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VM Consolidation by using Selection and Placement of VMs in Cloud Datacenters

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Abstract. The Cloud Computing model leverages virtualization of computing resources allowing customers to provision resources on-demand on a pay-as-you-go basis. During recent years, the power consumption of datacenters in cloud environment attracted researchers. Optimization of energy consumption can be performed by different methods including virtual machine (VM) consolidation. This technique can reduce energy consumption by preventing of wasting them. Also, VM migration can provide opportunity to reduce energy consumption. In this article, we want to study different methods and policies to select and place VMs and migration algorithms for underutilized and over-utilized servers in order to reduce energy consumption and SLA violation. We offer general and comprehensive framework on optimization of VM consolidation as its flowchart and at last, suggest combined idea to detect underloaded and overloaded hosts and also VM selection and VM placement policies.

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1. Introduction

Extension of cloud computing [2] established datacenter with large scale including thousand servers around the world. Thus, cloud datacenter consumes more electrical energy which has staggering costs and released more di oxide carbon to environment. Electricity used by datacenters worldwide increased by about %56 between 2005 and 2010 and in 2010; it was nearly between 1/1 to 1/5 percent of total electricity use respectively in the world [1] and also, di oxide carbon of information and communication technology was equivalent %2 of total scale which is equal to aviation industry [9]

According to studies of Natural Resource Defense Council of America, in 2013, electricity consumption of datacenter in US was estimated 91 billion KWh and it is predicated that till 2020, it reaches to up 140 billion KWh which costs equivalent 13 billion dollar and 100 million metric ton di oxide carbon emission annually [6]. The most important reasons for growth of consumption is not much computation resources but inefficient use of this resources. Information collected from 5000 servers during 6 months showed that in many cases, servers operate at 10 to 50 percent their full capacity which is leading to extra expenses on over-provisioning, and thus extra Total Cost of Acquisition [3].

Since virtualization is used in cloud datacenters as vast, one of the solutions is to dynamic VM consolidation on some of the active servers. Therefore, we focus on VM consolidation and VM migration in this article. Each VM needs specified resources such as processor, memory, disk and network bandwidth [8]. Virtualization allows user to assemble some virtual machine on a physical machine [4]. One of the most requirements of cloud computing is to provide confidential quality of services (QoS). QoS can be defined as specifications like minimum throughput, maximum response time etc. [5]

The most important challenges for energy consumption management in cloud environment are to minimize using of computation resources and SLA violation. In order to overcome this challenges, we classify physical machine to 3 groups:

1. Underloaded Nodes
2. Mid-load Nodes
3. Overloaded Nodes

Underloaded hosts are ones that their CPU utilization is under lower utilization threshold. Since each idle server consumes %70 energy of active server [7], all VMs of underloaded host shall migrate to other nodes to prevent from energy wasting by switching idle servers off. Mid-load server is host that its CPU utilization is between lower and upper threshold value. Overloaded host is server that its CPU utilization exceeds from upper utilization threshold value and causes SLA violation. In order to prevent from SLA violation, some of its VMs shall migrate.

The remaining is as following that in section 2, background, system architecture, and energy modelling, cost of VM live migration and SLA violation metric will be covered. In chapter 3, we review on related works and our contribution as process and flowchart will be offered in chapter 4 and at last, results and future works will be cited in chapter 5.

2. System Model

VM consolidation is one of the techniques which are used to reduce operational cost of datacenter. Thus, VM consolidation points to use physical server by placing more than one VM on it to use resources efficiently. VM consolidation reduce number of active physical servers and also server dispersion- the situation in which some servers with low utilization occupy more spaces and use many resources. Meanwhile, VM consolidation reduces number of active servers and reduces power consumption because of linear power-to-frequency relationship for active servers.

As for figure 1, host A has one VM only that its CPU utilization is so low but its energy consumption is high and produces more hot. Thus, its VM migrates to another host to save more energy by shutting down idle servers. Also, there are two other hosts namely B and C. Now, we have to decide which suitable host for VM of host A. As indicated figure 1, host C has four VM which is near to full capacity and critical temperature but server B has two VMs and their CPU utilization is so low. Then, sever can be suitable host for virtual machine of node A. as said before, node C is overloaded host then one of its VMs will transfer to node B to prevent SLA violation.

2.1. **System Architecture.** Our final system is a datacenter with large-scale which consists of N heterogeneous physical nodes. Each node i is characterized in terms of CPU performance defined in Million Instruction Per Second (MIPS) amount of RAM and network bandwidth. Some independent users submit their request for provisioning of M heterogeneous VMs that characterized by requirements to processing power defined in MIPS, amount of RAM and network bandwidth. In this environment, VM can captured by independent users and managed by them. Also, in this model, the users establish SLA to satisfy QoS and the provider pay penalty in the event of violation. We can convert VM

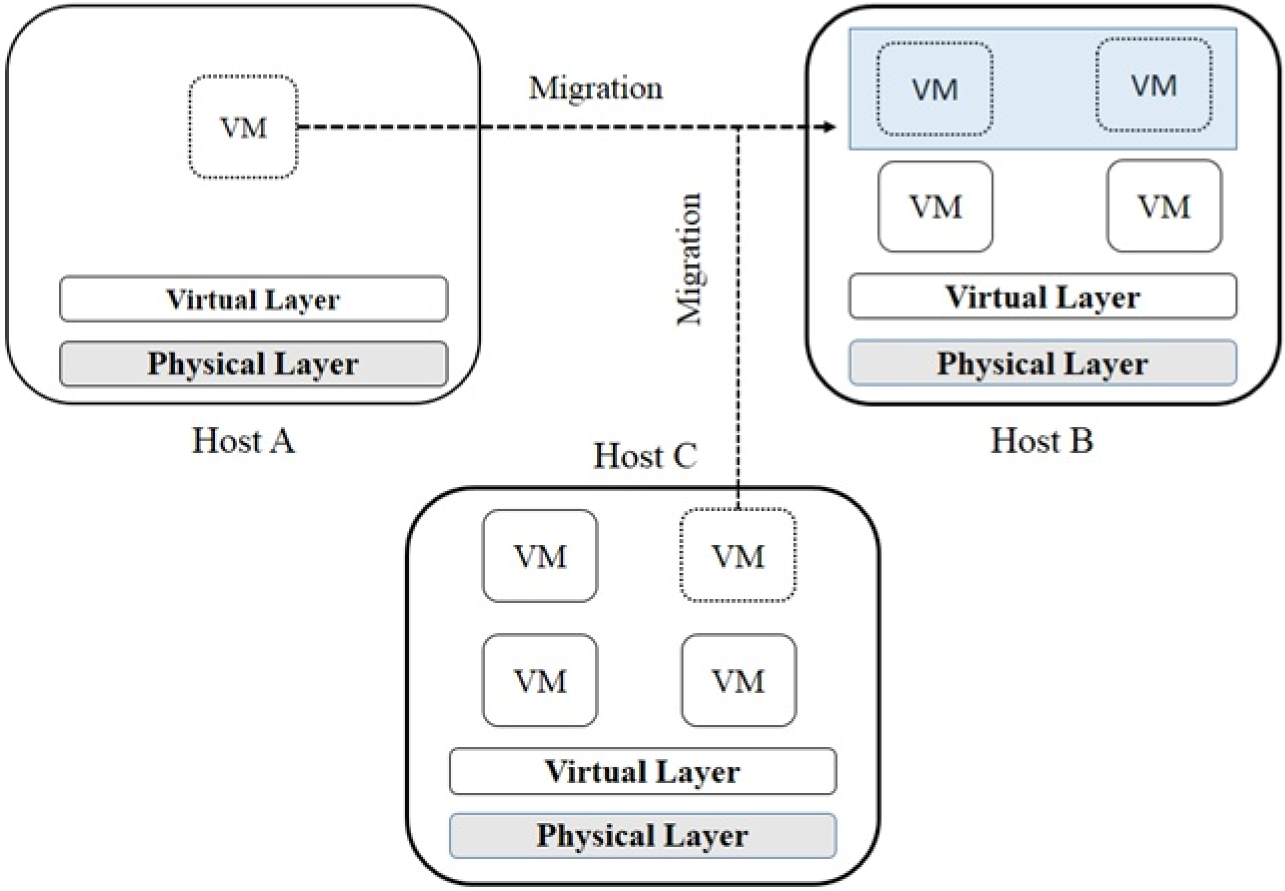

Figure 1. VM Consolidation

Consolidation problem to 4 following subproblems [4]:

1) Determining when a host is considered as being overloaded, requiring migration of one or more VMs from this host
2) Determining when a host is considered as being underloaded leading to a decision to migrate all VMs from this host and switch the host to the sleep mode
3) Selection of VMs that should be migrated from an overloaded host (VM Selection)
4) Finding a new placement of the VMs selected for migration from the

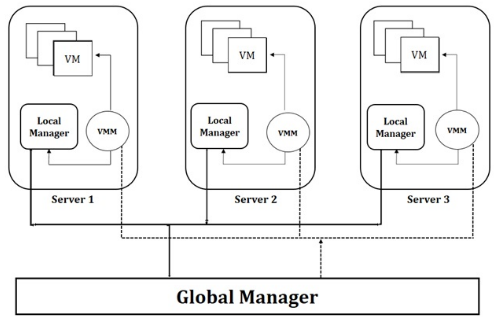

FIGURE 2. System Architecture

overloaded and underloaded hosts (VM Placement)

For this purpose, our system model has local and global manager (figure 2), local manager which locates on each node and its aim is to monitor CPU utilization continuously and recognize underload or overload situation. In the event of overloading, local manager apply VM selection algorithm to decide that which VM shall migrate. Global manager locates on master node and receives information from local managers to obtain general insight about system. Based on decisions of local managers, global manager migrates the VM from physical machine. In addition, placement actions are also ordered by global manager. It gets the status information from local manager and communicates also with VM manager. VM manager is hyper-visor and it converts orders sent by global manager, i.e. migration and placement to action in order to reduce energy consumption by switching idle servers off.

2.2. **Power Consumption Model.** Power consumption is mostly recognized by computation nodes in datacenter as CPU consumption, memory, disk, power suppliers and cooling systems [12]. As said before, power consumption by servers has linear relationship with CPU utilization even we use DVFS[2] technique. Moreover, these studies show that on average an idle server consumes approximately 70 percend of the power consumed when it is fully utilized. Therefore, for experimental studies the

[2]Dynamic Voltage and Frequency Scale

power consumption defined as a function of the CPU utilization P(u) as shown in below:

$$P(u) = k.P_{max} + (1 - k).P_{max}.u \tag{2.1}$$

In which, P_{max} is considered 250 W which is appropriate for modern computation servers, k is the fraction of power consumed by idle server ($k = 0.7$) and u is CPU utilization, thus:

$$P(u) = P_{max}(0.7 + 0.3u) \tag{2.2}$$

As the CPU utilization may change over time due to the workload variability, it is a function of the time; $u(t)$. Therefore, to define the total energy consumption by a server the model defined in [3]:

$$E = \int_{t_1}^{t_2} P(u(t))dt \tag{2.3}$$

2.3. **Cost of VM Live Migration.** VM Live migration provides transportation of VMs between physical machines without suspension and a short down time. However, live migration has a negative impact on the performance of applications running in VM during a migration. Voorsluys and et al. [13] have performed an experimental study to investigate the value of this impact and find a way to model it. They have found that for dynamic workload class, like class of web-application, the average of performance degradation including of down time can be estimated as approximately %10 of CPU utilization. That means each migration can cause SLA violation, thus, it is necessary to minimize number of migration. The length of a live migration depends on the total amount of memory used by the VM and available network bandwidth. Therefore, the performance degradation experienced by VM_j defined as below:

$$T_{Mj} = \frac{M_j}{B_j} \tag{2.4}$$

$$U_{dj} = 0.1 \int_{t_0}^{t_0 + t_{Mj}} U_j(t)\, dt \tag{2.5}$$

Where U_{dj} is the total performance degradation by VM_j, t_0 is the time when the migration starts, T_{Mj} is the time taken to complete migration, $U_j(t)$ is CPU utilization of VM_j, M_j is the amount of memory used by VM_j and B_j is available network bandwidth for VM_j.

2.4. **SLA violation Metric.** Meeting the QoS requirement is important in cloud computing environment. QoS requirements are formulated in the form of SLA which can be determined in term on such characteristics as minimum throughput or maximum response time delivered by

deployed system. Since these characteristics may vary for different applications, it is necessary to define independent metric to evaluate QoS for each VM which is used in IaaS[3]. Thus two metric for SLA violation in IaaS environment has been suggested:
1- Time period in which active host experiences %100 CPU utilization and it is named as SALTAH[4]
2- Total performance degradation which is experience in the time of migration and named as PDM[5]

Reason for SLA violation in first part is that if hosts experience %100 CPU utilization, applications performance is limited to node capacity and thus, no VMs provide for performance requested by user.

$$SLATAH = \frac{1}{N}\sum_{i=1}^{N}\frac{T_{si}}{T_{ai}} \tag{2.6}$$

$$PDM = \frac{1}{M}\sum_{j=1}^{M}\frac{C_{dj}}{C_{rj}} \tag{2.7}$$

In formulas, N is number of physical node, T_{si} is time period in which node j experiences %100 CPU utilization and results to SLA violation, T_{ai} is time period which node i is active (provides VMs), M is number of VM, C_{dj} is estimation of degradation of performance of VM_j because of its migration and C_{rj} is total capacity of processor which is requested by VM_j. In this article, it is supposed that C_{dj} is estimated to %10 of CPU utilization in MIPS in the migration time. Each two scales SALATH, PDM recognize SLA violation independently, thus, combined scale is applied to estimate SLA violation in the system.

$$SLAV = SLATAH.PDM \tag{2.8}$$

3. Related Works

Houri and et al [10] offered consolidation method for VMs in terms of QoS. They used Local Regression (LR) for overloaded host detection and in order to VM selection, applied minimize migration time (MMT) policy, whereas, in order to recognize underloaded nodes, VDT has been used. Also, they used utilization and minimum correlation method (UMS) in order to VM placement. The algorithms reduced number of migration and SLA violation significantly.

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[3] infrastructure as a service
[4] SLA Violation Time per Active Host
[5] Performance Degradation due to Migration

Hoang and et al [11] offered dynamic VM consolidation by consideration overloaded and underloaded hosts. They used local regression to recognize overloaded hosts and least increased power (LIP) has been used to VM placement procedure. Also, they offered new methods namely BFH, BFV for VM placement.

Fou and et al [8] unveiled a novel policy for VM selection which helps to reduce energy consumption in cloud datacenter. The policy firstly finds overloaded nodes in terms of methods offered by Beloglazov [4] and then, by MP technique, selects VMs which shall migrate. They used PABFD techniques and minimum correlation coefficient (MCC) for VMs placement. Their policy is good in simulation environment.

Beloglazovand et al [4] have define the problem of consumption of much amounts of power and emission of di oxide carbon and offered novel adaptive heuristic method for dynamic VM consolidation which acts in based on an analysis of data from the resource usage by VMs. The algorithm reduces energy consumption while ensuring a high level of the SLA. They used following methods for VM consolidation:

For overloaded host detection uses LR, IQR, MAD, LRR. In order to VMs selection uses RC, MMT and MC, and to detect underloaded host, simple method is used but their algorithm was failed to get short SLA violation period in each active host and small VMs migrations in virtualized datacenters. To solve these problem, they design a novel method for overloaded host and PABFD method for VM placement.

4. Our Contribution

Different researches tried to obtain best performance in management of energy consumption in cloud computing. One of the valuable works was offered by Hoang and et al [11]. As for works performed, following process is offered to reach suitable performance and then offer suitable result in reduce number of SLA violation and reduce energy consumption of datacenter.

4.1. **General Process.**

As seen from figure 3, we suggest a process to consolidate VMs. In datacenter, there are many servers. These servers are classified in three groups including underloaded, mid-load and overloaded host in terms of CPU utilization. Each node has many virtual machines. In overloaded node, some VMs are selected for migration. Also, the host(s) shall be selected for VMs. These hosts can be as underloaded and Mid-load hosts. Finally, when some of underloaded nodes did not receive any VMs, all their VMs must be transferred to Mid-load server in order to reduce energy consumption by turning off the idle servers.

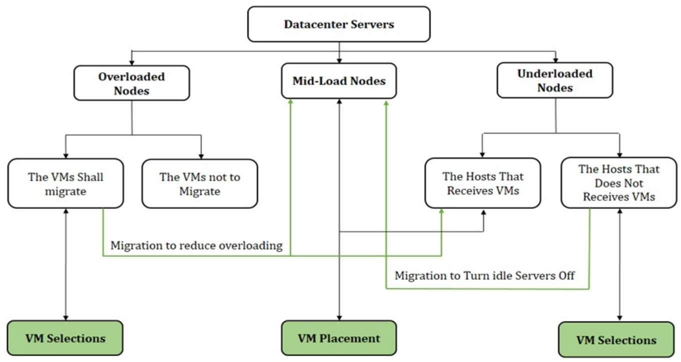

FIGURE 3. VM Consolidation Process

4.2. **General Flowchart.** According to flowchart (figure 4), firstly, select host from list of servers to determine the host is overloaded or not? In order to determine overloaded node, local regression (LR) is used because Beloglazov [4] showed that LR has better performance than MAD, IQR, and LRR. After detection of overloaded host, MP algorithm is used to determine VMs from overloaded host for migration. In this method, we maintain host utilization close to upper threshold and also, reduce number of migration. In order to VM placement, we use a combination of two methods, in first step, after selecting VMs from overloaded host and in second step, after selecting all VMs of underloaded host. In this method, it is tried to place VMs on mid-loaded nodes and in final step, consider the host with the lowest CPU utilization as an underloaded host and transfer all its VMs, and then again consider host with the lowest CPU utilization and transfer all its VMs. This is done till not exist enough resources for migration of VMs.

5. Conclusion and Future Work

The compromise between energy consumption and SLA violation provides real challenge for service providers. We studied and discussed some of valuable discussion and pointed that suitable use of policies and techniques can reduce energy consumption and reduce SLA violation. We offered idea which is established by combination of BFH, BFV so that for first placement, we use BFH technique after selecting virtual machine;

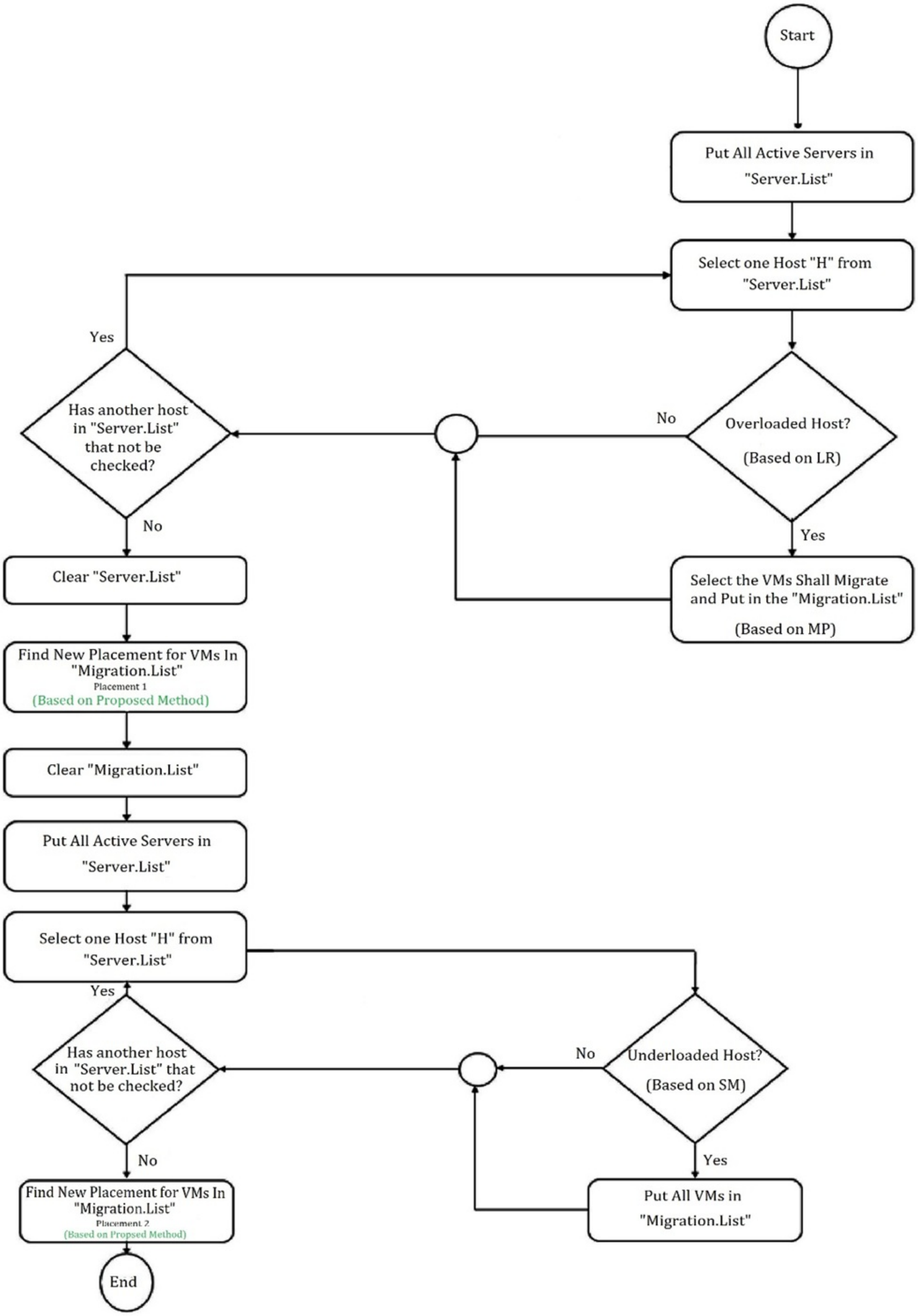

Figure 4. Virtual Machine Consolidation Flowchart

this reduces number of SLA violation significantly, we tried to establish methods by combining different techniques to reduce energy consumption. Results obtained from optimum performance changed by changing parameters and it shows combination of virtual machine is resulted to turn off of idle servers and reduce energy consumption. Of course, this idea shall be simulated and tested to find better results what will be consisted in our future work.

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