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A Hybrid Electrical and Optical Networking Topology of Data Center for Big Data Network

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***Abstract*— Now-a-days data centers are experiencing rapid increase in network traffic and the number of servers in racks due to exponential increase of data, at the same time they have to cope with the demands of cloud computing and several emerging web applications. Keeping all these in mind we also have to consider compatibility when we will interconnect several data centers. Present data centers network based on electrical packet switching consumes much power and has bottleneck issues. Several researches in optical fiber have made it possible to use optical circuit switch in data centers which provides promising solution offering high bandwidth, low latency, incredibly less power consumption. In this paper we present a possible bottom to top electrical and optical packet switch architecture of data centers and interconnectivity solution between them. Furthermore we propose two networks interconnects: an optical circuit switch (OCS) handling long-lived bulk data transfer using optical network and a secondary lower bandwidth electronic packet switch (EPS) network for handling short data transfer.**

Keywords*— *Big Data, Data Center Network, Electronic Packet Switch, Optical Circuit Switch.

I. INTRODUCTION

Over the last few years data center networking topology has improved significantly. Due to the commercial development of high speed switching device and multilayer architecture of data center, now we have more powerful data center with low latency, scalability and higher bandwidth. But due to the exponential increase of internet traffic and emerging web application, still data centers performance is not up to the mark to meet the requirement. Numerous applications that are running in servers are data sensitive require low latency communication among each other and also fulfill the bandwidth requirement [1]. At the same time we are consider system compatibility while interconnecting data centers. In interconnected data centers we might require long-lived bulk data transfer which sometimes not possible with traditional Ethernet (10 Gbps) electronic packet switch link between servers and access switch/top of the rack (ToR) switch. However, using electronic packet switch network it has to sustain the increased network traffic, while maintaining communication with servers as well other data centers. Furthermore, as more and more processing core are increasing into single communication chip also servers are increasing in rows due to rapid increase of data, depending on electronic packet switch between server to access/ (ToR) switch is inefficient and also increase power consumption. In order to face this increasing bandwidth demand and power requirement in the data centers, new connection scheme must be developed that can provide high throughput, low latency and less power consumption. Therefore the optimal solution would be using optical fiber link between sever to access switch/ (ToR) switch. [2]

Figure 1 shows a block diagram of a typical data center with four layers hierarchical network architecture from bottom to top, the first layer is the servers which are connected to upper access layer switch. In this second layer, access switch where many servers are connected which sometimes called ToR switch. The third layer is aggregation layer which are connected bottom access layer switch. Forth or highest layer is core layer where core switches are connected with router at top and aggregation layer at bottom form a data center block. When a request is generated by a user the request is forwarded through the internet to the top layer of the data center. The core switch devices are used to route the ingress traffic to the appropriate server. A request may require the communication with other servers such as a web request may require communication between application and database servers [3]. The main advantage of architecture is that it can be scaled easily and has a good fault tolerance and quick failover. However, the main drawback of this architecture is high power consumption due to the several layer architecture switches and latency introduce due to multiple store-and-forwarding processing [4].

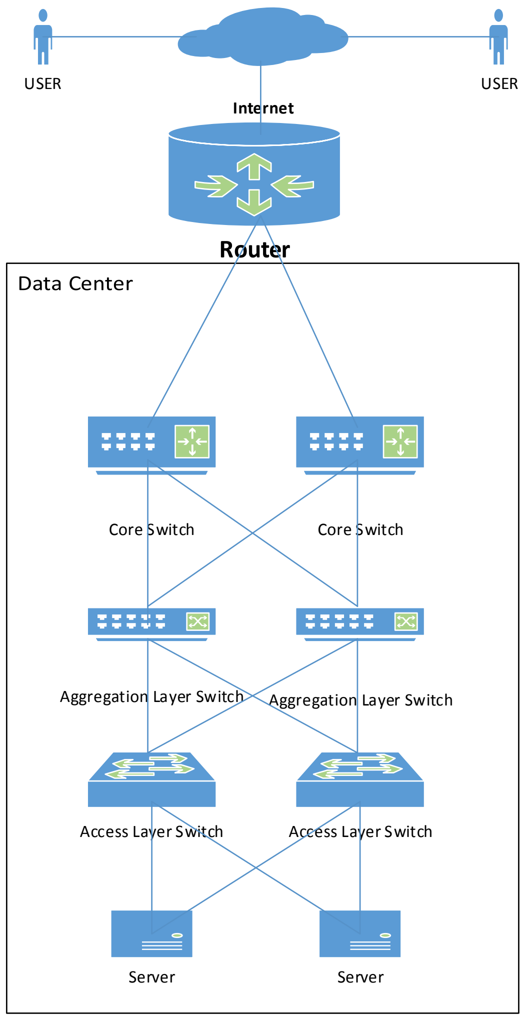

Fig. 1. Architecture of Present data center

II. BACKGROUND AND MOTVATION

Because the amount and size of traffic increasing exponentially the architecture of traditional a data centers are not sufficient to handle traffic and to meet the future challenges. The cluster- server architecture of data center uses Ethernet connection 10Gbps data rate per link between server and access switch or top of the rack (ToR) switch. Upper layer switches have both optical and electrical links. Due to the number of client increasing rapidly and numerous emerging web applications the traffic between servers is increasing dramatically. In the new architecture, servers are communicating with each other most of the time rather than serving the client. Recent studies suggest that an optimal performance could be achieved when servers spend 80% of their activities within their local segment [5]. In order to maintain system efficiency and providing support, large organization often are required to interconnect their data centers located in remote locations. Those considerations are the basis of motivations for a top-down optical-electrical link topological architecture of data center proposed for Big Data in this study.

III. RELATED WORK

Recently few optical interconnecting schemes are proposed for data center network and reviewed in this section with general insight of their architectures. An electrical-optical hybrid network has been proposed by G. Wang et al, called c-Through, which is an enhancement of current data center networks [10]. Figure 2 shows the access/ToR switches are connected to an electrical packet based network (i.e. Ethernet) and an optical circuit based network. To determine the configuration of the optical switch, a traffic monitoring system is required. This monitoring system is placed in the host and measures the bandwidth requirement with the other hosts. An optical configuration manager collects all these information and determines the configuration of optical switch based on the traffic demand. After configuring the optical switch, it informs all the access/ToR to route the packets accordingly. An algorithm is used to provide the solution called Edmonds algorithm [11].

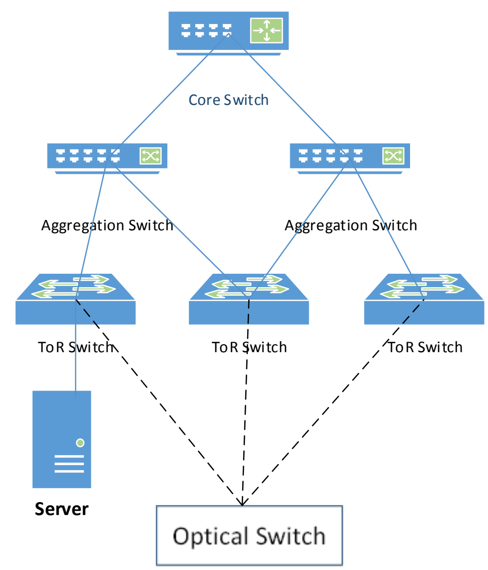

Fig. 2. Architecture of c-Through Network

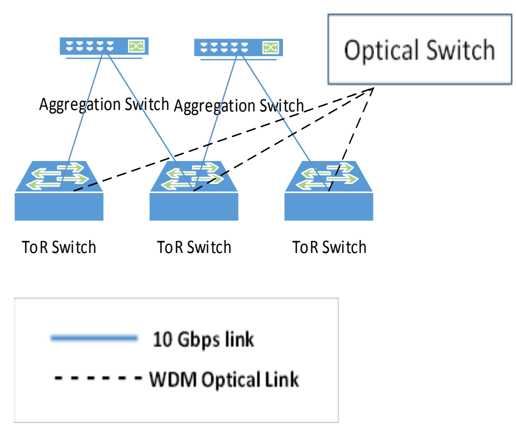

Fig. 3. Architecture of Helios data center network: Electrical/Optical Switch

N. Farrington et al. from UCSD proposed a hybrid electrical/optical switch architecture called Helios. Helios follows the architecture of typical 2-layer data center networks which is similar to the c-through architecture but its use WDM links. Figure 3, illustrates the setup used in [8] they define access/ToR switches as pod switches where the core can be electrical packet switch or optical circuit switch. The electrical packet switches provide all-to-all communication where high bandwidth slowly changing communication between ToR switches is provided by optical circuit switch. The Helios architecture tries to combine the best of optical and electrical networks.

IV. PROPOSED ARCHITECTURE

The architecture of current data centers suffer from some challenges such as latency, bandwidth, energy consumption and quick failover. In keeping future demand in mind, in order to maintain system efficiency large organization are required to interconnect their data centers located in remote locations. Hence we propose to connect servers with upper layer switch with high availability and low latency. Connecting servers directly with upper layer using both electrical and optical link would fulfill the requirement for the propose scheme. Figure 4 depicts the architecture that we propose which is an enhancement to current data center network. Here blue lines indicate electrical connectivity and black dashed line indicate optical connectivity.

Due to the emerging demand, now servers requires high bandwidth and low latency communication. Several process running in data center produce data-intensive workloads such as those generated by MapReduce, Hadoop are sufficiently less latency-sensitive require fast transfer for servers. Optical connectivity consumes less power at the same bandwidth provided by it is larger than electrical links. In our architecture, we propose to connect server directly using optical and electrical links which will meet the demand and at the same time better load balancing is achieved.

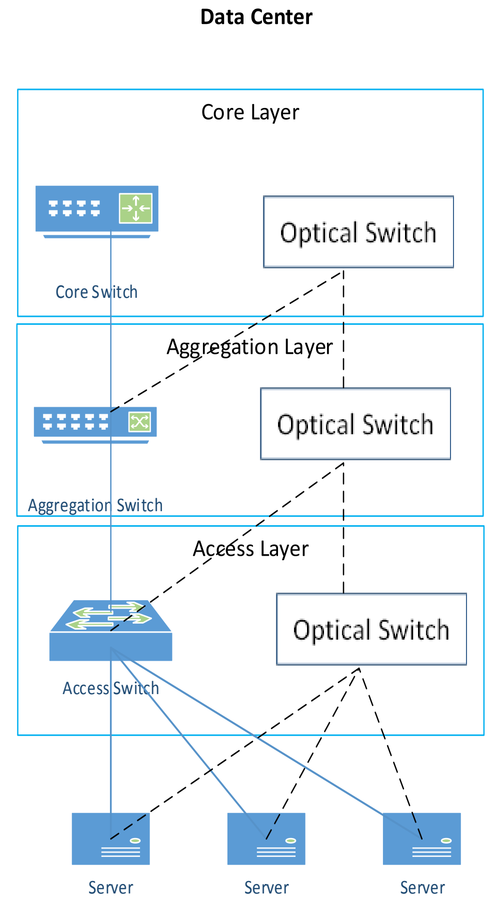

Fig. 4. Proposed architecture of data center

V. DATA CENTER INTERCONNECTIVITY

Data center interconnection could be provided by several schemes. Interconnection could be at layer 1, 2 or 3. Based on the transportation options available such as dark fiber, high bandwidth Ethernet we can select the interconnection process. Considering transportation option and layered architecture of data center, interconnection is recommended at layer 2 aggregation layer by [9]. Figure 5 shows a data center interconnectivity solution. Here each data center is connected at its aggregation layer using high speed optical fiber.

B. Cost and Power Consumption

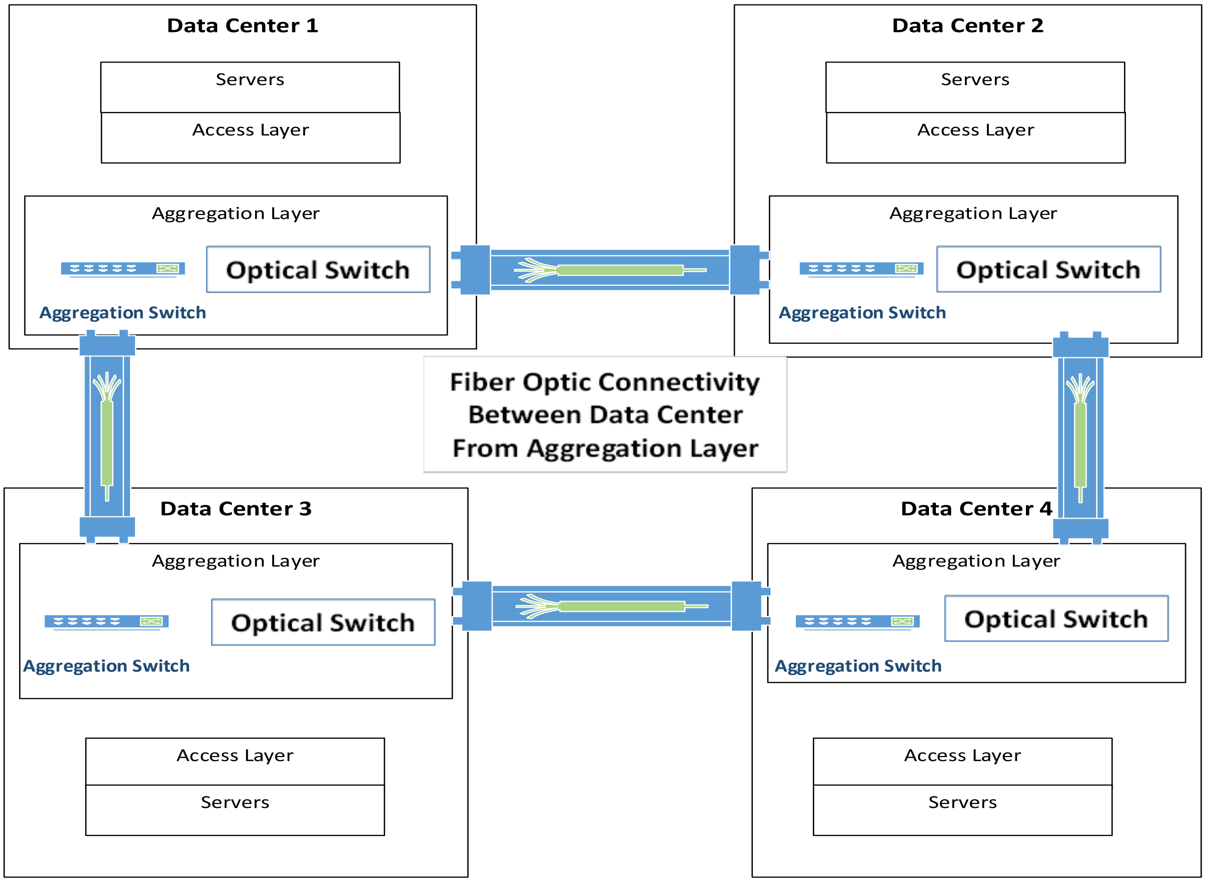

Fig.5 Data Center Interconnects Architecture

A. How this processes help for Intra and Inter data center networking

Figure 4 and 5 show each server has both optical and electrical connectivity. The electrical connectivity is usually useful for communication between servers and handling short data transfer, whereas optical connectivity is used for long bulked data transfer. This is necessary when transferring data between data centers that require large bandwidth and low latency. At the same time because of layered architecture server can communicate with each other via access layer and don't need to go the upper layer. Load balancing is achieved due to both hybrid electrical and optical links. Because of direct optical connectivity the main advantage would be in server virtualization. Virtual environments require greater bandwidth and higher performance with least overhead on the server. Due to the optical connectivity virtual Ethernet port aggregator switching situation enhanced. Now it's become easier to move server virtually not only within the data center but also among the data centers. The hybrid links intra and inter data center networking scenarios has significantly improved.

As the number of optical switches is introduced in every layer the load sharing capability of the network is increased and power consumption for data center is reduced. In each layer we are reducing electrical switch and replace them with optical switch overall cost and power consumption associated with electrical switches have reduced [7].

VI. Conclusion and Future Work

In this paper, a bottom to top possible electrical and optical architecture is presented. Use of optical connectivity has some advantage such as less power consumption, higher bandwidth and low latency. Introducing both types of switches in each layer helps in load balancing. This also helps us when we interconnect our data centers where we require large bandwidth between servers. Because of higher bandwidth, moving server virtually not only within the data center but also among the data centers becomes easier. So a hybrid electrical and optical networking topology improves the overall scenarios for data center and also for big data network.

In our work we are trying to measure the performance of optical circuit switch and electrical packet switch network between servers and ToR switches. We are running simulation to compare switching time of optical and electrical links. We also metering fault tolerance and quick failover time of optical network. Depend on the traffic characteristics and latency requirement of applications we will monitor the time required in packet switch and circuit switch network for handling short and long bulk data. Based on those analysis we will introduce QoS (Quality of Service) inside data center and discuss how this scenario work for big data network.

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