Network Energy Consumption Analysis and Dormancy Mechanism Based on Ant Colony Algorithm in Cloud Computing Environment for IOT Service and Real-time Embedded Industrial Control System

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Abstract: At present, cloud computing technology is widely used in IOT(Internet of Things) service and real-time embedded industrial control system energy consumption, problem in the cloud computing has always been the hot topic of industry and academic research. This paper analyzes the energy consumption of each equipment under the dormancy mechanism in the cloud computing environment. Meanwhile, this paper introduces the ant colony algorithm into a basic network energy consumption model, thereby building a new model for the energy consumption optimization. The simulation experiments were implemented on a cloud computing simulation platform CLOUDSIM. In comparison with two algorithms - Min LP and Dijkstra, the model presented in this paper was proved to be effective and more energy-efficient.

Key Words: cloud computing, dormancy mechanism, energy consumption analysis, ant colony algorithm, IOT service, real-time embedded industrial control system

1 INTRODUCTION

Currently, cloud computing as a new computing method is rapidly becoming a research focus industry, academic and research community due to its advantages of high scalability and high availability. But to realize its features like low-cost, efficient, safe and easy, cloud computing systems still faces many challenges. The high energy consumption is one of the most serious problems which the cloud computing system is facing.

While cloud computing is considered as a green computing, it still requires a high-energy approach to effectively implement green computing.It does not provide proven solutions to evaluate and reduce energy consumption.

According to the current status of domestic research, Lin Chuang et al. [1] studied the analysis of energy consumption. From the perspective of the resource allocation and task management, they reviewed Green Network's mechanisms and policies in their paper. In this paper, they described the model evaluation method in the green application and made a green evaluation framework based on a stochastic model. Dawei Sun et al. proposed a multi-dimensional energy consumption model M^2EC which is based on the analysis, quantification, modeling and evaluation of green-service level targets in the cloud computing environment [2]. Yiming Tan et al. [3] did a lot of research in cloud computing systems aiming at the idle computing nodes that waste a large amount of energy; and based on this idea they proposed a method to optimize energy consumption management by a task scheduling algorithm. The minimum energy constraint scheduling algorithm ME^3PC is designed to meet the performance expectations of the implementation in this paper.

The current cloud computing energy analysis is mostly based on the resource allocation and the task-mobilization perspective. Although the accuracy of these analyses is relatively high, they give only imprecise solutions. What's more, there are few algorithms based on the analysis of the energy consumption. So the research on the cloud dormancy mechanism in cloud computing systems which is based on the energy consumption analysis on algorithms of energy model can effectively reduce theenergy consumption for the dormancy mechanism in cloud computing systems [4, 5].

This paper mainly does the corresponding energy consumption analysis from the perspective of dormancy mechanisms. The second part of the paper is about the system modeling of the cloud dormancy and wake-up

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mechanism and analyzes the energy consumption for this mechanism using the ant colony algorithm. The third section describes the experimental environment, parameter settings, the experimental results and performance analysis in detail. The fourth part of this paper summarizes and concludes this paper and points out the deficiencies.

2 ANALYSIS OF NETWORK ENERGY SAVING MECHANISMS

2.1 dormancy mechanism and ant colony algorithm

Saving energy in the dormancy and wake-up mechanism (Fig. 1) means that without influencing the normal service the server should be turned from the high energy-consumption state to the low energy-consumption state as much as possible. So the system can be kept in a state of minimum energy consumption [1]. As the state transition shown in Figure 1, the energy consumption declines when the depth of dormancy increases, while the energy consumption of the state transition from dormancy to wake-up is increased. In the transition between different states of the server, the curve of the energy consumption must get to a maximum point somewhere.

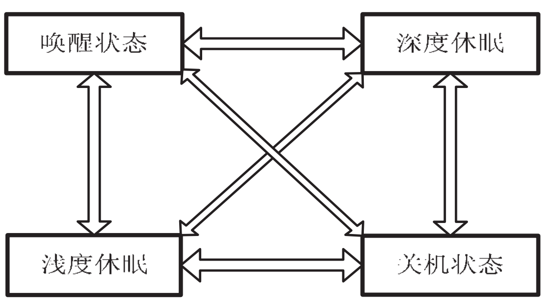

Figure 1 the state diagram of the dormancy and wake-up mechanism

Ant colony algorithm (ant colony optimization, ACO), has been widely understood as ant algorithm. It was proposed by Mroco Dorigo after he did a lot of research on the process of numerous ants finding a path to food. And then he applied this new idea in his doctoral thesis. Ant colony algorithm is a non-probability algorithm used to find the optimal path in a large number of random paths [6], as shown in Figure 2.

As shown in Figure 2, ants in the nest need to avoid obstacles to find food in the lower right corner.

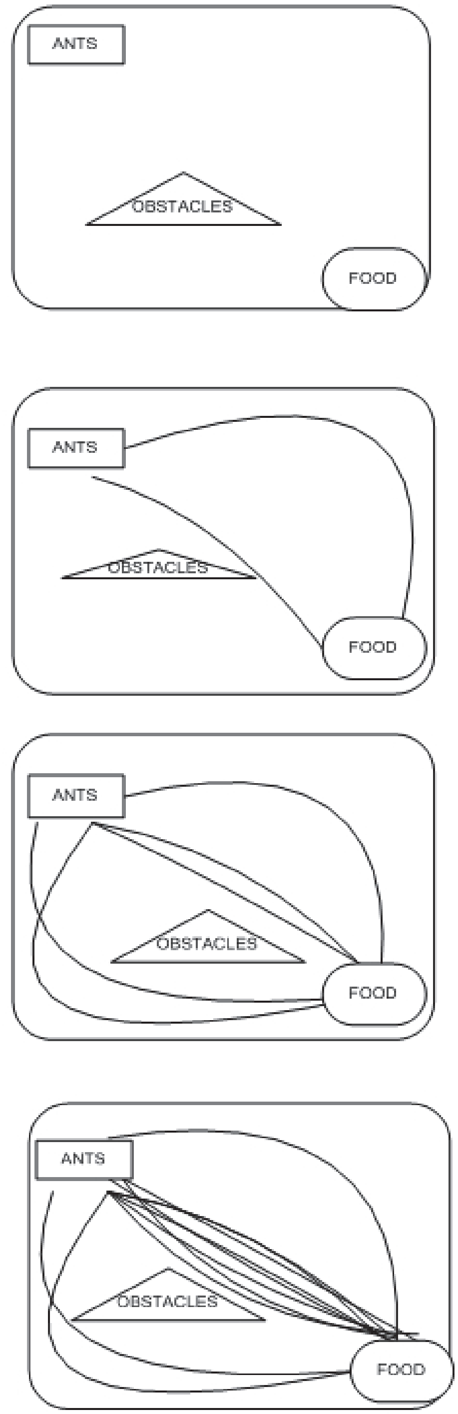

Figure 2 ant colony in search of food routes

There are many paths in this process. And through the accumulation of time, ants tend to find the way that the ant colony is able to avoid obstacles and figure out the shortest distance to food. This phenomenon is because the ants will leave some special chemicals as a signal on its way to looking for food. The same group of ants can detect such chemicals, and according to the concentration of this substance they can determine the direction of their advance.
Finally the route with the maximum concentrations of chemicals is the shortest path through which the Largest number of ants are going. Dormancy mechanism for the

cloud server is composed of many nodes. Each state of the device sends different information concentrations, and then depending on the concentrations of the information to calculate the probability of the state transition between the respective devices. By using the improved algorithm to select a different state, an optimal path is found to achieve the purpose of minimizing energy consumption. The idea of this paper is according to the network granularity making the ants walk down from the higher energy consumption in the state to the dormancy state and this is one of the complete paths. The process does not stop until an optimal path is obtained. Through analysis on this path, energy consumption optimization model based on dormancy mechanism can be built.

2.2 Energy Consumption Analysis of Dormancy mechanism

Dormancy mechanism is the transition of states based on the energy status of system resources, which need the support of the actual hardware. ACPI (Advanced Configuration and Power Interface) defined the global state of the computer, device power state and processor power status [2].

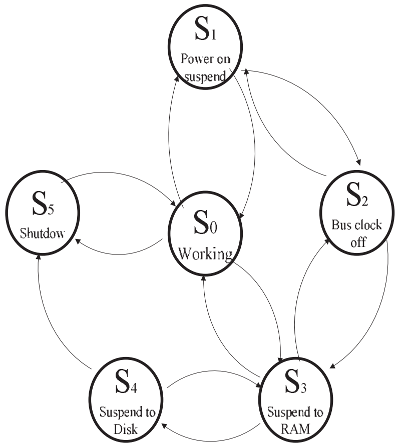

Fig3.The global state of the computer system

As shown in Fig.3, the global state of the computer system is divided into state S0, state S1, state S2, state S3, state S4, state S5. Normal working state is S0, which means all the equipment turned on. S1 means the state only the CPU turned off, also known as Power on Suspend (POS). The difference between S1 and S2 is that the bus clock was off only. S3 only supplies power for the main memory and the related equipment, but the other equipment are turned off, this state is also widely known as Suspend to RAM (STR). S4 is more energy-efficient than the S3 state, also widely known as Suspend to Disk (STD). In S4 the machine will turn off the main power system, and the hard disk will store the data before the state S4. S5 is the most energy-efficient state (power consumption is 0), that is shutting down.

In different operating states S_0, S_1, S_2, S_3, S_4 and S5, each of them are divided into five conditions: A_0, A_1, A_2, A_3 and A_4 depending on the operating conditions of each state. In the five conditions, it takes the least time to turn from the condition A_0 to the awaked state S_0. It takes the longest time to turn from the condition A_4 into the awaked state S_0. It takes shorter time to transit from A_1, A_2 and A_3. The system is set to four cases W_0, W_1, W_2 and W_3 according to different operating condition in which the different devices of the system are. W_0 means that the equipment is in working condition. W_3 indicates that the device is turned off. W_1, W_2 indicates that the device is in a condition different from the working and the turned-off state. The energy consumed when the system transit between different states, i.e. transition cost, is not the same [7] (strictly speaking, the transition cost also includes the transition time of consumption, and the transition process which affects the performance of the computer equipment, this paper only considers the energy consumption).

Therefore, when establishing a mechanism for dormant energy model based on ant colony algorithm [8], we do not only need to consider the transition time and the start-end state, but also need to take into account the asymmetry of the transition state, i.e. the transition direction.

Assuming that the total energy consumption of the model is E_{all}, and the corresponding energy consumption of the model is shown in Equation (1)

$$E_{all} = \sum_{i \in S} \left[E_i \times \mathrm{P}_{\mathrm{r}(s_i)} + \sum_{j \in W} E_{ij} \times \mathrm{P}_{\mathrm{r}(W_j, S_i)} \right] \quad (1)$$

In Equation (1), S_i represents each element of the system in different states. E_i represents an average energy consumption of the system in different states. $\mathrm{P}_{r(S_i)}$ represents the transition probability of two different states. E_{ij} represents the energy consumption during the transition of the device, $\mathrm{P}_{r(W_j, S_i)}$ represents the transition probability of the energy consumption during the transition of the device.

3 ANALYSIS AND VERIFICATION

3.1 The equipment energy consumption analysis in the dormancy mechanism

In the dormancy mechanism of the ant colony algorithm, each device consumes energy when it makes a decision to turn itself into different states. And in order to receive information transferred by other adjacent equipment, the device needs to consume energy.

Specifically, the simulation is divided into three steps: Step 1,setting up a corresponding energy consumption optimization model mentioned in the paper by using mathematical analysis software and programming.Step 2 respectively, using ant colony algorithm, the Dijkstra algorithm,Min LP algorithm programming to achieve the optimal energy consumption equipment allocation.Step 3, Contrastive analysis the data obtained from step 1 and 2 .

The simulation experiments were implemented on a cloud computing simulation platform CLOUDSIM. In comparison with two algorithms - Min LP and Dijkstra, the model presented in this paper was proved to be effective and more energy-efficient.

Thus, first we analyze the comparison of the self-generated energy consumption of three different algorithms at different states of the device in the dormancy mechanism, as shown in Figure 4.

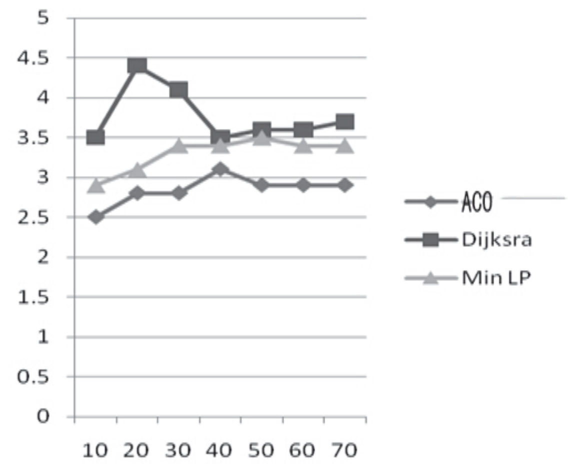

Fig4. the optimal energy consumption of different algorithms during the different transformation states

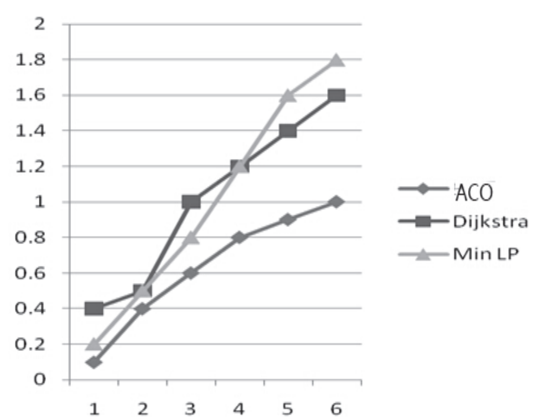

Fig5. In different algorithms, each device selected the optimal timeout time

Results from a large number of experiments show that the ant colony algorithm can find the optimal energy state faster when the device does not prevent the computer from finishing the task.

3.2 Comprehensive energy analysis of dormancy mechanisms

In order to more accurately analyze the dormancy mechanism of the energy consumption calculation, the experiment introduces the parameter θ , and the energy optimization of formula is shown as (2):

$$E_{all} = \sum_{i \in S} \left\{ \theta \left[E_i \times P_{r(S_i)} \right] + (1 - \theta) \left[\sum_{j \in W} E_{ij} \times P_{r(W_j,\ S_i)} \right] \right\} \quad (2)$$

Table1. Comparison of Different Parameters to Optimize Energy Consumption and Delay Time

Parameters	Energy Saving	Time Increasing
θ=0.95	55.7%	39.6%
θ=0.90	54.3%	35.4%
θ=0.85	52.5%	27.3%
θ=0.80	51.8%	18.2%
θ=0.75	48.9%	8.5%
θ=0.60	45.6%	4.3%
θ=0.50	43.2%	3.9%
θ=0.40	38.9%	2.5%
θ=0.30	15.8%	1.9%

N groups of data is input, and from the data in Table 1 it can be observed that when $\theta \in [0.4, 0.75]$, the energy model does not only ensure the high energy saving proportion, but also ensures the delay time decrease.

4 CONCLUSION

This paper analyzes the energy consumption of the network model and dormancy mechanism in the cloud computing environment for IOT(Internet of Things) service and real-time embedded industrial control system. And the energy optimization model of dormancy mechanism based on ant colony algorithm is proposed in this paper. By taking the advantages of ant colony algorithm, the system allows each device in the system to find the lowest energy consumption status within the effective time without affecting the normal working conditions. And the data have been analyzed at different levels by Min LP algorithm, Dijkstra algorithm and ant colony algorithm. The following conclusions from the data analysis is that energy optimization of the Min LP and Dijkstra algorithm model can be improved to a certain extent aiming at the energy consumption and delay of dormancy mechanisms. However, the analysis on the experimental results in this paper proves that energy consumption model of dormancy mechanism based on ant colony algorithm can better optimize and improve the impact of delay. For example, when θ = 0.60 in the model, the energy consumption is reduced to 46.5%, and the delay was only 4.3%.

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