Wireless techniques/approaches in Data Centers

Abstract

Data centers are the facilities which stores and distribute the data on the internet. Data centers has lots of data stored in it. Almost two billion users access the websites in the world and the data exchange rate is unbelievably high nowadays, it's so much important for the data centers to take care about the cabling mechanism inside it because the efficiency of a data center relies on it so much.

Generally a data center network consists of copper and optical fiber cables are used for intra- and inter-rack connections in the network. But in this case wired data center network can face two inevitable problems; cabling complexity and hotspots. Wireless technologies are proposed as a solution for this problem as it has the capability and flexibility to offer efficient and comparably easy results. In this report there's a deep investigation on wireless technologies in data centers and how it can enhance the performance of the data center network and pros and cons of using the above technic.

Recent advancements in the unlicensed 60 GHz spectrum have given rise to transceivers that can support high bandwidth links, comparable to wired links found in most data centers. These wireless links also exhibit promising characteristics such as spatial reusability which make them suitable within a data center environment. By taking advantage of emerging 60 GHz wireless technologies, data centers can utilize these high speed wireless links to satisfy bandwidth demands while simultaneously reducing their power consumption and cabling requirements.

Table of Content

List of Figures

List of Tables

Glossary

ToR: Top of Rack

DNC: Data Center Network

CHAPTER I

1.1) INTRODUCTION

Data centers are the facilities which provides the data storing and distributing mechanisms, on the internet. In another way it's a huge group of networked computer servers which are used by organizations (i.e. Google, Microsoft, and NSA) for the remote storage, processing, or distribution of large amounts of data.

There are about 100 billion web pages on over 100 million websites where it's very much clear the amount of data contain in a data center. Almost two billions users access these websites, which gives an indication on how efficient the data centers should be to server that kind of traffic. The main functions of a data center are to centralize and consolidate information technology (IT) resources, house network operations, facilitate e-business and to provide uninterrupted service to mission-critical data processing operations.Data is usually stored on big fast hard drives and data centers are filled with tall racks filled with electronics like these hard drives connected by cables. Likewise all the computers, routers, switches are connected by cables with each other.

According to a research done by the Natural Resources Defense Council (NRDC) in 2013, data centers consumed 91 billion kWh of energy, and are expected to consume 140 billion kWh by 2020. As the number of servers increase day by day the interconnecting mechanism becomes so much important. Generally the data center network is organized in tree based topologies using wired links. Mostly copper and optical fibers. These requires huge amount of power, also cooling mechanisms. Then these things can cause problems within the data centers like inefficient cooling can cause complexities in networking and cabling.

As the speed of data center is a primary concern wireless data center is a good way to the above mentioned problems. Because wireless data centers can be faster, cheaper and greener. But not only the speed it can increase, it's been found that using wireless technique can reduce power consumption, heat generation as well.

CHAPTER 2

Background and related Work

2.1) Data Center Network Challenge

Several problems can cause inefficiency in data centers. But in here 3 main problems will be discussed. Power consumption, cabling complexities and traffic congestion observed in multiple layers of aggregation.

2.1.1) Power Consumption

Power consumption is one of the main concern in data centers. The table below proves the amount of electricity it uses. Statistics of electricity usage in United States and worldwide us shown in the table 1.

Location	Year	Communication Infrastructure Electricity Usage (billion KWh)	Total Data Center Electricity Usage (billion KWh)	Total Data Center Electricity Usage (% of total worldwide electricity usage)
Worldwide	2000	3.8	70.8	0.53%
US	2000	1.4	28.2	0.82%
Worldwide	2005	7.3	152.5	0.97%
US	2005	2.7	56	1.53%
Worldwide	2010	15.6	271.8	1.50%
US	2010	4.9	85.6	2.20%

Table 1: Electricity usage by data centers

These numbers are expected to increase in future. Cooling equipment's consume majority of power inside a data center made people to more concern about the power consumption of data centers. Efficient energy saving method are arising with this problem where energy consumption is still a major concern. But without these improvement data centers in United States may consume more 40 billion

KWh than the power consumed in 2010. According to a research done by US Department of Energy in collaboration with researchers from Stanford University, Northwestern University, and Carnegie Mellon University emphasizes that energy efficiency improvements will have saved 620 billion kWh between 2010 and 2020, the study forecasts.

2.1.2) Cabling Complexity

Inefficient cooling can be a result of cabling complexities. Well structured cabling mechanism will have less effect on the heat generation inside the data centers but still these cables cause a airflow blockage which ultimately result In inefficient cooling which leads again to the above problem of energy consumption. Complexity of cables is shown in below (Figure 1)

Figure 1: Data Center Cabling

These cable can cost a high maintenance cost and has to be cooled down continuously as the air flow through the wires are limited. It remains as a major concern in the data centers.

2.1.3) Traffic Congestion

Other than power consumption and cabling complexities one of the major issue is congestion in traffic as links become aggregated. It's been found that 70% of the data center traffic will circulate within the data center. There are hundreds and thousands of servers inside a data center which makes it almost impossible and costly to provide full link bandwidth from all servers to every other server. Due to this issue tree based topologies immerged where links aggregated to a switch and then further aggregated according to the user requirements using some additional switches. FatTree and ThreeTier are two popular topologies used. Diagram of them are shown below .

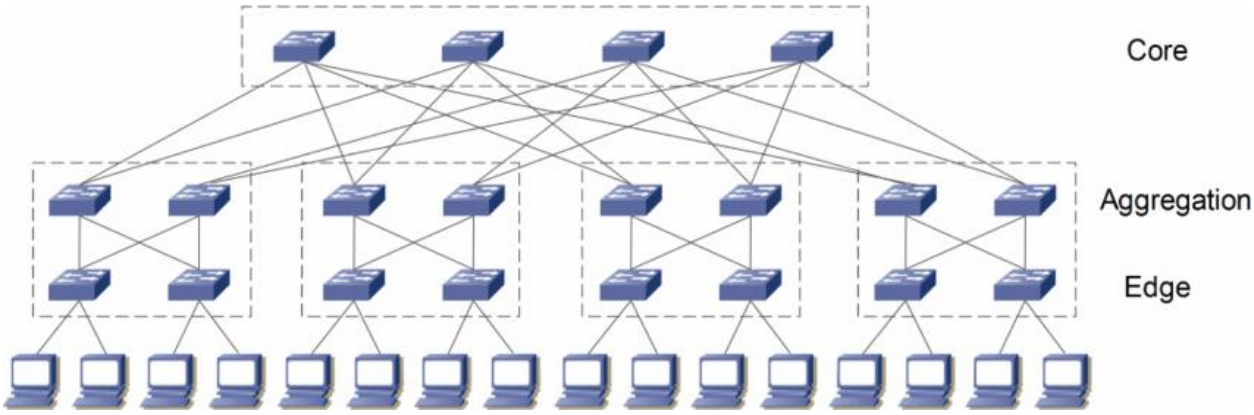

Figure 2: Simple 3 level Fat Tree topology

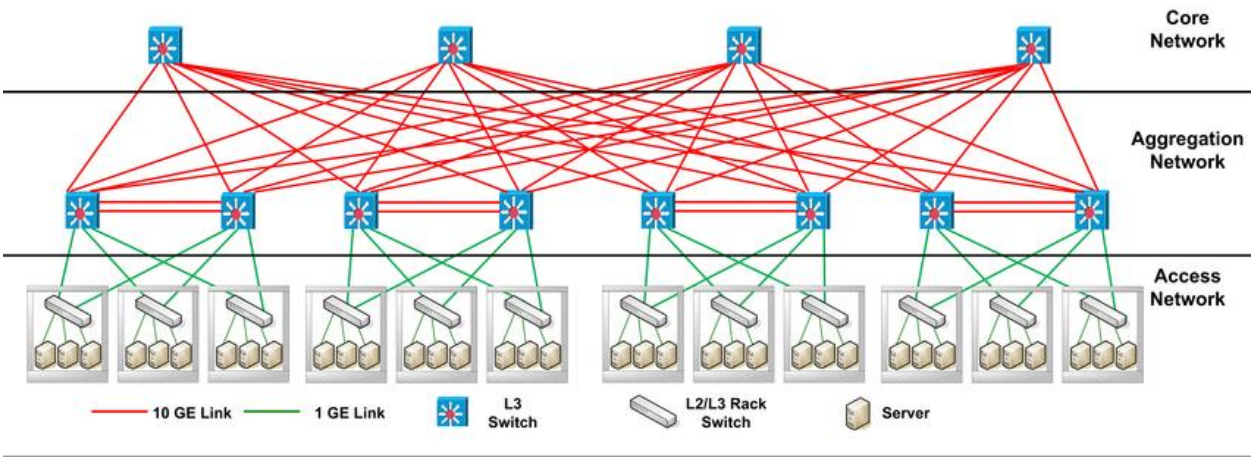

Figure 3: Three Tier Architecture

2.2) Related Work

This sections talks about how the Wireless DNC can improve a data center performance and efficiency. This sections begins with a short description about data centers and it shows how wireless DCN mechanism can improve the result of a data center and how and why it suits the current state of a data center.

2.2.1) Data Center Network

Data center networking architectures has categorized into four groups.

1. Electronic switching technologies,
2. All optical switching,
3. Hybrid optical and electronic switching,
4. Wireless data center technologies

All these four categories try to improve the issue talked about in section 2.1. The table below shows the different network architectures and its performance.

Name	Networking architecture	Switching granularity	Scalability	Energy Consumption
Fat-Tree	Electronic	Fine	Low	High
BCube	Electronic	Fine	Low	High
DCell	Electronic	Fine	Low	High
VL2	Electronic	Fine	Low	High
Schemes in [9]	Wireless	Fine	Low	High
Schemes in [15]	Wireless	Fine	Low	High
HyPaC	Hybrid	Medium	Medium	Medium
Helios	Hybrid	Medium	Medium	Medium
DOS	Optical	Coarse	High	Low
Scheme in [16]	Optical	Coarse	High	Low

Table 2: Comparison of DCN architecture

As it's shown in the table 2 electronic architecture has low scalability and high power consumption as it mainly relies on copper cables, twister pairs. Hybrid architecture consists of both copper cables and fiber optics. In the other hand fiber network architecture provides the best performance here providing high scalability and low power consumption.

2.2.2 Wireless Data Centers

There are several proposed methods for wireless data centers. They will be discussed here one by one.

The wireless technologies which are suggested to implement inside data centers are classified into two groups. One is to augmenting existing wired networks to provide supplemental bandwidth to alleviate highly congested "hot-spots". This method have proposed interconnecting entire racks of servers at the top of rack level with wireless links between the tops of towers. Second method is to replace all the wires with wireless links. So it's be a fully wireless data center. Both of these methods use the benefits of 60 GHz wireless frequency band to realize high bandwidth wireless links. Wireless frequency at 60GHz can provide high speed data transmission over a distance around 10 meters. Highly directional antennas can be used to set the data flow directions in this scenario. But the line of sight is an issue because of a data center has so many devices which act as obstacles.

Another approach for wireless data centers is known as "3D beamforming" which was invented by scientist of University of California, Santa Barbara. Main point that they emphasize is that, the data center traffic may get tied up at some moments, due to congestion associated with short bursts of activity. In these scenarios usual action will be to keep the maximum bandwidth to handle those situations. So in other scenarios the bandwidth will be in an idle state. So the scientist suggest to send those bursts of traffic directly between the servers which need the information ultimately results in avoiding competition with other servers and applications and to do so at top speeds. ^0GHz beams will be transmitted in this scenario too. These wireless links can be turned off easily, so it can save the bandwidth. But has to make sure that the connections can be stopped and restarted when needed.

According to "Heather (Haitao) Zheng", one of the scientist who works on this technology, the design created bounces data over server racks, off metal plates on the ceiling, to specially designed antennas on each server. Scientists are working on creating protocols for the above mechanism at the moment.

Cornell computer scientists have proposed an innovative wireless design that could greatly reduce the cost and power consumption of massive cloud computing data centers, while improving performance.

This design (named Ceyley data center) uses the newly invented 60 gigahertz (GHz) wireless transceiver developed at Georgia Tech based on inexpensive CMOS chip technology. The transceiver capable of transmitting in a narrow cone, and 60 GHz radiation is quickly attenuated by the air and it can reach about up to 10 meters. So without interfering with other devices nearby, devices can do short range communication.

Servers are mounted vertically in cylindrical racks. There will be two 60 GHz transceivers inside end of the server and outside end of the server. See the figure 4 below.

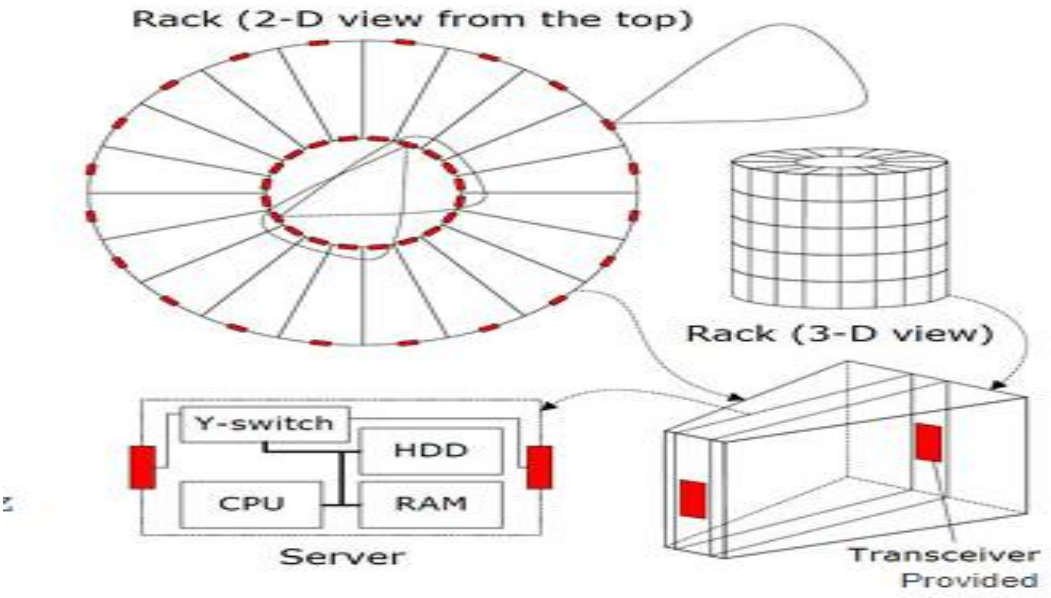

Figure 4: Servers in a Cayley Data Center would be mounted in cylindrical racks. Each sever could send 60 GHz wireless signals to nearby racks or to other servers in the same rack

Racks are mounted in rows. So each rack has line of sight wireless connectivity to eight other racks (except at the edges). Transceivers at the inner ends connect servers within the rack. Servers has their own routing depending on the physical location of the destination. So servers do not depend on switches. Signals will be

passed from rack to rack in a shortest path as possible. This design is more resistant to failure because a research on a model showed even if a single rack died signal went around it.

Cost of the above design cannot calculated this much early because the 60GHz transceivers are not commercially available yet and the design has lot more to improve.

Chapter 3

Wireless Data Center Network Design

3.1) Architecture

This section discuss about the topologies, the antenna and how the 60GHz technology is used, how the racks connect with each other in details.

3.11) Topology

Racks are connected with each other using 60 GHz links. Any two racks can communicate using 60GHz wireless transceivers. Serves within a rack are connected using cables to ToR network switches which are augmented with a ToR wireless module. This wireless module contains a transceiver and an antenna which can communicate with the other ToR wireless modules installed in the other racks. Wireless transceiver and the antenna is mounted at the top of the rack. Every ToR module has an identification mechanism like having an ID with its physical location. Figure 5 shows a diagram of how the devices are installed in a data center.

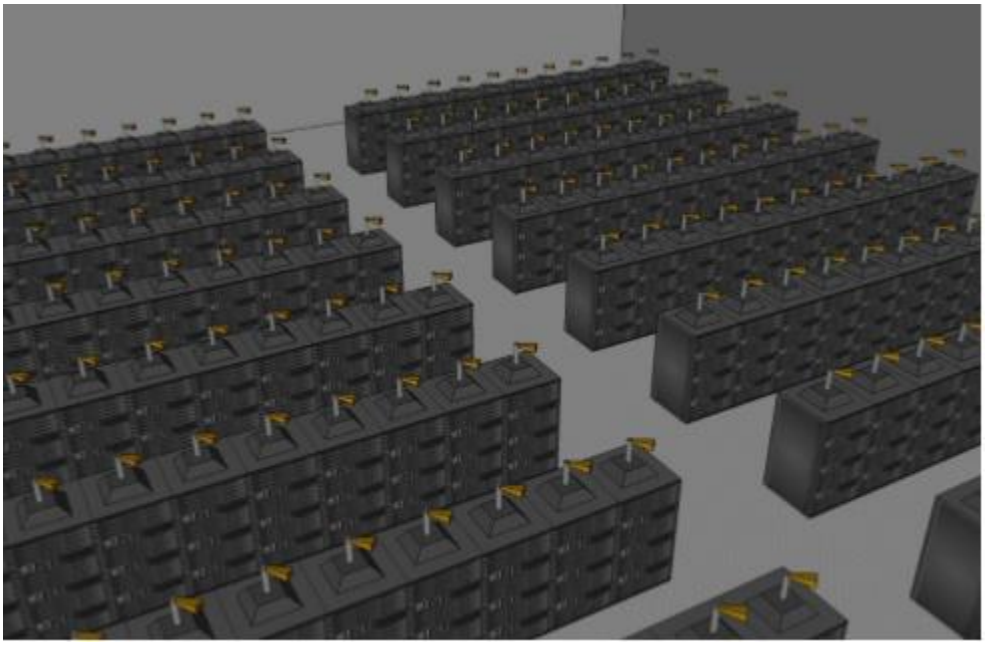

Figure 5: Data Center Arrangement

3.1.2) Antenna Technology

Antenna is mounted inside racks to direct (line of sight) the wireless module. This antenna is chosen in a way that it can direct the wireless module to connect with the most distant rack in the data center in a fastest way. Horn antennas are chosen due to its capability of achieving the above target.

3.1.3) Establishment of Wireless Links

Any rack can connect to another rack but it's not fully connected. Whenever a wireless module wants to connect to another wireless module it can connect using a channel but using the same channel a wireless module can't connect to multiple wireless modules at once. But there are methods to connect with multiple wireless modules but there can be interference between connections which can cause erroneous results. SO the link selection should be scheduled according to the demand.

A simple greedy algorithm can be used to decide the above problem.

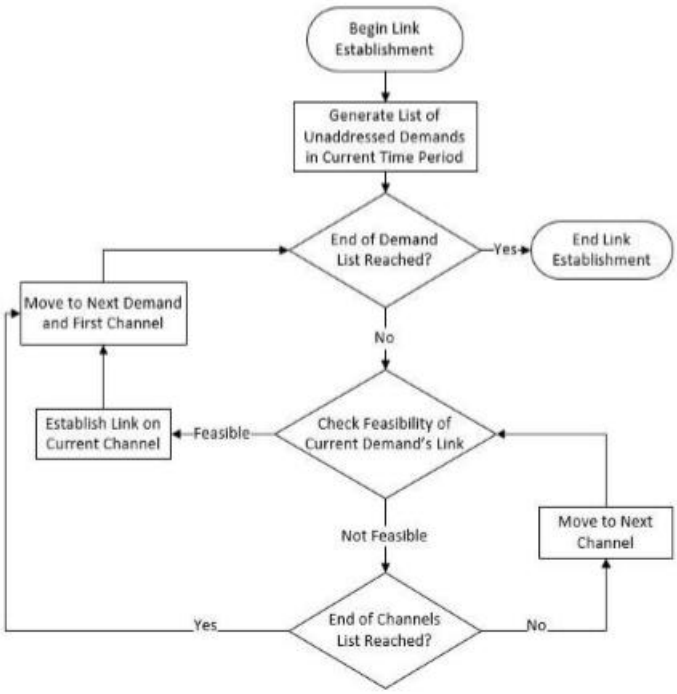

Figure 6: Greedy Algorithm

Chapter 4

Conclusion

Present days it's clearly seen that data centers are having many issues with power consumption, cost, and some other issues. When compared the past records of what was going on with data centers it seems to be moving to wireless data centers can give lots of benefits to the data center management in many ways. It can be seen that the technology is coming up to achieve the present issues with the data centers where the engineers started to build and test wireless data centers. However this technology is still in a situation which has lots of challenges. But with the 60GHz DCN shows a promising future.

Chapter 5

Reference

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