

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

DILAWAER, Duolikun / ディラワリ, ドリクン

---

(出版者 / Publisher)

法政大学大学院理工学・工学研究科

(雑誌名 / Journal or Publication Title)

法政大学大学院紀要. 理工学・工学研究科編 / 法政大学大学院紀要. 理工学・工学研究科編

(巻 / Volume)

57

(開始ページ / Start Page)

1

(終了ページ / End Page)

2

(発行年 / Year)

2016-03-24

(URL)

<https://doi.org/10.15002/00013365>

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

Dilawaer Duolikun

Supervisor Makoto Takizawa

Dept. of Advanced Sciences, Hosei University

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 performed 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 energy can be reduced in the MG algorithm.

## 2. Energy-efficient Process Migration

### (1) Process migration

Suppose a cluster  $S$  is composed of multiple servers  $s_1, \dots, s_n$  ( $n \geq 1$ ) 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  $c_s$ .

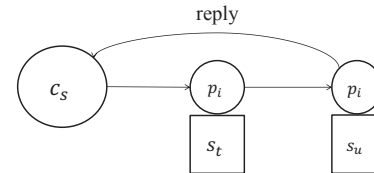


図 1 Process migration.

### (2) Server 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. There 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  $\tau_1$  and every other process terminates at time  $\tau_2$ . Here, the expected energy consumption is  $EE_t = \max E_t \cdot (\tau_2 - \tau_1)$ . 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  $s_u$ .

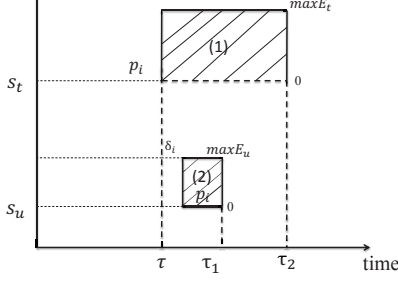


图 2 Expected termination time.

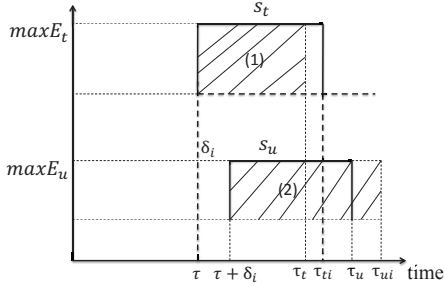


图 3 Expected energy consumption.

### 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  $s_1, \dots, s_n$ . 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  $20 \times 10^6$  [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

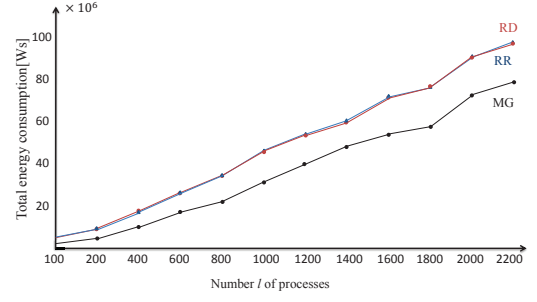


图 4 Total energy consumption.

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.

### References

- 1) S. Ghemawat, H. Gobioff, and S. T. Leung: The Google File System, *Proc. of ACM 19th Symposium on Operating System Principle (SOSP 03)*, 2003, pp. 29 - 43.
- 2) P. A. Bernstein and N. Goodman: The Failure and Recovery Problem for Replicated Databases, *Proc. of the 2nd ACM Symposium on Principles of Distributed Computing*, 1998, pp. 114-122.
- 3) T. Enokido, A. Aikebaier, and M. Takizawa: A Model for Reducing Power Consumption in Peer-to-Peer Systems, *IEEE Systems Journal*, vol.4, issue.2, May 2010, pp. 221-229.
- 4) T. Enokido, A. Aikebaier, and M. Takizawa: Process Allocation Algorithms for Saving Power Consumption in Peer-to-Peer Systems, *IEEE Transactions on Industrial Electronics (TIE)*, vol.58, no. 6, June 2011, pp. 2097 - 2105.
- 5) D. Duolikun, S. Nakamura, T. Enokido, M. Takizawa: An Energy-efficient Process Migration Approach to Reducing Electric Energy Consumption in a Cluster of Servers, *International Journal of Communication Networks and Distributed Systems (IJCNDs)*, 15/ 4, 400-420, 2015, pp.1754-3916.
- 6) D. Duolikun, A. Aikebaier, T. Enokido, M. Takizawa: Energy-Efficient Dynamic Clusters of Servers, *Journal of Supercomputing*, 71/ 5, 1573-0484, 2015, pp.1642-1656