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A Leading-Edge Environs and Power Stratagems for Green Data Centers via Cloud Networks

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Abstract

In this prodigies we are estimating the Power Utilization criteria followed by the data centers through Green cloud Adoption. Since Cloud computing data centers are becoming increasingly popular for the accommodation of computing resources. The outgoings and operating expenses of data centers have skyrocketed with the increase in computing dimensions. More than a few governmental, industrial, and academic soundings indicate that the energy exploited by computing and communication troops within a data center contributes to a considerable segment of the data center operational costs. In this critique, we extant a simulation environment for energy-aware cloud computing data centers. Laterally with the workload distribution, the green cloud simulator is designed to capture details of the energy consumed by data center components (servers, switches, and links) as well as packet-level communication patterns in pragmatic setups. The imitation results obtained for various-tiers, and three-tier high-speed data center architectures demonstrate the efficacy of the simulator in utilizing power depletion schema, such as voltage scaling, frequency scaling, and dynamic shutdown that are applied to the computing and networking ingredients.

Keywords: *Energy efficiency, Workload distribution, Cloud simulations, High speed data centers, Power consumption.*

1. Introduction

Over the last few years, cloud computing amenties have become increasingly admired due to the evolving data centers and parallel computing prototypes. The perception of a cloud is typically defined as a puddle of computer resources organized to provide a computing function as a utility. The foremost IT companies, such as Microsoft, Google, Amazon, Salesforce and IBM, pioneered the field of cloud computing and keep increasing their offerings in data distribution and computational hosting. The maneuvering of large geographically distributed data centers requires considerable amount of energy that accounts for a large slice of the total operational costs for cloud data centers [4].

Gartner assembly estimates energy consumptions to account for up to 10% of the current data center operational expenses (OPEX), and this estimate may rise to 50% in the next few years [6]. However, computing based energy consumption is not the only power-related share of the OPEX bill. High power intake generates heat and involve an accompanying cooling system that expenses in a range of $2 to $5 million per year for classical data centers. Failure to retain data center temperatures within operational ranges drastically decreases hardware reliability and may potentially violate the Service Level Agreement (SLA) with the customers. A major ration (over 70%) of the heat is generated by the data center infrastructure [16]. Therefore, optimized infrastructure installation may show a significant role in the OPEX reduction. From the energy efficiency viewpoint, a cloud computing data center can be defined as a puddle of computing and communication resources organized in the way to transform the received power into computing or data transfer work to satisfy user pressure. The first power saving solutions focused on building the data center hardware components power proficient skills, such as Dynamic Voltage and Frequency Scaling (DVFS), and Dynamic Power Management (DPM) [9] were broadly studied and widely deployed. Because the aforementioned techniques rely on power-down and power-off criteria's, hence efficacy of these techniques is at best limited. In fact, an immobile server may consume about 2/3 of the peak load [2].

Because the workload of a data center fluctuates on the weekly (and in some cases on hourly basis), it is a common practice to overprovision computing and communicational resources to accommodate the ultimate (or expected maximum) load. In the mean while the

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middling load accounts only for 30% of data center resources [12].However, achieving the above compels central coordination and energy-aware workload scheduling techniques. Distinctive energy-aware scheduling solutions attempt to: (a) concentrate the workload in a least set of the computing resources and (b) maximize the volume of resource that can be put into sleep mode. However, as recorded in earlier inquiry, more than 30% of the aggregate computing energy is consumed by the communication links, switching and aggregation elements. However, slowing the communicational fabric down should be performed carefully and based on the pressure of user applications. Otherwise, such a practice may result in a bottleneck, thereby restricting the overall system performance.

A number of studies demonstrate that often a simple optimization of the data center architecture and energy-aware scheduling of the workloads may cause significant energy savings. The writer of [13] demonstrates energy savings of up to 75% that can be achieved by traffic management and workload consolidation techniques. This research work presents a simulation environment, termed GreenCloud, for advanced energy-aware studies of cloud computing data centers in pragmatic setups. Green Cloud v2.0.0 is advanced as an extension of a packet-level network simulator Ns2. Unlike only some existing cloud computing simulators such as CloudSim or MDCSim, Green Cloud extracts, aggregates, and compels information about the energy consumed by computing and communication elements of the data center available in an unprecedented fashion. The respite of the article is organized as follows. Sector 2 surveys the most demanded data center architectures outlining the reasons for their choice through the analysis of their physical composition. Sector 3 presents the main simulator components and related energy models; Sector 4 focuses on the thorough evaluation of the developed simulation environment and finally Sector 5 concludes the paper providing the guidelines for edifice energy-efficient data centers and outlining directions for future work on the issue.

2. Elaborating Data Center Core Architecture

The array of servers in today's data centers overcomes 100,000 hosts with around 70% of all communications performed internally [14]. This complains a challenge in the design of interconnected network architecture and the set of communication protocols. Specifically, the availability of 10 Gigabit Ethernet (GE) components and their price well-defined the way the data center architectures evolved. The 10 GE transceivers are still too affluent and probably offer more capacity than needed for connecting individual servers. However, their dispersion level keeps increasing in the different architectural level of networks.

Two-tier data center architectures track the structure presented in Fig. 1. In this scenario, computing Servers (S) physically organized into racks form the tier-one network. Especially the tier-two networks, Layer-3 (L3) switches provide full mesh connectivity using 10 GE links. The Equal Cost Multi-Path (ECMP) routing is used as a load balancing technology to optimize data flows across multiple paths. It applies load balancing on TCP and UDP packets on a per-flow basis using express hashing techniques requiring almost no processing from a switch's CPU.

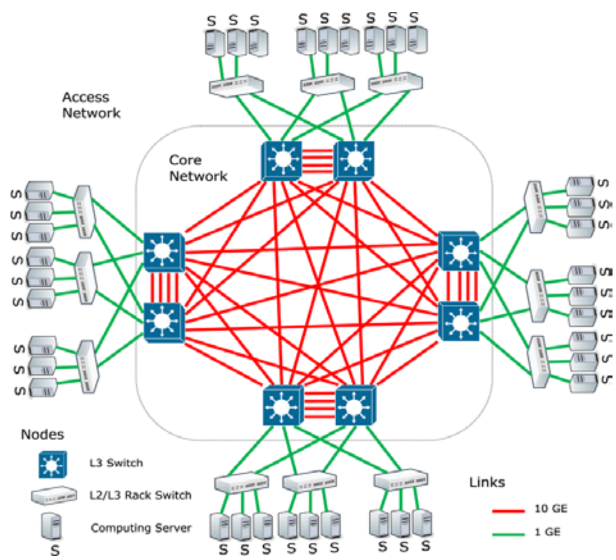

Fig.1 Two-tier structure in data center architecture

Other traffic, such as ICMP [15], is classically not processed by ECMP and forwarded on a single predefined path. The two-tier architecture worked well for initial data centers with a limited number of computing servers. Depending on the mode of switches used in the access network, In this paradigm the two-tier data centers may support up to 5600 nodes [3].

Three-tier data center architectures are the maximum shared nowadays. The sophisticated core layers as presented in Fig. 2. The availability of the aggregation layer facilitates the increase in the number of server nodes (to over 10,000 servers) while keeping inexpensive Layer-2 (L2) switches in the access network, which endow a loop-free topology. Because the maximum number of ECMP paths allotted is eight, typical three tier architecture consists of eight core switches (only four are presented in Fig. 2).

Such architecture implements an 8-way ECMP that comprise 10 GE Line Aggregation Groups (LAGs) [10],

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which permits a network client to address several links and network ports with a single MAC address. While the LAG technology is an outstanding methodology to increase link capacities, its usage has several fundamental drawbacks that frontier network flexibility and performance. LAGs make it difficult to plan the capacity for large flows and make it unpredictable in case of a link failure. In addition, quite a few types of traffic patterns, such as ICMP and broadcast are usually defeated through a single link only. Hence full mesh connectivity at the core of the network entail considerable amount of cablings.

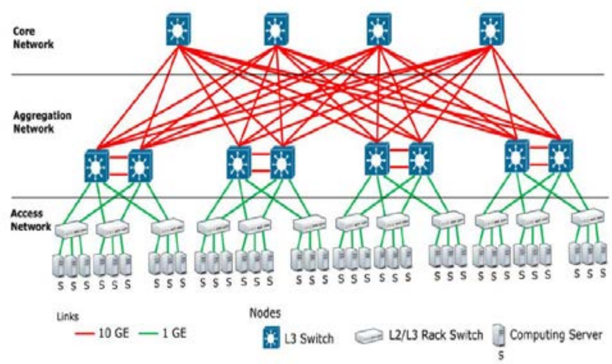

Fig.2 Three-tier structure in data center architecture

The aforementioned disadvantages have readdressed the design choices for the next generation data centers to consider: (a) increasing the capacity of the core and (b) accessing parts of the network with beyond 10 GE links.

Three-tier high-speed data center architectures are designed to enhance the number of nodes, size of core, and aggregation networks that are currently a bottleneck, which limit the maximum number of nodes in a data center or a per-node bandwidth (see Fig. 3). With the readiness of 100 GE links (IEEE 802.3ba), standardized in June 2010 [11], between the core and aggregation switches, diminish the number of the core switches, avoids the shortcomings of LAG technology, trim down cablings, also considerably increases the maximum size of the data center due to physical limitations [5].

Fewer ECMP paths will prime to the flexibility and increased network performance. While the fat-tree topology is the most broadly used in modern data centers other more advanced architectures have been proposed. For example, architectures such as DCell [7] or BCube [8] incorporate server centric approach relying on miniswitches for interconnection. Both architectures do not depend on the core or aggregation layers and offer scalability to millions of servers.

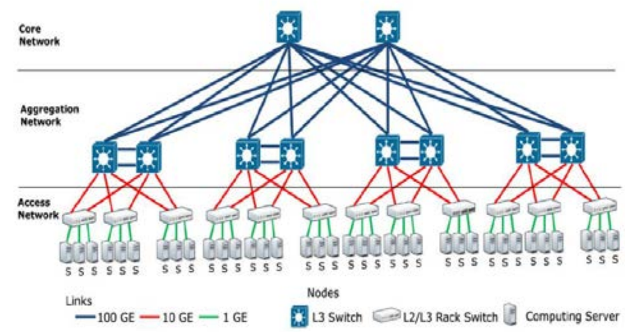

Fig.3 Three-tier high-speed Data Center Architecture

The routing process is performed by the servers themselves, requiring a definite routing protocol to ensure fault tolerance. This is mainly due to the fact that both architectures are only latest research proposals which have not been tested in real data centers and unveil their advantages in very large data centers, we consent their performance evaluation out of the scope of this paper, concentrating on more widely used architectures.

3. Simulation Methodologies in Energy-Efficient Data Centers

3.1 Energy efficiency

Only a part of the energy consumed by the data center gets delivered to the computing servers directly. A major section of the energy is utilized to maintain interconnection links and network equipment operations. The respite of the electricity is wasted in the power distribution system, dispersed as heat energy, and used up by air-conditioning systems.

We distinguish three energy consumption components: (a) computing energy, (b) communicational energy, and (c) the energy component related to the physical infrastructure of a data center. The efficiency of a data center can be defined in terms of the performance delivered per watt, which may be quantified by the following two metrics: (a) Power Usage Effectiveness (PUE) and (b) Data Center Infrastructure Efficiency (DCiE) [17]. Both PUE and DCiE describe which portion of the totally consumed energy gets delivered to the computing servers.

3.2 Structure of the simulator

GreenCloud is an extension to the network simulator Ns2 which we developed for the study of cloud computing environments. The GreenCloud offers users a detailed fine-grained modeling of the energy consumed by the elements of the data center, includes servers, switches, and links. Mainly, Green Cloud offers a thorough investigation of workload distributions. Also a specific focus is devoted on the packet-level simulations of communications in the data center platforms, which provide the finest-grain control and is not present in any cloud computing simulation environment. Fig. 4 presents the structure of the GreenCloud extension mapped onto the three-tier data center architecture. **Servers** (S) are the staple of a data center that are responsible for task execution. The servers are arranged into racks with a Top-of-Rack (ToR) switch connecting it to the access part of the network. As reported in [1, 8], an idle server consumes about 66% of energy compared to its fully loaded configuration. Because of the fact that servers must manage memory modules, connected disks, various I/O resources, and other peripherals in an acceptable state. Then, the power consumption linearly increases with the level of CPU load. As a result, the aforementioned model allows implementation of power saving in a centralized scheduler that can provision the consolidation of workloads in a minimum possible amount of the computing servers.

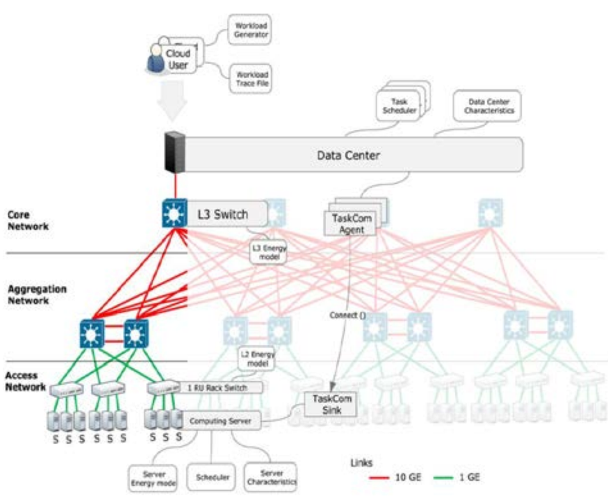

Fig.4 Architecture of the GreenCloud simulation environment

Another option for power management is Dynamic Voltage/Frequency Scaling (DVFS) [1] which introduces a tradeoff between computing performance and the energy consumed by the server. Also a DVFS is based on the fact that switching power in a chip decreases proportionally to V 2 · f , where V is voltage, and f is the switching frequency. Moreover, voltage reduction requires frequency downshift. This implies a cubic relationship from f in the CPU power consumption. Observe that server components in the data centers do not depend on the CPU frequency. Hence, the power consumption of an average server can be expressed as follows [2]:

$$P = P_{fixed} + p_f \,.\, f^3, \qquad (1)$$

Where P_{fixed} accounts for the portion of the consumed power which does not scale with the operating frequency f , while P_f is a frequency-dependent CPU power consumption. Fig. 5 presents the server power consumption model implemented in Green-Cloud. The curve is built for a typical server running an Intel Xeon processor. It consumes 301 W of energy with around 150 W allocated for peak CPU power consumption and around 181 W allocated for other peripheral devices.

The scheduling depends on the server load level and operating regularity, and targets at capturing the effects of DVFS and DPM techniques. Switches and Links form the interconnection fabric that delivers workload to any of the computing servers for execution in a timely manner.

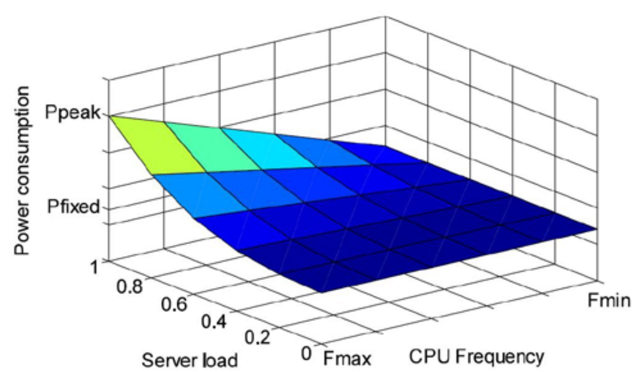

Fig.5 Computing Server Power Consumption

However, for the organization of 10 GE links it is common to use optical multimode fibers. The multimode fibers allow transmissions for up to 300 meters with the transceiver power of 1 W. The number of switches installed depends on the implemented data center architecture as previously discussed in Sector 2. However, as the computing servers are usually organized into racks, also the most public switch in a architecture is the Top-of-Rack (ToR) switch.

The ToR switch is typically placed at the top unit of the rack unit (1RU) to reduce the amount of cables and the heat produced. Due to the comparability needs, just few standard link transmission rates are allotted, such as for GE links 10 Mb/s, 100 Mb/s, and 1 Gb/s are the just options. Also on the other side, the power efficiency of DVS links is limited as only a portion (3–15%) of the consumed power scales linearly with the link rate. As demonstrated

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by the experiments in [14], the energy consumed by a switch and all its transceivers can be defined as:

$$P_{switch}=P_{chasis}+n_{linecards}+P_{linecard}+\sum_{i=0}^{R} n_{ports},r+P_{r} \qquad (2)$$

Where $P_{chassis}$ is related to the power consumed by the switch hardware, $P_{linecard}$ is the power consumed by any active network line card, P_r corresponds to the power consumed by a port (transceiver) running at the rate r. In (2), only the last component appears to be dependent on the link rate while other components, such as $P_{chassis}$ and $P_{linecard}$ remain fixed for all the duration of switch operation. Therefore, $P_{chassis}$ and $P_{linecard}$ can be avoided by turning the switch hardware off or putting it into sleep mode. The proposed GreenCloud v2.0.0 simulator implements energy model of switches and links according to (2) with the values of power consumption for different elements taken in accordance as suggested in [13].

The implemented powers saving schemes are: (a) DVS only, (b) DNS only, and (c) DVS with DNS. **Workloads** are the objects designed for universal modeling of various cloud user services, such as social networking, instant messaging, and content delivery. In grid computing, the workloads are typically modeled as a sequence of jobs that can be divided into a set of tasks.

4. Data Center Performance Evaluation

In this sector, we extant case study simulations of an energy-aware data center for two-tier (2T), three-tier (3T), and three-tier high-speed (3Ths) architectures. For comparison reasons, we fixed the number of computing nodes to 1836 for all type of topologies, hence the figure and interconnection of network switches varied. Table 1 summarizes the major simulation setup parameters. In contrast with other architectures, a 2T data center does not include aggregation switches. The core switches are connected to the access network directly using 1 GE links (referred as C2–C3) and interconnected between them using 10 GE links (referred as C1–C2).

Table.1.Parameter Consideration for Simulating 3tier Architecture

Simulation Duration(sec.):	65.0
Datacenter Architecture:	3-tier debug
Switches (core):	1
Switches (agg.):	2
Switches(access):	3
Servers:	154
Users:	1
Power Mgmt.(Servers):	No
Power Mgmt.(Switches):	No
Average Load/Server:	0.5
Datacenter Load:	28.8%
Total Tasks:	3452
Average Tasks/Server:	18.1
Tasks Rejected by DC:	0
Task Failed by Servers:	0
Total Energy:	762.5W*h
Switch Energy(core):	53.4W*h
Switch Energy (agg.):	108.5W*h
Switch Energy (access):	7.0W*h
Switch Energy:	588.2W*h

While the main object is the minimization of the time needed for the computing of all jobs. The jobs tend to be more self regulated and less computationally intensive, but having a strict completion deadline specified in SLA's.

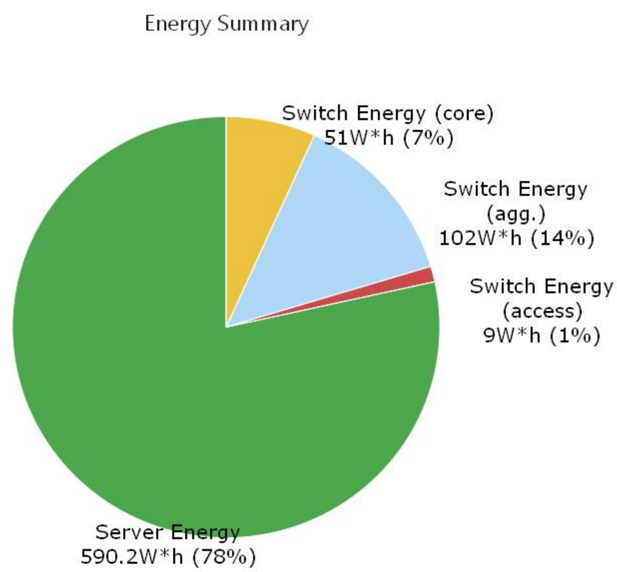

Fig.6. Distribution of Energy Consumption in a Data Center

To incorporate the vast main stream of cloud computing applications, we define three sorts of jobs:

A. Computationally Intensive Workloads (CIWs) model High-Performance Computing (HPC) applications aiming at solving advanced computational problems. CIWs load computing servers considerably, but it needs almost no data transfers in the interconnection network of the data center. The process of CIW energy-efficient scheduling should focus on the server power consumption footprint trying to group the workloads at the minimum set of servers as well as to route the traffic produced using a minimum set of routes. Hence the distribution of energy

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Consumption can be represented in Fig. 6.There is no danger of network congestion due to the low data transfer requirements, hence by putting the maximum of the switches into the sleep mode will ensure the lowest power of the data center network.

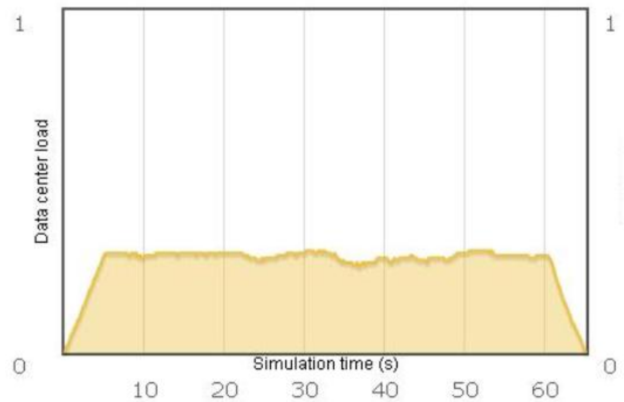

Fig.7 Estimation of Load on Data center Networks

B. Data-Intensive Workloads (DIWs) produce almost no load at the computing servers, but require heavy data transfers. DIWs intend to model such appliances like video file sharing where each simple user request turns into a video streaming process.

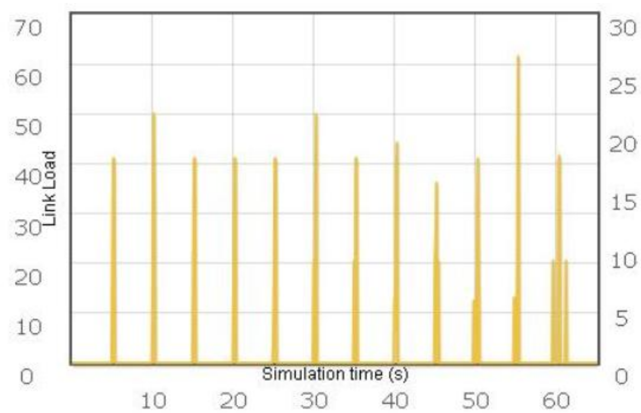

Fig.8 Effect of Load on Link Host to Rack

The load on a connected Data Center Networks can be estimated in a particular simulation time (See Fig. 7).As a result, the interconnection network and not the computing capacity becomes a bottleneck of the data center for DIWs. It will avoid sending workloads over congested links even if certain server's computing capacity will allow accommodating the workload.

C .Balanced Workloads (BWs) this aimed to model the applications having both computing and data transfer requirements. BWs load the computing servers and communication links proportionally. By involving this type of loads the average load on the servers and the loads on link host can be plotted based on Link Load (See Fig. 8) and it equals to the average load of the data center network. BWs can model such applications as geographic information systems which require both large graphical data transfers and heavy processing. Planning of BWs should account for both server's load and the load of the interconnection network.

The execution of each workload object in Green-Cloud requires a successful completion of its two main components: (a) computing and (b) communicational. The computing component defines the amount of computing that has to be executed before a given deadline on a time scale and the estimation of queue size on a single host can be plotted (See Fig. 9).The deadline aims at introducing Quality of Service (QoS) constraints specified in SLA.

The communicational component of the workload defines the amount and the size of data transfers that must be performed prior, during, and after the workload execution. It's a combination of three parts: (a) the size of the workload, (b) the size of internal, and (c) the size of external to the data center communications.

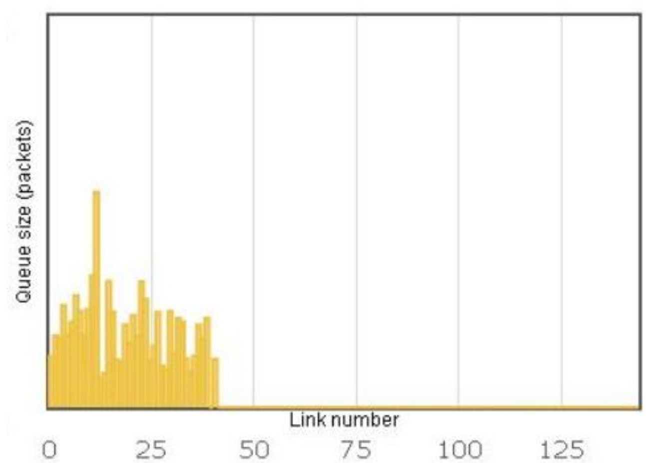

Fig.9. Estimation of Queue size on Host to Rack

In a recent implemented version of the Green-Cloud v2.0.0 simulator, internal communication is performed with a randomly chosen workload. However, in the next version inter-workload communication patterns will be defined at the moment of the workload arrival and communication-aware scheduling will be studied. Furthermore, the trace-driven workload generation is designed to simulate more realistic workload arrival process capturing also intraday fluctuations, which may influence simulated results greatly.

5. Conclusion and Future Works

In this paper, we turned-out a simulation environment for energy-aware cloud computing data centers. Green-Cloud is designed to catch the details of the energy consumed by data center components as well as packet-level communication patterns between them. The simulation results gained for different leveled tiers, mainly three-tiered high-speed data center architectures demonstrate applicability and impact from the application of various power management schemes like voltage ascent or self-motivated shutdown applied on the computing as well as on the networking composition. The future work will spotlights on the simulator extension adding storage area network techniques and further fine-tuning of energy models used in the simulated components. On the algorithmic part, the research will be focused on the enlargement of different workload consolidation and traffic aggregation techniques.

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