Multiagent-Based Resource Allocation for Energy Minimization in Cloud Computing Systems

Wanyuan Wang, Yichuan Jiang*, *Senior Member*, *IEEE*, Weiwei Wu

Abstract Cloud computing has emerged as a very flexible service paradigm by allowing users to require virtual machine (VM) resources on-demand and allowing cloud service providers (CSPs) to provide VM resources via a pay-as-you-go model. This paper considers the CSP s problem of efficiently allocating VM resources to physical machines (PMs) with the aim of minimizing the energy consumption. Traditional energy-aware VM allocations either allocate VMs to PMs in a centralized manner or implement VM migrations for energy reduction without considering the migration cost in cloud computing systems. We address these two issues by introducing a decentralized *m*ultiagent(MA)-based VM allocation approach. The proposed MA works by first dispatching a cooperative agent to each PM to assist the PM in managing VM resources. Then, an auction-based VM allocation mechanism is designed for these agents to decide the allocations of VMs to PMs. The theoretical analyses suggest that this auction-based mechanism has a high performance on reducing energy cost. Moreover, to tackle system dynamics and avoid incurring prohibitive VM migration overhead, a local negotiation-based VM consolidation mechanism is devised for the agents to exchange their assigned VMs for energy savings. We evaluate the efficiency of the MA by using both static and dynamic simulations. The static experimental results demonstrate that the MA can incur acceptable computation time to reduce system energy cost compared with traditional bin packing-based and genetic algorithm-based centralized approaches. In the dynamic setting, the energy cost of the MA is similar to that of benchmark centralized resource consolidation approaches, but the MA largely reduces the migration cost.

Index Terms Cloud computing systems, resource allocation, energy cost, migration cost, multiagent, negotiation.

1 INTRODUCTION

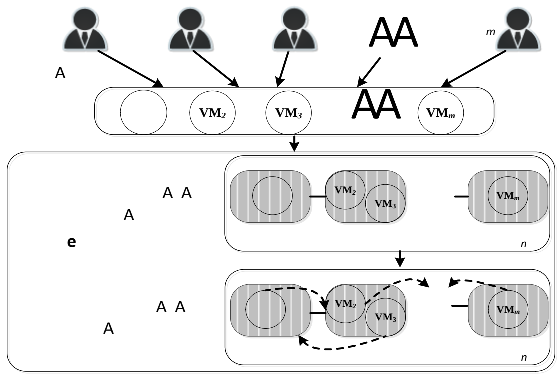

Fig. 1. The multiagent-based resource allocation framework.

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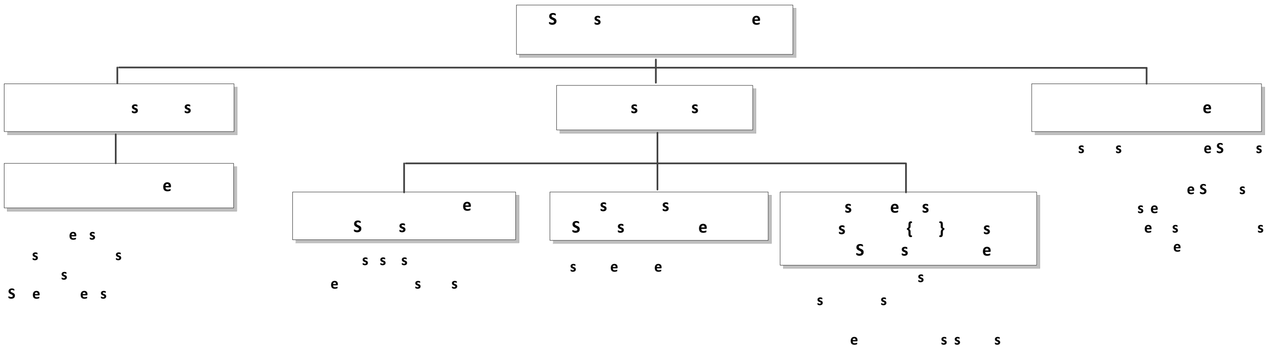

Fig. 2. Classification of resource allocation researches in cloud computing systems.

2.2.1 Bin Packing-Based Static Resource Allocation

2.2.3 Energy and SLA-Aware Dynamic Resource Consolidation

2.2.2 Energy-Aware Dynamic Resource Consolidation

PROBLEM DESCRIPTION

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$$\bigcup_{p_i \quad P} \quad (p_i) \quad , \quad (p_i) \bigcap \quad (p_j) \quad , \quad 1 \quad i, j \quad m, i \quad j$$

$$_{j \quad (p_i)} r_j \quad c_i, \quad 1 \quad i \quad m$$

2.3 Multiagent-Based Resource Allocation

$$e_i(u_i) \quad \begin{matrix} _i \quad _i \quad (1 \quad _i) \quad _i \; u_i, & u_i \quad 0; \\ 0, & u_i \quad 0. \end{matrix}$$

$$\text{Minimize } E = \quad _{i \; 1}^{m} e_i(u_i)$$

Subject to:

$$_{j \; 1}^{n} r_j x_{ij} \quad c_i, \quad i \quad 1, \ldots, m$$

$$u_i \quad _{j \; 1}^{n} r_j x_{ij} / c_i, \quad i \quad 1, \ldots, m$$

$$x_{ij} \quad \{0,1\}, \quad _{i \; 1}^{m} x_{ij} \quad 1, \quad i \quad 1, \ldots, m, \; j \quad 1, \ldots, n$$

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$$a_i^{*} \quad \arg\max_j\{r_j \mid c_i \quad {}_k \quad (p_i)\, r_k \quad r_j \quad 0\}$$

MULTIAGENT-BASED RESOURCE ALLOCATION

$$S(A) \quad \sup\{A(\quad ,P) / OPT(\quad ,P)\}$$

4.1 Auction-Based VM Allocation

$$x_i \;\; X_{k_1} \, x_i \qquad y_i \;\; Y_{k_2} \, y_i$$

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$_{1 \; i \; k_1} w_i \qquad _{k_1 \; 1 \; j \; k_2} l_j$

Consolidation

$_{1 \; i \; k_1} w_i \qquad _{1 \; i \; k_1 \; 1} w_i \quad l_{k1}(\mathrm{Opt}) \quad l_{k1}(A1) \qquad _{k_1 \; 1 \; j \; k_2} l_j$

$_{1 \; i \; k_1} w_i \qquad _{k_1 \; 1 \; j \; k_2} l_j$

$$S(A1) \quad \sup \frac{A1(\;\; , P)}{OPT(\;\; , P)} \quad \frac{OPT(\;\; , P) \qquad _{k_1 \; i \; k_2} e_i(u_i)}{OPT(\;\; , P)}$$

$$1 \quad \frac{_{k_1 \; i \; k_2} \;\; _i \;\; _i \quad (1 \quad _i) \;\; _i u_i}{_{\min} k_1} \quad 1 \quad \frac{_{k_1 \; i \; k_2} \;\; _i}{_{\min} k_1} \quad 1 \quad \frac{_{\max}}{_{\min}}$$

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4.2 Negotiation-Based VM Consolidation

4.2.1 The Reason for Negotiation-Based VM

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4.2.2 A Local Negotiation-Based VM Consolidation Mechanism

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$$OPT_{LB} \quad {}^{k\ 1}_{i\ 1} \quad {}_{i} \quad \frac{(R \quad {}^{k\ 1}_{i\ 1} c_i) \quad {}_{k}}{c_k}$$

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summary

6 CONCLUSIONS AND FUTURE WORK

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REFERENCES

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