A new optimization algorithm for multi-dimensional cloud data centre resources scheduling based on PSO

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Received 1 August 2014, www.cmnt.lv

Abstract

In order to solve the problem of multidimensional cloud resources low utilization ratio and the high energy consumption of cloud communication between tasks, proposed a new cloud data centre resource scheduling algorithm, which combined resource fusion principle, particle swarm optimization algorithms and taboo search algorithm and it's with a low-power scheduling computing, storage and bandwidth resources integration scheduling method. Simulation results show that the algorithm has the advantage of cloud resources using stable, high-dimensional cloud resource utilization and low-power cloud data centres.

Keywords: particle swarm optimization, cloud computing, cloud data centre, data scheduling

1 Introduction

With the large-scale development of distributed technology, cloud computing has become a key research area. Cloud computing is a kind of service providers and service users protocol based on the distributed system [1], Cloud users can access the cloud services according to the requirement, there has five main features, that is: high scalability, flexibility, on-demand services and billing, large scale and virtualization. Cloud data centres [2, 3] is composed of hardware and software in cloud computing environment pine that resource sharing framework. The user can according to the needs of the dynamic use of these hardware and software resources, and according to the service quantity to pay service fees. It has five characteristics, that is: resource pooling, intelligent and efficient service and transparent, on-demand service and billed by consumption.

Cloud computing [4] according to the level of abstraction provided resources can be divided into three layers: the cloud data centre layer, application layer and service layer software function operation. Cloud data centre layer through the virtual technology and other infrastructure hardware abstraction and physical resources available to the massive cloud users, cloud data centre layer allows the user to dynamically apply or release the node and on-demand access to resources, according to usage billing [4, 5]. The application ability running layer to the underlying physical resources had higher level of abstraction; it provides a platform to run the cloud user applications, the application ability run layer to provide a platform for software application development as the centre, deployment, operation-related platform resources. Software service layer functions are encapsulated into services, and through the network to the cloud user. The hierarchy of the cloud data centre layer, application ability running layer and software service layer is as shown in Figure 1.

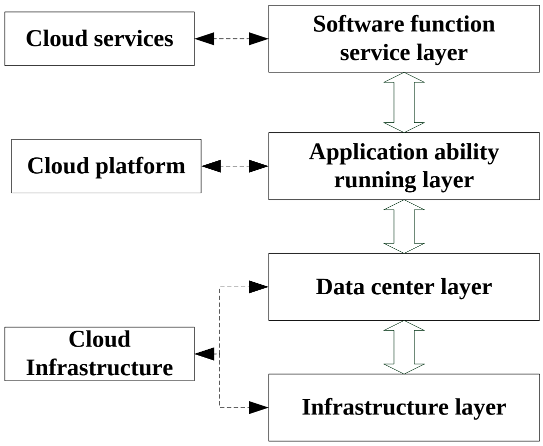

FIGURE 1 The hierarchy of the cloud data center layer

In this paper, cloud data center layer are studied. Because of the high energy consumption of multiple types of cloud communication resources existing cloud data center, and ignore the huge energy, multi resource consumption did not consider the multi-dimensional cloud resource scheduling, energy cloud did not fully consider the communication between tasks, So the presence of an existing cloud data center cloud resource providers low income, multi-dimensional cloud resource utilization and low power consumption high cloud data center issues. This article given a research on the problems of using particle swarm and taboo algorithm based on the above background as the starting point of the research.

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2 Cloud data centre resource scheduling technology

Cloud data center is the user-centric to provide various types of cloud services resources sharing architecture according to need to use the distributed technology [6, 7]. Users can use these on-demand dynamic hardware and software resources, and to pay for services based on service usage. It mainly has five characteristics: resource pooling, intelligent and efficient service and transparent, on-demand service and billed by consumption. As shown in Figure 2:

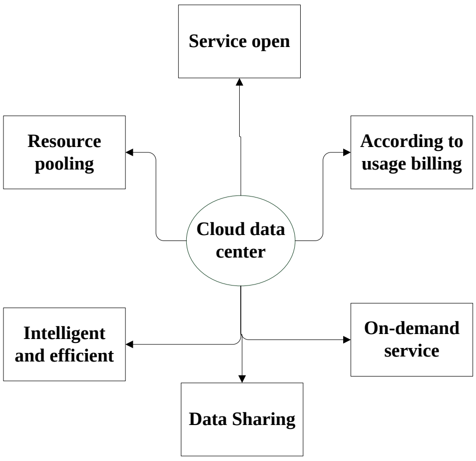

FIGURE 2 On-demand service and billed by consumption.

As the existing cloud data center did not fully consider scheduling a multidimensional cloud resources, did not fully consider the energy consumption of cloud communication between tasks, so there is low cloud resource providers gain, low dimensional cloud resource utilization of existing cloud data center and cloud lack of data center energy consumption is high.

Multidimensional cloud resource efficient scheduling technique is based on three types of resources (compute, storage and bandwidth) resource scheduling technology [8]. Because the demand is not the same of each user task computing, storage, and bandwidth resources, so the cloud data center will have the task of the user can not satisfy a certain category or categories of cloud resources objective situation demands, thereby generating a cloud data center large fragment idle resources [9]. Through using of multi-dimensional cloud resource efficient scheduling technology, more debris resources are fully utilized; more cloud user tasks can be run on the processor, thus effectively improving the multi-dimensional cloud resource utilization and user tasks to meet the more cloud computing, storage and bandwidth requirements.

3 Scheduling algorithm based on particle swarm optimization

3.1 PARTICLE SWARM OPTIMIZATION ALGORITHM

Particle swarm optimization (PSO) algorithm is proposed by Kenney and Eberhart in 1995 population parallel search algorithm based on global optimization [10, 11], through cooperation and competition between groups in the community to achieve optimal particle. Mathematical description of PSO: a population size is *n*, the *i* particles in *m* dimensional search space representation of $X_i = (X_{i1}, X_{i2}, ..., X_{ij}, ..., X_{im})$, flight speed is $V_i = (V_{i1}, V_{i2}, ..., V_{ij}, ..., V_{im})$, the optimal position of individual so far to search is $P_i = (p_{i1}, P_{i2}, ..., P_{ij}, ..., P_{im})$. The particle swarm optimal position is $P_{gbesti} = (p_{gbest1}, P_{gbest2}, ..., P_{gbestm})$. It can update the particle velocity and position according to the Equations (1) and (2):

$$v_i(t) = wv_i(t-1) + \rho_1 \frac{xP_{gbest} - x_i(t)}{\Delta_t} + \rho_2 \frac{xG_{best} - x_i(t)}{\Delta_t}, \quad (1)$$

$$x_i(t) = x_i(t-1) + v_i(t)\Delta_t, \quad (2)$$

$$v_{ij}(t+1) = \omega.v_{ij}(t) + c_1.r_1.(p_{ij} - x_{ij}(t)) + c_2.r_2.(p_{gbestj} - x_{ij}(t)), \quad (3)$$

$$x_{ij}(t+1) + x_{ij}(t) + v_{ij}(t+1), \quad (4)$$

where, *t* represents the *t* iteration, *j* = 1,2,…,*n*; *j* = l, 2,…, *m*; $c_1, c_2 > 0$ are respectively the individual learning factor and social learning factors; *t* is the current number of iterations, r_1 and r_2 are uniformly distributed random numbers in the range of [0, 1]. ω is the inertia weight coefficient, used to control the effect of history on current speed. In order to balance the global and local search ability, make the ω along with the increase in the number of iterations decreases linearly, can significantly improve the performance of the PSO algorithm. It is given:

$$\omega = \omega_{\min} + (iter_{\max} - iter) \times (\omega_{\max} - \omega_{\min}) / iter_{\max}, \quad (5)$$

where, $\omega_{\min}$, $\omega_{\max}$ respectively the maximum and minimum weighting factor, *iter* is the current iteration number, $iter_{\max}$ is the total number of iterations. $\omega_{\max}$ is the initial inertia weight; $\omega_{\min}$ is the last inertia weight; $t_{\max}$ is the maximum number of iterations. Flight speed is $v_i \in [-V_{\max}, V_{\max}]$, the constraint conditions to prevent particle speed missed optimal solutions, through the improvement of the algorithm further improves the global searching ability of particle swarm.

Particle swarm optimization algorithm works as follows:

1. Random initialization of the position and velocity of a particle.
2. Calculate the fitness value of each particle.
3. If the fitness value is better than the best historical fitness value P_{best}, set the current value of the new P_{best}.
4. Choose the best fitness value of all particles as G_{best}.

5. According to the Equation (1) calculate the particle velocity; according to the Equation (2) to update the position of particle.

6. Stop counting when the termination condition is satisfied, otherwise return to step 2. Generally set as a termination condition is good enough to adapt to reach a preset value or the maximum iteration algebra.

Flow chart of particle swarm optimization algorithm as shown in Figure 3.

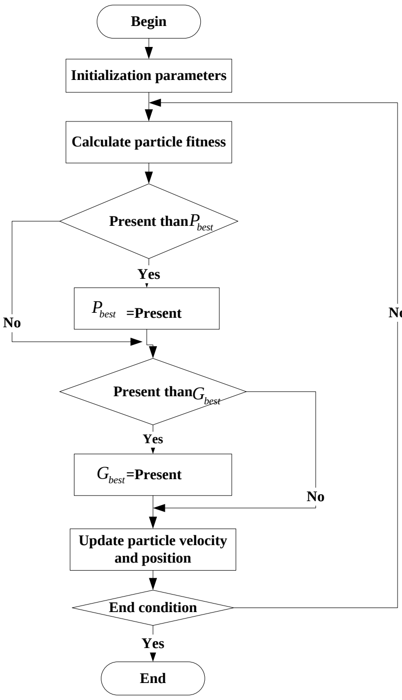

FIGURE 3 Flow chart of particle swarm optimization algorithm

3.2 MULTIDIMENSIONAL CLOUD RESOURCE EFFICIENT SCHEDULING SYSTEM ARCHITECTURE

There is a multidimensional cloud resources existing cloud data center (computing, storage and bandwidth) [12], Because of not considering multidimensional cloud resource scheduling leads to waste of resources and serious debris, and generally is low cloud resources multidimensional resource utilization, as shown in Figure 4, under the existing cloud data center environments:

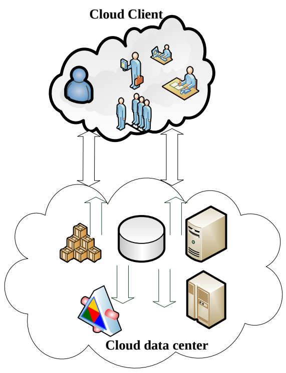

FIGURE 4 cloud data center environments.

1. The advent of cloud user tasks Poisson distribution, resource demand is greater than the actual cloud user tasks demand for resources.

2. Improve resource utilization through effective multi-dimensional cloud multidimensional resource scheduling methods. Cloud data centers use abstract, key technology virtualization, instantaneous deployment to achieve interconnection cloud data center resources through the network interworking and interoperability. It uses the multi terminal, multi platform, multi network browser access at any time, any place in the distribution according to need, dynamic configuration, flexible expansion, low price, high availability and high reliability computing, storage and bandwidth resources service.

3.3 TABOO SEARCH ALGORITHM

Particle swarm optimization algorithm is a heuristic optimization algorithm proposed by Kennedy and Eberhart, the particle can represent a potential solution to a particular problem, Also is the N dimension optimal solution in $x_i = (x_{i1}, x_{i2}, ..., x_{in})$ vector.

Taboo search is a heuristic method for solving combinatorial optimization problems. It is a global neighbourhood search algorithms, simulation optimization features with human memory function [13]. It is through the local neighbourhood search mechanism and corresponding detour to avoid the taboo search criteria, and to release some of the excellent state of being taboo breaking the ban by the level of diversification and thus guarantee effective exploration to eventually achieve global optimization.

The basic steps taboo search algorithm is as follows.

1. Initialization, create the initial solution; the taboo list is set to null.

2. Determine whether the stop condition is met, if met, the output of the algorithm is stopped; otherwise continue with the following steps.

3. For the best solution candidate solution concentration, whether it meets the aspiration level. If meet the aspiration level, update, update the current solution, turn to step fifth; otherwise, continue to the following steps.

4. Choose the best candidate solutions focused solutions are not taboo as the current solution.

5. Update taboo list.

6. Return to step 2.

Flow chart of taboo search as shown in Figure 5.

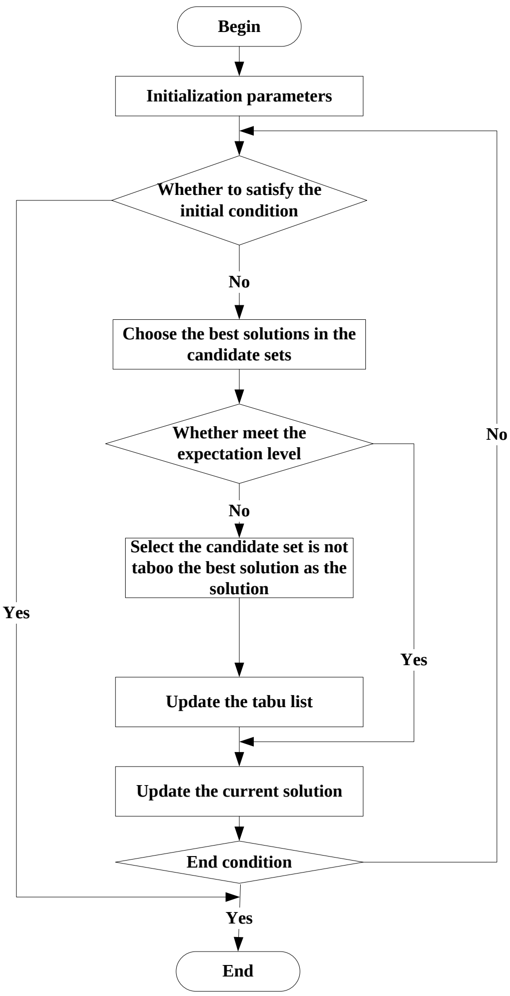

FIGURE 5 Flow chart of taboo search

3.4 PARTICLE SWARM AND TABOO UNION ALGORITHM

Based on the particle swarm optimization algorithm is easy to fall into local optimal solution of the shortcomings, combined with a taboo search algorithm "taboo" and "amnesty" thought. Combined with taboos algorithms, this improved particle swarm algorithm from three aspects. That is:

1) inertia weight;
2) neighbourhood topology;
3) learning factor and reproduction.

The proposed algorithm can avoid falling into local optimization solution space, so the three areas for improvement are as follows:

1. The inertia weight is replaced by:

$$\omega = 0.6 + Random / 2 . \tag{6}$$

2. Neighbourhoods topology improved modified for ring topology;

3. Learning factor is modified for the shrinkage factor:

$$v_{id}^{k+1} = k[v_{id}^k + c_1\xi(p_{id}^k - x_{id}^k) + c_2 r(p_{gd}^k - x_{id}^k)], \tag{7}$$

where, K is a function of c_1 and c_2.

$$k = \sigma^2 - \sqrt{\sigma^2 - 2\sigma} / 2 . \tag{8}$$

Reproductive process is as follows: In the each iteration of the PSO algorithm, based on a fixed probability between particles randomized crossover. Then select n optimization particle application of evaluation function in order to maintain the particle population size.

Mapping mechanism is as follows: Cloud data center scheduling matrix corresponds to a user task number line number, column number corresponding to the cloud data center physical processor number. Each element in the matrix represents a user task is running on a physical processor. If the value of the matrix element is "1", then the task on behalf of the user should be able to get the resources and run on the corresponding physical processor. Otherwise, indicating that the user does not get proper task on a physical processor resources and are not operation.

Particle swarm optimization algorithm and taboo process is described as follows:

1. Start, generate the initial population of particles, the number is n, including the position and velocity of each particle. In the particle populations, each particle represents a user task scheduling matrix results.

2. Contraindications cross, the existing population of each particle taboo crossover operation. In the each iteration, the particles in the group are based on certain probability taboo crossover operation.

3. Evaluation, value assessment of each particle in the population is calculated according to the evaluation function of low energy consumption. Reselect the optimization of n particles retain the same population size.

4. Selection. Optimum choice of n particles based on the assessed value of each particle, and the n particles to assess the merits of values in descending order.

5. Movement. According to Equations (9) and (10) is to update the position and velocity of each particle.

$$x_{i+1} = x_i + v_i \cdot t , \tag{9}$$

$$v_{id}^{k+1} = k[v_{id}^k + c_1\xi(p_{id}^k - x_{id}^k) + c_2 r(p_{gd}^k - x_{id}^k)] . \tag{10}$$

6. Update History optimal position and global best position.

P_{best} is the particle's histories that have experienced the best position, and G_{best} is the position of the particles have a global optimum.

In the each iteration, the fitness function of each particle's position and gain new experiences optimized to compare their position and the position of the entire particle swarm optimization withstand algebra. If it is more than the current P_{best} or G_{best}, then update P_{best} or G_{best}, return to the first two steps.

The flow chart of Particle swarm and taboo union algorithm is as shown in Figure 6.

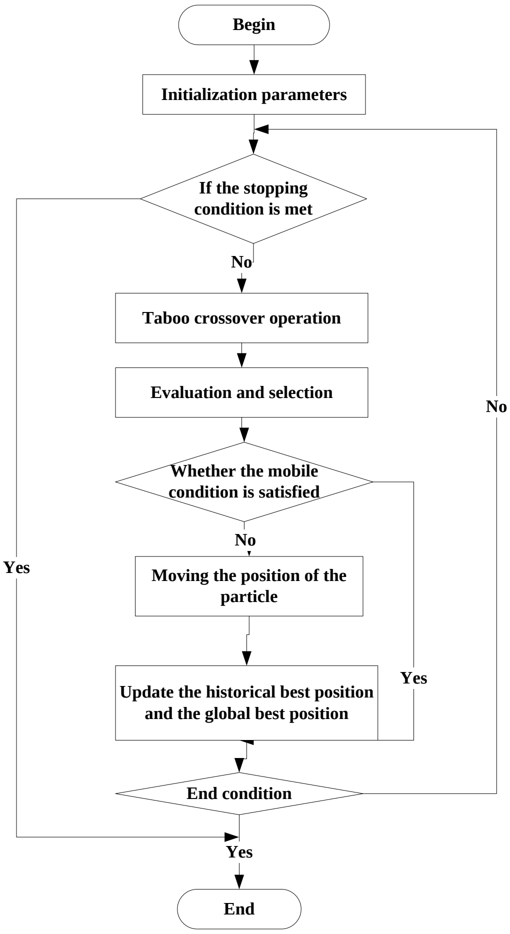

FIGURE 6 Flow chart of Particle swarm and taboo union algorithm

4 Experiment and analysis

In order to verify the stability of particle swarm optimization algorithm and taboo search (PSO-TAO). This paper conducted a series of experiments. Experiments run on the CloudSim architecture. CloudSim combines the flexibility and dynamic characteristics of the economic model and service quality, and these features are not supported other cloud emulator [14].

CloudSim provides four types of entities that is the cloud information service registration, data center; broker represents the interests of users and the auction market manager [15]. CIS cloud information service registry mapping user requests to the cloud data center. Cloud data center combines the distributed hardware, database, storage equipment, application software and operating system to build a pool of resources and according to the needs of users to create virtual machine computing, storage and bandwidth resources. In the cloud data center, users need to consider their offer and reasonable deadlines and restrictions on their tasks offer.

Particle swarm optimization algorithm, tabu search algorithm and random searching algorithm (RS) compare the performance; Use a different set of virtual machines through a lot of experiments. Experimental environment settings are as follows: Experimental environment setting is 500-3000 different numbers of virtual machines; the processor number is from 300 to 12,000, the interval is 2000. Interval task arrives subject to random distribution of a range of 5-100, and consider the three resources: computing, storage and bandwidth resources. This article is a set of experiments performed, and the resource range is from 100 to 12,000, is 500. In each experiment, automatically generates a virtual machine nodes ranging from 50 to 10,000. Right weight for each virtual machine is a virtual machine needs three resources: computing, storage and bandwidth resources.

First, integration of resources and scheduling mechanisms of particle swarm optimization algorithm proposed taboo compare and random search algorithm. Secondly, the resource scheduling mechanism fusion experiments with the proposed scale can reduce the energy consumption of a cloud data center.

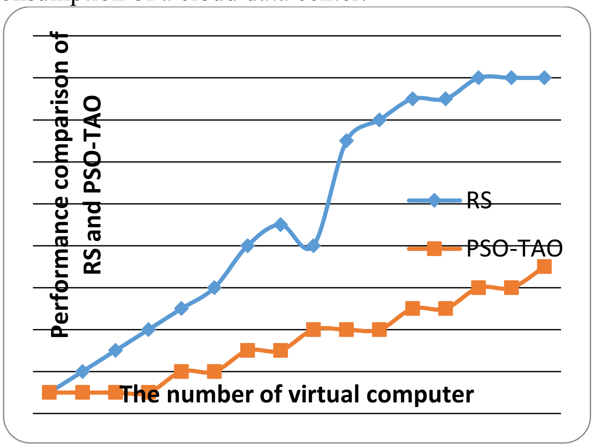

FIGURE 7 Curve graph for the performance comparisons of RS and PSO-TAO

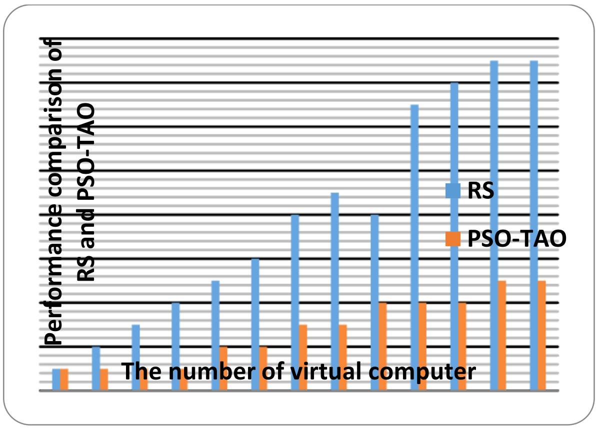

FIGURE 8 Bar chart for performance comparisons of RS and PSO-TAO

Figures 7 and 8 show the particle swarm and taboos through histograms and graphs random search algorithm to optimize the energy consumption of the algorithm comparison. The results from the 10 groups on particle swarm optimization algorithm and taboo search algorithm randomly display: First, particle swarm optimization algorithm and taboo energy consumption is lower than the random search algorithm from 50.31% to 76.30%, it average value is 63.6%. Secondly, the proposed particle swarm optimization algorithm and taboos less than the effect of random search algorithm became clear, as the number of virtual machines increases. Finally, when the number of virtual machines is increasing, energy particle swarm optimization algorithm is proposed and taboos consumption stabilized. In summary, the proposed particle swarm optimization algorithm and taboos energy consumption was significantly lower than the random search algorithm, and with the increasing number of virtual machines, the energy saving effect became clear and stable. Particle swarm optimization algorithm and taboo search is proposed heuristic optimization. So the particle swarm optimization algorithm and taboo energy consumption is lower than the random search algorithm stability. With the increasing number of virtual machines, idle processor also increases the number of idle processors will consume more energy. Thus, the particle swarm optimization algorithm and taboo energy consumption along with the increasing number of virtual machines is less than the effect of random search algorithm increasingly apparent. All in all, as heuristic optimization algorithms and resources to integrate new ideas, particle swarm optimization algorithm and taboos raised more than random search algorithm suitable for large-scale cloud data centers. These experiments show that the energy consumption according to the characteristics and needs of the proposed resource scheduling mechanism integration cloud users can fully meet the quality service and effectively reduces the computing, storage and bandwidth consumed energy.

5 Conclusions

Current cloud data center resource scheduling technology exists residual computing and storage resources are still consuming energy in an idle state, inter task communication bandwidth resource energy consumption has been neglected. To solve these problems, we propose a scheduling mechanism based on PSO optimized integration resources designed to minimize the task completion time under the premise of reducing the energy consumed by data centers in the cloud. Based on the experimental architecture CloudSim comprehensive experiments and randomized algorithms by comparing the energy consumption, this paper verifies the minimum completion time under the premise of the proposed particle swarm optimization algorithm and taboos can save energy consumption by up to 63.6%. With the increase in the number of virtual machines, particle swarm optimization algorithm and taboo energy consumption will be lower than the random search algorithm and stabilized. This fully verifies the advantages of the integration of resources scheduling mechanisms include: large-scale, stability and integration of resources.

Acknowledgments

This work is partially supported by Natural Science and Technology Project Plan in Yulin of China (#2011SKJ07), Natural Science and Technology Project Plan in Xi'an of China (#CXY1352WL10). Thanks for the help.

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