Fig. 6.

i	1	i	2	i	3
K	0.2015	K	0.1868	K	0.1028
mA	0.2727	mA	0.4706	mA	0.5263
mB	0.7273	mB	0.5294	mB	0.4737

Fig. 6. The values of mass function and normalized coefficient

Among the results, the following conclusions can be drawn from the diagram. During the connection between fog server A and cloud server, tasks are handled in the fog server. During the connection between fog server B and cloud server, tasks are handled in the cloud server. During the connection between fog server C and cloud server, tasks are handled in the cloud server.

To get the relationship between the selected server and the change of each parameter, we select one of the parameters and fix the value of the other two parameters to get the graph of mass function of cloud server and fog server changing with a single parameter. And we take the first fog server mentioned above as example to get the changing curve. And the relative parameters are 0.3, 2, and 0.4.

First, keep the relative processing capacity and relative energy consumption the same and change the relative delay from 0 to 2, and the graph is shown in Fig. 7. In the figure, the red one is *mA*, and the blue one is *mB*. From the last part, we can get that *mA* is the mass function of cloud computing, and *mB* is the mass function of fog computing. And we choose the bigger one as the server of the task. From Fig. 7, we can see that the when the relative is little, *mB* is bigger than *mA*, and the fog server is chosen to process the task. With the increase of delay, *mA* is increasing, and when *mA* is bigger than *mB*, the cloud server is chosen.

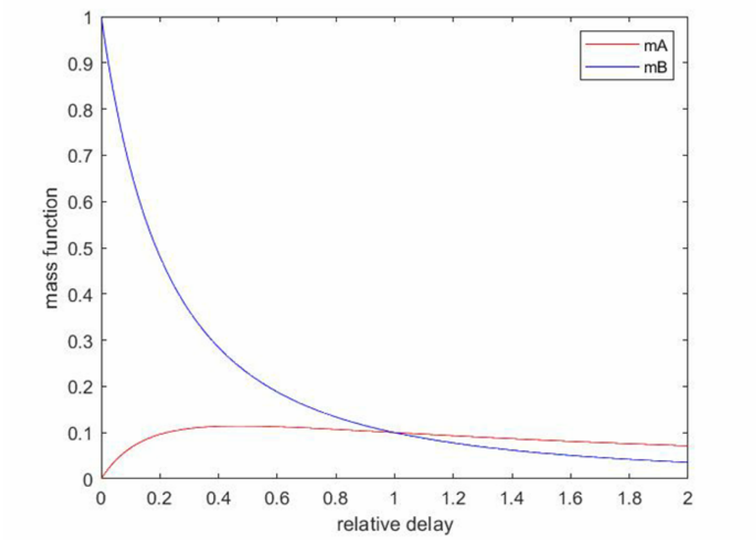

Fig. 7. Graph of relative delay and mass function

Then, change relative energy consumption and the relative processing capacity from 0 to 2 respectively, and keep the other two parameters the same. And we can get the two graphs as Fig. 8 and Fig. 9. And these two cases are as same as each other. When the parameter is small, *mA* is bigger than *mB*, and the cloud server is chosen. With the increasing of relative energy consumption, *mB* will be bigger than *mA*, and the fog server is chosen to process the task.

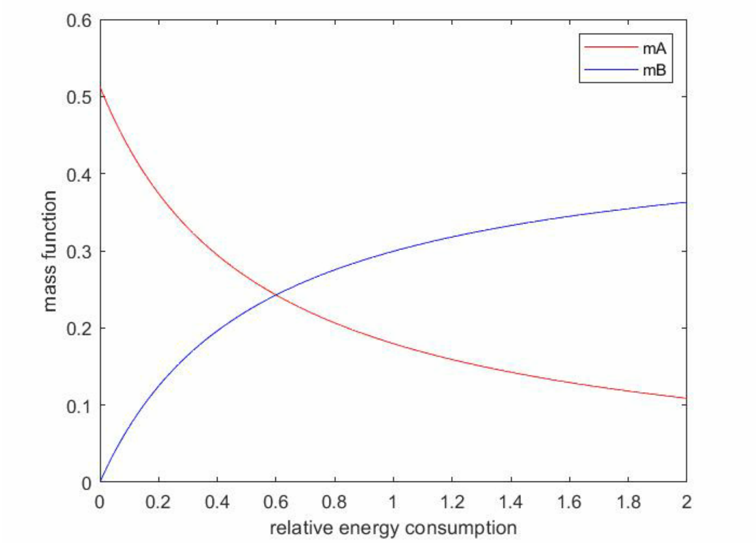

Fig. 8. Graph of relative energy consumption and mass function

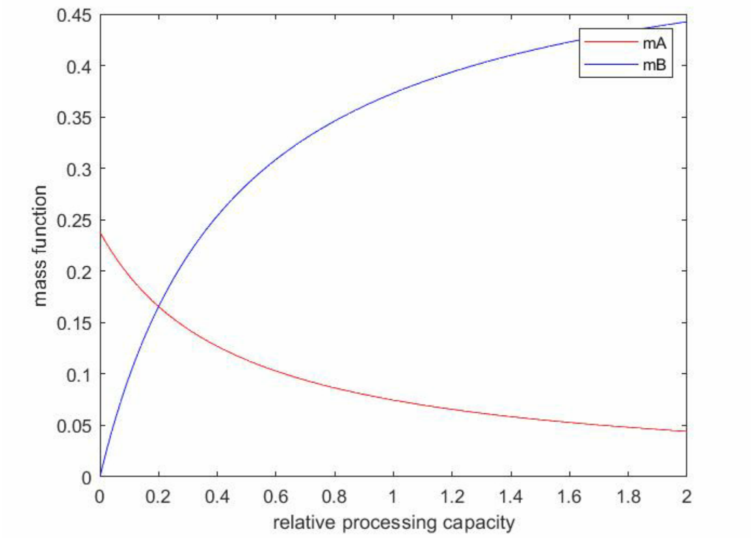

Fig. 9. Graph of relative processing capacity and mass function

Take the above three factors into consideration, we should categorize tasks according to the delay, energy consumption and processing capacity. And take the task of low delay, high energy consumption, and high need of processing capacity processing in the cloud server, and process the other task in the fog servers.

From the above experimental results, we can see that in the process of communicating with the same cloud server, there will be different ways of task assignment for fog servers with different performance indexes. By using the proposed task allocation method based on the evidence theory, not all tasks will be processed in cloud server or fog server, so that the resources of each server can be fully used and the utilization rate of the whole system can be improved.

6 Future Prospect

In this paper, under the background of the integration of law enforcement of the court, an intelligent platform based on the integration of cloud and fog computing is raised, to meet the need of data returning in the process of law enforcement. The platform uses a three-layer structure, and it is deployed with three types of equipment, the cloud equipment, the fog equipment, and the terminal equipment. In the platform, cloud computing and fog computing are used synthetically, and they work together to make the platform have the high performance and large capacity of cloud computing as well as the flexibility and distribution of fog computing. Meanwhile, to make the communication between different kinds of equipment have a higher integrity and effectiveness inside the platform, the paper raises a three-level authentication way, and it makes three kinds of equipment work together in the identity authentication. This allows the authentication of the users more safety and effective, and it can also avoid the cloud center taking up too much resources. To make the task allocation more efficient, a task assignment method based on D-S evidence theory is raised. And through the experiment, we can see that the method can realize the reasonable task assignment function.

For the platform in this paper, the prospect of future research is followed. A more secure two-way authentication method is needed. In this paper, the identity authentication method is a one-way method. And it can only realize the recognition of high privilege devices to low privilege devices. Although this method of authentication is simple and is easy to achieve, when the cloud server at the highest level or the fog nodes in the middle layer is attacked or modified, the devices at the lower level still request authentication to upper devices. In this case, the object of authentication may be wrong, and the authentication is invalid, which can’t prevent the leakage of messages caused by the wrong identify of the lower layer to the upper device. While the two-way identity authentication realizes the identification of the upper layer to the lower layer, the lower layer can also confirm the identity of the upper layer. Such authentication can prevent messages from leaking because of sending messages from lower level devices to the wrong upper level devices. Therefore, under the premise of ensuring the effectiveness of communication between devices at every level of the platform, the two-way authentication method can further improve the reliability of communication.

Acknowledgements

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