Green Data Center Architecture: An Opportunity and Responsibility

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Abstract

Current data center trends show that they do not adopt green measures in their architecture thus deteriorating the environment. Green Information Technology aims at designing an efficient and effective design of hardware and architectures with no or minimal impact on environment. It is also used to promote various enterprise wide environmental initiatives. The implementation of new measures that will take into consideration the green concept is the need of the hour. A solution to this can be of developing a new data center architecture that will apply this green concept in terms of space, power and performance. Small and medium industries can make use of these parameters to create and expand into large scale industries in an optimal way without affecting performance and environmental factors.

Keywords: Green IT Concept, Data Center, Tessellations, Greedy Routing Algorithm

INTRODUCTION

A data center is an infrastructure used by organizations for data storage, management, and sharing. These data centers use lot of energy, covers lot of land and they even require a lot of cooling systems as they work only in air conditioned environments. Data centers work daily and continuously emit a lot of greenhouse gases affecting the environment at a very large extent. Data centers, beside their ongoing high energy consumption, also produce carbon dioxide that riddles with Information Technology inefficiencies. Green Information Technology suggests that if Information Technology can give feasible and economic solutions to various day to day problems then in case of never ending expansions of data centers it is not just a problem creator but a savior of environment. Data center design is a very important process specially in case of small scale industries. If Data centers are designed considering future needs and scalability they can be more cost effective in long run though they are following green parameters.

The purpose of this paper is to compare the current topologies that are used in the data center to the topologies that must be used to help the data centers evolve as green data centers in terms of space, power and performance.

This paper is organized as follows. First, we will be discussing about how space is to be considered in designing green data center architecture in section II. Then we will discuss performance of the green data center architecture against non-green data center architecture in section III. In section IV, we will discuss how power is to be considered while going for a data center architecture contributing for green concept. Finally, we conclude the paper in section V.

SPACE

Space is one of the important parameters to be considered while designing a small data center that in long run would be easily scalable into a large data center. Space in Information Technology of data center is thought in number of servers, switches and routers that are required for data center and also the topology that is being used to connect all these servers in the data centers such that the data center is functioning appropriately. Another important aspect in space to consider is the network diameter of the data center architecture. Low diameter of data center architecture is the need for implementing green data center concept and thus resulting in Green Information Technology.

Many data centers from small scale to large scale use variety of topologies for constructing the architecture of

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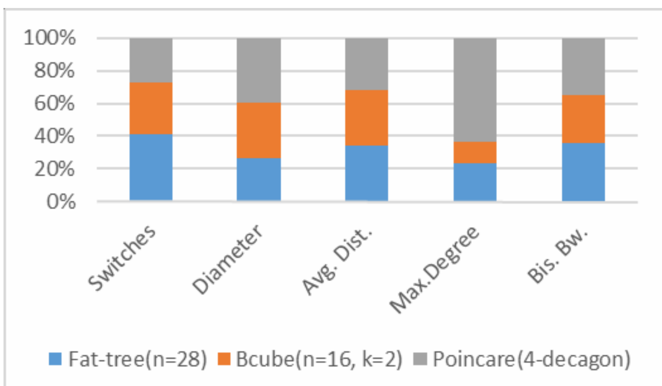
their respective data centers such as BCube[1], Dcell[2], Clos Network[3], Basic tree[4] and Fat tree[5], [6], [7]. All these architectures do consider the space factor to some extent but not fully, thus not contributing to Green Information Technology successfully. There is one algorithm called hyperbolic tessellations [8] which is implemented in an architecture called Poincare [8] and it considers space parameter and contributes to Green Information Technology. Table I shows the comparison of different topologies, here n is the n-port switch and k is the number of levels. As seen, Poincare topology when compared with other data center topologies such as Fat-Tree and BCube gives better results in terms of space, thus contributing to Green Information Technology. Thus instead of using Fat-tree and BCube architectures for the data center we can adopt Poincare architecture for the data centers as this architecture greatly takes into account the green factors that are defined in terms of space thus helping in evolution of green data centers.

Table I Comparison of Different Topologies



PERFORMANCE

A great performance equals an efficient data center functioning which in turn makes it more environment friendly. As data centers are growing, the need of using algorithms to make them more optimized is being realized. This section presents the overview of greedy routing algorithm, its straightforward extensions and its effects on performance of a data center. Greedy routing algorithm uses the information about the distances between link neighbor nodes and sends the data to the immediate node. The algorithm fails if the distance between a node and its immediate neighbor is more than the distance between it and its destination. BCube, a data center architecture uses a different type of greedy routing called single path routing algorithm. This approach is also not free from this phenomenon. The use of hyperbolic tessellation structure can provide a solution or can at least lessen its probability of occurrence. It is possible since the next hop using shortest path is the same as using greedy path in this structure. The extensions of greedy routing, multicast and multipath, bring into play various other requirements of data center routing such as error tolerance, TCP, map reduce support and VM migration. In multicast, a common path if available to reach two destinations is used instead of two different paths as shown in Fig.1. Thus it saves link capacity as opposed to xcast[9]. This also makes the upgradation process hassle free as old device coordinates are used to make new connection. The outcome is a smooth replacement of switches and devices.

Multipath makes use of the path diversity of hyperbolic tessellation structure. The path or link with the least traffic is selected for transferring packets to the destination. Hence the transferring process is completed in a short haul of time.

Greedy routing algorithm can also handle link failures with ease. Let us consider a situation in which a link failure occurs between two switches. The first switch recognizes the failure and computes the next hop. Hence time is required only for failure detection and hopping to the failed node is avoided. The success ratio of greedy routing for 50000 source destination pairs is plotted as shown in Fig. 2.

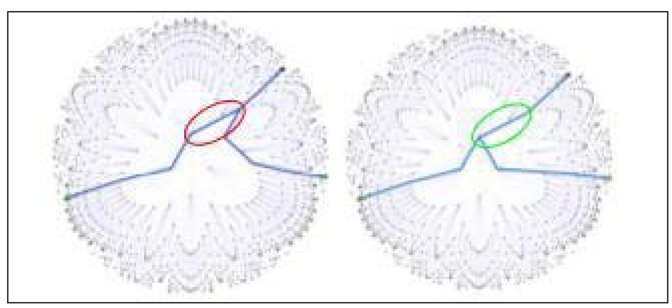


Figure 1 Xcast Algorithm and Greedy Multicast Algorithm Respectively [8]

The comparison of throughput of fat tree and Poincare is shown in the table. A flow level traffic simulator is used for the comparison. The number of switch ports is related to the experienced aggregate throughput. The use of high capacity links can further magnify the working of the system.

TABLE II Throughput (Mbps) Comparison of 4000-server fat-tree and Poincare DCs with Different Topology Parameters. [8]

Topology	*Switches*	*Server ports*	*Runtime*
Poincare economic	640	13510	1334.67
Fat tree(n=28)	980	4000	680.5
Poincare high throughput	640	13510	573.17
Fat tree(n=32)	1280	4000	680.17

Forwarding burden in Poincare is very less as compared to the server based routing of fat tree, requiring no extra resources. Server nodes also play an active role to ensure that the system is connected and guaranteed.

Load balancing is achieved as Poincare supports path diversity. As the load on a path increases, several paths can be generated as needed to be used for transferring the load. The table shows the comparison of multipath [10] throughput capability of fat tree and Poincare.

TABLE III Comparison of Multipath throughput Capability of 4000 Server fat-tree and Poincare Systems (Mbps) [8]

Topology	*Average MP Throughput*	*Variance*	*Min.*	*Max.*
Poincare	1527.41	406.43	1000	2898.55
Fat-tree	1000	0	1000	1000

POWER

With the rapid increase in the capacity and size of data centers, there is a continuous increase in the demand of energy consumption. Reducing emissions of carbon dioxide (CO2) in data centers represents an open challenge, driving the future research work for green data centers power management group. Information Technology load consumes very less amount of overall energy consumption as compared to constant cooling and other electrical facilities. Some easily upgradable architectures focus on this power consumption issue as well as to make it more sustainable and green.

Power consumption due to Information Technology equipment in a data center can be measured in terms of Information Technology hardware used, time consumed for processing and Information Technology waste generated at the time of expansion or reconstitution of a part of data center. An architecture is said to be feasible and optimized if following parameters give good results [11]:

1. Degree of the servers: Average number of network ports in the servers of the data center depends on diameter which is the longest of the shortest paths between two servers in a data center. A smaller diameter leads to more effective routing, and lower transmission latency in practice. For most topologies, the diameter grows logarithmically with the number of servers.
2. Number of switches: Larger amount of switches lead to more cost and hence more power consumption. With the complexity of network, the number of switches increases. Most of the architectures use the same kind of switches.
3. Number of wires: This parameter shows number of wires required for deploying a data center. Cost of cabling can be minimized with proper study of future requirements and network demands. Type of wire varies from layer to layer as bandwidth requirements are different which is also a cost deciding factor.
4. Number of servers: This parameter shows scalability of an architecture. More the number of servers more scalable is the network.

A feasible architecture choice can lead to an efficient and effective design, manufacture, use and disposal of computer hardware, software and communication systems with no or minimal impact on the environment. Due to the hyperbolic tessellations the degree of servers, number of switches, cabling cost and number of servers is reduced. Information Technology contributes to greenhouse gas emissions but it can provide a better way to manage hardware and waste generated in reconfiguration and reconstruction of data centers.

CONCLUSION

In this paper, we discussed why data centers should adopt green methodologies so that they help in the reduction of greenhouse gases and thus protect our environment. While implementing these green methods for designing the data center architecture we also take into consideration its efficiency such that it is the same even after adopting green methods. We measure the efficiency by taking into account the following three parameters space, performance and power. Space parameter uses hyperbolic tessellation concept and helps in preserving space as it was before adopting to this new green data center architecture. Performance parameter is enhanced by using greedy routing which in turn improves availability, fault tolerance, throughput, forwarding burden and load balancing. Power parameter is concerned with degree and number of servers, number of wires and number of switches. In this way, we help in making the data centers green without compromising its efficiency.

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REFERENCES

Guo, C., Lu, G., Li, D., Wu, H., Zhang, X., Y. Shi, C. Tian, Zhang, Y., & Lu, S. (2009). Bcube: A high performance, server- centric network architecture for modular data centers. *ACM SIGCOMM Computer Communication Review,* 39(4), 63-74,

Guo, C., Wu, H., Tan, K., Shi, L., Zhang, Y., & Lu, S. (2008). DCell: A scalable and fault-tolerant network structure for data centers. *ACM SIGCOMM Computer Communication Review,* 38. 75-86.

Greenberg, A., Hamilton, J. R., Jain, N., Kandula, S., Kim, C., Lahiri, P., Maltz, D. A., Patel, P., & Sengupta, S. (2009). Vl2: A scalable and flexible data center network," SIGCOMM Comput. *Commun. Rev.*, 39(4), 51-62.

Al-Fares, M., Loukissas, A., & Vahdat, A. (2008). A scalable, commodity data center network architecture," in Proceedings of the ACM SIGCOMM 2008 conference on Data communication. ACM, 63-74.

Niranjan, R., Mysore, A., Pamboris, N., Farrington, N. Huang, Miri, P., Radhakrishnan, S., Subramanya, V., & Vahdat, A. (2009). Portland: A scalable fault-tolerant layer 2 data center network fabric. *ACM SIGCOMM Computer Communication Review*, 39(4), 39-50.

Al-Fares, M., Radhakrishnan, S., Raghavan, B., Huang, N., & Vahdat, A. (2010). Hedera: Dynamic flow scheduling for data center networks. *In Pro-ceedings of the 7th USENIX* conference on Networked systems design and implementation. USENIX Association, p. 19.

Csernai, M., Gulyás, A., ő rösi, A. K., & Sonkoly, B. (2012). Poincare- A hyperbolic data center architecture," 32nd International Conference on Distributed Computing Systems Workshops in 2012.

Imai, Y., Feldman, N., Boivie, R., Livens, W., & Ooms, D. (2007). Explicit multicast (xcast) concepts and options, RFC 5058 IETF. Retrieved from https://tools.ietf.org/html/rfc5058

Raiciu, C., Barre, S., Pluntke, C., Greenhalgh, A., Wischik, D., & Handley, M. (2011). *Improving datacenter performance and robustness with multipath TCP.* ACM SIGCOMM, 11.

Yao, F., Wu, J., Venkataramani, G., & Subramaniam, S. (2014). A Comparative Analysis of Data Center Network. *In IEEE ICC- Next-Generation Networking Symposium.*