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Energy-Efficient Cloud Servers: an overview of Solutions and Architectures

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Abstract

Because of the changing from traditional paper-based systems to a digital systems and the evolution of online storage and cloud computing, datacenters are becoming fundamental to almost every sector of the economy and the main energy consumers in the universe. With the acceptance of High Performance Computing (HPC) and cloud computing, the area and number of cloud datacenter grow quickly; hence, it has become significant to optimize datacenter energy consumption. With modern energy efficient design in cloud datacenter infrastructure and cooling devices, active items like servers and cooling devices consume most of the power. In many researches, it was shown that cloud datacenters consume enormous energy; therefore researchers are looking for metrics of energy efficiency. The goal of energy efficient researches is to sufficiently take benefit of reachable resources such as processors and network devices, or to reduce thermal cooling expenses and energy consumption. In this paper, we discuss the state of the art researches and provide an overview of energy efficient solutions and architectures for cloud servers in processor design, power distribution unit, and server cooling management.

Keywords: *Energy efficient, Datacenter, Server cooling management, Thermal management, Cloud servers.*

1. Introduction

Datacenters are computing structures housing a large number of ICT devices set up for storing, transmitting, and processing information. Datacenters also are the essential infrastructure for Cloud Computing to prepare the resources needed for data storage and processing at all scales. Along with the rising necessity from end-users and their readiness to use cloud services, common applications have become data-intensive, which grows more critical requirement for the storage capacity of cloud datacenters. An expanding number of datacenters have been constructed around the universe to store the enormous amount of data, which not only consumes a massive amount of energy to support their capabilities, but also becomes a significant source of pollution and carbon emissions [1]. In cloud datacenters, servers are always over-provisioned in an active mode to meet the highest demand of requests, and therefore wasting an enormous amount of energy. In recent years, datacenters are extending quickly to meet the ever rising demand for cloud computing capacity. It is the powerful cloud servers that consume a large amount of energy. To handle the potential highest demand of user requests, cloud servers are always over-provisioned, wasting a large number of energy as a result. Hence, there is a pressing need to improve energy efficiency for servers in cloud datacenters [2]. Cloud computing has appeared as the main pattern for IT businesses. Cloud computing prepares a structure and platform to control and convey services over the Internet worldwide. Cloud computing services take advantage of services on demand without early capitalizations. Cloud computing services have maintained their development, which has caused raises in the number and area of datacenters. Datacenters with abundant computing components are expanded as back end to prepare cloud computing services. Cloud computing services have to become a significant energy consumer because of joining with many industries and rapid growth. In today's world, energy efficiency is a universal challenge, where formal resources of energy are being spent at an extremely fast rate, and request for alternative resources of energy is rising. Hence,

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numerous information technology companies have concentrated on reducing energy by introducing energy efficient techniques, architectures, infrastructures and protocols [3]. Albeit, cloud computing is denominated as a naturally energy efficient platform because of multitenant ability, scalable character of its resources and densely inhabited datacenters. In recent times, many kinds of research have concentrated on the energy consumed in datacenters [4], [5]. The Environmental Protection Agency (EPA) studied and appraised that energy consumption of datacenter would twofold from 2006 to 2011 [4]. In 2009, datacenters reported almost two percent of worldwide electricity usage with a financial effect of 30 billion dollars [6]. Gartner Group predicted datacenter equipment outlay for 2012 to be at 106.4 billion dollars, a 12.7 percent rise from 2011, since cloud computing income, was predicted to leap from 163 billion dollars in 2011 to 240 billion dollars in 2016 [7]. Therefore, the extreme consumption of energy from the cooling and computing systems generates unusual electricity expenses, needing some datacenter operators to be restricted by a particularized budget of electricity. Energy consumption is a significant concern in distributed systems. The energy consumption of datacenters is 100 to 200 times higher than typical offices [9]. It is predicted that datacenters all around the world spend almost 26 GW that matches 1.4 percent of the energy consumption of the world with 12 percent annual development [9]. Furthermore, energy efficient designs of datacenters are the major goal, because they are able to decrease electricity usage and save money. Nevertheless, the crucial temperament of datacenter loads enhances abundant designs with energy efficiency criterion. Rack servers are the major factors of misspending energy. Server computers take place the largest area and execute the complete operation; therefore, recently comprehensive enhancements in the cooling system and specifically CPU of servers have been produced to decrease this misspent energy [9,10]. The energy consumption of datacenters can be apportioned into two classes: physical and computing resources. The results in [11,12] show that the computing resources energy consumption accounts for almost 50 percent of the total energy consumption.

Servers are the most prominent and energy-hungry element of the datacenters. Servers account for 50% of IT electricity consumption in a datacenter of different space types [11]. Datacenters are mainly composed of three kinds of servers, i.e., volume servers, mid-range servers, and high-end servers. The Environmental Protection Agency (EPA) study estimated in 2007 that the volume servers were the major server class used in data centers and consumed almost 40 percent of total data center electricity. As the same study pointed out the escalated electricity consumption values in the data centers, datacenter operators started search for energy efficient datacenter building blocks, specifically servers. A server node can be managed in different operational states according to the current workload to achieve temporal energy proportional computing [12]. Figure 1, shows the servers' computation, networking and communication equipment', storage devices, cooling and refrigeration systems, and power supply systems takes about 40 percent, 5 percent, 5 percent, 40 percent, and 10 percent of energy consumptions, sequentially [12]. We can conclude that servers are one of the most substantial energy draining facilities in datacenters. They account for a dominant portion of the total operating costs. Therefore, reducing energy consumption for servers is the key issue of the sustainable development of datacenters.

The remainder of this paper is arranged in this manner**.** In Section 2, we argue energy efficiency techniques for server processors of cloud datacenters. We present a detailed description of the power distribution unit in Section 3. We discuss server cooling systems in cloud datacenters in Section 4. Finally, in Section 5, we conclude the paper.

2. Energy-Efficient Solutions for Server Processors

We can deduce that one of the most important energy-draining devices in datacenters is the server. Thus, decreasing energy that consumes by servers is an important topic of the continuous evolution of datacenters. Nowadays, the processor is one of the critical power consumer devices in servers [18]. Modern processors, for example, Xeon Phi [19], contain multiple billions of transistors that cause to be them, take advantage of an enormous amount of energy. It has been indicated that in the server, power and energy consumption can be depicted by a linear relationship between the CPU utilization and power consumption [20]. CPU frequency, in an abundant scope, determines the present power utilization of a processor, and can have a high performance due to accuracy in progress, and can significantly improve processor energy efficiency. It also can decrease the processor average energy consumption at runtime depending on the applications [21]. Extensive CPU power consumption models count on certain details of the CPU microarchitecture and obtain strong accuracy regarding CPU power consumption modeling [22], [23].

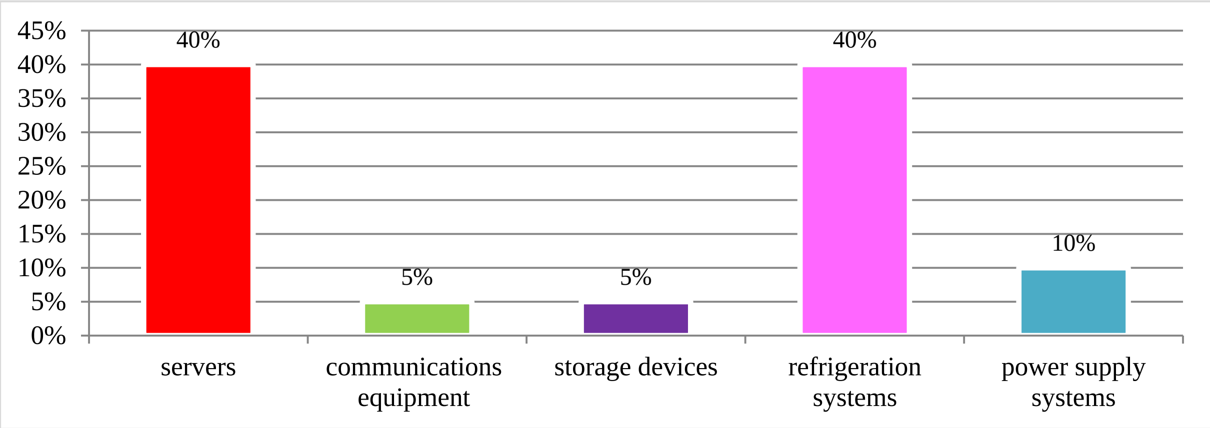

Fig. 1. Proportions of energy consumptions for cloud datacenter equipments.[12]

2.1 Multicore processors

Multicore designs are excellent for throughput-oriented computing in datacenters since they prepare extensive parallelism for search or analysis over enormous datasets. The server technology is changing more and more imbalances from the technology of memory in respect of speed and bandwidth. In addition, designs of servers rather than energy or work completed per unit cost, stress on performance.

Hamilton et al. [24] recommended a design that has been called "Collaborative Expandable Micro-slice Servers (CEMS)" for modular datacenter constructed on a rackable server chassis containing x86 cores sharing one power supply, DDR2 memories, and Input Output devices. Performance metrics, like energy consumption, requests per server (RPS), RPS per dollar and cost were appraised. The Results indicate that CEMS design causes to 50 percent reduction in energy consumption without moving performance metrics. The 3D stacked design like SoC design is one more favorable method for energy efficiency and area compaction in datacenters. Researchers recommended a 3D stacking architecture for server called PicoServer [25]. PicoServer architecture containing stacked cores and several DRAMs attached through buses with low delay, therefore removing the requirement of Level2 cache memories. Multiple cores enable frequency to be decreased, lacking influencing throughput and gratifying thermal restrictions. The nature of 3D stacking designs is the interfaces between core, and DRAM that prepare little delay, significant performance and destroy smaller energy. Various cores incorporated in single-chip design, increase power consumption and density of heat. Hence, designing densely inhabited modules needs particular attention of frequency, power, and throughput [26].

2.2 RISC-based systems

Reduced instruction set computer (RISC) architectures are inherently energy efficient than their counterpart Complex Instruction Set Computer (CISC) architectures. Therefore, they are predominantly used in mobile and embedded systems. RISC-based processors have lesser number of transistors and gates but require more instruction cycles for a task than a CISC-based processor.

RISC-based processors are designed to operate with a constant length and simple instructions (in an ideal manner all instructions have the equal size and perform in one cycle) while CISC-based processors have a diversity of complex instructions without constant length. As a result of instructions sizes in RISC-based processors are constant, instruction fetching is easier and opcode, and operand can be concurrently reached (due to the place in a known location of memory), therefore need for less power consumption and also simplifying the designing of the control unit [27]. Figure 2, shows the architectures of RISC and CISC processors.

RISC-based systems are naturally energy efficient than their partner CISC-based systems. Aroca et al. [28] have performed a comparison of various CISC and RISC processors for energy efficiency. The results indicated that the systems using RISC processors are 3 to 4 times more energy efficient than the systems using CISC processors.

2.3 System using DVFS

The shift to multicore processors, with tens or more of cores on a single chip, needs that the operation of the cores be dynamically managed to maximize energy efficiency of the processor. Dynamic voltage and frequency scaling (DVFS) is an efficient method for the energy saving in processors. DVFS, being greatly implemented in modern multicore processors, is identified as an effective method for obtaining the tradeoff between energy efficiency and system performance. With DVFS, the processor could adopt the working frequency dynamically, which causes to various energy consumption.
DVFS technique can be employed to decrease the energy consumption of the IT devices. The DVFS technique enables processors to perform at various combinations of clock frequencies and voltages to decrease the power consumption of the processor. Since processor power accounts for a large part of the total power consumption of the system, there have been an important study on processor power management. The greater parts of these studies are based on the DVFS technique. CPUs that support the DVFS technique can run at a lower frequency and voltage setting and hence consuming less the power. DVFS technique reduces power usage of CPUs dependent upon the reality that similar power consuming in CMOS circuits has a straight relation with practical frequency and the square of the supplied voltage. Therefore, DVFS techniques save energy by exchanging between the processor’s frequencies and voltages during slack times to run tasks. The processor energy consumption is nearly proportional to its frequency and the square of its voltage. Reduction the processor frequency and voltage will lower down the processor performance. Nevertheless**,** if the performance is not so significant, we can reduce the processor frequency and voltage to decrease the processor power consumption [57].

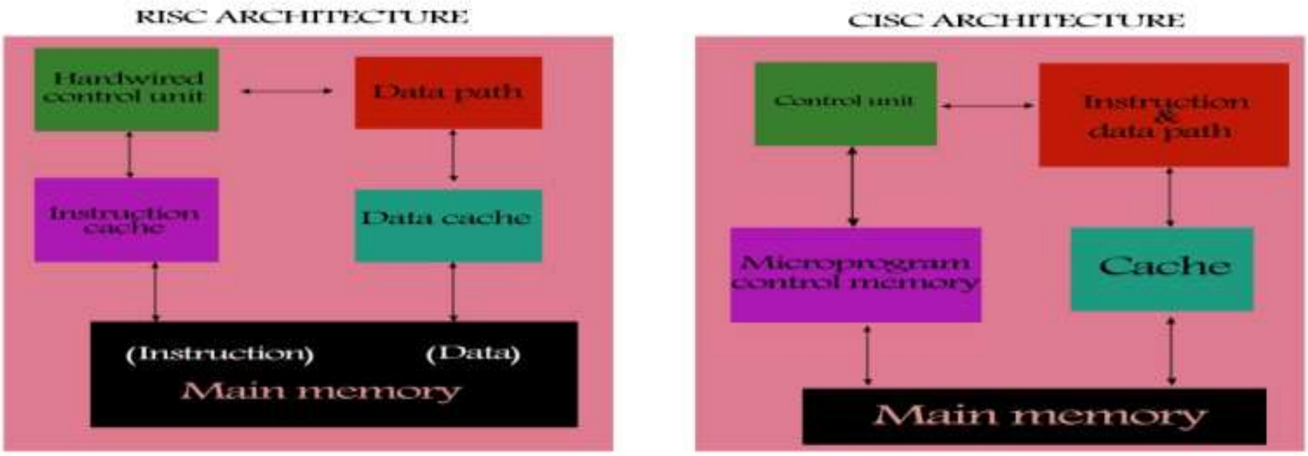

Fig. 2. CISC processor design (right) and RISC processor design (left).

Modern CPUs are equipped with DVFS techniques, which enable CPUs to be performed at various frequencies beneath multiple supply voltages. DVFS techniques have been demonstrated to be achievable solutions to decrease the power consumption of CPU. By lowering CPU supply voltage and clock frequency over given time slots, such as idle phases, power consuming can be obtained large reductions, with poor performance losses. The DVFS techniques, therefore, gives chances to decrease energy consuming of high performance computing (HPC) and have been implemented in the HPC areas, such as in enormous datacenters, to decrease energy consumption and obtain significant availability and reliability. DVFS technique can prepare considerable energy reduction; nevertheless, it has to be implemented carefully, as the result may vary for different software and hardware system architectures. DVFS decreases the number of instructions execute in a given time, hence decreases the performance and, therefore increases runtime of programs, specifically CPU-bound programs. Thus, it is a challenging effort to improve the DVFS algorithm.

There has been a lot of researches concerning the employment of the DVFS technique in order to energy efficiency of HPC workloads that running on datacenters [27, 29, 30, 31]. Rizvandi et al. [32] focus attention on the selection optimum frequency to minimize energy consumption based on DVFS, and their results indicated the efficiency of the proposed algorithm compared to other related techniques. Etinski et al. [38] recommended a model that foretells the upper bound on performance loss because of frequency adjusting. They realize whereby cluster characteristics, together with the sensitiveness of the application to frequency adjusting, determine the efficiency of the DVFS technique for optimization of energy consumption. Wang et al. [34] present an energy aware heuristic scheduling approach that investigates the slack time of non-critical tasks and stretches their completion time to reduce energy consumption without influencing the overall completion time of the task. They also aim to develop scheduling heuristics and to present application experience for reducing power consumption of parallel tasks in a cluster with the DVFS technique, and present formal models for precedence-constrained parallel tasks, DVFS-enabled clusters, and energy consumption. They study the slack time for non-critical jobs, extends their execution time and reduces the energy consumption without increasing the task's execution time as a whole. Vishnu et al. [35] for energy efficiency use the DVFS technique to leverage the slack in one-sided networking and communication primitives of PGAS. Lower frequency of the core also causes to lower temperature of core. datacenters [36, 37, 38, 39, 40, 41, 42]. Energy effectiveness has been tracked widely in the substance of large scale cloud computing, too [43, 44].

Rossi et al. [21] build power models to appraise the energy consumption of applications under various DVFS policies. Le Sueur et al. [26] exhibit that the DVFS technique is effective in decreasing energy consumption, even in conditions where tasks with precedence restrictions are scheduled. Chen et al. [24] combine the three methods of service management, request dispatching and DVFS to enhance energy efficiency for large scale computing. However, they suppose the servers that prepare different services are active all the time.

2.4 Near threshold server processors

Datacenters produce an enormous amount of warmth and need important investments in cooling and power infrastructure, resulting in an important social and environmental effects. Cloud service providers construct new datacenters to adapt the quick industry growing. Nevertheless, while the claim of cloud infrastructure increase continuously, the technology of semiconductor has been arrived the physical restrictions**,** not anymore being able to reduce the power consumption of the chip. These restrictions have become the predominant restricting factors for datacenters, due to the power claims cannot be gratified. The termination of Dennard's scaling faces processor designers forward of the power/utilization wall. Predictions explain that the gap between the amount of integrated cores on a chip and amount of cores that can be utilised will continue to expand in the future. The imminent challenge that designers faced is dark silicon (transistor number under-utilization because of power budget), not only low energy but also to ceaselessly convey worthwhile throughput with much less energy consumption. Dark silicon has been currently emerged as a major challenge of the processor design that endangers the well established core number scaling lane in the present and future chip generations. To direct the dark silicon phenomenon, researchers have presented methods extending from device level to microarchitectural level. One of them is Near-Threshold Voltage Computing (NTC) [45] depicts a method to reduce the impacts of dark silicon, permitting a lot of cores to perform simultaneously under a given manycore power wrapper. Processing and computations at NTC are executed in more energy effective mode compared with the formal Super Threshold Voltage Computing (STC). This is particularly significant in the datacenter, when an enormous amount of heat is produced and main investments in cooling infrastructure and power reduction are needed. Figure 3 shows the **e**ffect of voltage scaling on a variation of gate delay.

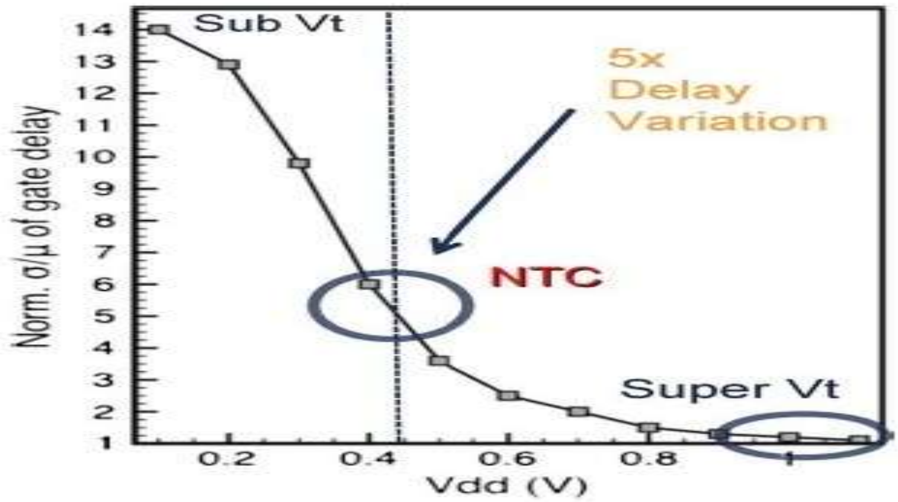

Fig. 3. Impact of voltage scaling on **alteration** of gate delay.[51]

In recent times, many kinds of research have been performed that utilized the NTC method such as a NTC x86 (IA32) CPU [47] and a NTC many-core processor [48]. In contrast with the STC, NTC domain processing and computations are executed in a more energy effective mode. Wang et al. [49] performed an extensive examination of area, energy effective, and performance tradeoffs by running emerging scale-out workloads. They also characterized various perspectives containing energy efficiency and performance within the context of NTC processors with scale-out workloads. They found NTC can enhance energy efficiency by 50 percent and improve performance by 60 percent. Table 1 presents the taxonomy of architectures and solutions for server processors in cloud datacenters.

Table1
Taxonomy of Server Processor Solutions

Reference	Architecture/technique	Description
Hamilton et al. [24]	CEMS	Introducing a design that has been called “Collaborative Expandable Micro-slice Servers” that evaluates low cost, low power servers for high-scale internet services in datacenters
Kgil et al. [25]	PicoServer	Using 3D stacking technology to build energy efficient servers
Rizvandi et al. [32]	DVFS	Focusing on selection optimum frequency to minimize energy consumption based on DVFS
Wang et al. [34]	DVFS	Presenting an energy-aware heuristic scheduling approach to reduce energy consumption without influencing the overall completion time of the task
Vishnu et al. [35]	DVFS	Using DVFS technique to leverage the slack in one sided networking and communication primitives of PGAS
Chen et al. [24]	DVFS	Combining the three approaches of request dispatching, service management and DVFS to improve energy efficiency for large scale computing platform
Le Sueur et al. [26]	DVFS	Demonstrating that DVFS is effective in reducing energy consumption, even in situations where tasks with precedence constraints are scheduled
Dreslinski et al. [48]	Centip3De	using the synergy between 3D integration and near-threshold computing to create a reconfigurable system that provides energy-efficient operation
Wang et al. [49]	NTC/dark silicon cloud processors	characterizing various perspectives containing energy efficiency and performance within context of NTC processors with scale-out workloads

3. Power Distribution Unit

High efficiency and reliability are the main requirements for the power distribution systems for cloud datacenters. However, many researchers have demonstrated that the traditional AC distribution system for cloud datacenter has low reliability and efficiency due to its multiple conversion phases. In recent years, DC distribution systems have become favorable due to its fewer conversion phases and high compatibility with renewable energy for example, wind energy or photovoltaic system. There are two fundamental DC distribution systems. First is the 48V DC distribution system, which has been implemented in the telecommunication industry for a long time. The second one is a 380V DC distribution system, which has been recommended recently. Usually, the power distribution system comprises four basic parts: First, Uninterrupted Power Supply, or UPS: This part converts the incoming utility AC power to the desired voltage level (DC or AC). The energy storage system such as battery pack, fuel cell or flywheel that is included in UPS begins delivering power to the distribution system when a power outage happens, and the utility power is off. Second, Power Distribution Unit or PDU: This part contains terminal, connectors, wiring, and circuit protection devices to deliver power from UPS to various server racks. Third**,** Power Supply Unit or PSU: The function of this part is converting the distribution voltage level to a lower DC voltage, usually 12V, for the motherboard. PSU converts the input AC voltage to 12V DC in an AC power distribution system. For DC distribution system, the input voltage of PSU is DC instead of AC, the input voltage level is either 380V or 48V depending on the system requirements. Fourth**,** Voltage Regulator or VR: This part is on the motherboard. VR converts 12V DC to different lower DC voltage such as 5V, 3.3V and 1.1V for the various electrical loads on the motherboard like cooling fans, CPU, and memory [59]. The power distribution units are arranged across the datacenter in wrapped topology, each PDU serves two racks, and each rack draws current from two PDUs. Power capping and multilevel coordination are required to limit the datacenter power budget across the cyber physical space. The server controller caps the power budget by varying P-states according to actual and reference utilization levels of the cloud server. Modern cloud servers are equipped with dynamic power management methods to cap local power budget [60]. Researchers have proposed a power capping method for datacenters that require coordination among different datacenter resources such as blade servers, racks, virtual machines, and containers [61]. In modern rack-based cloud datacenters, modular power distribution is adopted with redundant power distribution elements. Pelley *et al.* [63] adopt the method of shuffled power topologies, where a server draws the power from multiple power feeds. A central controller directs switching of servers to power feeds to: **1)** force power budgets by way of control loops with regulating processor voltage and frequency; 2**)** balance power draws across the three AC phases to avoid current and voltage spikes that decrease device reliability; and 3**)** distribute the load overfeeds in case failure of feed. The *power routing*, a powerful scheduling technique, sets budget of power for at the PDU each server. If power demand of a server heightens its budget cap, power routing looks for supplemental power on power feeds linked to the server. For underutilised servers, power routing controller decreases their budget caps and makes power slacks that might be needed in another place in power distribution system. Appraising cloud server power usage and provisioning cloud datacenter power, therefore needs thorough probing of: **1)** varying cloud datacenter workloads; **2)** nameplate versus real peak power values; and **3)** application-specific server resource utilization attributes [62].

4. Server Cooling Systems

Datacenters consume very large electrical energy and cause meaningfully to atmospheric carbon burden. This energy consumption is mainly used for active tasks and to remove heat from the datacenter. Most of the heat removed from cooling is refused to the atmosphere as waste [64]. The growing global demand for cloud services offered by datacenters has raised its total energy consumption and carbon emanation. A high part of energy exhausted in the cooling system is typical because of the intrinsic inefficiency of the multi-level heat ejection process existing in from the microprocessor level to the cooling infrastructure level. Depending on the type of cooling system, air or liquid-cooled, inefficiency can be meaningfully enhanced upon by utilizing different thermal management and efficiency improvement techniques at various levels [65]. The electrical energy principally goes to the IT equipment and the cooling system. It is found that an important part of this energy usage is typically for powering the cooling infrastructure. The major power consumers are the chillers, which supply the chilled water to the cooling coils in order to sustain the indoor environment conditions by ejecting the heat scattered by the servers [66]. Therefore, decreasing the power usage of server cooling systems by thermal management methods has been considered in the server operation. High power usage of server cooling infrastructure could be decreased through enhancing the operation by implementing and utilizing the state of the art cooling methods. Enhancing the server operation can be obtained by implementation of the energy efficient techniques such as efficient airflow management. The best practice approach but refers to the attainable potential efficiency that can be achieved through the existing technologies such as the implementation of more efficient cooling equipment. The state of the art techniques, on the other hand, refers to the implementation of maximum possible techniques in decreasing the total power consumption of the server cooling system. This could be obtained by the implementation of cogeneration systems and advanced liquid-cooled servers [65]. The performance and implementation of the aforementioned methods can change depending on the type of server cooling system that can be either air-cooled or liquid-cooled. In air-cooled datacenters, all racks housing servers are organized into rows that are partitioned by aisles that are either cold air intake or hot air exhaust. This organization is placed on a raised floor plenum. The condition that chilled air from computer room air handler (CRAH) units are distributed into the datacenter room by way of perforated floor tiles. The cold air, after crossing through the servers, sucks up the heat of servers and scatters it into the hot aisles. The hot air is eventually returned to the majority of datacenters that are thermally managed either by acquired experience or intuition. The appearance of websites with a worldwide audience and the democratization of cloud computing have caused the building of cloud datacenters worldwide. Datacenters are constructions that establish from several servers up to hundreds of thousands of servers hosted in rooms, particularly designed to prepare power and cooling for the servers. The ever-growing energy consumption by cloud datacenters has influenced intensified attention on the thermal effectiveness of these complicated constructions. A large amount of the energy consume by datacenters is ascribed to the energy required to cool the datacenters. Therefore, enhancing the thermal management and cooling efficiency of datacenters can cause to important economic advantages. However, datacenters are complicated systems containing an important number of devices or subsystems such as servers, pumps, fans, and heat exchangers that must be considered in any optimization effort for synergistic datacenter thermal efficiency. The cooling system acts an important role in a modern cloud datacenter. Designing an optimum control method for datacenter cooling strategy is a challenging effort. The common methods often rely on estimated system models constructed upon the knowledge of electrical and thermal management and mechanical cooling, which is complicated to design and may cause to unsteady or suboptimal performances. A great part of the energy consumed by computing components is transformed into heat. In the design of chip, the heat complication is very significant since it can intimidate to lead the chips to crack at the highest temperature [50]. The temperature range of 20°C to 24°C is optimum for component reliability [51]. Cloud datacenters house tens of thousands of servers and communication networks, whichever their cooling expenses for heat ejection, will enhance exponentially. Cooling takes a great part in the overall power consumption of cloud datacenter. To decrease cooling energy consumption, companies attempt to benefit from taking advantage of renewable energy and natural cooling mechanisms. Facebook built its first renewable datacenter in 2014. Then, a datacenter built near Arctic Circle, thus local weather prepared cooling of datacenter. Datacenter electricity sometimes will be produced from renewable resources. The Google company built a datacenter in Belgium that does not employ a chiller for cooling. It is advised, if available, to employ additional alternative retrieval energy, mainly the solar energy, during the time losing the residual energy from the datacenters is not sufficient to stay on the cooling system. To obtain a similar goal, various alternative energy resources and geothermal power supply can be employed. Fundamentally, the heat dispersed to the environment by way of the datacenter racks is disappeared the cooling factors and so perform the absorption Bromine water cooling chiller and cool the water employed for cooling the environment of the datacenter. To achieve the cooling unit while the heat absorbed from the servers is not sufficient, a twofold system is proposed to cool the water required for the absorption chiller, such as solar energy or other renewable energy resources [52]. The Computer Room Air Conditioning (CRAC) unit utilises airing methods to scatter heat produced by cloud datacenter sources. CRAC unit failures and higher utilization of server in special racks can cause non-uniform dissemination of heat and hotspots. The non-uniform heat profile of datacenters is required dynamic providing of cooling system resources [53]. The CRAC is liable for controlling the temperature and humidity in the datacenter such that all the electronic devices operate in an efficient and safe manner. The energy efficient design of this unit is one of the main challenges in the building and functions of datacenters. In most conditions, cloud datacenters for thermal management need separated cooling systems. The novelty is the adoption of CRAC units that convey cold air to the server racks through punctured tiles put over an under-floor plenum. Dynamic thermal management in datacenters results in advantages, for example: 1) uniform dissemination of temperature with reducing the number of hotspots, 2) decreased cooling costs, and 3) enhanced reliability of devices [54]. Dynamic thermal management techniques have changing methods to cooling datacenters, for example workload mapping in cool server racks [55] and workload placement and cooling management techniques [56]. The majority of datacenters still utilize a raised-floor configuration for the conveyance of cold air to IT devises. Therefore, optimizing the layout of the datacentre is important for decreasing the recirculation of hot air, thereby growing cooling and energy efficiency. At this time, air-cooled datacenters generally adopt a raised floor configuration to sustain a suitable temperature and humidity situation, as shown in Figure 4. In aforementioned configuration, cold air is provided from the CRAC units to a cold aisle through punctured floor tiles that face the inlets of the server racks. The compute nodes use power and eject hot air through the reverse end to a hot aisle.

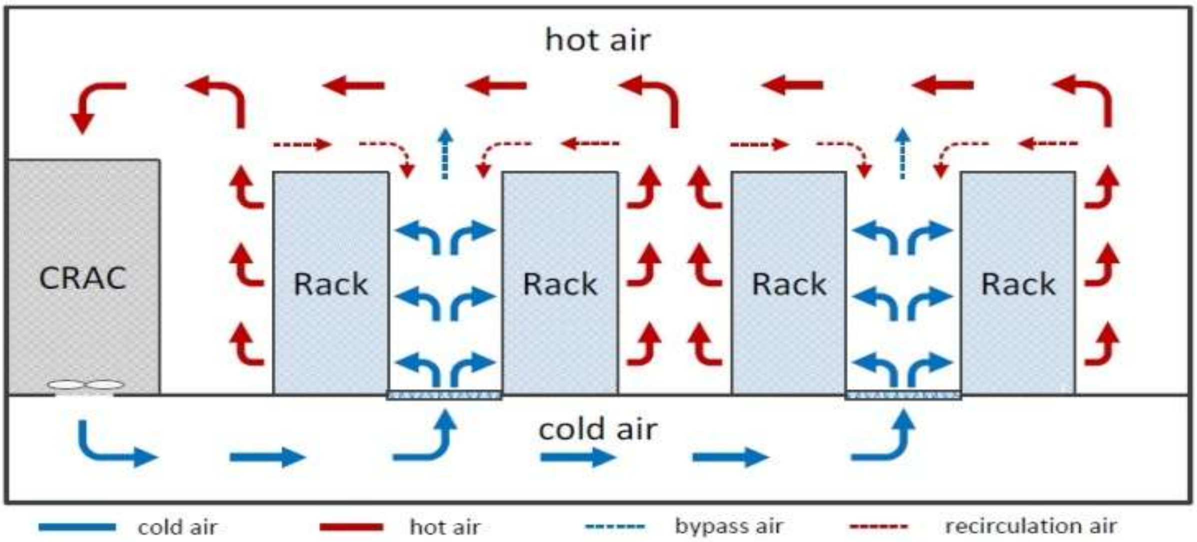

Fig. 4. Hot aisle/Cold aisle configuration with raised floor.

The air-cooled system is the most well-established cooling technique adopted for the current datacenter foundation. However, the air is basically an inefficient cooling method because of its low heat removal capacity and low density. Therefore, if the size of the datacenter grows because of development with high performance IT equipment, other cooling methods are needed. A liquid-cooled system is one of the most important and efficient methods that can be implemented indirectly or directly [65]. An indirect liquid-cooled system is a heat removal process without direct contact between the heat source and liquid coolant. So that implement this method, conventional air-cooled heat sink needs to be replaced with the evaporator or other liquid-cooled heat sinks. In a direct liquid-cooled system, in contrast to the indirect liquid cooling, the liquid coolants are in direct contact with electronic components, where dielectric fluids supply electrical insulation. One of the main advantages of this method is the adaptability of the cooled system since no sealed enclosures and piping are required at the server level to direct and maintain the liquid flow.

5. Conclusion

The evolution of energy efficient cloud datacenters has collected considerable attention due to their environmental and financial impact. Comprehensive research is being performed in order to decrease carbon emissions and energy consumption. In this article, we exhibit an extensive survey of the prevalent modern researches on energy efficient architectures and techniques for cloud servers in processor design, power distribution unit, and server cooling management. We provide an overview of energy efficient techniques and architectures for cloud processors, including RISC-based processors, systems using DVFS, and Near Threshold Cloud processors. We also present an overview of the power distribution unit in cloud datacenters. Finally, we discuss the server cooling system and thermal management in cloud datacenters. We summarize the existent methods and architecture, also emphasize the potential challenges and for bearings future studies with relation to each of these appearances.

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