Reduce Power Consumption in Servers Infrastructure under backup and availability constraints

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***Abstract*—IT Data centers and global network consume approximately 4 percent power of the overall worldwide power consumption [1]. A global challenging task is to optimize energy consumption in the field of computing, research community is not only focusing on finding ways for reduction of energy cost and maintain profitability, but also working on reduce environment effects of global warming. In this work, we aim to provide power consumption model for servers at data centers with the motive of savings in power utilization allowing servers to go into sleep mode without compromise on Quality of Services (QOS) in terms of availability and performance in terms of delay that occurs in activation from sleep mode when any service arrives at server.**

Our main focus is on backup servers (whose availability is high) and Data Recovery servers and also all those servers which are utilized less than 12 hours per day and remain idle rest of the time, we may call them application servers. Our objective is to propose a simple Dynamic Power Management (DPM) scheme for putting the server in sleep mode based on traffic load which will result in significant power savings in server infrastructure of data centers. We shall apply a different job scheduling method for each class of servers, i.e., force sleep mode for backup servers, active on job occurrence for data recovery servers and force active for application servers. We shall obtain results in a real time environment to evaluate the impact of our scheme.

I. INTROCDUCTION

Power reduction in servers network is very prominent research area due to increasing utility bills and environmental effects. Its effects on atmosphere by carbon emissions, energy consumption have major activity to contribute change in climate. Green House Gases CO2 (Carbon Dioxide) emission have main effect to warming earth. Discussion and observation about importance of power saving and climate effects in the information technology industry are reported by ITU in [2].

For a superior server with 330 Watt power consumption, the monthly energy cost of the server is around $18 [3]. This cost does not include cooling and some other components such as UPS, power generator, switches, network equipment etc. Only superior servers power consumption costs $0.074 per kWh [3]. Electricity cost of servers infrastructure is doubled after every five year worldwide [4][5]. Electricity utility bill for that server infrastructure was $7.2 billion in 2005 worldwide [6] and data center consumption turned out to be $7.4 billion only in U.S in 2011 [3]. Now we can imagine that after 10 years, what will be overall cost of electricity in the whole world.

Energy consumption in the servers is mainly on account of utilization of CPU and other components like memory, network equipment and disks etc. Idle server consumes 60% of power with respect to power consumed at full load [7][10]. Depending on traffic load, the power consumption varies from 60% to 100% on server [7][10].

Disaster recovery (DR) is a procedure to recover the technology and maintain continuity. Disaster recovery maintains IT and technology to support continuity in business functions. Disasters are classified into two categories, namely (i) natural, and (ii) man made. Disaster can be due to infrastructure failure, wrong implementation during change, hardware failure, Operating System (OS) failure and due to any other bad configurations. Now the objective of small and large scale organizations is to ensure 99.99% availability and continuity of servers. Business dependence on IT system is increasing and failure chances of IT System are increasing too due to large scale of natural disasters such as earthquakes, tsunami, tornadoes and flood related disasters. Our focus is on DR, backup and application servers that remain idle most of the time, mostly DR and backup server are used when any disaster occurs, either natural or human induced disaster.

Generally, backups are taken in three different ways, namely, (i) Full, (ii) Differential, and (iii) Incremental backup. When a complete or all data is saved in another media like CD, Disk, USB, then such backup is called full backup operation. Full backups are taken periodically after a specific time as per requirement. Sometimes, only that data is copied or backup which has been changed after last backup operation; such a backup is called an incremental backup. In Differential backup, initially a full backup operation takes place during any set main period and then incremental backup takes place during subsequent sub-period till another main period arrives. There are different strategies to take backups like full daily, full weekly with differential daily and full weekly with incremental daily.

Dynamic frequency scaling (DFS) is a technique which reduces the heat produced by chips and conserves power. DFS minimizes the set of instructions that a processor can complete in given time which results in reduction of performance. Therefore, it is useful only during the periods when tasks dont depend on CPU.

Dynamic Voltage Scaling (DVS) is a technique where voltage fluctuates (i.e., increases and decreases) is used in different components of computer such as CPU, memory, disk and fan. Decreasing voltage reduces the power consumption in computer components, while increase in voltage improves the performance of computer.

DVFS is now virtually available on latest processors like power now and speed step are available in AMD and Intel processors respectively. DVFS supported processor can also run at low voltage and frequency. When a processor is not performing any necessary working, then during that time DVFS method can force the processor to run at low frequency and voltage.

Dynamic power management (DPM) is a technique used for power control. The performance of the system depends on its work load. DPM allows system components to go in shutdown mode during idle periods or when work load is very low. However, such a technique can also diminish the systems performance due to overhead of shutdown and active state of components.

In [5] Dynamic power management (DPM) is a design methodology for dynamically reconfiguring systems to provide the requested services and performance levels with a minimum number of active components or a minimum load on such components. DPM encompasses a set of techniques that achieves energy-efficient computation by selectively turning off (or reducing the performance of) system components when they are idle (or partially unexploited).

In this thesis, our aim is to evaluate power consumption of a real time server infrastructure and present a mechanism to reduce the power consumption of servers network. Our focus is on all enterprises that have large or small server infrastructure. We observe that only a few companies serve 24/7, nearly about 70%companies serve 9 hours in a day and server remain in idle condition for the remaining 15 hours resulting in wastage of precious resource of energy as well unnecessary CO2 emission. Simple server infrastructure utilization is 20 to 30% only [11]. We adopt the Dynamic Power Management (DPM) scheme for turning the server in sleep mode and active mode as and when needed. The servers will be put in sleep mode when there is no traffic flow on these servers. If any change/new job occurs or necessity arises, then server is switched from sleep mode to active mode. Normally DR and backup servers are not providing services all the time; these servers are used only when any kind of disaster occurs.

A. *RESEARCH PROBLEM and MOTIVATION*

Computer users grow with passage of time due to paradigm shift from manual work to technology which saves time and cost. Large organizations have already adapted to the use technology in their business, but now small industries are also moving toward technology use as well. Therefore, the increased trend of technology use increases the server network infrastructure which results in increase of power consumption having greater effect on cost and environment. Now days, green computing is answer to reduce cost and environment effects of IT Industry.

Greater trend toward technology has greater effect on increasing power of data centers. It is really hard to maintain large server infrastructure because it utilizes maximum budget of the organization. So our focus is on power reduction in server infrastructure and our core area is DR and backup servers. We aim to reduce power of backup servers when they are in idle condition with a small compromise on availability and backup constraints.

B. *OBJECTIVES*

Our overall and main objective is to devise a mechanism focusing on reduction of energy consumption in server infrastructure and decreasing environmental effects. We want to Propose a scheme to reduce power consumption in DR, backup and application servers. Enable sleep mode of DR, backup and application servers during their idle time which may have a small compromise on backup and availability.

C. *RESEARCH APPROACH*

- Firstly, we observed the complete server infrastructure and network design of BM Pvt Ltd which is large scale organization, our main focus was to find the wastage of energy in the design of their server infrastructure network.
- We visited different educational Institutions and small business organizations; we conducted interviews of network administrators and personally observed their complete servers network design in order to find reasons of unnecessary energy usage in their network.
- We visited different educational Institutions and small business organizations; we conducted interviews of network administrators and personally observed their complete servers network design in order to find reasons of unnecessary energy usage in their network.
- We thoroughly reviewed the existing literature related to objective of reducing power consumptions for cellular networks and server infrastructure network in data centers.
- In this thesis, we made use of DPM methodology and job scheduling algorithm and provided detailed results.

D. *THESIS OUTLINE*

We organize this thesis as follow: in Chapter 1, we give brief introduction of topic green computing thats why its necessary and what we are going to do. After that we describe the problem definition and motivation. Then we discuss the objectives and our research approach. In Chapter 2, we present detailed background of green computing and related work. In Chapter 3, we present our methodology, its implementation, discussion and in chapter 4 findings about results and calculate power saving analysis. Finally, we provide the conclusion and further research dimensions.

II. BACKGROUD AND RELATED WORK

In this chapter we present background of green computing and business problems related to data centers and how work is growing in green computing and how different techniques can be used for reduction of power in IT devices and servers.

We provide comprehensive literature review related to green computing, especially for reduction of power usage through

Job Scheduling method, use of Dynamic Power Management (DPM) and Dynamic Voltage Frequency Scaling (DVFS) methodology, complete data center set up and load balancing technique, and other telecom sectors cellular networks.

A. BACKGROUND

The concept of green computing emerged because of power wastage of IT devices in early age. Now these devices are being replaced with new efficient devices which consume less power. The main objective of green computing is reducing hazards and problems which are being faced during power saving efforts. Government can play a greater role in implementation of new green technology through the use of power efficient IT devices and recycling of those old devices which waste more energy.

Data centers at small organizations contribute most of the power of their overall power consumption. Because of maximum part of power utilization is in data centers of organizations, so our main focus is to save power in data centers. There are already many ways devised for power reduction.

Efficient algorithms utilize less servers power as compared to complex algorithms. A complex algorithm takes more time to execute which increases CPU utilization resulting in more power consumption. Therefore, algorithm efficiency requires more attention. Thus, we are more focused towards algorithm efficiency and job scheduling efficiency. Further, virtualization concept helps in reduction of power consumption as well [12]. Virtualization allows logical division of a single physical server into multiple virtual servers through proper resource allocation. A single physical server can run multiple servers virtually on the basis of resources to maintain the load on the server, thus it saves power utilization. But in our scenario, we could not use virtual server because DR or backup server could never run on a single server. If crash occurs on a physical server, then both running and backup server (if virtually on the same server) will be no more available. Application, backup and DR servers are required to be separate physical servers, instead of being on a single physical server virtually. But these can also be different physical virtual servers. Another way is to improve cooling methods with the motive of improving servers performance and power consumptions. Server rack flooring and arrangement is very important to cool servers and airflow needs to be improved by positioning the cooling directly towards the servers. Moreover, server infrastructure can be moved cooled areas [14]. Many other techniques such as thin client [14][12], support of operating system, power supply efficiency, cloud computing[15]are also being used regarding reduction of power resources. Our aim is to devise such a procedure so that we can reduce power consumption from server network infrastructure through DPM and Job scheduling method. We propose a job scheduling method for different idle situations in Backup, DR and active servers.

B. RELATED WORK

Computer users are very sensitive about server response times. They are not ready to accept too much delay in any request and query. Every user wants fast response against his/her query. If server response is slow, it creates negative impact in the minds of customers about companys reputation. Thus, performance of servers is very important criteria and the same cannot be compromised.

Many research studies [3][11][17][18]follow Dynamic Voltage Frequency Scaling(DVFS) for reduction of power with minimal effect on servers performance. DVFS adjusts CPU power against offered load on server. DVFS is useful in scenarios where static power consumption (i.e., when there is no activity) is small as compared to overall power consumption. But in the context of our research problem, Dynamic Power Management (DPM) is better approach to reduce energy consumption during the idle periods of server.

Authors in [11] use a simple job scheduling technique for power reduction, i.e., when server does not have any job in its queue, then server is forced to go in sleep mode, and the same is activated (put in active mode) urgently when any job arrives at the server. In running state, the server works at full speed resulting in more power consumption.

Wang et al. [3] modified DVFS approach to improve performance, used DPM to put servers in sleep mode and also proposed a better job scheduling technique. The authors pointed out the following issues/problems related to [11] and provided the solutions as well: Issue 1: When server switches between sleep and active modes within short time, the same is very costly because it requires a lot of time during such transitions. Solution: Set idle period parameter, set the minimum time period for server to remain in idle mode. If there is no job in the queue, then server does not go to sleep mode instantly, instead it remains in idle condition till the expiry of idle period. Afterwards, if no job arrives during this period, then server is put in sleep mode. This helps in reducing the overhead that occurs between sleep and active mode transitions. Issue 2: Second is violation of response time when a job occurs during the servers sleep mode. Solution: Set the maximum value of sleep period parameter, so that the server is enforced to remain in sleep mode for this time provided no job occurs. But in case, a new job arrives before the expiry of sleep period, then the value of a new parameter called extra sleep period is fixed after which the server is put in active mode.

Kliazovich et al. [17] introduced Data center Energy-efficient Network-aware Scheduling (DENS) methodology to reduce energy consumption and to enhance network awareness. DENS approach is to take decision on the basis of received feedback from switches and links with respect to load. DENS methodology is used to (i) transfer traffic load from potential sleep server to candidate server, (ii) meet QoS, (iii) reduce power consumption in data center, and (iv) improve performance. They used two power methods, namely Dynamic Voltage Scaling and DPM, for reducing power consumption in computing. DVS is used for providing power to various components such as CPU, memory, disk, fan according to offered load on server. DPM methodology is used to put servers components in sleep mode during idle periods. They observed that servers overall utilization is 30

Huang et al. [18] used DVFS technique for reduction of power and used many type of optimizations like application software, hardware level, system software level, integrations of systems and middleware. They used system software level abstraction to energy optimization, system software support to identify the work load and identify how and when to use DVFS approach to optimize energy consumption. The authors introduced a novel methodology; characterization of workload is depending on stall cycles that occur due to off-chips. Memory access time is independent and does not depend on processor speed, so use of DVFS algorithm with memory activities is an attractive target. Program execution time is defined by multiple accesses of memory or I/O, then define limit how fast execution can be completed. This work also introduces eco algorithm that divides execution time in intervals, it is run time algorithm that is based on intervals. Firstly eco algorithm frequently accesses the I/O and memory to identify behavior of the application for every interval and identify at run time. At second step, eco algorithm predicts the workload for next interval based on first step of algorithm. At final step of eco algorithm, schedule the frequency of CPU based on second step and maintain the power management and reduce energy too much as possible.

Authors in [19] evaluated the performance of cellular network. In mobile telecommunication near about 80% power consuming nodes are base stations. They put some cell sites in sleep mode when their own traffic load is very low and selected surrounding sites can accommodate the traffic of such sites. There is a little bit compromise on coverage. The authors observe that switching off the unnecessary network resources with a small compromise on QoS in terms of coverage results in huge power savings. The base station sites are divided into two categories. Firstly, base station sites which can go in sleep mode during their low traffic periods. Secondly, those which are always in active mode and they accommodate the traffic of neighboring candidate sites for sleep mode. The base station site can be either in active or sleep mode at a time. The focus of this work is to let as many as possible sites to go in sleep mode provided QoS in terms of coverage does not fall below 95%. They consider 19 sites in total. When 7 out of 19 sites go in sleep mode, then coverage is compromise by 2% only but power savings are much more.

Beloglazov et al. [15] used DPM technique to power off and on server components after predicting the server load. If QoS requirement is fulfilled, then servers in idle mode and with low load can be powered off. In this work, DPM framework depends on the design of infrastructure having three type of servers pool, i.e., active server pool, sleep server pool and shut down server pool. SLA evaluator, CO2 emission estimator and resource demand predictor calculate the management environment effects and allocate the resources on the basis of QoSrequirements.DPM framework manages the power of server pools on the bases of demand of resources that is calculated by future traffic load. In this work, the authors propose an algorithm for power management that determines which server will go in sleep pool, active pool and shut down pool. When number of hosts is increased and QoS is no met, then it pulls the servers from sleep pool to active pool without violating the SLA requirements. If there is no need of server then put it back in sleep pool and remaining servers are in shut down pool. DPM algorithm decides which server will be in sleep pool, active pool and shutdown pool.

Niyato et al. [20] proposed Optimal Power Management (OPM) technique to reduce power consumption in a server farm while requirements of performance are fulfilled. They used a single server farm to implement OPM technique and used batch scheduler for distribution of users jobs to servers, which is used for operation of sleep and active mode of the server. They also make use of constrained Morkov decision process for the optimal decision. The server cannot immediately switch between sleep and active modes; instead it takes decision according to OPM. Job scheduling is merged with power management. Jobs are sent to the specific server farm for complete processing. Batch scheduler stores the jobs in its queue and then sends them to the server in idle mode and then selects server by applying FCFS technique. There is OPM part of the batch scheduler and it controls the operation of server (sleep and active mode).

In [22], authors provided a valuable tool for awareness of analysis and power scheduling. They introduced a mantis model that captures power characteristics of the system on the basis of hardware performance counter and user utilization characteristics, i.e., count the power consumption in its first calibration phase and then a linear program is used for the model parameter in second phase. In third phase accurate power analysis and work load on the system is calculated. Mantis demonstrate concentrating on the displaying approach for the primary segments of the framework and their instantiation for two unique classes of servers a low end blade system framework and a top of the compute server.

In [23], authors presented a study on disk based storage system that is used in large scale enterprises. Three different observations are found that might affect the future design of backup storage system: (1) components including storage controller except but disk consume high amount of power, (2) difference of power in active and idle mode is huge between models of storage controller, (3) large amount of power utilization impact between comparable hardware. In [24], the authors investigated the impact of energy saving techniques on the administration of PC frameworks, network and systems in cloud computing with virtualization. They pointed out major sources of energy consumption. Its provide work on cloud servers with constraints of energy efficiency and performance. They observed that in datacenters energy can be saved by virtualization. Authors in [25] thoroughly studied energy efficiency in virtualization servers. They considered a setup of three servers comprising of a simple physical server and two virtualized servers i.e., XEN and KVM. They obtained statistics of the simple server and virtualization servers to find tradeoff between them. The authors provided ways of energy saving in datacenters through virtualization. Authors in [26] introduced an energy efficient and logical multi zone (hot zone and cold zone) known as Green Hadoop Distributed File System (Green-HDFS) which is basically an enhancement technique. Both hot and cold zone are data Classes. Cold zone consists of less popular files which are rarely accessed and have low spatial or temporal popularity. Hot zone consist of files that are more popular that have maximum access with high spatial or temporal popularity. They found trade-off between performance and higher energy-conservation in these zones. Records are moved from the hot zone to the cold zone as their temperature changes after some time. They utilized age of a document, as characterized by the last access to the record. File migration policy monitors the age of the files and moves old files to the cold Zone. Green-HDFS strategy is applied on all hadoop clusters which exist on 38000 yahoo servers. They observed 26% energy saving by applying Green-HDFS on yahoo hadoop clusters.

C. PROBLEM WITH EXISTING APPOACHES

Authors in [3] showed that how we can reduce power consumption by job scheduling and how we can remove hazards during jobs occurring. Although, we adopt job scheduling method of [3] in our scenario, but job scheduling parameters of our infrastructure scenarios such as DR, backup and active servers are different from their scenario. Our special focus is on backup and disaster recovery servers but they mainly focused on active servers.

DENS [17] is an energy efficient methodology for complete data center design considering all components like links, switches and computing servers. It is also hint aware network design, congestion avoidance and load balancing approach. Their main focus is on data center design specific network components which consume low power. Our network design and scenario is quite different from that of [17], because we focus mainly on servers rather in switches, routers and links.

The use of DVFS methodology [18] reduces energy by decreasing frequency and voltage during the executions of jobs, but as a result the idle time decreases and execution time increases which effects performance. These parameters are handled by eco algorithm. Over all, there is minimum effect on energy efficiency which is not useful in our scenarios. Since we observe that more idle time exists in server infrastructures, we make use of DPM methodology for our scenario which is a better and useful technique to reduce power consumption.

The authors in [19] try to make optimize use of resources by putting unnecessary base stations sites in sleep mode in order to reduce energy consumption in cellular network. Our context is server network infrastructure rather than cellular network.

Authors in [15] apply DPM approach on cloud data center which is useful in cloud data center design only. But our focus is on small as well large organizational server infrastructure

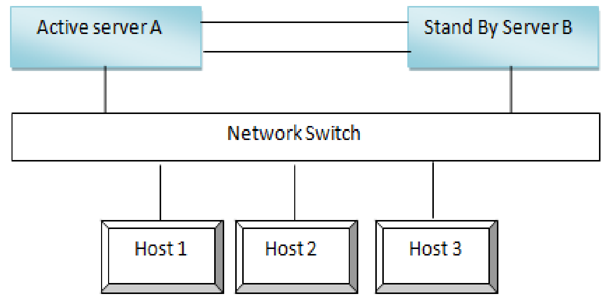

Fig. 1. Cluster computing with DAS

and we are also going to define a new DPM algorithm for our scenarios as below algorithms in every scenario.

D. OUR APPROACH

We observe problem in three type of servers infrastructure design, namely (i) backup servers which are always available, (ii) DR servers which are used for any larger disaster occurrence, and (iii) all other application servers which are active most of the time. We make use of DPM methodology like [3][17][15] to switch DR, backup and active servers between sleep mode and active modes. The main constraints are when server goes in sleep mode and when server wake up. Our objective is to propose an algorithm for different scenarios through job scheduling under DPM.

III. SYSTEM MODELS AND SOLUTION

Backup server is designed to recover IT system which collapses after any disaster, accident or configuration failure. Currently, backup servers are used for high availability of IT system and for decreasing down time of the server. Industry requirement for the availability of servers and reducing down time of server depends on business scenario and Service Level Agreement (SLA).

In cluster computing, two or more servers connect with each other and behave as a single server; aim of cluster design is fault tolerance, parallel computing and load balancing. Implementation and design of cluster computing is to gain high availability and high performance.

We identify four different scenarios in server infrastructure design of small and large industry, wherein servers consume more power and remain idle most of the time.

A. Scenario 1: Cluster computing with Direct Attach Storage

Cluster computing with Direct Attach Storage (DAS) is defined as high availability cluster [27]; actually this is used for failover. For example, as shown in Figure 1, if servers A gets crashed then redundant server B is readily available (i.e. switch to server B). In this scenario, two or more servers each with its own database and storage run in parallel. More than 70% companies use DAS servers in their datacenter setup.

Any change which occurs in database of server A is synchronized to cluster, i.e., server B in this case. Domain controller (DC) and additional domain controller (ADC) is

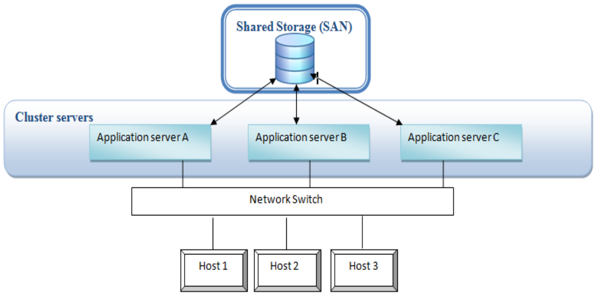

Fig. 2. Cluster Computing with SAN & Load Balancing

famous cluster design which is normally used in small and large organizations and computer labs of educational institutes. This design is used to manage users and computers in a domain under consideration.

Server A is in active mode and server B remains in passive or standby mode. Thus, server B remains idle most of the time in small companies having 100 users on domain. In fact, changes normally dont occur all the time in database, therefore we can synchronize changes with the interval of 3 to 5 minutes or even more by forcing the server B in sleep mode. In summary, we can attain significant power savings by compromising the synchronization of changes after every 3 minutes for the server B. In case, there is 3rd server, then synchronization can be made after every 10 minutes on that server.

B. Scenario 2: Cluster Computing with Storage Area Network & Load balancing

When storage devices are moved to an independent and high performance network instead of remaining in applications servers; then this design is known as Storage Area Network (SAN). Each server is directly connected with storage network with full access of shared resources and users have limited access to shared storage. Installation of the shared storage resources in cluster servers infrastructure is known as load balancing cluster [27].

When two or more servers are placed in a server rack for backup and high availability, then network designer use load balancing technique. Servers high availability design is used as backup for hardware failure such as power supply, RAM and disk, and software failure such as operating system, system software and application software. Unfortunately resources are utilized and load is divided among servers without considering actual calculation of load, QoS and SLA. For example, even if there are only 10 users active at any time, then it divides traffic of these users among 3 servers. This is not efficient way as it results in wastage of resources. As a matter of fact, we dont require 3 servers for only 10 users; rather only 1 server is enough to accommodate them. We need to focus on service level agreement which states number of users on one server. For example, if SLA is for 100 users, and number of users is less than 100, then only 1 server is sufficient for these users and other servers can be put in sleep mode. If number of users is more than 100, then one more server can be activated. It depends on SLA and QoS requirements i.e., no. of jobs per server, no of users per server etc. Our aim is to put all those load balancing servers in sleep and shutdown mode which do not have enough load. We want to put maximum load on a in order to make full use of resources and thus to save energy.

C. Scenario 3: Disaster Recovery

Disaster recovery (DR) is a procedure to recover the technology and maintain continuity of business. Disasters are classified into two categories, namely (i) natural, and (ii) manmade. Disaster can be due to infrastructure failure, wrong implementation during change, hardware failure, Operating System (OS) failure and due to any other bad configurations. Design of DR servers depends on business scenario that how many DR servers should be on backup. Normally DR servers should be in different locations as per business requirement.

There can be more than one DR servers depending upon the company requirement. First DR server runs in parallel with active server i.e., live synchronization with active server. Second DR server synchronizes with active server after 15 minutes or after one day as per requirement. This category of DR servers design is implemented due to occurrence of any manmade disaster and accidental error such as any database error and bad configurations from employee. Our aim is to decrease idle time of DR server which remains in running state all the time.

D. Scenario 4: Application Server in idle state

Application servers allocated for account system, payroll system, inventory control system and any ERP system are normally used only during office hours. Some application servers remain in use for 24 hours, for example, http web server dedicated for companys web site or students online systems for educational sector. Our focus is to put applications servers being used during office hours in sleep mode during their idle periods.

E. SOLUTIONS AND IMPLIMENTATIONS

When backup server is in sleep mode then we can active this server by Wake on LAN (WOL) feature. WOL is used to turn on your computer through a network message on LAN. It is implemented by magic packet which is sending on other computer with MAC address to power on computer. Although this feature is implemented on all systems but the same feature is not advertised. Backup servers wake up automatically by this feature when job or change arrives on backup server. For the purpose of saving power by sleep mode, we enable this feature in bios of backup servers. It is worth mentioning that WOL feature is also available on old systems. We use the following symbols to represent various concepts.

F. Solution of Scenario 1:

In any server infrastructure environment, servers remain active all time even during period of no activity. Considering scenario 1, our aim is to put server B (backup server) in

Term	Symbol	Description
Job Processing		This symbol represents job that becomes in CPU for processing and completes processing duration
Suspend Time		Server active to sleep state duration
Wake Up Time		Server sleep to active state duration
Job Occurrence		Time of job arrival
Sleep Forcedly		Sleep forcedly time server will never active at any condition
Wake Forcedly		Wake forcedly time server will never sleep
Idle Time		When no one job in queue and processing server in idle condition
Sleep Time		When server in sleep state

Fig. 3. Symbol Representations

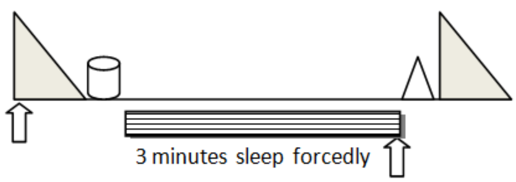

Fig. 4. Scenario 1

sleep mode for a certain period of time. Simply we want to put server B in sleep forcedly for three minutes (though the same can be put in this mode even for longer period as per requirement of the network). As shown in Figure 3, backup server goes in sleep forcedly mode at least for three minutes after completion of the job and then a small transition in suspended mode. Thus, backup server B is put in active mode for synchronization purpose with server A. In fact, the objective of activating server B is to incorporate any changes occurred in server A. After completion of the job, the server B is again put in sleep forcedly mode.

If any job occurs (i.e., change in server A) during sleep forcedly period (referred to Figure 4) , then server B will remain in sleep forcedly mode at least for period of three minutes and will not be put back in active mode suddenly as evident from Figure 4. It will complete the forcedly sleep time and then go in active sate to fulfill the job.

However, if job arrives during sleep period and server A crashes, then what is tradeoff between data loss and power saving? It is important to mention that server crash does not result in loss of stored data on disk, and thus the data from disk can be moved to server B within minutes. However, if a disk gets damaged then normally raid is configured on servers

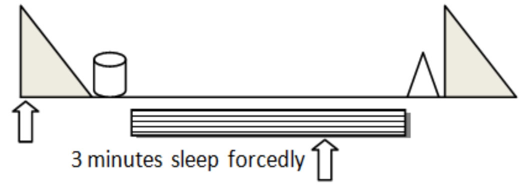

Fig. 5. Scenario 1

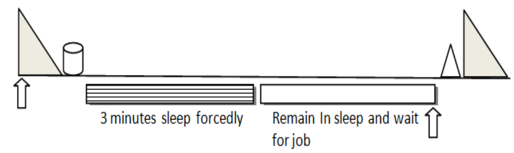

Fig. 6. Scenario 1

so data loss chances are minimum.

Another scenario is that if no change occurs in server A during sleep forcedly period, then logically there is no job occurrence at server B. If we activate server B after sleep forcedly period, then that activation will be useless resulting in unnecessary use of power resources. In this case, we let server B to remain in sleep mode until any job change occurs as shown in Figure 5.

```
// each time slot, length of three minutes
T = 60;
// total simulation time, say one hour
t= 0;
// it is current time
while t <= T do
    while job arrives on LAN card queue do
        if time >= SetTime then
            Then put server on active state;
            Complete the job;
            After completion of job put in sleep sharply;
            Reset time for sleep duration;
        else
            time < SetTime
        end
        Otherwise server remains in sleep state;
    end
    jobdoesnotarriveinqueue Then server remains in sleep state;
end
```

Algorithm 1: (for backup server):

G. Scenario 2:

Server which recently go active mode from sleep mode will remain active state for 10 minutes forcedly because stability

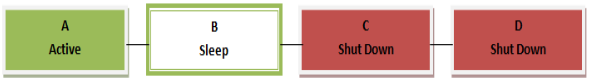

Fig. 7. Scenario 2

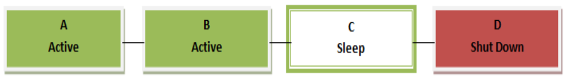

Fig. 8. Scenario 2

of load balancing on last server can be take some time to balance the load and to prevent change of state active and sleep overhead. In this scenario there can be many application servers with clustering and there can be cloud servers which can provide services of cloud computing and share resources. In this respect, our proposed solution is not only for Storage Area Network (SAN) configuration, but the same can also be used for configuration on Direct access Storage (DAS) as per network Design. According to our solution, server A will be in active mode and next server B will be put in sleep mode while remaining servers from server C onwards will remain in shut down mode. For example, if network infrastructure consists of 10 servers, then first server of this infrastructure will always remain in active mode to provide services; the second server will be in sleep mode and ready to provide services in case load on server increases. As evident from Figure 6, when server A SLA fulfills (say 90%), then put server B in active state and server C in sleep state.

If we set SLA 90 percent, it means that when server A uses 90% resources or more, then we active next server, i.e., server Band server C in sleep mode as shown in Figure 7. Our aim is to make maximum utilization of active servers.

Average Load: In order to calculate average load of all active servers, we get weight of load from all servers and calculate average load.

Avg_load = total weight on servers / no_of_active_servers

When to put new server in Active State: Server B is put in active state if active servers average load exceeded the set limit. Load Limit can be set based on criteria like utilization of server resources, number of users per server and any other criteria as per SLA.

We set the maximum load limit value as 90% as maximum affordable value depending upon scenario. The next server (currently in sleep mode) is put in active mode while the next to next one (currently in shut down mode) is put in sleep mode if average load becomes equal or greater than maximum load limit i.e., if avg_load ¿= Max_load_limit.

When to put last server in sleep State: We put last sleep server in shut down state and last active server in sleep mode when average load becomes below sleep limit i.e., if avg_load ¡= sleep_limit. **New load:** New average load is calculated when all active servers overload and a mew server is activated sleep mode. New_avg_load = (max_load_limit * no_of_active_servers) /(no_of_active_servers +1) **Sleep Limit:** Sleep limit is calculated for the unnecessary servers put in sleep mode. When load decreases and extra servers are in running state then put server in sleep and shut down state. Sleep_limit = (new_avg_load * no_of_active_servers 10) / no_of_active_servers

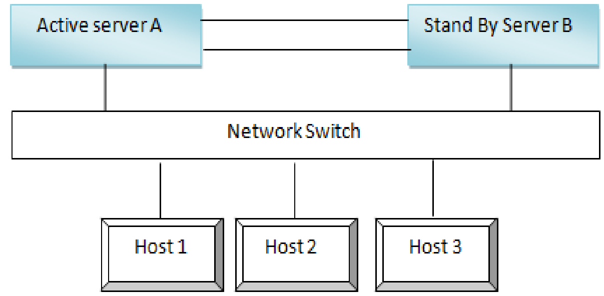

Fig. 9. Cluster computing with DAS

H. THESIS OUTLINE

I. THESIS OUTLINE

J. THESIS OUTLINE

IV. REFERENCES

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