Unified Fabric: Data Centre Bridging and FCoE Implementation

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Abstract

In the past decade cloud computing has become the buzzword in IT world. The implementation of cloud based computing and storage technology changed the way of how network infrastructure is built inside an enterprise. As technology has improved and the cloud based storage systems become more affordable, a number of enterprises started outsourcing their data management due to a number of reasons. But still a majority of large enterprises and SMB (small medium businesses) prefer to manage their own in-house data centers and storage area networks. The reason being is the control, security and integrity of stored data on cloud storage servers. In this paper, we will discuss the most commonly implemented SAN technology, fibre channel (FC) in comparison with the new technology called Fibre Channel over Ethernet (FCoE). These results will help SAN engineers and designers select the best technology between the two in terms of performance, scalability, cost, maintenance, space, cooling, equipment, cabling, management, adapters, labor cost and manpower. Implementation of FC and FCoE has been done to explore the different features of both technologies. Furthermore, how to build a reliable, scalable and secure storage area network has been demonstrated. This study has been carried out on Cisco Nexus, Cisco MDS and Cisco UCS platform.

Keywords: Storage Area Network, Data Centre, Fibre Channel, Fibre Channel over Ethernet, UCS.

1. INTRODUCTION

Data are the most important component of a computing environment. To store data, we need some sort of storage media. The allocation of storage disks can be done with a number of ways. This includes DAS, NAS and SAN. A brief introduction of these technologies is given below:

1.1 Direct Attached Storage (DAS)

DAS are physical disks locally attached to servers. It is a 1:1 relationship between storage and host [9]. The scalability of DAS has always been an issue [1]. In DAS implementation, each computer must be provisioned with sufficient additional storage space to ensure that the computer does not run out of storage space at an untimely moment. In DAS architecture, the unused storage on a computer cannot be utilized. These limitations led to the development of the NAS.

1.2 Network Attached Storage (NAS)

NAS is configured with its own network address. It provides file level [1, 2] access to the server using ethernet technology. It provides space to host in the form of shared network folders. A NAS is attached to an existing LAN (local area network) and assigned an IP address. In NAS implementation, the storage devices are communicating directly with a "NAS Server". This implementation makes the storage accessible at a file-level to other clients across the LAN. NAS can handle a number of network protocols like NFS, FTP, Samba, CIFS and SMB. Figure 1 shows a typical NAS architecture [1].

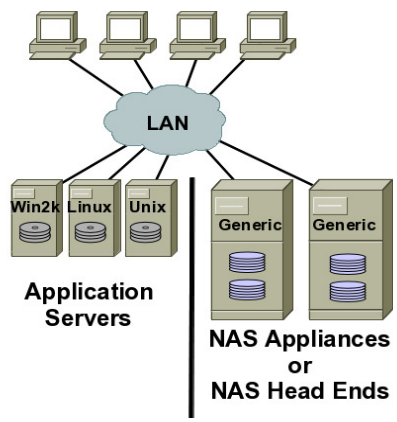

FIGURE 1: NAS (Network Attached Storage).

1.3 Storage Area Network (SAN)

SAN as compared to NAS has its own addressing scheme [2]. It is a many to many relationship between storage and hosts. It provides faster and reliable block level access to servers using FC (most of the time) and produces space to hosts in the form of disk. Figure 2 shows a typical SAN implementation [1]. There are number of SAN protocols, e.g. iSCSI, FCIP, FC and FCoE.

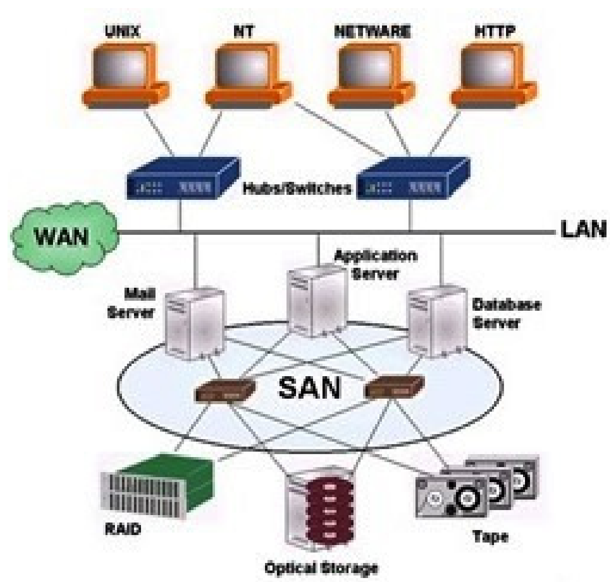

FIGURE 2: SAN (Storage Area Network).

While using a SAN, resources can be centrally managed and storage space can be allocated and de-allocated to hosts when needed. Components are hot-swappable; this results in eliminating downtime of servers. Storage can be accessed by multiple servers simultaneously with more robust and faster fashion. It eliminates restrictions on the amount of data that can be accessed by an individual server as opposed to server with direct attached disk [8].

In most SMB and large enterprises, a SAN is an important part of data center infrastructure. SAN itself can be implemented using a number of protocols and technologies [1]. The most common implementation of SAN in large enterprises is the FC (Fibre Channel). An FC SAN provides lossless data transfer between the initiator and target. The data is transferred on credit based flow control mechanism. Though FC SAN is the most popular implementation, however it comes with some issues as well. It requires two different networks inside your data center. One network carries your data traffic and the other one carries the storage traffic. This implementation introduces some issues in terms of management, cost, labor, maintenance, cooling, power and space.

Ethernet came up with a new technology known as FCoE (Fibre Channel over Ethernet) [3,4,5]. Using FCoE, we can merge the LAN and SAN into one unified network without any compromise on performance. The FCoE has a number of advantages over the native FC implementation:

1. Combines the lossless nature of FC and the simplicity of ethernet, known as a pause-frame concept.
2. Provides more speed as compared to FC i.e. 10, 40 and 100 Gbps.
3. Uses LAN infrastructure for transferring storage SCSI commands which results in:
    a) Less space
    b) Less cooling
    c) Less cabling
    d) Less management
    e) Less labor
    f) Less power
    g) Less cost
    h) Less number of switches
4. Less number of adapters, i.e. a CNA as compared to HBA and Ethernet NIC.

The purpose of this paper is to demonstrate the advantage of FCoE over native FC and highlighting some of areas for improvement in future. Different technologies, that form the backbone of a storage area network has been implemented. The rest of the document is organized as; the technical background, the design and implementation of the UCS server, JBoD, Nexus 5K, MDS and Nexus 9K series switches.

2. RELATED TECHNOLOGIES

This section discusses the contemporary technologies used in storage area networks.

2.1 Fiber Channel (FC)

FC is a method of processing of storage data with less delay and more efficiency. FC is very flexible and reliable while processing of data among different devices like laptops, switches and other peripherals. FC can handle both input/output communication and network traffic. Fiber Channel began in 80s as part of IPI (Intelligent Peripheral Interface) Enhanced Physical Project. Those efforts made Fiber Channel as approved project in 1988 by ANSI X3t9. The standard for FC covers networks, storage and ethernet data. FC is a set of functions that help a number of existing protocols like SCSI and IP. Unlike SCSI, it is not a high level but is a low-level protocol for managing link operations.

A 100MB FC port can be an alternate of five 20MB SCSI interfaces in terms of raw throughput. Fiber Channel gives a cumulative network bandwidth of about 1Gbps. Fiber Channel runs over both copper wire and fiber optic at expandable distances. Using repeaters or switches FC can be scalable. Fiber Channel provides full duplex communication with separate fiber optic for transmitting and receiving. FC uses small connectors which is another benefit. Serial connector for FC uses few pins and reduces chances of physical damage. SAN and other devices like Nexus can be easily interconnected in existing FC setup [4].

2.2 Fiber Channel over Ethernet (FCoE)

FCoE is a new protocol that is being developed by INCITS T11. The FCoE maps Fiber Channel over Ethernet and is capable of forwarding Ethernet frame and storage data as well. One of the advantage of FCoE is it maintains latency and forward data with same security. FCoE is an approach that simplifies customers' environment by using existing ethernet infrastructure and forwards storage data on top of these links. Now a day's almost every data center has Ethernet, TCP/IP network and SAN traffic and use of FCoE will make it very simple and economical solution. Ethernet networks are used when users are transmitting relatively small amount of data as compared to SAN networks where data are in huge volume. FCoE maintains low latency in different distributed networks. SAN has immense importance in today's data centers and most companies are spending a lot in making SAN a scalable and reliable source of data storage. Virtualization in data centers is one of the reason of high demand of FCoE. Demand for FC in this case is led by the need of hypervisors to give operating systems with virtualized storage which can be accessible by FC enabled network.

Fibre Channel host bus adapters (HBA's) and two or more NICs are the basic requirement of having FCoE enable network infrastructure. The adapter requirements could only grow when 32 CPU cores become commonplace. Fiber Channel over Ethernet (FCoE) reduces the number of adapters required for communication. FCoE is not only capable of 10GE but it can run over networks with increased interface speeds [5, 6].

2.3 Unified Computing System (UCS)

Data center environments are a result of assembling different individual components. There is need of a lot of manual work done by employees working on data centers to accomplish integrations. Today industry is moving towards more flexible and virtualized approach on achieving different designs and functionality within network data centers.

The Cisco Unified Computing System™ which is a new-generation DC platform is capable of computation, network, storage access, and virtualization in system designed to decrease total cost and increase agility. UCS provides a low-latency, lossless 10 Gigabit Ethernet unified network fabric and x86-architecture servers. The system is an integrated, scalable, multi-chassis platform in which all resources participate in a unified management. The Cisco Unified computing system is composed of computing hardware, switching fabric, management software and virtualization capabilities. The purpose behind all this system is to reduce cost, increase scalability, ease in management of network, easiness in deployment and to make a cohesive environment with a lot of redundancy options available [7].

2.4 Just Bunch of Drives (JBoD)

One of the main functions of data centers is to generate and replicate data and there is a huge need of data storage. The ways to check standards of storage are to check and examine their block, file and object that they use. Storage with fast function usually depends on block level storage and SAN architecture is example of that. File storage example is NAS. There is another type that uses objects in storing data such as cloud computing. JBoD is most commonly and widely used type of data storage. There are several advantages of using JBoD. It has more manageability, availability, scalability and serviceability. Choice of the right JBoD solution for different storage types (block, file, and object) is very important to balance performance and cost for data centers. RAID function implementation enables fail-over settings by having dual port drives. JBoD by having swappable components like power supply, disks and controllers minimize the downtimes during extensive working and usages. There are up to 60 drives which are swappable with single or dual controllers. Redundant power supply makes it easy to failover and increase performance. AIC's fully hot swappable gives comprehensive specification and values to satisfy storage requirement in data centers. JBoD also helps in improving performance by the power features of 6G SSAS expander chips. Generally, dual expander is designed to increase storage capacity, high availability and scalability. JBOD has typically two loops that can be used as separate loops for redundancy. There are ports in JOBOD and also equipped with controller which do configurations on disks and loops. Additionally, JBODs can be utilized with RAID application which can raise the performance and also to give the redundancy for security of data. However by doing so the JBOD can only be reached by the host it is connected to. In general, JBODs are cost effective than RAIDs but are more limited in their capabilities. [8, 13]

3. SYSTEM DESIGN

This section elaborates the physical infrastructure used to build the system.

3.1 Low Level System Design

In a typical SAN design we should have switches in the middle to provide faster connectivity between the servers and storage. These can be FC switches or normal ethernet switches with the capability of transferring/ processing storage commands over the physical links. In our topology, we are using Cisco 3 MDS 9K (MDS 9222i, MDS 9124 and MDS 9116) series switches and 2 Nexus 5K series switches. These are the actual physical devices where real data are stored. These arrays provide block level storage access to the servers. There are two popular ways to configure storage arrays in SAN. These are JBoD and RAID.

In this topology, we are using a JBoD implementation of storage array in the form of arbitrated-loop. Servers are the physical devices which initiate requests for read or write to the target. It can be a physical Dell, HP or a Cisco U/C series server running a standalone operating system or a virtualized server running multiple VMs on top of a Hypervisor. For our implementation, we are using Cisco UCS server. Adapters provide an interface between the server and physical communicating medium. For FC implementation it is an HBA and for FCoE the implementation it is a CNA. In our topology we are using both HBA and CNA.

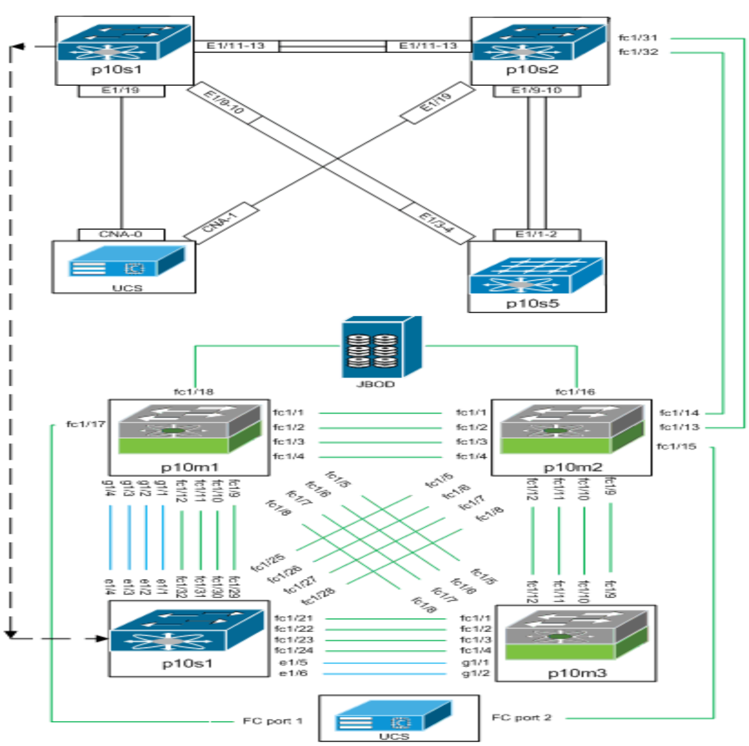

FIGURE 3: Low Level System Design.

a) Operating System: On both, MDS and Nexus we are using NX-OS version 5.2 (8C). On the server side we have windows server 2008 R2.
b) Protocols: There are a number of protocols being used in a SAN implementation. These are Ethernet based (iSCSI), Fibre Channel based (native FC and FCoE) and a hybrid known as FCIP. In this case study, we will be discussing FC and FCoE protocols.
c) Physical Cabling: The most common cabling mechanism in a SAN is fibre optic and Ethernet. In our topology we have 4 Gbps fibre optic cables used for the FC implementation and 10 Gbps Ethernet for the FCoE.

3.2 High Level System Design
UCS servers are connected to N5K which are Fiber Channel Forwarders. LAN and SAN networks are connected to these FCF. Traffic is flowing between servers and end users along the path through FCF switches. Connection between servers and FCF are capable of carrying both storage and ethernet data.

Below figure shows an overall view of logical design and flow of data for both LAN and SAN. Here, instead of having two separate network setups for LAN and SAN from UCS, we are having one merged network that is facilitating both types of data.

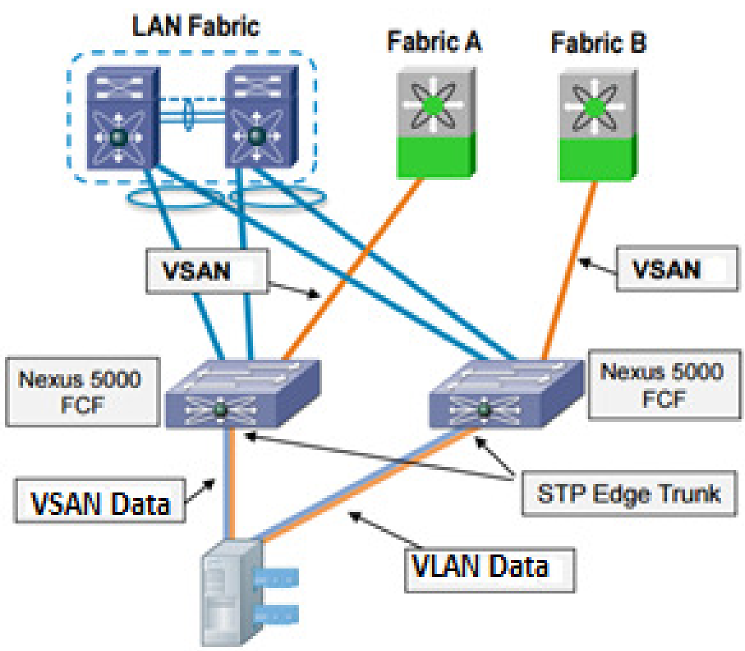

FIGURE 4: High Level Diagram.

FCoE links carry both traffic, this means there is VSAN and also for VLANs there is spanning tree working as normal. So whenever there is FCoE there must be spanning tree active and enable. Switch 5K1 is carrying VSAN and VLAN.

4. IMPLEMENTATION
The implementation of different features of FC and FCoE has been done to check the performance of both technologies. For both technologies, we provide end-to-end connectivity between the UCS server and storage disk (JBoD) using MDS and Cisco Nexus switches. The following two figures shows the design of the FC and FCoE topologies being implemented.

4.1 Fibre Channel Implementation

Native FC implementation is the most commonly implemented technology in today's SAN. In this section, we will start from basics and will then go through the advance features of the Native Fibre Channel.

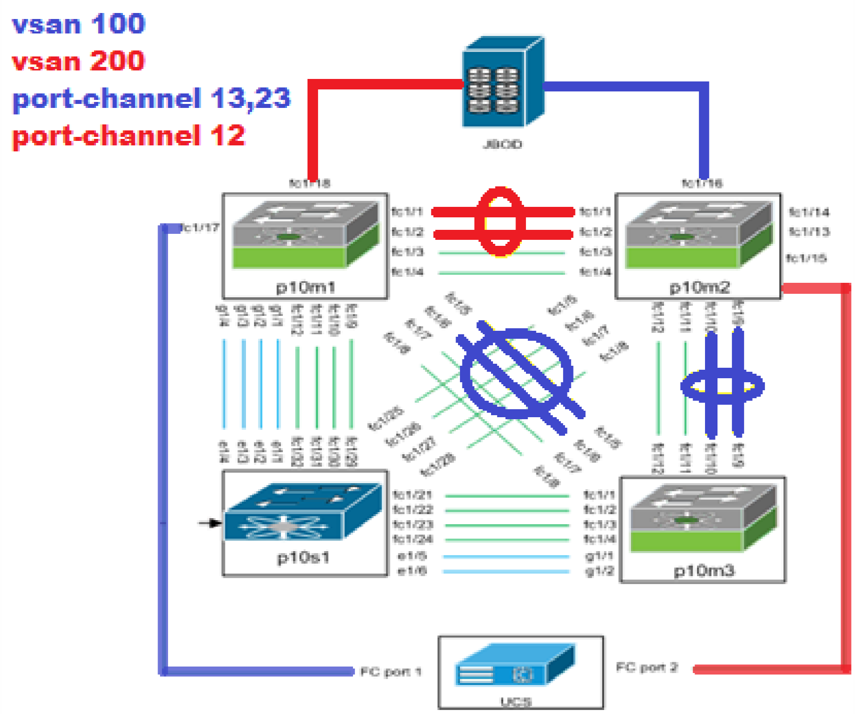

FIGURE 5: Fibre Channel Implementation.

a) **Fabric login process:** All the attached devices in the fabric, go through a fabric login process. When we connect a server or storage to the fabric switch, it registers itself with the switch using its WWNN and WWPN. In return, the fabric switch assigns a logical ID known as FCID to the server or storage device. The following output shows the result of registered devices directly connected to the fabric switch. In the following output on interface fc1/17 we are connected to the HBA of UCS server while fc1/18 is connected to storage array (having 4 storage disks). In this process if ports are being accepted in association of other ports these will go to initialization phase. In case if these ports are not accepted with the sign of class is not supported their ports will get s higher number whichever is available. These port ans fabric needs to have same class of service. [10]

```
MDS1(config)# sho flogi database
---------------------------------------------------------------------------
INTERFACE       VSAN    FCID            PORT NAME               NODE NAME
---------------------------------------------------------------------------
fe1/17           1     0x010100 21:00:00:1b:32:8f:f6:23 20:00:00:1b:32:8f:f6:23
fe1/16           1     0x0100e1 22:00:00:04:cf:67:d0:2c 20:00:00:04:cf:8f:d0:2c
fe1/16           1     0x0100e2 22:00:00:04:cf:67:d4:a5 20:00:00:04:cf:8f:d4:a5
fe1/16           1     0x0100e4 22:00:00:04:cf:67:cf:e6 20:00:00:04:cf:8f:cf:e6
fe1/16           1     0x0100e8 22:00:00:04:cf:75:24:de 20:00:00:04:cf:8f:24:de
```

FIGURE 6: Show Fabric Login Database Details.

b) **VSAN Database and Interface Assignment:** VSAN information is saved in the VSAN database. The following commands are used to create VSAN database, VSANs and assigning interfaces to a VSAN. We assigned VSAN 100 to interface fc1/17 and VSAN 200 to interface fc1/18:

```
MDS1(config)# vsan database
MDS1(config-vsan-db)# vsan 100
MDS1(config-vsan-db)# vsan 200
MDS1(config-vsan-db)# vsan 100 interface fc1/17
MDS1(config-vsan-db)# vsan 200 interface fc1/18
MDS1(config-vsan-db)# exit
```

FIGURE 7: VSAN Database Commands.

c) Port Channeling and Bandwidth Setting: We can create port channels to **connect** MDS1 to MDS2. There are some requirements for this communication to take place. First, it should be in mode E. Second, the rate mode should be dedicated. By default, the fibre channel interfaces operate at 4Gbps in dedicated mode. For this bandwidth to be accommodated properly, we need to adjust the bandwidth to be 2Gbps. Another solution is to disable the over subscription restriction on the module. This can be achieved by using the following commands:

```
MDS1(config)#
MDS1(config)# interface fc1/1-2
MDS1(config-if)# switchport speed 2000
MDS1(config-if)# switchport rate-mode dedicated
MDS1(config-if)# switchport mode E
MDS1(config-if)# channel-group 12 force
MDS1(config-if)# interface port-channel 12
MDS1(config-if)# channel mode active
MDS1(config-if)# switchport trunk allowed vsan 100
MDS1(config-if)# switchport trunk allowed vsan add 200
MDS1(config-if)# no shut
```

FIGURE 8: Port Channel and Bandwidth Commands.

d) Fibre Channel Zoning: Zoning is one of the most important features of SAN. Without an active zone(s) a SAN will not work. It is the grouping of servers and storage devices that want to communicate. One of the requirements for servers and storage nodes is that they should be part of the same zone. A VSAN can have multiple zones assigned to it. A Zone can be implemented in two ways, i.e. standard and enhanced. We can make different sub-network within FC network to make the visibility of end devices. By this process servers can reach storage in the same defined zone. This is more beneficial in case of tap drives without LUN masking. Zoning is used to differentiate and separate incompatible HBA by putting them in different zones. [11]

In this case study, we implemented enhanced zoning to overcome the deficiencies in standard/basic zoning. In enhanced zoning, once a zone is created and distributed among all the switches in the fabric, changes are not simultaneous. Only one administrator can make changes in the zones. When an admin is making any changes, the zone is locked among all the fabric. Once the change is committed, then other administrators can make changes. The following output shows our enhanced zoning configuration:

```
MDS1(config)# zone name zoneA vsan 100
MDS1(config-zone)# member pwwn 22:00:00:04:cf:67:d0:2c
MDS1(config-zone)# member pwwn 22:00:00:04:cf:67:d4:a5
MDS1(config-zone)# member pwwn 22:00:00:1b:32:8f:f6:23
MDS1(config-zone)# exit
MDS1(config)# zoneset name zonesetA vsan 100
MDS1(config-zoneset)# member zoneA
MDS1(config-zoneset)# zoneset activate name zonesetA2014 Aug1
MDS1(config-zoneset)# zoneset activate name zonesetA vsan 100
```

FIGURE 9: FC Zone Creation Commands.

4.2 FCoE Implementation

FCoE is a state of the art technology implemented in most of the modern enterprise data centers. The beauty of FCoE is that you do not need to maintain two different networks, i.e. one for data and the other for storage. You can make use of the existing infrastructure to transfer iSCSI commands over the ethernet. This new network has the simplicity of ethernet, reliability of fibre channel technology, ethernet network infrastructure and transport storage commands. FCoE gained huge attention these days because storage over Ethernet need more lossless connectivity and storage devices are less tolerate of dropping of frames. In this section, we will discuss the implementation of a converged FCoE network. [12]

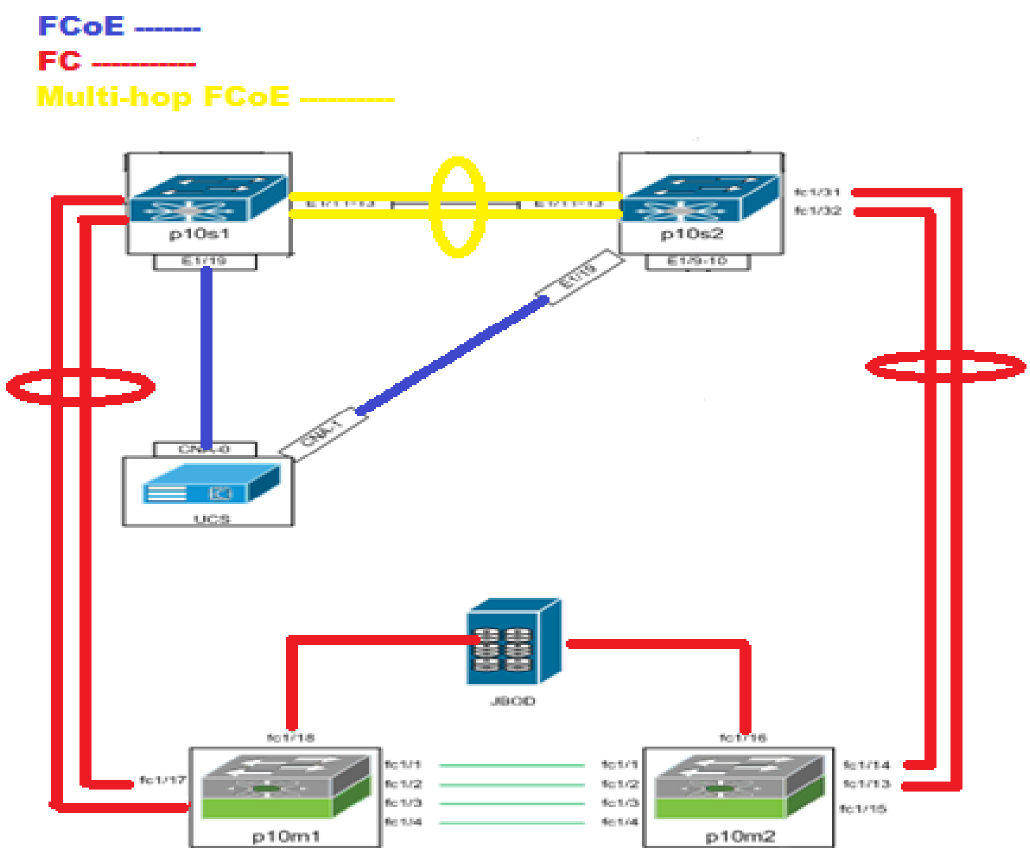

FIGURE 10: FCoE Implementation.

a) N5K FCoE Connectivity with the Server: On nexus 5K FCoE feature is not enabled by default. We have to enable this feature first to run different FCoE commands. In the first step, we are configuring N5K1 towards the server. On the UCS server, we have a Converged Network Adapter (CNA). CNA has the ability to carry/transport both data and storage traffic. In the topology, the ethernet interface e1/19 of N5K1 is connected to the CNA of the UCS server. This interface is configured as a trunk. The purpose is to carry both the vlans, i.e. 100 and 10. Vlan 10 is carrying the data traffic while the other is carrying storage traffic encapsulated inside vlan 100. We then create a VFC 19 (Virtual Fibre Channel interface) and bind that to the physical interface e1/19. All these configuration steps along with their descriptions are shown below:

```
5k1(config)# feature fcoe
5k1(config)# vsan database
5k1(config-vsan-db)# vsan 100
5k1(config-vlan)# exit
5k1(config)# vlan 100
5k1(config-vlan)# fcoe vsan 100
5k1(config-vlan)# exit
5k1(config)# vlan 10
5k1(config)# interface ethernet 1/19
5k1(config-if)# switchport mode trunk
5k1(config-if)# switchport trunk allowed vlan 100
5k1(config-if)# switchport trunk allowed vlan add 10
5k1(config-if)# interface vfc 19
5k1(config-if)# bind interface e1/19
5k1(config-if)# switchport trunk allowed vsan 100
5k1(config-if)# vsan database
5k1(config-vsan-db)# vsan 100 interface vfc 19
5k1(config)# interface vfc 19
5k1(config-if)# no shut
```

FIGURE 11: N5K FCoE Connectivity Commands.

b) Connectivity between MDS1 and N5K1: This section is a two-step process. In the first part, we are configuring MDS1 towards N5K1. In our topology the FC interface 1/9 of MDS1 is connected to the FC interface 1/29 of N5K1. In the second part, we are configuring the N5K1 towards MDS1. This is pure Native FC communication. Here we are using the FC interface of nexus rather than ethernet. These configuration steps are shown as below:

1. **MDS Connectivity with N5k**

```
mds1(config)# vsan database
mds1(config-vsan-db)# vsan 100
mds1(config-vsan-db)# interface fc1/9
mds1(config-if)# switchport rate-mode dedicated
mds1(config-if)# switchport mode e
mds1(config-if)# switchport trunk mode on
mds1(config-if)# switchport trunk allowed vsan 100
```

FIGURE 12: MDS Connectivity with N5K.

2. **N5K1 connectivity with MDS1**

```
5k1(config)# interface fc1/29
5k1(config-if)# switchport mode e
5k1(config-if)# switchport trunk mode on
5k1(config-if)# switchport trunk allowed vsan 100
5k1(config-if)# no shut
```

FIGURE 13: N5K1 Connectivity with MDS1.

c) MDS Connectivity with Storage: In this section, we are configuring MDS for the connectivity towards the storage. In our topology, MDS1 FC interface 1/18 is connected to the JBOD. Further, we did zoning as well in this section. That allowed a hard-drive inside the storage array to be accessed by the server. Two PWWN are used. On the other side we used the PWWN of the HBA. Then the zoneset is activated and distributed along the whole fabric.

d) Verification of Connectivity:

```
mds1(config)# show fcns database
Vsan 100:
--------------------------------------------------------------------------------
FCID        TYPE      PWWN                      (VENDOR)          FC4-TYPE:FEATURE
--------------------------------------------------------------------------------
0x8200e1     NL      22:00:00:04:cf:67:d0:2c   (Seagate)         sci-fcp:target
0x8200e2     NL      22:00:00:04:cf:67:d4:e5   (Seagate)         sci-fcp:target
0x8200e4     NL      22:00:00:04:cf:67:cf:e6   (Seagate)         sci-fcp:target
0x8200e5     NL      22:00:00:04:cf:75:24:de   (Seagate)         sci-fcp:target
0xb70000     N       10:00:00:00:c9:c0:16:31   (Emulex)          ipfc scsi-fcp:init

Total number of entries = 5
mds1(config)# sho zoneset active
zoneset name zonesetA vsan 100
zone name zoneA vsan 100
* fcid 0x8200e1 [pwwn 22:00:00:04:cf:67:d0:2c]
* fcid 0x8200e2 [pwwn 22:00:00:04:cf:67:d4:a5]
* fcid 0x8200e3 [pwwn 10:00:00:00:c9:c0:16:31]
```

FIGURE 14: Verification Commands.

5. COMPARISON

In this paper, the general concepts of most widely used technologies inside a data center in general and SAN in particular are discussed. The concepts of DAS, NAS and SAN are presented in order to understand the performance issues behind it. This study is conducted using the latest Nexus 5K, MDS 9K, JBoD, and UCS server to get the real and optimum results.

As FCoE uses two existing technologies which include Ethernet and Fiber Channel hence meeting the high expectations of industry. In simple words, if any organization wants to reduce capital expenses (CAPEX) and operational expenses (OPEX) should deploy FCoE.

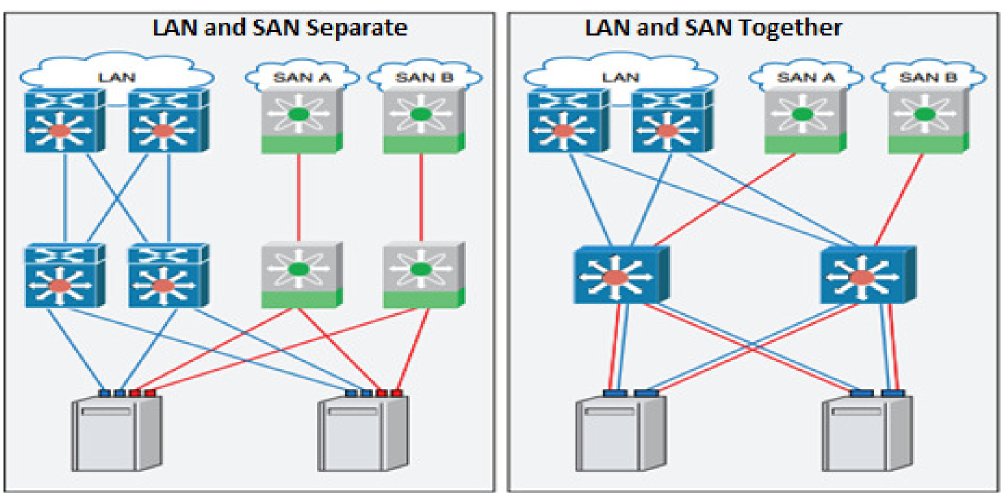

FIGURE 15: Comparison.

We observed that while running two different networks inside your data center i.e. one for storage traffic and other for data traffic increases the overall cost in terms of adapters. While keeping two different networks you should have an Ethernet adapter (NIC) and an HBA. However, if you are running a converged network (FCoE) then only one CNA is enough to carry your storage and data traffic.

Other parameters that are taken into consideration are the overall cost in terms of capital purchases. The main reason of adapting FC technology inside a data center is to provide high reliable and lossless transport of storage traffic. This implementation comes with an extra cost of keeping a separate network of specialized equipment. FCoE comes with a better solution while keeping your existing ethernet network. FCoE itself is a highly reliable technology which makes use of pause-frame concept for the flow control and reliability.

	Network Design	Cost/ Administration	Bandwidth Gbps	Features
FC	Storage & data Network/HBA+NIC	High/Complex	4, 8, 16, 32	Encapsulated FC Frames Lossless through throttling in congestion Load balancing using RR Path selection FC encapsulated frames Support VSANs/zoning to isolate storage infrastructure Used in mission critical environments Latency remains normal during increased traffic load
FCoE	Single Network/CAN	Low/Modest	1, 10, 40, 100	Flow control, Reliability, Ethernet frames Lossless using pause-frame in congestion No encapsulation overhead Load balancing through concurrent LUNs Jumbo frames Support VSANs/zoning to isolate storage infrastructure Traffic consolidation Higher latency during increased traffic load

TABLE 1: Comparison of FC and FCoE.

As networks grow in size, in most of the modern SMB and large enterprises, maintenance is also an issue. Keeping two different networks needs separate administrations. This administrative cost can be reduced by keeping one network for both data traffic and storage traffic. The solution is the implementation of FCoE. Another benefit that FCoE implementation brings is that, less space is consumed as less number of devices are used.

In FC only SAN inside a data center, the bandwidth in only utilized by the storage traffic and most of the time the link bandwidth is not utilized properly. FCoE comes with a better link utilization/ bandwidth management options. Depending on the business critical applications and data center requirements, FCoE implementation classifies the data traffic and storage traffic on the physical link. This solution helps us make use of better link utilization depending on our needs.

6. FUTURE WORK

The implementation of FCoE in a data center significantly reduces the overall infrastructure cost, however, network virtualization in Data Center can further reduce the operational as well as capital cost. East-west traffic in the data center can be easily managed in a virtualized environment between servers, focusing on virtual switching, routing, storage, firewalls, and load-balancers. SDN (Software Defined Networking) and NFV (Network Functional Virtualization) are the directions where future research needs to be done.

7. CONCLUSION

The study presented a detailed implemented approach to assess the two most widely used technologies, fibre channel (FC) and fibre channel over Ethernet (FCoE), inside a modern SAN. The results can help SAN designer understand how well FC and FCoE implementation works inside a DC. The results also make the selection easy for a SAN designer to select between FC and FCoE.

FCoE is offering less capital and operational costs. Introducing FCoE to the existing FC SAN is convenient, practically that is being handled by existing management software and support existing SAN functions such as logical partitioning and security features. This is a technology that will unify datacenter networks.

In terms of speed, bandwidth management and link utilizations, FCoE is on the far better edge than FC. Ethernet comes in 1Gbps, 10Gbps and 40Gbps. 100Gbps will be in the standards soon. FC is operating at 2Gbps, 4Gbps, 8Gbps, 16Gbps and 32 Gbps. This huge difference in speed makes FCoE a better choice in SMB for their future growth.

FCoE is transporting iSCSI specifically over Ethernet which is different from FC, as FCoE send iSCSI over TCP/IP. FCoE gives us option to utilize maximum resources of a network. Native FC and other related technologies (e.g. FCIP) are compatible with FCoE. System, network and storage administration can be significantly reduced by implementing FCoE.

8. REFERENCES

[1] V. R., A. Nasreen. “Survey on Recent Technologies of Storage Area Network and Network Attached Storage Protocols”. International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, Vol 2., pp 1784-1789, 2014.

[2] Brocade Communications Systems, “Comparing Storage Area Networks and Network Attached Storage White Paper”, USA, 06/01 GA-WP-084-01, May 2013.

[3] P. Kale., A. Tumma., H. Kshirsagar., P. Tamarkhyani. and T. Vinod. “Fibre channel over ethernet: A beginners perspective.” In Proc. IEEE International Conference on Recent Trends in Information Technology, 2011, pp 438-443.

[4] M. Primmer. (1996, October). “An Introduction to Fibre Channel.” Hewlett-Packard Journal. [online]. Article 11, pp 1-7. Available: www.hpl.hp.com/hpjournal/96oct/oct96a11.pdf [Dec, 26, 2015].

[5] G. Lemasa., S. Gai., Cisco Systems, “FCoE Introduction White Paper” , USA, © Fibre Channel Industry Association, 2007.

[6] C. DeSanti and J. Jiang. “FCoE in perspective,” in Proc. International Conference on Advanced Infocomm Technology, 2008, pp. 29-31.

[7] Cisco Systems C45-523181-05. “Cisco Unified Computing System, Delivering on Cisco's Unified Computing Vision.” Internet: www.cisco.com/c/dam/en/us/solutions/collateral/data-center-virtualization/unified-computing/at_a_glance_c45-523181.pdf, 2010 [Jan. 3, 2016].

[8] AIC (Building Efficient Solutions Together), “Hot-Swappable JBOD Series White Paper” Internet: www.aicipc.com/hsjbod/JBOD_WhitePaper_Rev%201.pdf, Seagate Taiwan, 2012 [Dec. 12, 2015].

[9] P. Radzikowski. “SAN vs DAS: a cost analysis of storage in the enterprise.” Internet: http://capitalhead.com/articles/san-vs-das-a-cost-analysis-of-storage-in-the-enterprise.aspx, Oct. 28, 2013 [Dec 28, 2015].

[10] Robert W. Kembel.“Fibre Channel Switched Fabric.“Chapter28. Node Port Initialization, Internet: http://www.nlabooks.com/downloads/Node%20Port%20Initialization.pdf [2004, 2001].

[11] Mainz, Germany “Networks Explained Basics and Application of Fibre Channel SAN” IBM Storage Software Development, Mainz, Germany. A John Wiley and Sons, Ltd.

[12] Bouchard, Roger “SECURING FIBRE CHANNEL FABRICS” SECOND EDITION SAN Protection for Storage and Security Professionals. Brocade Communications Systems, Inc. All Rights Reserved. [05/12] Internet: https:// -types/ebook/securing-fibre-channel-fabrics-bk.pdf.

[13] Norman, David “CS553A Introduction to Networking Technology [02Dec2001]. Rivier College Department of Math and Computer Science. Internet: http://www.river.edu/faculty/vriabov/cs553a_paper_norman.pdf.