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Techniques for Optimizing Power Utilization in Data Center Network Architectures: A Survey Report

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Abstract

Objectives: The Data Center Network (DCN) is the collection of diverse classes of resources providing storage, processing and network functionalities. The technology has evolved to a large extent such that the DCN is capable of dealing a huge quantum of data being used by people worldwide throughout the day. The DCN also produces enormous heat which requires an additional cooling kit to lessen the radiation. The power consumed by the DCNs is more than 1% of the total power consumption worldwide. This survey includes the objectives and the advantages of various methods proposed to optimize the energy utilization in the DCN. **Methods/Statistical Analysis**: There are several techniques which mainly focused on two main factors: 1. The topology of the DCN; Topology is built by using less number of high capacity routers and servers. 2. Optimized Selection of Routers available in the Topology to handle the traffic. There are technologies which use the resources based on the Service and Traffic Load. The resources which are unemployed are put into sleep mode. **Findings**: In this study, we presented a survey on various techniques and methodologies that are used to reduce the amount of power consumed in the data centers**. Application/Improvement:** This survey provides a wide knowledge about various methods to optimize the power consumption in the DCN. It can be referred by those who desire to explore and do experiments with the power optimization of the DCN.

Keywords: DCN, Dynamic Power Allocation, Energy-Saving, Power Optimization, Recycling Energy, Routing, Topology

1. Introduction

Data Centers accommodate vital resources utilized for different purposes in a well-supervised environment which makes the firms function incessantly or depending on organization's necessity. These processing resources comprise various categories of servers and the operating system necessary to operate them and the network amenities. The utilization scenarios include the transaction and storage of data of organizational and trade sectors. The advantages offered by a Data Center embrace conventional industry-oriented targets such as the aid for trade resiliency, depleting the total price of the process, the ownership, suppleness.

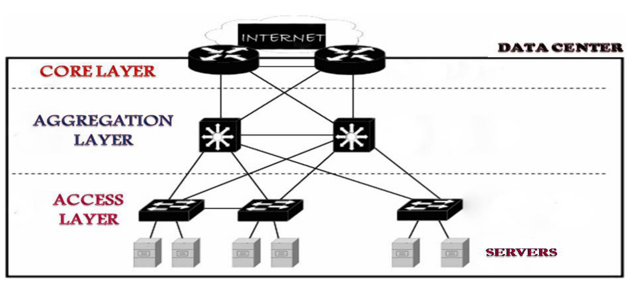

Figure 1. Data center network.

1.1 Structural Design of a Data Center

The Data Center structural design encompasses wide-ranging operational areas. DCN comprises the following three layers as illustrated in Figure 1.

- Access layer: Grants workgroup/user admittance to the system
- Aggregation layer: Offers rules-oriented interconnection of systems and manages the margin between the access and core layers

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- Core layer: Makes availability of swift transmission among the allocation switches within the premise.

1.2 The Access Layer

In a LAN atmosphere, the access layer facilitates the accented grants widgets connect to the network. In the WAN setting, it affords far-off sites, right to use the organization's network across WAN connections.

1.3 The Aggregation Layer

The Aggregation layer combines the data arriving from the access layer switches before diverting the data to the core layer for addressing to the ultimate endpoint. The aggregation level device is the heart of the cabling cabinet. An aggregation layer switch offers upstream provisions for a large number of access layer switches.

The aggregation layer cumulates LAN or WAN connections. It offers replication and distributes the traffic among the nodes. It serves as a separation line involving transmission realms.

1.4 The Core Layer

The core layer is also known as the link vertebrae. It comprises rapid interconnecting components. It is essential for linking the level distribution tools. The core must be ready to use and replicated. The layer sums up the passage of data from all the distribution level elements, making it proficient of transporting bulk records swiftly.

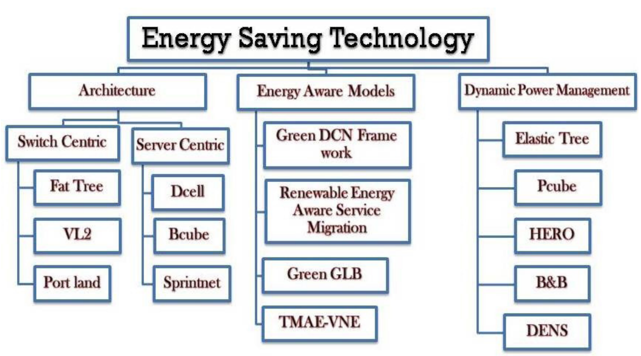

Figure 2. Energy saving technologies.

It offers the fast relay of packets. It is trustworthy and unbiased with the faults. The size of the layer can be changed by utilizing less number of rapid elements. The management of operations which involve the rigorous use of the Central Processing Unit is eliminated.

2. Survey

The routers, bridges, switches are an external component of DCN. The heat emitted by these devices is considered as that of DCN. In most of the papers referred in our survey explicitly or implicitly mention this notion.

The energy saving technologies is divided into several categories as illustrated in Figure 2.

2.1 Switch Centric Architecture

2.1.1 Fat Tree Topology

Fat-Tree Topology[1] consists of units which contain edge and aggregation switches. Each unit is linked to the core switches constructing a graph. The fault tolerance, high-cost switches, and the oversubscription issues are resolved by using the topology. Search of Location is done in two steps:

1. The Ternary Content Addressable Memory (TCAM) is scanned to select the greatest identical prefix.
2. The identical address is employed to situate the Static-Random-Access-Memory having the particulars of Internet Protocol address and the output connection point to reach the recipient.

Topology consumes very moderate quantum of energy which is proportionate to the count of switches as well as load of the traffic.

2.1.2 VL2

VL2[2] is used to provide the agility among the servers. It uses an addressing method that divides the server name (SA) from its location (LA), and the mapping between these two is taken care by a directory-based system. Systems and the interfaces are assigned with LAs, and the applications are addressed by SAs. The packets contain the headers with LA with the end point SA. The servers send an ARP request to the VL2 agent which in turn responds with the position of the node through which the traffic must flow.

2.1.3 Portland

Portland[3] is based on Fat-Tree Topology containing three different layers: Edge, Aggregation, and the Core Layer. It assigns the Pseudo MAC (PMAC) to all the destinations whenever the host is changed. The router cuts off the ARP Request for the mapping of Internet Protocol Address to Medium Access Control Address and routes it to the admin. The admin will reply the actual end host.

2.2 Server Centric Architecture

2.2.1 DCell

DCell[4] is a topology which deals with the fault tolerance, capacity and the scalability issues of the network. It replaces the costly switches with the cheap mini-switches. It can be stretched devoid of the need to provide new wiring. DCell implements a fault-tolerant routing algorithm to prevent the network from various kinds of failures. The energy consumption increases when the count of mini-switches increases.

2.2.2 BCube

BCube[5] is also made of low-cost mini switches connected with multiple servers. The packets can be sent in multiple parallel paths among the servers. It supports all kinds of traffic behaviors and delivers high capacity. It provides fault tolerance with the lower manufacturing and cooling costs. The routing algorithm in the BCube consumes the high multipath capacity and automatically provides the load balancing. It eliminates the regular updates about the state information of the nodes. The power consumption increases if the number of servers increases.

2.2.3 Sprintnet

Sprintnet[6] is a new powerful server oriented design. The Naive Routing method is used to figure the minimum length route for all the senders to the receiver. The routes are saved in the routing table. Then, the Traffic Adaptive Routing (TAR) was customized and used. TAR mainly helps in avoiding packet jamming and accomplishing traffic optimization. Forwarding Unit is a peripherally oriented technique that separates the server from the set of connections and functions as the bridge. Sprint Net has the minimum width, maximum cross bandwidth, good resistance from failing and high cumulative hold-up efficiency. Forwarding Unit transfer the forwarding tasks from the servers to the networks. This leads to logically flat DCN. The average packet loss is decreased only if the count of forwarding switches is increased. So, the cost of switches may increase.

2.3 Energy Aware Models

2.3.1 Green DCN Framework

Green DCN[7] is the framework that combines the topology design based on the traffic rate and the algorithm for a routing decision to lessen the energy consumption. The multi-tier topology is chosen to afford the scalability. The framework is divided in to 3 phases.

1. Map Reduce is used to form the regular pattern of communication with the intention of reducing or eradicating the data loss scenarios and to cut short the expenses of network by considering the QoS parameters.
2. The incoming jobs are partitioned and assigned to separate Virtual Machines (VM).
3. Energy Efficient Routing (EER) Algorithm randomly assigns the required number of active switches. Multi-Path Transfer Control Protocol (MPTCP) is used to route the data.

The power utilization is reduced to 50%. On the downside, EER algorithm is not efficient to deal with the online data.

2.3.2 Renewable Energy Aware Service Migration

Renewable Energy Aware Service Migration[8] replaced one-third of fossil energy usage by recyclable source. Live Migration of Web Services is carried out using WAN. The information about the available Renewable Energy Sources (RES) is periodically maintained. First, a connection is formed connecting the sender and the receiver. The transmission period depends on the diskette dimension of the Virtual Machine. Two types of traffic are formed:

1. The traffic between the end user and the switch
2. The passage of data caused due to live relocation over the various DCN premises.

The DCN is provided with the additional cooling components. The framework is devised to produce the green energy after consumption of brown energy resources. The following traffic rate is also predicted which helps to select the next available energy resource. The model reduces the quantity of brown energy consumption and the emission of carbon from the Data Center Network. The power utilized by the data movement operation remains unchanged. The frequency of data transmission should also be compressed to most favourable level.

2.3.3 Green Geographical Load Balancing

Green Geographical Load Balancing (GLB)[9] optimizes the cost of energy consumed in the DCN. Three algorithms compute the best routing path for migration of the request to available renewable resource needed for the operations of DCN. However, the algorithms ignore some of the basic QoS factors of the DCN–availability and reliability. Switch costs involved during the operation of DCN is neglected. The algorithm devised for load balancing is efficient, and it is used to calculate the routing tables locating the source of renewable energy resources.

2.3.4 TMAE-VNE

Topology and Migration-Aware Energy Efficient Virtual Network Embedding (TMAE-VNE)[10] Algorithm curtails the power utilization considering the operation and origination. In the algorithm, they check the sets of Data Centers with sufficient ready-to-use components to determine the optical infusion in Data Center granularity. The acceptance ratio is directly proportional to the count of Data Centres. The hierarchical fat tree architecture optimizes the network resource usage. TMAE-VNE saves 40% of energy resource usage compared to MAE-VNE. The resources and links are put in snooze state if not needed. But, the usage of bandwidth is not efficient. Robustness of the links is not provided.

2.4 Dynamic Power Management

2.4.1 Elastic Tree

ElasticTree[11] topology contains optimizer which administers the traffic flow in the Data Center Network. It selects the random amount of active elements and switches off the remaining elements. Elastic Tree shortens the count of links and switches power needed to meet the demand and flow conservation limitations. The savings of energy is about 25-30% *in the Data Center Networks.*

2.4.2 PCube

Pcube[12] topology is depicted employing the essential quantity of switches and the count of ports contained by every plane. It turns off the links depending on the behavior of the traffic. The count of active links is directly proportional to the traffic rate. The dedicated monitor gets the request from the servers and decides the topology structure. The topology is broadcasted to all the servers. The Pcube can reduce the energy consumption up to 50%.

2.4.3 HERO

Hierarchical Energy Optimization (HERO)[13] is an optimized method for reducing the power utilization of the DCN. DCN is divided into 2 stages: Core Level and Pod Level. Core Level Optimization determines the core switches which are required to be active and serve the outgoing pod level traffic. Pod Level Optimization states the aggregation switches count headed to deal with the intra pods traffic. Capacity Constraint Multi-Commodity Flow Optimization (CMCF) predicament is devised in favour of a given traffic flow for each level to switch off the links and switches based on the demands. More energy is conserved while the additional amount of links/switches is powered off.

2.4.4 Buffer and Burst

Buffer and Burst (B&B)[14] is a technique used to switch off the power links and the routers if all the links are off. Frequent transitions issue which is caused by small packets are stated, and a solution was formulated. The routers group the packets that have the same endpoint address and then forward them. As a result, the routers can sleep for more time and consumes very less energy compared to other methods.

2.4.5 DENS

Energy Aware Scheduling Data Center Energy-efficient Network Aware Scheduling (DENS)[15] manages the power utilization of a DCN with demands of traffic. The feedback channels between the network channels for the aggregated workload distribution changes to neglect the congestions within the network. Congestion notification signal from the overloaded switches prevent the occurrence of congestion and sustain the over use of the Data Center Network. The count of servers raises based on the necessity. The overloaded switches are avoided using a metric combing the operations at different layers.

2.5 Virtual Infrastructure

Energy Efficient in Virtual Infrastructure[16] focused on application virtualization and desktop virtualization in cloud setting. The virtual desktop is activated based on the load in the network. Server optimization is done using the same technique. The intelligent management suggests the least possible power consumption and lessen the carbon tracks in cloud computing.

The results of these techniques are summarized in Figure 3.

Name of the Technique	Approach	Methods	Results
Fat Tree Topology	Architecture	Shape of the Topology	Moderate energy consumption. Values lies between the Dcell and the Bcube
VL2	Architecture	Mapping of Address	High energy Efficiency
Portland	Virtualization	Agile	Agility is achieved. Migration of services is smooth
DCell	Architecture	Hybrid (Switch +Server)	Low Energy Efficient
BCube	Architecture	Hybrid	Low Energy Efficient
Green DCN Framework	Energy Aware Model	Virtualization + Routing Scheme	50% of energy saved
TMAE – VNE	Energy Aware Model	Algorithm	40% of energy savings
Elastic Tree	DPM	Shape of the Topology	25-30% of energy saved
Pcube	DPM	Topology Monitor	50% of energy saved

Figure 3. Energy saving technologies: A summary.

3. Challenges

Based on the survey, the power saving technologies involves the temporary deactivation of the devices, choosing the shortest paths among the devices in the network for data transmission. The power usage efficiency should be increased. The intelligent management system[17] should be proposed to improve the real time green DCN.

3.1 Traffic Forecast

The forecast of upcoming traffic in a network precisely is critical to avoid SLA infringement during the reduction of energy. While dynamic server allocation, it is important to switch on the required servers before the raise of the load is hard when the load is not exactly determined. The performance of the dynamic allocation methods would be efficient if the peak-usage time is predicted to make the elements be put in the snooze mode in advance'. If the traffic is varied increasingly, the prediction gets tough.

3.2 Scalability

The efficient energy-saving method should be supple with regards to the network range to ensure the runtime functions which is the critical act, which is crucial in satisfying the requisites of Service Level Terms, particularly in the response period. The transaction among the energy saver and the complexity of the methods should be balanced.

3.3 Organization of Multi-layer Energy

The multi-layer products have been emerging in the recent times as the Internet has become more diverse. The co-ordination of servers at multiple tiers of DCN becomes more demanding.

3.4 Power Relative Servers

Modern servers guzzle more than 50% of their ultimate energy at snooze mode. Hence, in present electricity - saving techniques, devices are required to be put into snooze mode to accomplish better energy-saving servers need to be put to sleep to achieve the best power-saving outcome. This kind of process consumes various kinds of costs. The future servers must be intended with better power proportion based on the present operation-based tendency of hardware design.

4. Conclusion

This study provides the information about various topologies, algorithms, architectures, routing methods, dynamic power systems and the use of renewable energy resources which is widely utilized in DCN. The technology could be improved to facilitate the reduction of the electricity utilized by the components or recycling the heat emitted from the center into electricity or for other use.

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