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DESIGN AND IMPLEMENTATION OF DATA CENTER (CASE STUDY OF NEW BULGARIAN UNIVERSITY)

Vassil Fournadjiev, Ionka Gancheva

New Bulgarian University
e-mails: vsfur@yahoo.com, igancheva@mail.bg
Bulgaria

Abstract: The article contains an analysis of data center architecture and technologies that are used at modern data centers. On this basis an working solution at New Bulgarian University is presented.
Key words: Data center, virtual networks, network architecture, data center design.

1. INTRODUCTION

The data center is a centralized or geographically distributed group of departments that houses the computing systems and their related storage equipment to data libraries. A data center has centralized management that enables an enterprise to operate according to business needs [1].

Modern data center provides a complete, highly efficient infrastructure. The proper planning and design is critical for its performance, resiliency, and scalability.

It integrates all computer's resources, security and management into a complex architecture delivering outstanding performance and ability for the business, simplifying operation and lowering the cost for IT.

Another important aspect of the data center design is flexibility in quickly deploying and supporting new services. Designing such architecture having the ability to support new applications in a short time can result in a significant competitive advantage. Such a design requires solid initial planning and thoughtful consideration in the areas of port density, access layer uplink bandwidth, true server capacity, and oversubscription, to name just a few.

The primary goal of the data center is to deliver adequate resources for the applications. The data center must be tailored according to them [1].

The other goals are to provide flexibility for future data center changes, including nondestructive scalability of applications and computing resources and infrastructure for future needs.

The important business aspect of Data Centers is the ability to adapt and respond to the risks in order to maintain continuous business operations. On that sense there are four primary requirements of business processes continuity:

- High availability (disaster tolerance)
- Continuous operations
- Disaster recovery
- Disaster tolerance

Any organization, whether it is commercials, nonprofit, or public sector (include healthcare), has applications that are mission critical to its operations and survival. In all cases, some form of data center operations and infrastructure supports those applications, running on a reliable, cost-effective, flexible data centers [8].

The purpose of this paper is to share the experience of the authors, related to the design and the implementation of Data Centre, based on New Bulgarian University.

2. EVOLUTION OF DATA CENTERS

At the beginning of computer era, data centers were centralized, composed by terminals and mainframes on which users perform their work. The mainframes are still used in the finance sector because they are an advantageous solution in terms of data security, availability, resilience etc.

The second era of data centers started with the appearance of microcomputers and widely spread computer networks. This period is characterized by client-server architecture and distributed computing, based on integrated memories, disks and other devices, located in the servers.

The new era of the data centers appeared due to the low costs of computers' infrastructure, the increasing computational power and expanding of communication lines. The new solution is equipment virtualization, making the utilization of servers more common that in the distributed approach [3].

Latest data center designs and implementations have three things in common:

- consolidation;
- virtualization;
- management simplification.

Consolidation is defined as the process of bringing together different separated devices to work under common control.

The primary reasons for consolidation are to prevent the sprawl of equipment and processes that are required to manage the equipment. It is important to understand the functions of each piece of equipment before consolidating it [7].

Virtualization offers flexibility in designing and building data center solutions. It enables enterprises with diverse networking needs to separate a single user group or data center resources from the rest of the network.

The main goal is to reduce operating costs of maintaining different type of equipment when it is not really needed or is not fully utilized. Virtualization of the data center network services has changed the logical and physical data center network topology view [6].

Other aspect of the virtualization is to prevent any undesired access across the virtual entities that share a common physical infrastructure.

Management simplification enable the creation of virtual pool of servers, virtual pool of adapters, virtual pool of processing units, virtual pool of networks, etc. [5].

An appliance attached to an existing data center monitors application processing, computing storage and network resource utilization, can detect the missing processing power or the lack of an application storage resources, and can automatically react to it. Such management can configure a virtual server, activate a virtual adapter, configure a server I/O channel, connect the channel across a virtual network to the dynamically allocated virtual disk and then start the application on the newly allocated infrastructure.

The modern enterprise is being changed by shifting business pressures and operational limitations. While enterprises prepare to meet demands for greater collaborations, quicker access to applications and information, and ever-stricter regulatory compliance, they are also being pressured by efficient asset utilization, escalating security and provisioning needs, and business continuance. All of these concerns are central to data centers.

The importance of security is rising as well, because more services are concentrated in a single data center. If a cyber- attack occurs in such a condensed environment the result can have unpredictable damages. The same consequence can have physical conditions such as floods, fires, earthquakes, and hurricanes.

Modern data center technologies, such as multi-core CPU servers and blade server, require more power and generate more heat than older technologies and moving to new technologies can significantly affect data center power and cooling budgets [4].

3. ANALYSIS OF THE EXISTING TECHNOLOGIES FOR DATA CENTER

With the growth of data centers, the number of applications and services supported by them, there is also a need for high availability, higher bandwidth, and the use of all available ones.

A big step forward in building next generation data center design is the promising technology defined in the RFC5556 standard called **TRILL** (**T**ransparent **I**nterconnection of **L**ots of **L**inks) - Fig. 1. [1].

TRILL is an open standard protocol that provides simultaneous access to Layer 2 on multiple paths between two points without the use of the **STP** (**S**panning **T**ree **P**rotocol).

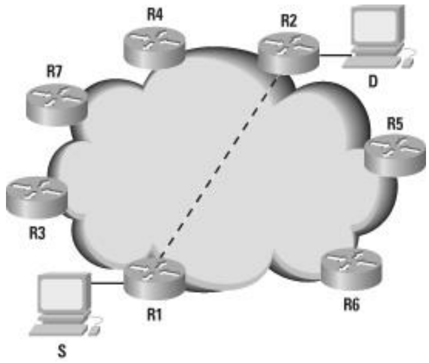

Fig. 1. TRILL technology, managing "unicast" traffic

TRILL calculates the data center topology and transmits layer 2 packets using the "IS-IS" protocol. It includes the functionality of effectively forwarding unicast packets, simultaneously redirecting them across many parallel paths, making multicast traffic by eliminate the use of STP from the backbone of the network.

Additionally, **TRILL** also reduces the delay time of the traffic. It is also the basis of today's "**FabricPath Technology**" [1].

CISCO "FABRICPATH" ARCHITECTURE combines the advantages of routing with the simplicity of switching – Fig. 3. The changes in the configuration: connection of new devices, flexible expansion, simultaneous use of multiple access routes, rapid convergence and expandability to build a flexible and scalable Layer 2 fabric network [3].

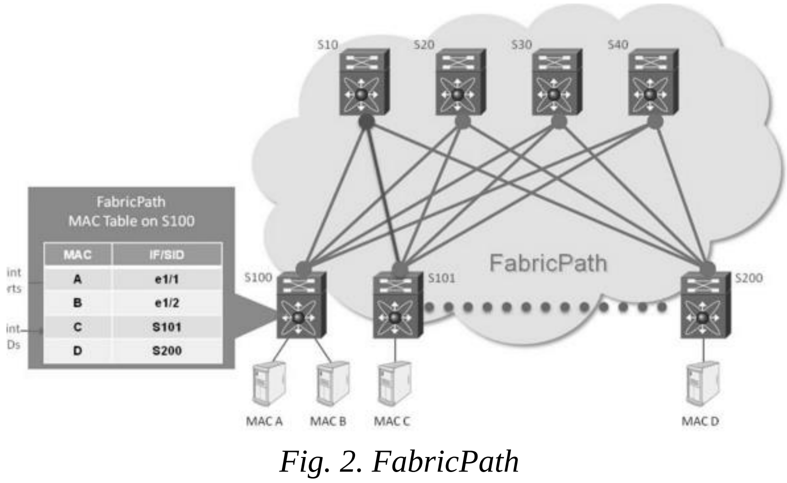

Fig. 2. FabricPath

With the use of **FabricPath** technology, the need for a STP is eliminated. All parallel access paths between two points are used, the packet delay time decreases [4].

Advantage of "layer 2" traffic The FabricPath technology can use 16 identical access paths between two points. Packages are forwarded in the shortest way possible to their destination, thus reducing the delay time to a maximum, as compared to the "spanning tree" solution [2].

The implementation of Cisco FabricPath can be made between the distributions of the core layers of the network. The packets between the different zones, composed by PODs are routed. The traffic between different VLAN ends in the distribution layer does not go to core. The advantages are that the STP does not work between POD. By this, it is possible to increase the bandwidth when needed.

The **Cisco Nexus Operating System 7010** assures switching and routing features, modularises and supports virtualization. Also, it provides flexible separation and distribution of software components and hardware resources. The System supports 32-port 10Gbs Ethernet 48-port 10/100/1000 cards.

VDC (**V**irtual **D**evice **C**ontext) [2] technology, delivers virtualization or flexible partitioning of the physical device to a very logical one. Usually before, the computing centers were often divided into separate domains or areas that are implemented by different physical infrastructures. The construction of such infrastructures implementing various administration and security policies certainly leads to the need for additional large capital expenditures.

Through VDC, the physical network will be separated into separate logical modules completely isolated from one another, applying the same security policies and different routing rules.

Each VDC has the same functionalities as the physical switch. Physical ports can be easily assigned to the various virtual switches or re-coupled between VDCs. In addition, the same switches can create the same VDC for the same services, which in turn are aggregated for resource resources in excess.

MSTP (**M**ltiple **S**panning **T**ree **P**rotocol) [11] – Fig.3 enables multiple VLANs to be mapped to the same spanning-tree instance, reducing the number of spanning-tree instances needed to support a large number of VLANs.

MSTP provides multiple forwarding paths for data traffic and enables load balancing. It improves the fault tolerance of the network because a failure in one instance, or forwarding path, does not affect other instances.

In addition, it will allocate and balance the traffic load from the different virtual networks between the network switches.

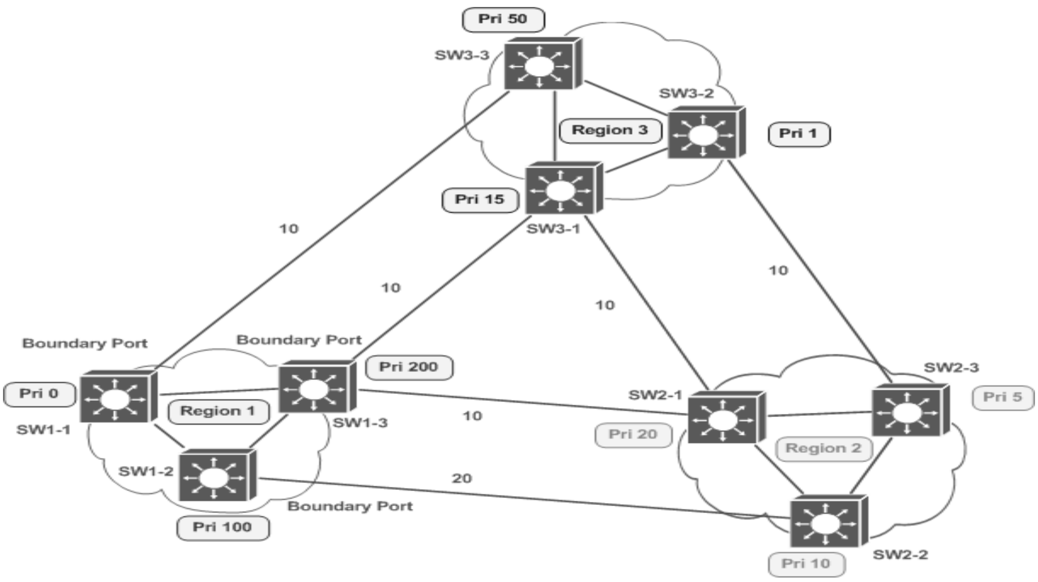

Fig. 3. Multiple Spanning Tree [11]

4. CISCO MODEL OF THE DATA CENTER ARCHITECTURE

The data center network design is based on a proven layered [9] model approach – Fig. 4. The model has been tested and improved over the past several years, basically with its scalability, performance, flexibility, resiliency, and maintenance.

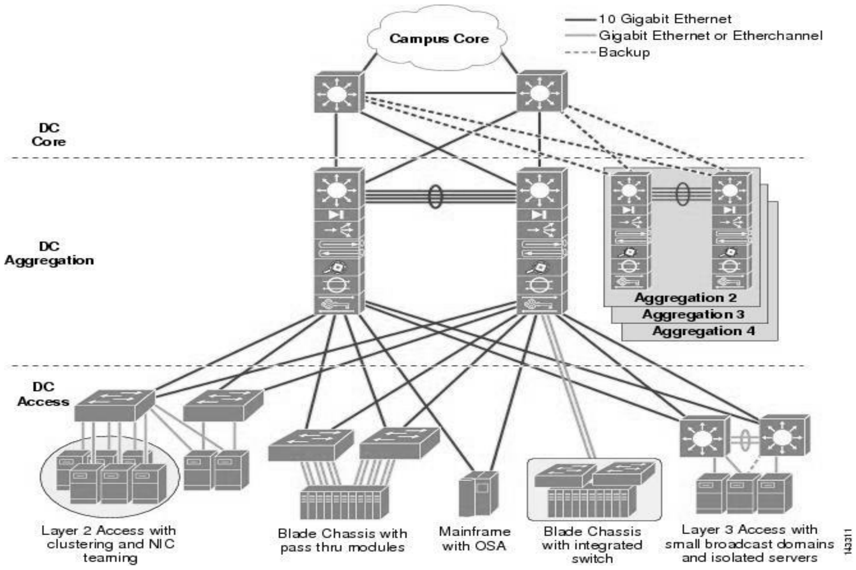

Fig.4. Basic Layered Design CISCO [9]

The layers of the data center design are the core, aggregation, and access layers. The functions of these layers are:

Core layer: provides the high-speed packet switching backplane for all flows going in and out of the data center. The core layer assures connectivity to multiple aggregation modules with no single point of failure. The layer balances traffic between the campus core and aggregation layers.

Aggregation layer: provides spanning tree processing, default gateway redundancy. Other important services are content switching, firewall, offload, intrusion detection, network analysis, and more.

Access layer: connects the servers physically attached to the network. The access layer consists of modular switches, providing both Layer 2 and Layer 3 topologies, fulfilling the various servers broadcast domain or administrative requirements.

5. DESIGN OF THE DATA CENTER

The design process will combine the discussed technologies. The components and architecture for the implementation of the project, CISCO is chosen. According to "Infonetics Research"[10], published on 2013, as a leading company for equipment and necessary documentation delivery, CISCO is indicated. The percentage of CISCO in the market for different Data Centers components is higher than other companies:

- technology innovation: 55%;

- security: 42%;
- management: 50 %.

The CISCO layered model of Data Center architecture offers the possibility for modular design with a remarkable flexibility. This is not only for new communication devices, but also for new emerging technologies that can be very easily implemented into this model.

Other argument to choose CISCO for the implementation of the Data Center in New Bulgarian University is the fact, that the University has network and communication equipment as well as necessary system software of CISCO.

Using expandable, modular equipment or clustered devices that can be easily upgraded to increase capabilities. Device modules can be added to the existing equipment to support new features and devices without requiring major equipment upgrades. Some devices can be integrated in a cluster to act as one device to simplify management and configuration [7].

There are a lot of requirements in the design process, concerning the structure, settings of the devices, communication lines, routing etc. Some of these requirements are the same as in the case of installation of new HW or SW.

But in the project the major design principles that are followed were:

Modularity and Flexibility: using POD, the structure of the Data centers can be upgraded in every moment, according to the real needs of the customers.

Reliability: uninterrupted service and continuous access are critical to the daily operation and productivity of the business. The infrastructure must consistently support the flow of data without errors that cause retransmission and delays. As networks expand and bandwidth demands increase, the data center infrastructure must be able to maintain constant reliability and performance [7].

Manageability: is the key to optimizing the data center. The infrastructure should be designed as a highly reliable and flexible utility to accommodate disaster recovery, upgrades and modifications [7].

The design process includes the following phases - Fig. 5.

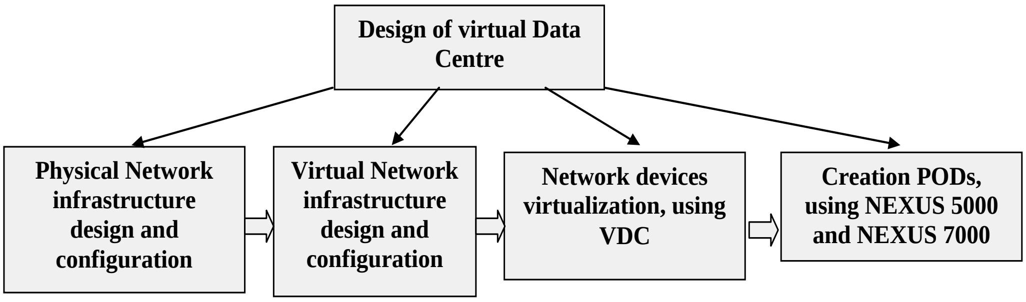

Fig. 5. Design Process

In the initial phase, it is necessary to design the real network infrastructure, switches, routers, communication lines, etc. This is the phase where all necessary physical devices must find their position and roles within the Data Center, i.e. to build the topology of the Center – Fig. 6.

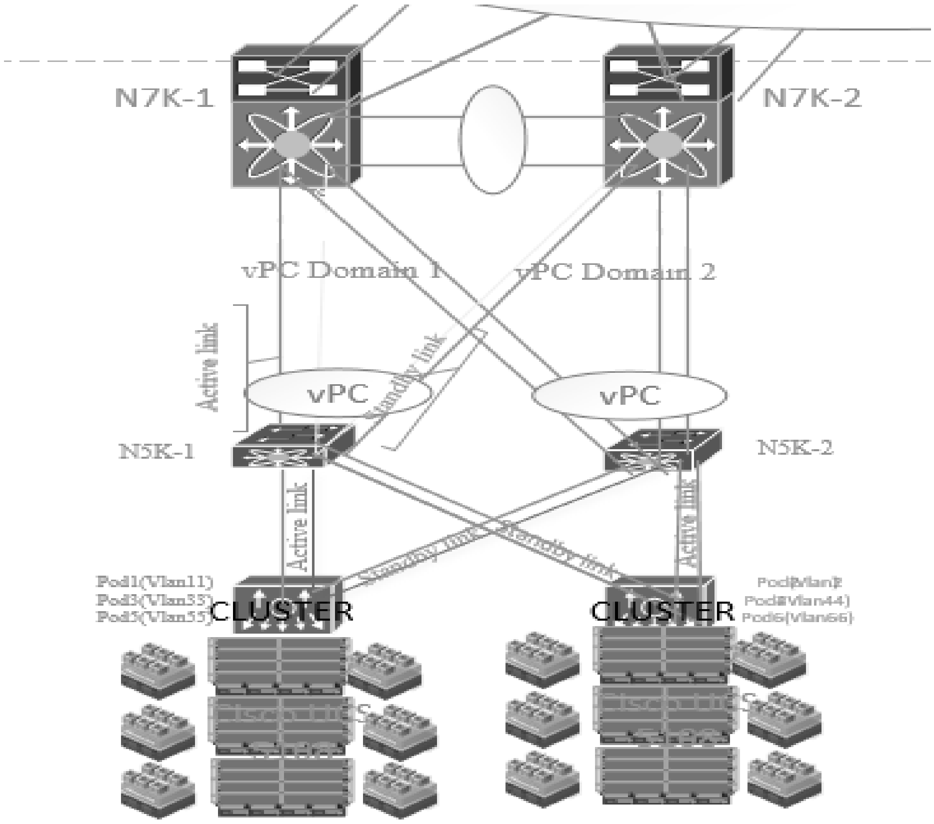

Fig. 6. Logical view of network topology, with the traffic path of the various PODs

To be considered as one system under centralized control, this real infrastructure has to be virtualized. This is done by the second and by the third phase of the design process.

The last phase of Data center design is to create the modular building blocks of whole system so called **POD** (**P**ool **O**f **D**evices). POD combines several physical devices under common control by the Operating system. In the project creation of POD is done by NEXUS 5000 and NEXUS 7000. For the users such POD are considered as one virtual device, regardless how many physical devices are inside it.

The comparison between Physical and Virtual POD is shown in Fig. 7.

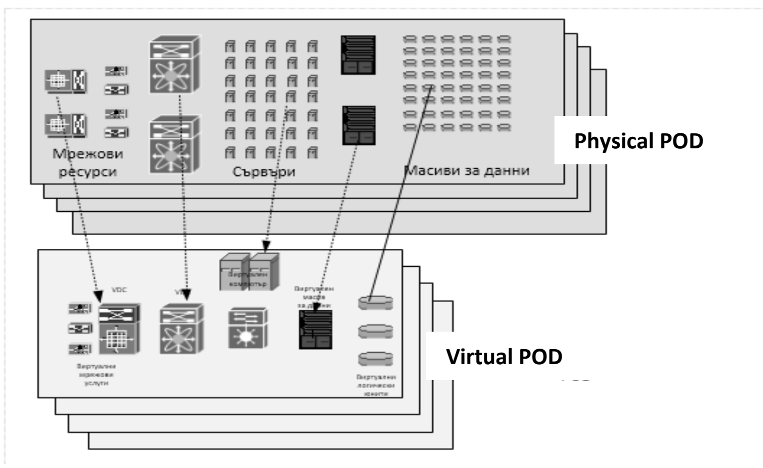

Fig. 7. Physical and Virtual POD

Within a POD, Layer 2 switching is handled by **VPC** (Virtual Port Channels), which provide an environment that does not depend on **STP** (Spanning Tree Protocol), but converges quickly in the event of failure, using **MSTP** (Multiple Spanning Tree Protocol) –Fig.8.

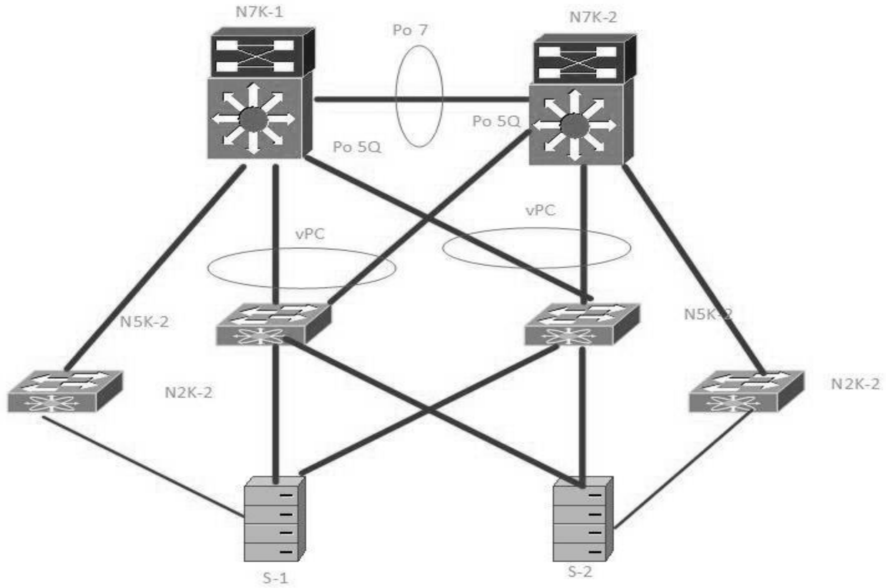

Fig. 8.Part of the topology, implementing MST

6. IMPLEMENTATION

The discussed phases are implemented, using **CISCO Unified Computing System Manager** (**UCS**). It is graphically based and it is very user-friendly.

The system controls all resources of the Data Centers: LAN, unifying Network controllers, by real MAC addresses of them, design of VLANs, IP addresses allocation, etc.

The navigation panel is divided by 2 parts: on the left are the objects to be configured, on the right – configuration settings – Fig.9.

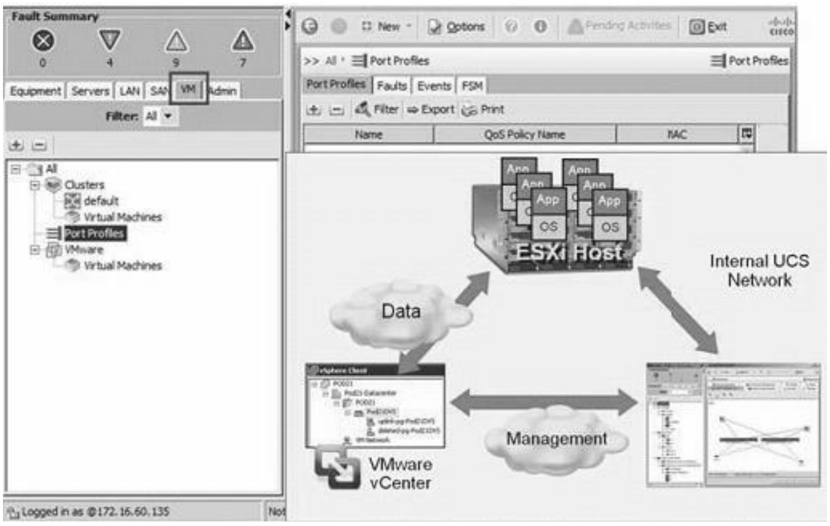

Fig. 9.UCS Manager Navigation panel

Project demarcations:

- the data center must contain 6 POD, composed by 4 virtual machines with installed on them OS, applications, etc.;
- each of these machines represents separate Virtual LAN;
- access and aggregate layers to be configured using the technologies VPC (Virtual Port Channel) and MST (Multiple Spanning Tree);
- virtualization of the switches to be configured using VDC (Virtual Device Context);
- the different PODs to be configured as follows:
  - POD 1 and POD 4 – using **FabricPath**;
  - POD 2 and POD 5 – using **VPC**;
  - POD 3 and POD 6 – using **VRFs** (Virtual Routing and Forwarding)

Implementation of the Project

After creation of the topology, using CISCO Unified Computing System Manager allows the settings of all components of the Center.

This includes:

- allocation of MAC addresses;
- definition of MAC pool;
- creation of the table for VLANs as a pool of MAC addresses. Part of the table is given in Table 1;

Table 1.

VLAN	*VLAN Number*	*IPv4 Subnet*	*Fabric*
pod101-mgmt	*10*	*10.1.99.0/24*	*A, B*
pod101-vmotion	*19*	*10.1.19.0/24*	*A, B*
pod101-data1	*11*	*10.1.11.0/24*	*A, B*
pod101-data2	*12*	*10.1.12.0/24*	*A, B*

- allocation of IP addresses and passwords for the access to the interfaces - Part of the table is given in Table 2;

Table 2.

Device	*Interface*	*IPv4 address*	*Default gateway*	*username*	*Password*
UCS Cluster	*mgmt0*	*192.198.10.200*	*192.168.10.254*	*admin*	*NXos123*
fi6100-A	*mgmt0*	*192.168.10.101*	*192.168.10.254*	*admin*	*NXos123*
fi6100-B	*mgmt0*	*192.168.10.102*	*192.168.10.254*	*admin*	*NXos123*

- assignment of „service profile“ to physical server;
- assignment of POD of servers, combining physical servers in one or many sever pools;
- assignment of created sever pools to end-user compute server pool;
- virtual routing tables creation.

Due to the page number restrictions, it is impossible to quote the necessary settings files. But they can be found in [12].

7. TESTS‘ RESULTS

First tests, created are for applied process automation to provide for virtual machines additional hardware resources when needed, reducing maintenance and process management time.

With a view to implementing the computing center and conducting the tests, real experiments were carried out to distribute traffic from the end hosts united in PODs on parallel open paths between access and aggregation layers.

In each of the layers of Cisco, the hierarchy model illustrates and tests the access, productivity, and performance of the newly-built Data center.

Second tests was tests for the distribution of traffic from available hosts and virtual machines between access and aggregation layer switches were conducted instead using the FabricPath technology, combinations of virtual technologies Port Channel "together" Multiple spanning Tree ".

With the initial input of 24 virtual machines distributed across 6 virtual networks, traffic from 12 virtual networks is redirected to VPC domain 1, with the root bridge from the MST Nexus7K-1 switch and traffic from the other 12 Virtual machines are redirected to "VPC domain 2" with "root bridge" from the "MST" switch "Nexus7K-2" / fig.12/ . Accordingly, the other uplinks are back-up for the corresponding virtual networks in case the primary access path fails.

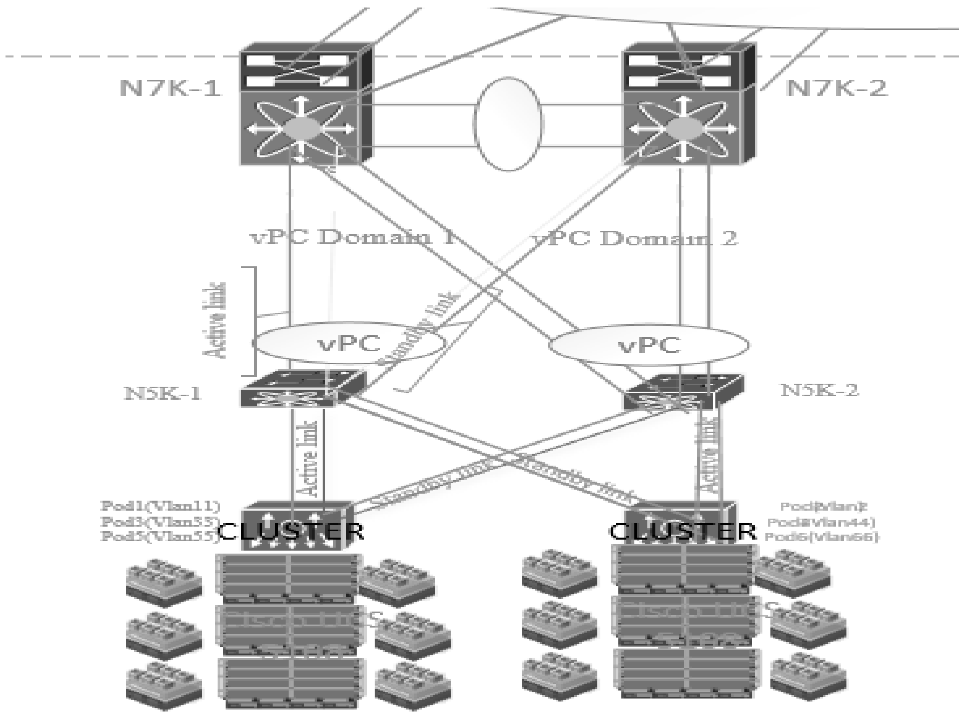

Fig.12. Logical view of network topology, with the traffic path of the various PODs

For the purposes of the second stage tests, the distribution of traffic on the same access paths is configured for configured vPC with MSTs between access and aggregation layer switches. The distribution of traffic is on the virtual networks of the respective PODs, respectively the odd in the active connection up to the Nexus7K-1 switch, and the even is the active link upwards Nexus7K-2 switch.

Also described is the creation of a network of pool of devices, each consisting of one access layer switch and two switching layer switches. The virtual channels of the physical network infrastructure have been built and tested, balancing the traffic from the terminal devices in parallel to the two aggregation layer switches. The network PODs are divided into MST regions and is balanced traffic to the two Nexus switches from an aggregation layer, synchronized by an active virtual channel with a root bridge switching over an aggregation layer. Each of the switches has a separate VDC, through which the corresponding switch belongs to the individual PODs.

At the first stage, with the VDC, the network pods were created, in the second stage - in the VDC with VRF themselves, the traffic is segmented and managed with different routing rules. Consecutively, static access paths between end devices and virtual switch interfaces are configured in the first "VRF".

The second VRF is configured routing protocol OSPF, and the third - EIGRP. The configurations for the different VRFs are described, the logical topologies are illustrated in graphical form and the results for successful communication are shown.

Traffic is divided by the odd numbers VPC with odd regions of MST, respectively Root Bridge is the left-handed Nexus 7K-1 switching layer switch.

To illustrate the results in applications are presented the configuration files of the switches from an access layer and aggregating prior to the configuration of the respective technologies distributed by PODs and the results achieved after the configuration Fig.13.

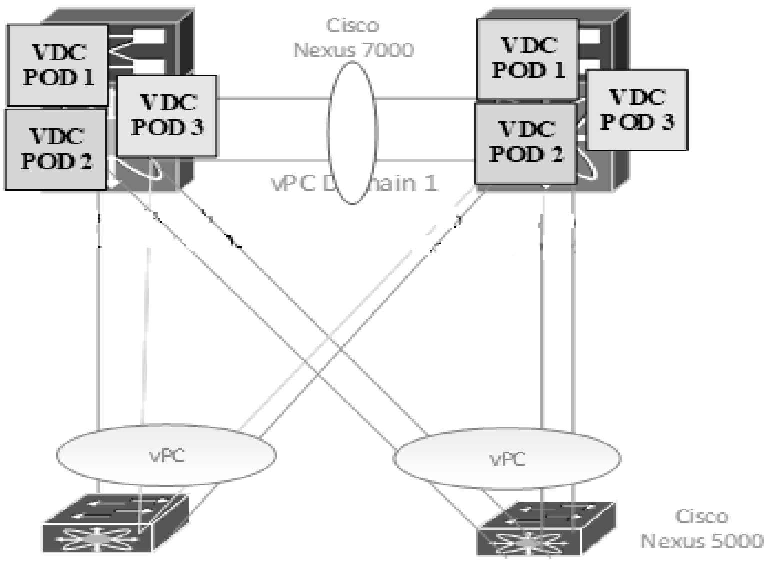

Fig. 13. Logical view of VRFs and PODs.

8. CONCLUSION

The observations made during the 6 months test period have shown that configured network architecture operates, manages and distributes traffic from the end PODs to virtual machines of the various VDCs without compromising productivity and tolerance for errors.

During this period, the number of virtual machines increased and the various virtual networks PODs were terminated by shutting down the physical ports of the switches. In these conditions the traffic from the available channels for parallel access to the available VDC were automatically switched.

The analysis of the results indicated that despite the changes in switching and routing, network performance is maintained and latency does not increase accordingly.

The network works even under extreme conditions. As a result of the built-in denial of one of aggregation network switches and downstream of odd PODs traffic from hosts to the virtual network is automatically redirected to the even PODs on the second switch. This failure did not in any way affect successful communication between end hosts.

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