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A Process Migration Approach to Energy-efficient Computation in a Cluster of Servers

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Application processes have to be efficiently performed on servers in a cluster with respect to not only performance but also energy consumption. In this paper, we newly propose a process migration (MG) approach to energy-efficiently performing application processes on servers in a cluster. First, a client issues an application process to a server in a cluster. A process performed on a current server migrates to another server if the server is expected to consume smaller electric energy to perform the process than the current server and the deadline constraint on the process is satisfied on the server. In the evaluation, the total energy consumption of servers is shown to be smaller and the average execution time of each process to be shorter in the MG algorithm than the round robin and random algorithms.

Key Words *: Energy-aware cluster, Power consumption model, Computation model, Process migration, Energy-efficient process migration*

1. INTRODUCTION

In a cluster of servers like cloud computing systems [1], application processes have to be efficiently preformed on servers in terms of not only performance but also energy consumption. The energy-aware active replication of a process [2] on multiple servers is discussed. In order to reduce the electric energy consumption of a server cluster, the algorithm where the other replicas are forced to terminate once one replica successfully terminates is discussed. Furthermore, every replica is not simultaneously started as discussed. The passive replication of a process is discussed to reduce the total energy consumption of a cluster, where only a primary replica of the process is performed. In this paper, we newly propose a process migration (MG) approach where a process migrates to another server in order to reduce the electric energy consumed by server. We evaluate the MG algorithm in terms of the total energy consumption and energy average execution time of each process model compared with the round robin (RR) and Random (R) algorithms. We show the total electric enrgy can be reduced in the MG algorithm.

2. Energy-efficient Process Migration

(1) Process migration

Suppose a cluster S is composed of multiple servers $s_1, \ldots, s_n$ ($n \geq 1$) and clients which are interconnected in an underlying reliable network N. Each server s_t is assumed to support clients with computation service.

A client c_s first finds a server s_t in the cluster S and issues the process p_i to a server s_t. Every process p_i is assumed to do the computation in this paper. The process p_i is performed on the server s_t. Then, the process p_i migrates to another server s_u as shown in Figure 1. If the process p_i terminates on the server s_u, the reply is sent to the client c_s.

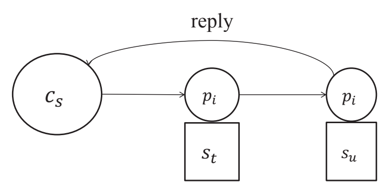

図 1 Process migration.

(2) Sever selection

In papers [5, 6, 7], algorithms are proposed to estimate electric energy to be consumed by a server to perform all the current processes and how to estimate when each current process terminates under an assumption that no additional process starts. The are two cases, a process p_i on a server s_t does not move or moves to another server s_u. In the first case, the process p_i is expected to terminate at time τ_1 and every other process terminates at time τ_2. Here, the expected energy consumption is $EE_t = maxE_t \cdot (\tau_2 - \tau_1)$. In the second case, the process p_i migrates to the server s_u. Here, the expected energy computation NE_t of the server s_t is reduced and NE_u of the server s_u increases. If $EE_t + EE_u > NE_t + NE_u$, the process p_i migrates to the server s_u.

By using the estimation models of electric energy consumption and termination time, we discuss the energy-efficient migration (MG) algorithm for each process to decide on whether the process stays on the current server or is migrated to another server. If a process can be energy-efficiently performed on another server s_u than the current server, the process is migrated to the server s_u.

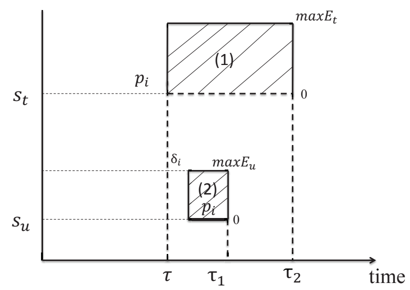

図 2 Expected termination time.

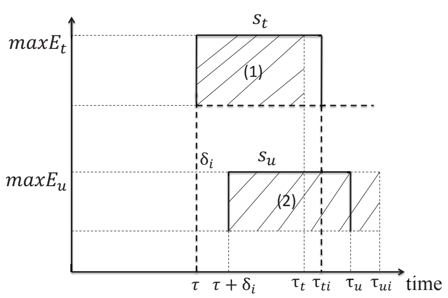

図 3 Expected energy consumption.

3. EVALUATION

We evaluate the (MG) algorithm in terms of total energy consumption and total execution time. We consider a cluster S composed of n servers $s_1, \cdots, s_n$. Each server s_t follows the simple power consumption model [3, 4] with maximum power consumption $maxE_t$ and minimum power consumption $minE_t$. As shown in Figure 4, the total electric energy of server can be about 20×10^6 [Ws] reduced consumption with the RD and RR algorithm.

4. CONCLUDING REMARKS

In this paper, we discussed the energy-efficient process migration (MG) algorithm for realizing energy-efficient executions of processes in a cluster of servers. Based on the SC and SPC models [3, 4], we discussed how to obtain the expected energy consumption of a server to perform all the current processes. We also discussed how to estimate

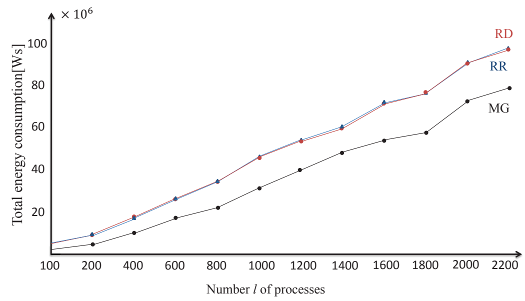

図 4 Total energy consumption.

the expected termination time of each current process. If the process is expected to be more energy-efficiently performed on another server, the process is migrated to the server. Here, a most energy-efficient server is selected for a process. In the evaluation, we showed the total energy consumption of servers to perform processes can be smaller in the MG algorithm than the random (RD) and round-robin (RR) algorithms. The average execution time of each process can be also reduced in the MG algorithm compared with the RR and RD algorithms.

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