INFORMATION OF DOCTORAL DISSERTATION

Research title: **Energy-efficient Resource Management in Cloud Computing**
Major: **Computer science**
Major code: **62480101**
PhD student: **NGUYỄN QUANG HÙNG**
Scientific advisors:
1. **Assoc. Prof. Dr. THOẠI NAM**

2. **Dr. NGUYỄN THANH SƠN**

Education Organization: **HCMC University of Technology - Viet Nam National University Ho Chi Minh City**

Dissertation Summary:
Cloud computing, which is a large-scale distributed computing paradigm, has been becoming an utility computing model and is driven by economies of scale. Infrastructure-as-a-Service (IaaS) cloud provides cloud users with computing resources in terms of virtual machines (VMs) to run their applications in cloud virtualized data centers. A study has estimated the energy cost of a single data center is more than $15M per year. The power consumption is increased with the increasing scale of these data centers. Therefore, advanced scheduling techniques for reducing energy consumption of these cloud systems are highly concerned for any cloud providers to reduce energy cost.
This dissertation investigates the energy-efficient virtual machine scheduling problems in IaaS clouds where users request multiple resources in fixed intervals and non-preemption for processing their virtual machines and physical machines have bounded capacity resources. Many previous works are based on migration techniques to move on-line VMs from low utilization hosts and turn these hosts off to reduce energy consumption. However, the techniques for migration of VMs could not use in our research. The scheduling problem is NP-hard and is one of the hot topic research.

Results of the dissertation:

The key contributions are:

1. Dissertation proposes new approach to the problem of energy-aware virtual machine scheduling with the execution time of virtual machines and each virtual machine requires multiple computing resources simultaneously.
2. Dissertation exploits the execution time of each virtual machine (between the start time and end time of each virtual machine) to find out the equivalent scheduling goal is "Minimizing total busy time of the physical machines". Instead of minimizing the number used physical machines, the dissertation proposes scheduling algorithms to minimize the sum of total busy time of all physical machines that is equivalent to minimize total energy consumption. The dissertation proposes two approaches:
   i. Using the execution time of each virtual machine the dissertation proposes the *Minimizing Differential Finishing Time (MinDFT)* algorithms, which is denoted as *MinDFT-ST*, *MinDFT-FT*, *MinDFT-LDTF* and *MinDFT-LFT* (in the chapter 5). All of MinDFT-ST, MinDFT-FT, MinDFT-LDTF and MinDFT-LFT algorithms differ in sorting of list of virtual machines to be allocated by core MinDFT algorithm. The MinDFT algorithm is a Best-Fit Decreasing heuristic to allocate a virtual machine to a physical machine that has enough available resources and minimum of the increasingly finishing time of the physical machine. The time complexity of MinDFT algorithm is O($n.m$) where n is the number of virtual machines to be scheduled, m is the number of physical machines.
   ii. The energy-aware virtual machine scheduling algorithms based on both the time and length (Euclidean norm) of multiple dimensional vector where each dimension of the vector is the residual resource utilization (after allocation for placed virtual machines) of a physical machine. The dissertation proposed the *Energy-aware Minimizing Differential Time and Resource Efficiency* algorithms, which are denoted as *EMinTRE-ST*, *EMinTRE-FT*, *EMinTRE-LDTF* and *EMinTRE-LFT* (in Chapter 6). The

EMinTRE-ST, *EMinTRE-FT*, *EMinTRE-LDTF* and *EMinTRE-LFT* algorithms are proposed using a new metric (denoted as *TRE – different Time and Resource Efficiency*) to allocate virtual machines to physical machines. The TRE metric is sum of squared of ratio of increasing finishing time of a physical machine (multiplied by the time weight) and length of the residual resources vector of the physical machine (each resource multiplied by percentage of residual resources with weight). A physical machine that has enough available resources and minimum of the TRE value will be selected to allocate a virtual machine. Core EMinTRE algorithm is Best-Fit Decreasing on the TRE. The EMinTRE-ST, EMinTRE-FT, EMinTRE-LDTF and EMinTRE-LFT algorithms differ in sorting of list of virtual machines to be allocated by the core EMinTRE algorithm. The EMinTRE algorithm has the time complexity is $O(n.m)$ where n is the number of virtual machines to be scheduled, m is the number of physical machines (assume that $m \geq \log n$).

3. Dissertation evaluates performance of these proposed scheduling algorithms by simulations. Dissertation chooses CloudSim, which is a popular Cloud data centers and virtual machine allocation algorithms simulation software. There are many extensive simulations using parallel workload models in Parallel Workload Archive show that the proposed algorithm has the least total energy consumption compared to the state-of-the-art algorithms include Beloglazov's Power-Aware Best-Fit Decreasing (denoted as PABFD), Tian's Modified First-fit Decreasing Earliest (denoted as Tian-MFFDE), vector bin-packing heuristics (denoted as VBP-Norm-L1, VBP-Norm-L2).

Scientific advisors	**PhD student**
Assoc. Prof. Dr. Thoại Nam and Dr. Nguyễn Thanh Sơn	**Nguyễn Quang Hùng**