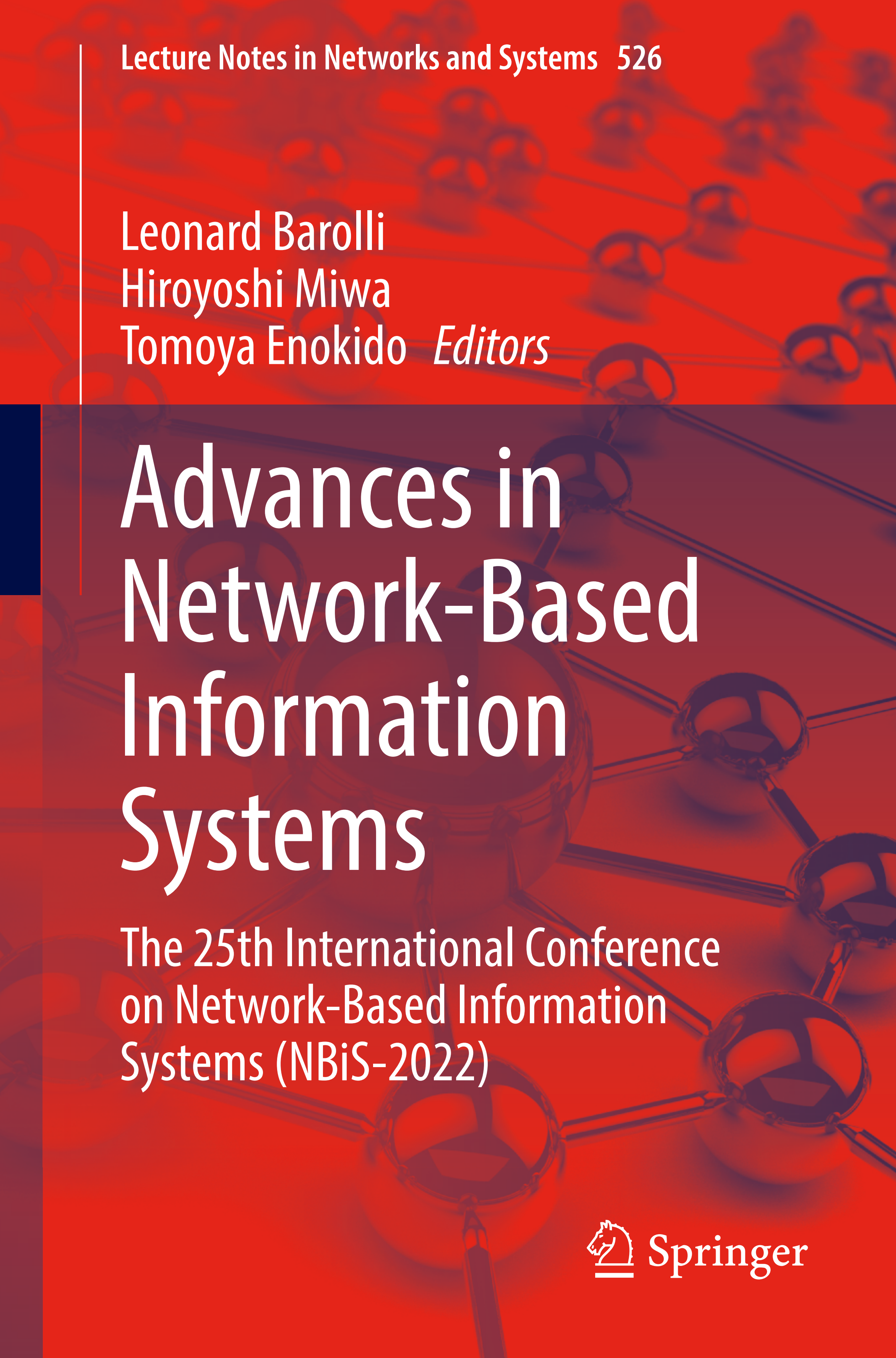

Lecture Notes in Networks and Systems 526

Leonard Barolli
Hiroyoshi Miwa
Tomoya Enokido *Editors*

Advances in Network-Based Information Systems

The 25th International Conference on Network-Based Information Systems (NBiS-2022)

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Editors
Leonard Barolli
Department of Information and
Communication Engineering
Fukuoka Institute of Technology
Fukuoka, Japan

Hiroyoshi Miwa
School of Science and Technology
Kwansei Gakuin University
Sanda, Japan

Tomoya Enokido
Faculty of Bussiness Administration
Rissho University
Tokyo, Japan

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Preface

Welcome Message from NBiS-2022 Organizing Committee

We would like to welcome you to the 25th International Conference on Network-Based Information Systems (NBiS-2022), which is held from September 7 to September 9, 2022.

The main objective of NBiS is to bring together scientists, engineers and researchers from both network systems and information systems with the aim of encouraging the exchange of ideas, opinions and experiences between these two communities.

NBiS is one of the important conferences in the field. Extensive international participation, coupled with rigorous peer reviews, has made this an exceptional technical conference. The technical program and workshops add important dimensions to this event. We hope that you will enjoy each and every component of this event and benefit from interactions with other attendees.

Since its inception, NBiS has attempted to bring together people interested in information and networking, in areas that range from the theoretical aspects to the practical design of new network systems, distributed systems, multimedia systems, Internet/web technologies, mobile computing, intelligent computing, pervasive/ubiquitous networks, dependable systems, semantic services and scalable computing. For NBiS-2022, we have continued these efforts as novel networking concepts emerge and new applications flourish. In this edition of NBiS, many papers were submitted from all over the world. They were carefully reviewed, and only high-quality papers will be presented during conference days.

The organization of an international conference requires the support and help of many people. A lot of people have helped and worked hard for a successful NBiS-2022 technical program and conference proceedings. First, we would like to thank all the authors for submitting their papers. We are indebted to Track Co-Chairs, Program Committee Members and Reviewers who carried out the most difficult work of carefully evaluating the submitted papers.We would like to express our great appreciation to our keynote speakers for accepting our invitation as keynote speakers of NBiS-2022.

We hope that you have an enjoyable and productive time during the conference.

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NBiS-2022 Keynote Talks

Fundamental Model of Online User Dynamics Based on a Causal Framework

Masaki Aida

Tokyo Metropolitan University, Tokyo, Japan

Abstract. User dynamics in online social networks have come to have a great impact not only on online society but also on real life. Therefore, understanding online user dynamics is an important issue. Of course, it is difficult to understand all of the complex online user dynamics, but it may be possible to describe their characteristics in a particular way. This talk introduces an attempt to give a mathematical model of online user dynamics based on a causal framework in which the mutual influences working between users are propagated at finite speeds via an online social network. This model can theoretically explain various phenomena including the intensity of user dynamics diverges, such as online flaming phenomena, and the phenomenon that information propagation is restricted only within a specific community, such as polarization.

Big Data Analytics on COVID-19 Epidemiological Data

Carson K. Leung

University of Manitoba, Manitoba, Canada

Abstract. In the current era of big data, high volume of big data can be generated and collected from a wide variety of rich data sources at a rapid rate. Embedded in these big data are useful information and valuable knowledge. Examples include healthcare and epidemiological data such as data related to patients who suffered from viral diseases like the coronavirus disease 2019 (COVID-19). Knowledge discovered from these epidemiological data via data science helps researchers, epidemiologists and policymakers to get a better understanding of the disease, which may inspire them to come up with ways to detect, control and combat the disease. This talk presents big data analytics solutions for analyzing COVID-19 epidemiological data. The solutions help users to get a better understanding of information about COVID-19 cases. Evaluation on real-life COVID-19 data across Canadian provinces shows the benefits of big data analytics in discovering useful knowledge from COVID-19 epidemiological data.

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A Negotiation Protocol Among Servers for Virtual Machines to Migrate to Reduce the Energy Consumption

Dilawaer Duolikun[1](✉), Tomoya Enokido[2], and Makoto Takizawa[1]

[1] RCCMS, Hosei University, Tokyo, Japan
`dilewerdolkun@gmail.com`, `makoto.takizawa@computer.org`
[2] Faculty of Business Administration, Rissho University, Tokyo, Japan
`eno@ris.ac.jp`

Abstract. It is critical to reduce the electric energy consumption of information systems to realize green societies. Here, each server has to negotiate with other servers to decide on which virtual machine to migrate to and from which servers. In this paper, we newly propose an NM (Negotiation for Migration of virtual machines) protocol for servers to negotiate with one another where not only each host server selects a guest server but also each guest server selects a host server so that the total energy consumption of the servers can be reduced. In the evaluation, we show the total energy consumption of the servers can be reduced to 40 to 60 [%] of non-migration algorithms in the migration algorithms using the NM protocol.

Keywords: Green computing systems · NM protocol · ML (Macro-level estimation) model · NMRB · NMEA

1 Introduction

In order to decrease the carbon dioxide emission, the total electric energy consumption of clouds of servers [2–7,16] has to be reduced. In this paper, we consider the live migration approach [1,16] of virtual machines [1,4–7,16]. Energy-aware algorithms [8,12–14,22–25] are proposed to select a host server to perform an application process issued by a client. In addition, virtual machines migrate from host servers to guest servers to reduce the energy consumption of the servers in the live migration approach [8,16–19,24]. Virtual machines are also used to make systems tolerant of stop-faults of servers by replicating each process on multiple virtual machines [9–11] and making virtual machines migrate to operational servers [26].

Power consumption and computation models of servers in clouds [4–7,14] and fog nodes in the IoT [28,29] are proposed. By using the models, the execution time and energy consumption of a server to perform processes are obtained as discussed in papers [12–14]. In the MI (Monotonically Increasing) model [20–23],

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the energy consumption of a server is more precisely estimated by considering the computation residue of each active process. However, it take time and more data is required to do the estimation. In this paper, we propose an ML (Macro-Level estimation) model by considering the total computation residue of all the active processes on a server in order to make the estimation simpler.

In our previous studies on the live migration approach [12–24], a centralized coordinator is assumed to exist to make a decision on which server sends which virtual machine to which server. It is not easy to realize the coordinator in scalable clouds due to overhead. In this paper, we newly propose an NM (Negotiation for Migration of virtual machines) protocol by which each server communicates with another server to make a virtual machine migrate among the servers. Here, each server estimates the energy consumption of servers in the ML model. We also propose a pair of NMRB (NM Round-roBin) and NMEA (NM Energy-Aware) algorithms where virtual machines autonomously migrate from host servers to guest servers by using the NM protocol. In the NMRB algorithm, a host server is selected to perform a new process issued by a client in the RB way. A host sever whose energy consumption is estimated to be smallest in the ML model is selected in the NMEA algorithm.

In the evaluation, we show the total energy consumption of the servers in a cloud can be about 40 to 60[%] reduced in the NMRB and NMEA algorithms using the NM protocol compared with non-migration algorithms.

In Sect. 2, we present the system model. In Sect. 3, we propose the ML model. In Sect. 4, we propose the NM protocol. In Sect. 5, we evaluate the NMRB and NMEA algorithms.

2 System Model

A cloud C is composed of servers $s_1, \ldots, s_m (m \geq 1)$. Each server s_t is equipped with $np_t (\geq 1)$ CPUs, each of which supports $cn_t (\geq 1)$ cores and each core supports $tn_t (\geq 1)$ threads. The server s_t totally supports nt_t $(= nc_t \cdot tn_t)$ threads. In this paper, a *process* stands for an application process which uses CPU resources [5]. A process being performed is *active*. Time is modeled to be a discrete sequence of time units [tu]. Processes issued by clients are performed on a virtual machine vm_k [1] on a server s_t. $SP_t(\tau)$ and $VP_k(\tau)$ $(\subseteq SP_t(\tau))$ are sets of active processes on a server s_t and a virtual machine vm_k, respectively, at time τ. For a pair of virtual machines vm_k and vm_h, vm_k is *smaller* than vm_h $(vm_k < vm_h)$ iff $|VP_k(\tau)| < |VP_h(\tau)|$. A virtual machine vm_k on a host server s_h can migrate to a guest server s_g in a live manner [1]. Active processes on vm_k do not terminate but are just suspended during the migration time tm. The migration time tm is about two [sec] according to the experiment [24]. VM_t is a set of virtual machines on a server s_t. The execution time of a process p_i on a server s_t is the same as a virtual machine vm_k on s_t [27]. A server and a virtual machine are *active* if at least one process is active, otherwise *idle*.

In the MLPCM (Multi-Level Power Consumption) model [13–16], the power consumption $NE_t(n_t)$ [W] of a server s_t to perform n_t active processes is:

$$NE_t(n_t) = \begin{cases} minE_t & \text{if } n_t = 0. \\ minE_t + n_t \cdot (bE_t + cE_t + tE_t) & \text{if } 1 \leq n_t \leq np_t. \\ minE_t + np_t \cdot bE_t + n_t \cdot (cE_t + tE_t) & \text{if } np_t < n_t \leq nc_t. \\ minE_t + np_t \cdot bE_t + nc_t \cdot cE_t + n_t \cdot tE_t & \text{if } nc_t < n_t < nt_t. \\ maxE_t (= minE_t + np_t \cdot bE_t + nc_t \cdot cE_t + nt_t \cdot tE_t) & \\ & \text{if } n_t \geq nt_t. \end{cases} \quad (1)$$

Each time a CPU, core, and thread are activated, the power consumption of a server s_t increases by bE_t, cE_t, and tE_t [W], respectively. The power $E_t(\tau)$ [W] consumed by a server s_t to perform n_t $(= |SP_t(\tau)|)$ processes at time τ is $NE_t(n_t)$. Energy consumed by a server s_t from time x [tu] to time y is $\sum_{\tau=x}^{y} NE_t(|SP_t(\tau)|)$ [W tu].

The execution time of each process depends on how many processes are active on a thread. $minT_{ti}$ is the *minimum execution time* [tu] of a process p_i on a server s_t where only the process p_i is active on a thread without any other process. Let $minT_i$ be a minimum one of $minT_{1i}, \ldots, minT_{mi}$ in the cloud C. The total amount of computation of each process p_i is defined to be $minT_i$ [4–7]. In well-formed applications, most processes are daily used and it is easy to obtain $minT_i$ of each process p_i. The *computation residue* RP_i of each process p_i is $minT_i$ when p_i starts. $minT_i / minT_{ti} = minT_j / minT_{tj} = TCR_t$ (≤ 1) for any pair of processes p_i and p_j on a server s_t. Here, TCR_t is the *thread computation* rate of a server s_t. If l (> 0) processes are active on a thread, each p_i of the processes is performed at rate TCR_t / l, i.e. the computation residue RP_i of p_i is decremented by TCR_t / l for one time unit. On a server s_t with n_t active processes, each process is performed at rate $NPR_t(n_t)$ in the MLC (Multi-Level Computation) model [12–14] where $NPR_t(n_t) = TCR_t$ for $0 < n_t \leq nt_t$, $TCR_t \cdot (nt_t / n_t)$ for $n_t > nt_t$. The *server computation* rate $NSR_t(n_t)$ $(\leq nt_t \cdot TCR_t)$ of a server s_t is $NPR_t(n_t) \cdot n_t$ for $n_t > 0$. The total computation residue RS_t of a server s_t is $\sum_{p_i \in SP_t(\tau)} RP_i$. RS_t is decremented by $NSR_t(|SP_t(\tau)|)$ at each time τ.

The *power-computation rate* $PCR_t(n_t)$ of a server s_t is $NE_t(n_t) / NSR_t(n_t)$ $(n_t > 0)$. One unit of computation is defined to be the computation which takes one time unit [tu] on the fastest server s_t where $TCR_t = 1$. $PCR_t(n_t)$ shows the power consumption of a server s_t to perform one computation unit, where n_t processes are active. If $n_t \geq nt_t$, $PCR_t(n_t)$ is $PCR_t(nt_t) = maxE_t / (nt_t \cdot TCR_t)$.

We discuss how processes are performed on a server s_t based on the MLPCM and MLC models. Variables C_t, T_t, and E_t denote a set of active processes, active time and energy consumption of each server s_t, respectively. RP_i and T_i show the computation residue and execution time of each process p_i, respectively. At each time τ, if a process p_i starts on a server s_t, RP_i is $minT_i$. T_i is incremented by one if $RP_i > 0$. E_t is incremented by $NE_t(|C_t|)$. RP_i of each process p_i in the set C_t is decremented by $NPR_t(n_t)$. Then, if $RP_i \leq 0$, p_i terminates and is removed from the set C_t. Initially, $E_t = 0$, $C_t = \phi$, $T_t = 0$, and $\tau = 1$.

[Computation model of processes on a server s_t]

```
while () {
for each process $p_i$ which starts on a server $s_t$ at time $\tau$,
{$C_t = C_t \cup \{p_i\}$;   $RP_i = minT_i$;   $T_i = 0$;};
```

$n_t = |C_t|$; $E_t = E_t + NE_t(n_t)$; **if** $n_t > 0$, $T_t = T_t + 1$;
for each process p_i in C_t,
$\{T_i = T_i + 1$; $RP_i = RP_i - NPR_t(n_t)$; **if** $RP_i \leq 0$, $C_t = C_t - \{p_i\}$; $\}$;
$\tau = \tau + 1$; $\}$;

3 An ML (Macro-Level Estimation) Model

We discuss how to estimate energy to be consumed by a server to perform processes based on the MLPCM and MLC models. In papers [20–22], the estimation algorithms like the MI [20] and SMI [22] are proposed where the computation residue RP_i of each active process p_i is taken into consideration. The energy consumption of the server s_t can be more precisely estimated [20]. However, the estimation algorithms are more complex, i.e. it takes longer time and requires more data to perform the estimation algorithms.

We consider the total computation residue RS_t of all the active processes on each server s_t at a *macro* level and do not consider the computation residue of each active process as discussed in papers [17,27]. Let n_t be the number of active processes on a server s_t, i.e. $n_t = |SP_t(\tau)|$ at time τ. Initially, each server s_t is idle, i.e. $n_t = 0$ and $RS_t = 0$. We assume that the minimum execution time $minT_i$ of each process p_i is *a priori* known. If a process p_i is issued to a server s_t, RS_t is incremented by $minT_i$. At each time unit, RS_t is decremented by the server computation rate $NSR_t(n_t)$.

Suppose n_t processes are active on a server s_t at time τ whose total computation residue is RS_t. It takes *execution time* $ET_t(RS_t, n_t) = RS_t/NSR_t(n_t)$ [tu] and s_h consumes *energy* $EC_t(RS_t, n_t) = RS_t \cdot PCR_t(n_t)$ [W tu] to perform n_t processes.

First, we consider the energy consumption $HGEC_{hg}$ of the servers s_h and s_g among which no virtual machine migrates. Since the servers s_h and s_g consume the energy $HEC_h = EC_h(RS_h, n_h)$ and $GEC_g = EC_g(RS_g, n_g)$, respectively, $HGEC_{hg}$ is as follows:.

$$HGEC_{hg} = \begin{cases} RS_h \cdot PCR_h(n_h) + RS_g \cdot PCR_g(n_g) + \\ \qquad mE_{hg}(RS_h/NSR_h(n_h), RS_g/NSR_g(n_g)). \end{cases} \tag{2}$$

In order to take into consideration the energy consumption of idle servers, the function mE_{hg} is defined in papers [13,21,22]. Here, $mE_{hg}(x, y)$ is $minE_h \cdot (x-y)$ if $x \geq y$, otherwise $minE_g \cdot (y - x)$.

Next, suppose a virtual machine vm_k with $nv_k (\leq n_h)$ active processes migrates from a host server s_h to a guest server s_g at time τ. Processes on vm_k are suspended at time τ to time $\tau + tm$ and restarts on the guest server s_g at time $\tau + tm$ where tm is the migration time. Since the nv_k processes leave the server s_h, the computation residue of the virtual machine vm_k is $RS_h \cdot (nv_k/n_h)$ and the computation residue of the host server s_h is reduced to $RS_h - RV_k = RS_h \cdot (1 - nv_k/n_h)$. The number of active processes on s_h is also reduced to $(n_h - nv_k)$. The total execution time VHT_h is $RS_h \cdot (1 - nv_k/n_h)/NSR_h(n_h - nv_k)$ [tu] and s_h consumes the energy $VHEC_{h:k} = EC_h(RS_h - RV_k,\ n_h - nv_k) = RS_h \cdot (1 - nv_k/n_h) \cdot PCR_h(n_h - nv_k)$ [W tu].

Here, suppose n_g processes are active at time $\tau+tm$ when the virtual machine vm_k restarts on the guest server s_g, i.e. $tm < RS_g/NSR_g(n_g)$. For tm time units [tu] from time τ, n_g processes in the set $SP_g(\tau)$ are performed on s_g while active processes on vm_k are suspended. Here, the computation $NSR_g(n_g)\cdot tm$ is performed, i.e. the computation residue of s_g is reduced to $RS_g-NSR_g(n_g)\cdot tm$. The guest server s_g consumes the energy $NE_g(n_g)\cdot tm$ since the power $NE_g(n_g)$ [W] is consumed for tm [tu] until vm_k restarts on s_g. The computation residue RS_g of the server s_g is reduced to $RS_g-NSR_g(n_g)\cdot tm$. At time $\tau+tm$, since nv_k processes on vm_k newly restart in addition to the n_g processes on the guest server s_g, the computation residue increases by the computation residue RV_k, i.e. $(RS_g - NSR_g(n_g)\cdot tm) + RS_h\cdot(nv_k/n_h)$. The number of active processes also increases to n_g+nv_k. Hence, the total execution time $VGT_{g:k}$ of the guest server s_g is $tm + [RS_g - NSR_g(n_g)\cdot tm + RS_h\cdot(nv_k/n_h)]/NSR_g(n_g+nv_k)$ [tu]. The guest server s_g consumes the energy $VGEC_{g:k} = NE_g(n_g)\cdot tm + [RS_g - NSR_g(n_g)\cdot tm + RS_h\cdot(nv_k/n_h)]\cdot PCR_g(n_g+nv_k)$ [W tu].

Next, suppose no process is active at time $\tau+tm$, i.e. $tm \geq RS_g/NSR_g(n_g)$. That is, all the n_g processes terminate at time $\tau+RS_g/NSR_g(n_g)$ $(< \tau+tm)$ and then no process is active until time $\tau+tm$ when vm_k restarts on the server s_g. The nv_k processes on vm_k are performed on s_g at time $\tau+tm$. It takes $ET_g(RV_k, nv_k) = RS_h\cdot(nv_k/n_h)/NSR_g(nv_k)$ [tu] to perform the nv_k processes and s_g consumes the energy $EC_g(RV_k, nv_k) = RS_h\cdot(nv_k/n_h)\cdot PCR_g(nv_k)$ [W tu]. Thus, the total execution time $VGT_{g:k}$ to perform the n_g processes and the nv_k processes is $tm + RS_h\cdot(nv_k/n_h)/NSR_g(nv_k)$ [tu]. The server s_g consumes the minimum power $minE_g$ [W] from time $\tau+RS_g/NSR_g(n_g)$ to $\tau+tm$ since s_g is idle. Hence, the guest server s_g consumes the energy $VGEC_{g:k} = RS_g\cdot PCR_g(n_g) + minE_g\cdot[tm - RS_g/NSR_g(n_g)] + RS_h\cdot(nv_k/n_h)\cdot PCR_g(nv_k)$.

$$VGEC_{g:k} = \begin{cases} NE_g(n_g)\cdot tm + [RS_g - NSR_g(n_g)\cdot tm + RS_h\cdot \\ \quad (nv_k/n_h)]\cdot PCR_g(n_g+nv_k) \quad \text{if } tm \leq RS_g/NSR_g(n_g). \\ RS_g\cdot PCR_g(n_g) + minE_g\cdot[tm - RS_g/NSR_g(n_g)] + \\ \quad RS_h\cdot(nv_k/n_h)\cdot PCR_g(nv_k) \quad \text{otherwise.} \end{cases} \tag{3}$$

The servers s_h and s_g totally consume the energy $VHGEC_{hg:k} = VHEC_{h:k} + VGEC_{g:k} + mE_{hg}(VHT_h, VGT_g)$ if vm_k migrates from s_h to s_g.

If the following *MG* condition $MG_{sg:k}$ holds for a host server s_h, a guest server s_g, and a virtual machine vm_k, the total energy to be consumed by the servers s_h and s_g can be reduced if vm_k migrates from s_h to s_g.

[MG (MiGration) condition $MG_{hg:k}$] $HGEC_{hg} > VHGEC_{hg:k}$.

4 An NM Protocol

4.1 Selection of a Virtual Machine

We newly propose an *NM* (Negotiation for Migration of virtual machines) protocol for servers to negotiate with other servers to decide on which virtual machine on which host server migrates to which guest server. On each server s_h, n_h

processes are active, the total computation residue of the n_h active processes is RS_h, and VM_h is a set of virtual machines.

Suppose a client issues a process p_i to a cloud C of servers $s_1, \ldots, s_m$ $(m > 0)$. First, a server s_h is first selected in the cloud C. In the round-robin (RB) algorithm, a server s_h is selected for the process p_i after s_{h-1}. In the EA (Energy-Aware) algorithms [12–14], a server s_h whose expected energy consumption $EC_h(RS_h{+}minT_i, n_t{+}1)$ is smallest is selected in the cloud C. Then, a local virtual machine vm_k is selected in the set VM_h to perform the process p_i in the following *VMP* algorithm:.

[VMP (Virtual Machine for a Process) selection algorithm]

1. If every virtual machine is idle, one idle virtual machine vm_k is selected.
2. If there is an active virtual machine vm_l where $nv_l < nt_h$, a largest virtual machine vm_k is selected where $nv_k \leq nt_h$.
3. If $nv_k \geq nt_h$ for every virtual machine vm_k in VM_h, a smallest virtual machine vm_k is selected.

If a smallest virtual machine is selected each time a process is issued to a server s_h, processes are uniformly allocated to every local virtual machine. This means, only virtual machines with too small number of active processes might migrate to another server even if the severs consume less energy if a virtual machine with more active processes migrate.

In the migration approach, a virtual machine vm_k to migrate is selected on a host server s_h in the following *VMM* selection algorithm:

[VMM (Virtual Machine to Migrate) selection algorithm] A virtual machine vm_k is active, i.e. $nv_k > 0$ and smallest in VM_h of a server s_h.

4.2 NM Protocol

If the *MGC* (migration check) condition is satisfied at current time τ, a server s_h selects a local active virtual machine vm_k to migrate in the VMM algorithm.

[MGC condition] $\tau \geq lastmgt_h + mgint$ and $n_h/nt_h > 2$.
Here, $lastmgt_h$ shows most recent time a local virtual machine on a server s_h migrates and *mgint* is the minimum migration interval. The condition $n_h/nt_h > 2$ means that at least two processes are active on each thread of a server s_h.

The server s_h obtains the expected energy consumption $HE_h = EC_h(RS_h, n_h)$ and execution time $HT_h = ET_h(RS_h, n_h)$ to perform n_h processes, where no local virtual machine migrates to another server. The server s_h also obtains the energy consumption $VHE_{h:k} = EC_{h:k}(RS_h{-}RV_k, n_h{-}nv_k)$ and the execution time $VHT_{h:k} = ET_h(RS_h{-}RV_k, n_h{-}nv_k)$ to perform $(n_h{-}nv_k)$ processes, where vm_k migrates to another server. As discussed in Sect. 3, the computation residue RV_k of vm_k is $RS_h{\cdot}(nv_k/n_h)$. Th server s_h sends an *MGQ* (MiGration reQuest) message with data $\langle vm_k, RV_k, HE_h, HT_h, VHE_{h:k}, VHT_{h:k}\rangle$ to other servers to ask if the servers can be guest servers of vm_k. Let GS_h be a set of servers to which the server s_h sends *MRQ* messages.