Analysis of Energy Saving Technique in CloudSim Using Gaming Workload

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***Abstract*—The IT industry has been totally revolutionized in the past few decades. Cloud Computing companies (Google, Yahoo, Gaikai, ONLIVE, Amazon and eBay) use large data centers which are comprised of virtual computers that are placed globally and require a lot of power cost to maintain. Demand for energy consumption is increasing day by day in IT firms. Therefore, Cloud Computing companies face challenge towards power costs. We address the solution for this energy saving problem by the enabling dynamic voltage and frequency scaling technique (DVFS) for gaming data centers. This helps service providers to meet the quality of service (QoS) and quality of experience (QoE) constraints by meeting service level agreements (SLAs). CloudSim platform is used for implementation of the scenario in which game traces are used as a workload for testing the technique. This can help gaming servers to save energy cost and maintain better quality of service for users placed globally in comparison with generally used Non-Power Aware technique. The results demonstrate that less energy is consumed by implementing a DVFS approach in comparison with Non-Power Aware technique when tested with same workload.**

Keywords- Energy Saving Technique; DVFS and Non-Power Aware Method; Gaming Workload; CloudSim Platform.

I. INTRODUCTION

Cloud Computing is one of the latest technologies that is growing across the globe rapidly. It is forming pillars for upcoming advancements in computing covering all aspects of parallel and distributed computing. Cloud computing is providing users with a substantial number of pay-per-use services, using the internet as a communication backbone. With the era of globalization, computing is also being transformed into a model where service is provided based on user requirements instead of hosting them permanently [1]. These advancements and innovations in the field of cloud technology provisions the industries to have unlimited computational power while maintaining good quality of service (QoS). Cloud industries must maintain several service level agreements (SLAs) to meet good quality of service from the user and service provider perspective. The service provider is also responsible for availability of the resources whenever and wherever they are required by the user. IT industry can save energy and power cost using service oriented architecture alongside cloud computing. Whether from the domain of parallel or distributed computing there are three major service models, namely Software as Service (SaaS), Platform as Service (PaaS), and Infrastructure as Service (IaaS) [2]. The corresponding large amount of data management and streaming leads to an increase in energy consumption. This causes a major rise in cost and threat to the environment as large amount of carbon dioxide (CO_2) is produced by these data servers [3]. Consequently, data centers are becoming unmaintainable. Therefore, a lot of work is being carried out and different kind of algorithms and techniques are being developed and implemented by researchers. Dynamic voltage and frequency scaling is one such technique that helps in reduction of power consumption. It reduces the use of underutilized resources by dynamically controlling the frequency parameter and uses different strategies to reduce static consumption by shifting load to the underutilized servers dynamically. Therefore, for the implementation of DVFS one needs to understand different factors like frequency and static power consumption. The amount of power that is being used in the data center can be managed by exploiting the trade-offs between service quality and service level agreement. Services that clouds are providing vary with time and have different workloads that require dynamic allocation of resources especially for Big Data Applications and MultiPlayer Games. Therefore, such techniques are required to be implemented in gaming with awareness of both DVFS and energy consumption while maintaining quality of service and quality of experience [4].

There are number of simulation tools which are being used for this research purpose, each having their defined use. All these tools have one thing common, namely they all use a stack based design as cloud computing is a combination of internet, grid, and distributed computing. The stack based design model provides users with the ability to add their own designed code in the model. This helps in implementation of optimization techniques and management of resources for improvement of quality of services. Better experimentation and development of algorithm can help in saving energy cost and in increasing profits. Therefore, for testing of new algorithms in IT industry researcher needs to have a secure platform. The selected platform should be fail safe and must avoid risk of customer's data privacy and data impairment [6]. Most cloud computing platforms are software based as it is very difficult and expensive to set a cloud server for test and trials purposes for each researcher. For example, it is practically difficult for researcher to use a data server consisting of 150 physical machines because of maintenance costs (e.g., energy, space, power, and cooling requirements) [5]. There is also no specific platform due to the following

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reasons: relocation of the virtual machine, confidentiality and data integrity, need for energy management, and cost modelling [8]. The main purpose of carrying this research is therefore to find the ways in which resource optimization can be performed in the gaming data centers. In our work we consider the following aspects of service quality: energy consumption and service level agreements, by using online gaming data in our experiments. In this paper, DVFS and Non-Power Aware technique will be tested and implemented for improvement of energy consumption and SLAs. Better results are expected to be achieved using DVFS technique as compared to Non-Power Aware technique; this hypothesis will be verified using real time gaming workload. The rest of this paper is organized as follows, Section II describes the related work; Section III describes basic details about DVFS and the platform; Section IV addresses the simulation environment; Section V discusses performance analysis and provides a discussion of our approach while, conclusions and future work close the article.

II. RELATED WORK

Recently, work has been carried in the field of cloud computing particularly relating to the cluster servers and virtualized servers. Energy saving techniques have been suggested for large amount of data using the concept of changing voltage and frequency values. It has been demonstrated that this concept can save more energy as compared to dynamic power management technique when implemented in the real world [8]. Here, the authors use a single system by implementing and comparing three different energy saving concepts i.e., DVFS (supply voltage of underloaded servers is reduced), DNS scheme (idle servers are left in sleep mode) and DNS + DVFS. The author proposes that dynamic voltage and DNS together provide better results for energy saving. However, the paper does not compare and analyze the cost comparison by maintaining quality of service metrices [9]. A solution is provided to save cost and to earn more profit on a large data scale by managing the scheduling of heterogenous machines with multiple users. This work is limited to just one quality of service metric i.e., cost from the service provider perspective [10]. Another algorithm was designed to optimize energy by using the concept of multi objective workflow and dynamic voltage scaling. However, the user was given the ability to choose between the cost or energy criterion [11]. In the field of computing, distributed computing provisions user with fault tolerance, organization, and support for resources. Typically, resources are allocated to the users based on load balancing technique where all the resources are allocated to the broker that is wholly responsible for provisioning of resources when required [12].

In [16] the authors propose several energy saving algorithms using scheduling policies. However, the work was related to virtualization mechanism only for large scale global data centers [16]. Further work was carried out relating the energy saving mechanism to different kinds of workflow on the Green Cloud Platform using bi-objective scheduling to meet the quality of service metrices for energy consumption [11]. By looking at the related work to date, it is clear that most of the work carried out related to energy saving has involved single servers and unique tasks. However, these days cloud computing platforms like Gaikai, OnLive, and Amazon EC2 have servers that are using multipurpose applications that are dispersed geographically. There is a research gap in the field of gaming especially for multiplayer games with users placed far apart from each other. On the other hand, some work in relation to energy saving has been carried using Big data with single purpose applications [6].

III. DVFS AND PLATFORM

CloudSim is one of the platforms which provides QoS parameters such as: energy, cost model, latency, virtual machine characteristics, federation policy, and analyzing the network communication model. Based on this platform, several popular models have also been designed, namely iFogSim, Cloud Analyst, Network CloudSim and iCaroCloud. Therefore, it provides enough leverage for researchers to use it to perform tests and develop new models as required. CloudSim has a layered architecture which provides user with the ability to design and implement applications. It supports core functions, such as handling of events, creation of cloud servers, hosts, brokers, and virtual machines [13]. The CloudSim simulation layer supports creation of hosts under virtual machines, application execution and application monitoring. A researcher who wants to implement an application relating energy, hosts, VM and data centers will be doing at this level. This layer supports the SaaS platform and provides users with defined quality of service levels with complex load reporting and application performance reports [14]. The topmost layer in the architecture is where a user writes a code and it allows the user to define a number of virtual machines, hosts, data centers, brokers, tasks etc. Therefore, it allows researchers to extend this layer and perform different tasks such as: generation of workload for monitoring designed experiments, designing of different cloud scenarios for robust testing and implementation of conventional applications in the cloud environment [13]. IaaS services can be simulated by extending different entities present in the cloud environments such as data centers. Such data centers consist of many hosts which are assigned to more than one virtual machines depending upon the rules defined by the service provider [15]. The data center can also manage more than one host (physical components representing the computing server) which further manages virtual machines. Host provisioning supports single and multiple core nodes. Similarly, virtual machine allocation creates virtual machine scenarios on hosts for storage and memory related tasks [16]. After modelling and designing of the application, it is allocated to a running virtual machine through a specific defined procedure. The virtual machines required to host multiple applications are provided on a First Come First Serve basis depending upon different hardware factors (storage, memory, cores etc.,). Therefore, simulation test scenarios relating to CPU cores are dependent upon factors such as time usage, space sharing policy or allocating virtual machines as and when required [7].

CloudSim has the capability to calculate the power consumption of data centers using the DVFS technique. It uses the current metric for cloud host input and returns calculated power as an output. Therefore, this provides researchers with the ability to design energy consumptions models and calculate the total power consumed during the designed experiment. CloudSim also provides developers with the capability for experimentation of dynamic scenarios i.e., different number of data centers or hosts can be created and deleted for testing unpredictable events in which users can join and leave the cloud application [17]. The DVFS scheme is limited to CPU optimization and adjusts the CPU power according to the workload that is being run on it. However, other components of the system that is memory, storage, RAM, bandwidth and network interfaces keep running on the same original frequency and no scaling is applied on them. The use of Dynamic Power Management (DPM) can turn down the power consumption for all the components of the system. The CPU has number of states for frequency and voltage which suggests that it has ability to provide better power performance as compared to basic approach [18]. Thus, powering up of system will require a large amount of energy using DPM as compared to DVFS technique [11].

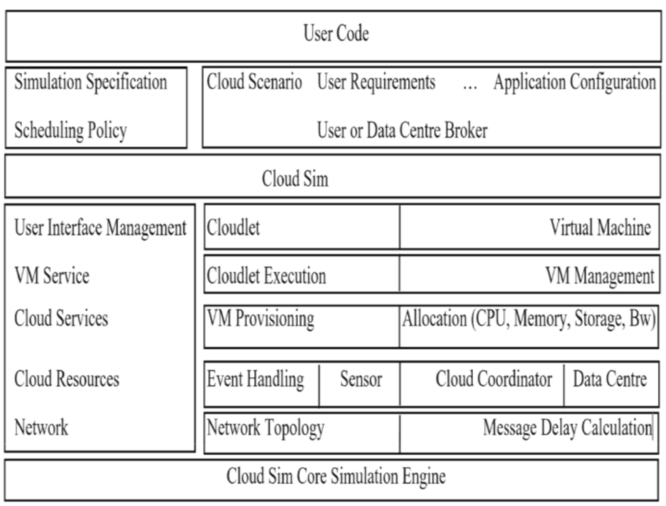

Figure 1: Layered CloudSim Architecture

IV. SIMULATION

For the implementation and evaluation of the proposed experiments the CloudSim simulation platform is used to provide users with the ability to perform the desired tests. These tests are carried out by using traces from a game as workload for the DVFS technique. The designed simulation consists of heterogeneous data centers consisting of 800 physical hosts and 1000 virtual machines which are dynamically allocated by the broker. Half of the hosts are HP ProLiant ML110G4 (Xeon3040) and other half are HP ProLiant ML110G5 (Xeon3075) servers. The systems frequency characteristics are defined based on how many instructions can be executed in one second (MIPs). Therefore, HP ProLiant ML110G4 (Xeon3040) and ML110G5 (Xeon3075) have MIPs rating of 1860 MHz and 2660 MHz, both being dual core servers. The defined system specifications are suitable to the hardware requirements for the experimental workloads envisaged. Detailed parameters are given in Table I.

TABLE I: DETAILS OF THE SYSTEM PARAMETERS

System (HP ProLiant)	MIPs Rating	Cores	RAM	Hard Disk
ML110G4 (Xeon3040)	1860 MHz	Dual	4 GB	1 GB
ML110G5 (Xeon3075)	2660 MHz	Dual	4 GB	1 GB

No dynamic allocation of virtual machines is performed in this test and host power adjustment is done based on their CPU utilization. A fixed MIPs value is provided having a value of 1000 MIP per second for a virtual machine. The simulated model has a bandwidth rate of 1 Gbits per second and RAM 4 GB for each system. A fixed defined gaming workload is provided in this experiment that consist of traces from a popular multiplayer online game, namely World of Warcraft having a data set size of 3.5 GB. The data set consists of traces from real data of the popular massively multiplayer online game, World of Warcraft (runtime of 1107 days, 91065 avatars, 667032 sessions, users located globally in 3 continents with different time zones) collected to analyze the quality of service parameters and consisting of game time, race attributes, current position, profession info, game position information, game level etc., [18]. It provides execution time of each host and energy is calculated based on power consumed by individual host. It uses time shared policy and rating of the processing elements is calculated by having millions of instructions per second. The total MIPs, i.e., total execution time is the sum of all the MIPs from each processing element (PE). Here, it is assumed that all the processing elements have same rating in the used machine. The service level agreements are also required as it is necessary to maintain the quality of service matrices [20]. The detailed parameters are summarized in Table II.

TABLE II: DETAILED DESCRIPTION OF SYSTEM PARAMETERS

Host MIPs	Host RAM	RAM	Host PE(s)
1860	4096 MBs	1Gbit/s	02
2660	4096 MBs	1Gbit/s	02

The reasoning behind the SLA violation time per active hosts is based on the observation that if there is an application that is managing the virtual machine migrations and it is busy with a host that has 100% utilization, it will not be able to address other hosts waiting for service provisioning. Therefore, virtual machines are deprived of the desired performance level causing service SLA violations [19]. The mathematical definitions and formula follow,

$$SLAV(H) = \frac{1}{H(n)} \sum_{i=1}^{n} \frac{SLAH(t)i}{AH(t)i} \tag{1}$$

The SLA level is the product of two matrices i.e., how many SLA violations there are per unit time of active hosts and how much of the performance degradation is because of virtual machine migration (Equation 3). *SLAV(H)* is the violation of per unit time for active hosts, *H(n)* is number of hosts, *SLAH(t)i* represents the time duration that leads to SLA violation by reaching CPU utilization of 100%, *AH(t)i* is the total number of *hosts(i)* in the active state.

$$P(vm) = \frac{1}{VM(n)} \sum_{i=1}^{n} \frac{Pd(k)}{Cpu(k)} \tag{2}$$

P(vm) is the effect on the performance because of virtual machines migration, *VM(n)* represents the total number of virtual machines, *Pd(k)* represents the level of degradation in the service of a particular virtual machine when it is migrated, *Cpu(k)* represents the total utilization of CPU of a particular virtual machine. Therefore, whenever a cloud server is considered for service level agreement violations it always depends on the above two factors independently described in (1) and (2). Therefore, service level violation is because of two factors: one is virtual machine migration and the other is when a host is overloaded resulting in SLA violation *(SLAV)* as follows [19],

$$SLAV = SLAV\,(H) \times P\,(vm) \tag{3}$$

SLAV(H) represents time required to have 100% CPU utilization by the active host and *P(vm)* shows performance degradation because of virtual machine migration. The overall performance of cloud servers can be analyzed by using the following equation,

$$Perf\,(DC) = Energy \times SLAV \tag{4}$$

The CPU time is calculated from the following formula,

$$CPU(t) = \frac{C(Le)}{PE * (1.0 - C(Lo))} \tag{5}$$

CPU(t) = CPU Time, *PE* = MIPs of one Processing Element, *C(Le)* = Length of Cloudlet, and *C(Lo)* = Load of Cloudlet. Here, MIPs represent how many instructions can be executed in one second, *PE(x)* the number of MIPs of one processing element, *PE(y)* represents MIPs of *N* number of hosts,

$$Total\ MIPs = PE(x) + PE(y)N(host) \tag{6}$$

Cost per million instructions related to a resource is calculated as follow,

$$MI = \frac{Cost(s)}{PE(MIPs)} \tag{7}$$

Cost(s) = cost per second and *PE(MIPs)* = calculating MIPs of one processing element. The execution time is calculated as follows,

$$Time = \frac{Sys(t) - Exe(t)}{1000} \tag{8}$$

Sys(t) is current time in millisecond, *Exe(t)* is system execution time and *1000* is the defined MIPs rating. Thus, energy consumed by each host, performance measure, CPU utilization, total execution time, and SLA violations count can be calculated by using the above equations. Experimentation results are shown in Section V.

V. PERFORMANCE ANALYSIS AND DISCUSSION

This test calculates the energy performance across the data center in the given simulation environment. All the tests are carried out in the simulation environment i.e., the CloudSim package which is configured using Eclipse Luna and Java IDE. The dynamic voltage and frequency scaling technique has been applied to analyze the gaming workload of the World of Warcraft multiplayer game. The workload consists of data traces from servers which are collected over time of 1107 days. An unaltered version of DVFS is used; however, a typical game workload has been provided for testing the behavior of the proposed technique. The Non-Power Aware simulation model with the same specifications is used for power analyzation of same gaming workload. The main difference between the Non-Power Aware and DVFS models lies in how resources are allocated to the hosts. All the parameters (RAM, bandwidth, storage, I/O file size etc.,) are defined however, for DVFS, resources are allocated based on dynamic voltages and frequency fluctuations of the central processing unit for the active hosts.

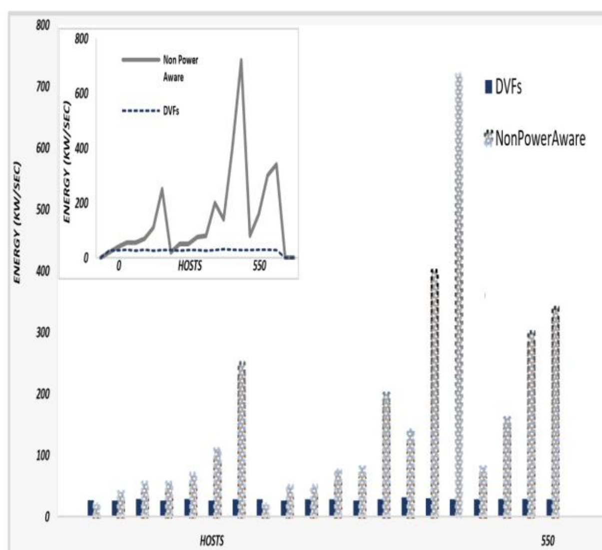

Figure. 2: DVFS vs Non-Power Aware Consumption in a Data Center

In the Non-Power Aware model hosts consume the maximum amount of power, thus increasing cost of services and causing loss of profit for service providers. Figure 2, shows power consumption in the cloud environment with a fixed number of hosts and MIPs using Non-Power Aware and

Dynamic Voltage Frequency Scaling. For DVFS, the data show a linear trend for CPU power consumption as compared to Non-Power Aware technique. The results in Figure 2 are by way of a reality check and verify the theoretical concept that in DVFS, the CPU adjusts frequency according to the workload to minimize the power consumption and thus provides a linear trend. The hosts using dynamic voltage and frequency scaling technique for the same gaming data consume less energy as compared to the Non-Power Aware technique. It can also be demonstrated (Figure 2) that in the Non-Power Aware technique hosts are loaded to maximum values and consume more energy resulting in greater values of CO_2 emissions.

The results also prove that quality of service is directly proportional to service level agreements i.e., if QoS is not observed for a certain amount of time then we have a SLA violation. Thus, by using DVFS, performance can be improved and energy consumption can be minimized resulting in a lot of cost saving from the commercial point of view (Figure 3). It can be seen that DVFS provides better trade-off for exploitation of SLAs per host for maintenance of quality of service and quality of experience. Figure 3, shows different parameters that can be analyzed towards quality of service. During the whole experiment DVFS uses less resources in the host when analyzed. Less energy consumption, mean time and number of host shutdown are performed during the experimentation. These results show that overall the best quality of service can be achieved by implementing DVFS in gaming servers placed globally.

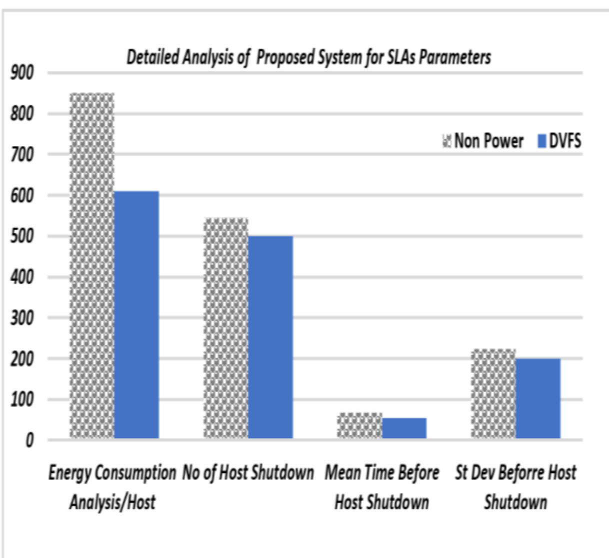

Figure 3: Detailed Analysis of the Proposed System

It can be seen from the results that minimum service level agreement degradation (SLAV) is achieved using dynamic voltage frequency scaling technique. Therefore, by using dynamic voltage and frequency scaling technique overall SLA violation can be reduced and quality of service can be improved through having less service level agreement violations in the proposed system (Figure 4).

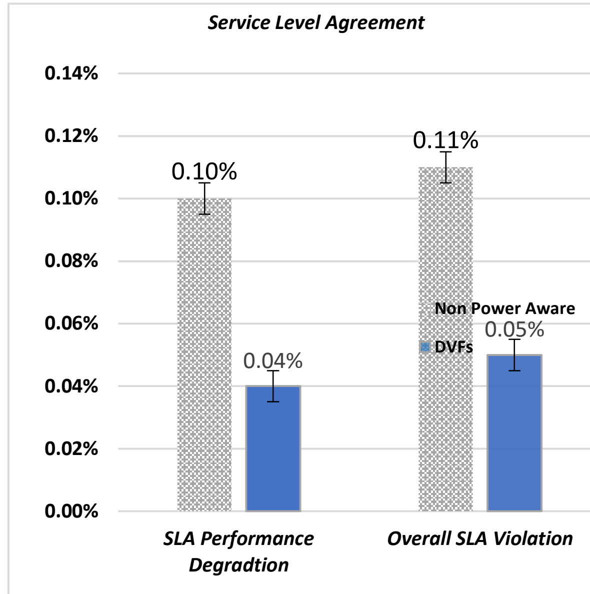

Figure 4: Service Level Agreement Violation (SLAV)

The difference in the amount of energy consumption, service level agreement and quality of service degradation can be seen through the results which is estimated on the basis of CPU utilisation. From the results, it can be seen

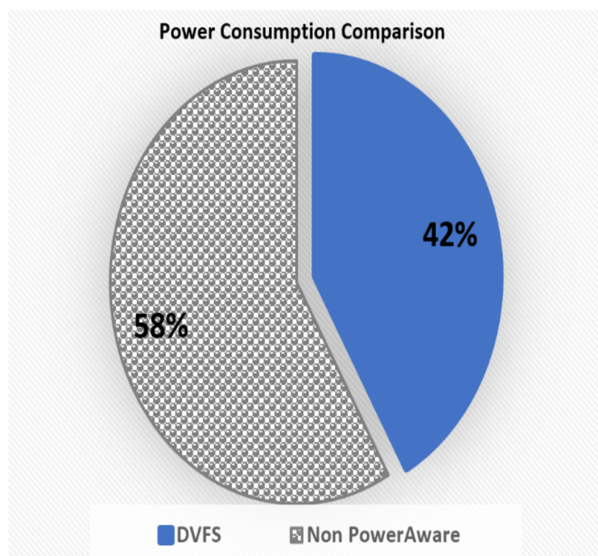

Figure 5: Detailed Analysis of the Proposed System

that if the DVFS technique is used, the best results for energy utilisation are achieved and 16% of energy could be saved in comparison to Non-Power Aware technique using the same gaming workload (Figure 5).

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VI. CONCLUSION AND FUTURE WORK

The simulation tests that have been designed using CloudSim platform are based on two power consumption approaches i.e., DVFS and Non-Power Aware. The same workload (game data) and data center specifications are set for testing which technique performs better for power saving. The workload provided demonstrates that DVFS saves more energy as compared to general Non-Power Aware approach and obtains less SLAs violations which is important for maintaining QoS and QoE. CloudSim provides the ability to test the same workload scenario on two different power saving approaches. By using this simulation environment, a researcher can experiment and determine the amount of resources required (e.g., the number of Cloudlets, bandwidth, RAM, cost etc.,) for maintaining quality of service. Therefore, from the simulation results, it can be verified that cloud gaming data centers with the proposed DVFS technique can yield less energy consumption while fulfilling service level agreements for maintaining good quality of service leading to better quality of experience (QoE) for users placed globally.

In the future, this work will be enhanced and better ways and techniques to save energy will be explored for Big Data, Internet of Things and Gaming data centers.

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