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Virtualization in Networks: A Survey

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ABSTRACT

Virtualization is considered an integral part of any network. Many new features and services can be introduced with a mere implementation in software and without deploying extensive hardware. In this survey we will be looking at the history and motivations that led to the realization of virtualization techniques. We will be studying its architecture, current technologies followed by challenges and future of virtualization.

Keywords – *Virtualization, VLAN, VPN, Cloud Computing, Virtualized Data Centers.*

1. INTRODUCION

Virtualization may be considered as implementing or creating a virtual version of any service/technique. Virtual implementation has many benefits as compared to the practical real implementation. Many new techniques are implemented in test beds which are set up virtually, may be in a single system implemented as virtual machines. Old implementation of virtualization dates back to the concepts of Virtual LAN's. We still see its implementation in today's environment. The motivations behind the idea of virtualization becoming a reality were to improve scalability, improve hardware resource utilization and of course to centralize management and administration of resources.

Virtualization can take any form; it is not just limited to one aspect of networks. Some types include Hardware, Desktop, Software, Memory, Storage, Data and Network Virtualization. Virtualization has found its implementation in all the walks of life, starting from networks to medicine, defense and sports etc. Legacy virtualization was present in the form of VLAN's, VPN's and Overlay networks. Nowadays we are seeing virtualization at a new level with cloud computing, virtualized data centers, data warehousing, software defined networking and many more [1].

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2. LEGACY VIRTUALIZATION TECHNIQUES

2.1 Virtual Local Area Network (VLAN)

Before the invention of VLAN's, scientists and network administrators were facing issues which were related to the increasing number of network users and distributed administration. Due to the fact of increasing network, there was a need to connect multiple Ethernet networks together and to administer it centrally or locally. Around the year 1985, there was no unique and safe way to connect multiple Ethernet networks without addressing the issues of Ethernet being a single broadcast domain, administration and security issues. A number of other techniques were also proposed to achieve this task. Such as IP Routing to connect multiple networks together. However, this was achieved at the cost of deploying hardware way costlier at that time. Dr. W. David Sincoskie, was working at that time in Bellcore and was dedicated to find a solution to this problem. In the process of doing so he came out with the self-learning Ethernet switch which solved this problem. However, Sincoskie also found out that the implementation of this Ethernet switch would be in a redundant fashion to ensure redundancy and off course with multiple links connecting Ethernet networks together. This implementation required a Spanning Tree configuration causing less resource utilization and a centralized point of failure and congestion. This very issue restricted the scalability issue. So having found so, Sincoskie set out to develop a unique solution and invented Virtual LANs. He accomplished this by adding a tag to Ethernet packets and making the Ethernet switches smart enough to handle different families of tags, thus, creating separate different virtual instances of networks all connected together over the single Ethernet channel. Link aggregation was also implemented with this technique to ensure better network availability and speeds.

Nowadays, we know this tag as the VLAN tag present in the Ethernet Header. VLAN's have, in the modern times, found application not just addressing the main motivations for its inventions but many new implementations which as per the demand of the time got developed and VLAN's were polished and developed even further.

Another motivation that led to the invention of VLAN's was that in the old times, users were grouped into networks based on their geographic location and Ethernet implementation techniques. Two users on the opposite side of the globe can be logically made a part of a single Ethernet network using VLAN's irrespective of the geographic location and topologies as well as implementation techniques. Asynchronous Transfer Mode (ATM), Ethernet, Fiber Distributed Data interface (FDDI), Infiniband & HiperSockets all are capable of implementing VLAN's and thus solves almost all the problems being faced by the researchers in the year and before the invention of VLAN's. VLAN's also provide increased security and easy network management by logically grouping users as a part of different Ethernet Networks [2].

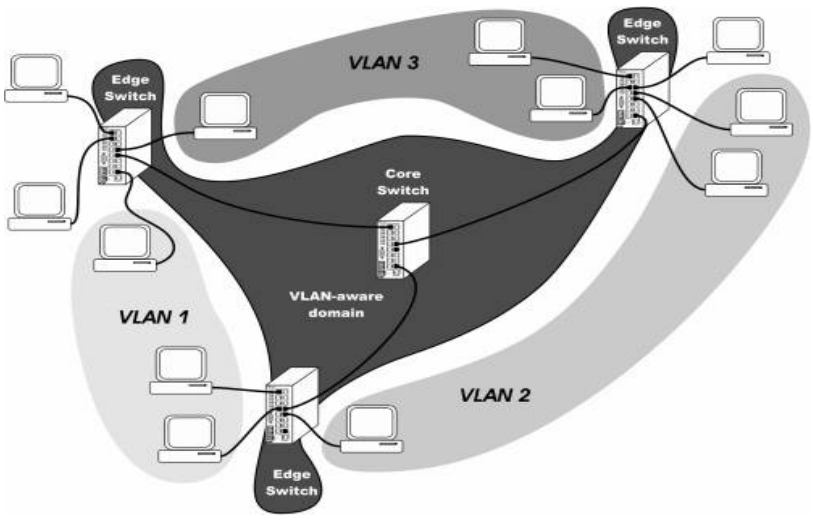

Figure 23: Example VLAN implementation over three geographically distant networks [3]

2.2 Virtual Private Network (VPN)

Virtual Private Network extends a local private area network on the WAN links to users geographically apart by using the public or shared networks. Users who are a part of a single VPN can share files, resources and perform all the functions that the users of a private network perform. End users are not aware of the implementation and the fact that they are being a part of a single Private LAN over multiple other public and shared networks. End users see themselves as a part of a single network. VPN offer us with enhanced features such as increased services, better security and better network management.

Virtual Private Networks exists in many forms and types based upon its implementation and type of service it provides. We can categorize VPNs under OSI Architecture as being Layer-2 and Layer-3 VPNs. In a more general sense we categorize VPN by level of security in provides, live or remote connectivity, termination point (customer or network end) and by the protocols it uses to channel and route traffic. Legacy implementation was rather different from current implementation. In the old days, VPN connectivity was generally provided through dial up connections over leased lines acquired from operators using frame relay or ATM technology. If we compare these implementations with today's implementation we won't call this implementation to be a true VPN based implementation. Actual implementation includes IP Based and MPLS based VPNs provided over DSL Lines or fiber optic cables providing high data rates and speeds. Such implementations are cost efficient as well [4].

Explaining further, we may notice that VLANs and VPN are practically the same as they provide the same features of bringing end users over a single private network irrespective of their geographic location. Here there is a difference; VLANs are a subnet of VPNs. More specifically VLAN are Layer-2 VPNs. VLAN may spread over a small area like a Metropolitan Area Network; however, VPNs generally extend over WAN networks. VPNs also allow connectivity between two similar networks over a different network, such as connectivity between two IPv4

networks over an IPv6 Core and vice versa. This is achieved with the concept of Tunneling. Virtual Private Networks offer many new and enhanced security features that were developed after the first implementation of VPN. VPNs usually provide security by tunneling protocols coupled with security protocols such as encryption. Encryption provides over man in the middle attacks, as only the sender and the destined user will be able to decrypt the sent data. Encryption is another domain that is way too complex to discuss here. Apart from encryption we also have authentication procedures as well. After the message is received its integrity is also verified in order to avoid data from being tampered along the path over the Public Internet.

In the modern word, VPNs are being used at a whole new level. VPN's are nowadays being used in environments where end users roam around in the network and are subject to mobile IPs may belonging from different subnets. Such implementations provide remote/live access to critical and important applications and services to intended users by providing them with access to their home network. A lot of issues are faced by implementation engineer regarding this technique. A new research is underway which deals with another method of identifying hosts on the move or mobile hosts a part from their IP Addresses to provide VPN Access. This technology is known as Host Identity Protocol (HIP) which provides VPN services by use host/device identification techniques.

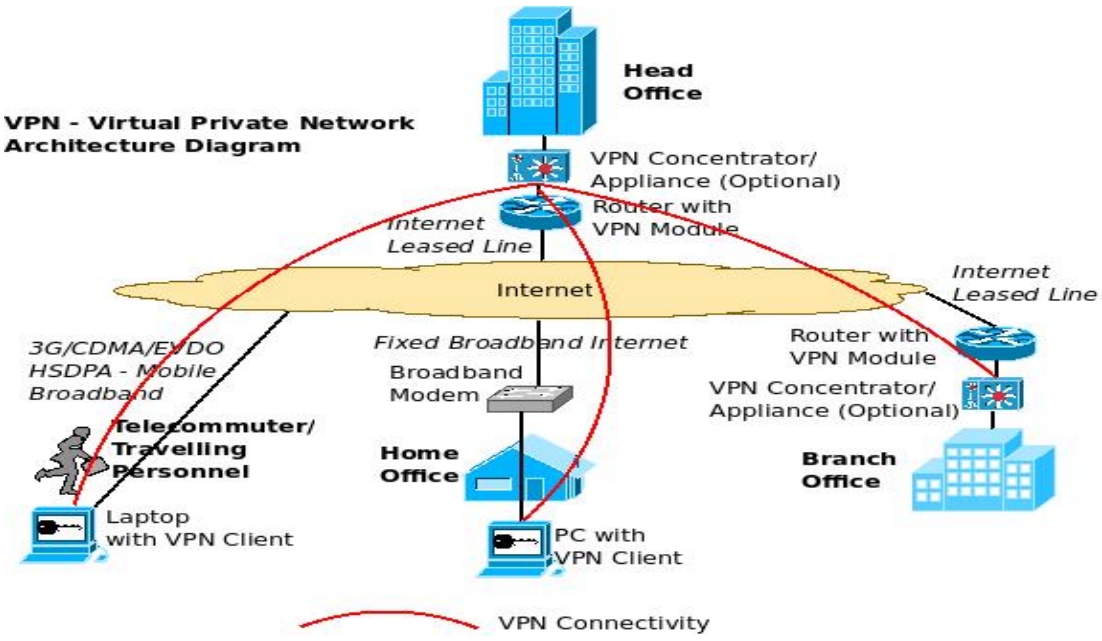

Figure 24: Example of VPN implementation over the public Internet [5]

2.3 Overlay Networks

Overlay networks are networks built on top of other networks. Overlay networks may be connected to existing networks by logical, physical or virtual links. Overlay networks uses the functionality of underlying networks are provide new features. Overlay networks are a good

example of virtualization. As such networks may not involve deployment of physical network or infrastructure or modify any protocols or software. Overlay network on the other hand may require more processing power as compared to normal existing networks which may be physically deployed and are not meant to provide enhanced features.

The concept of overlay networks dates back to the early times of the development of Internetwork. Internetwork was known as the interconnection of various networks geographically distant. Internet is an example of overlay network built on top of existing Public Switched Telephone Network (PSTN) providing enhanced features and services such as packet switching to support the needs and requirement of the research community at that time. Internet was officially launched as a commercial utility in the 1980s. Since that time the overlay networks have evolved [4]. Overlay networks provide Peer to peer services being used for file sharing, content delivery to allow localized caching and storage to minimize delays and transportation charges, routing, security and many other services including Electronic mail service, VoIP etc.

The key benefits of overlay network services are that overlay networks need not to be deployed on every node of the network for its working. These networks are deployed centrally and other nodes access these via local or remote connectivity directly or by VPNs. Overlay networks on the other hand may increase complexity and increase processing delay as any extra virtualization layer has been added to the normal operation procedure. But this issue has been taken care of by implementing servers and nodes having increased processing capabilities and heavy storage space to facilitate a large number of users. Overlay network implementations exists in commercial, industrial and private applications. Over the years many new and advance services have been developed based on the test bed implementation on the overlay networks. Some examples of Overlay Networks are MBone, 6-Bone, the X-Bone, Yoid/Yallcast and ALMI [6].

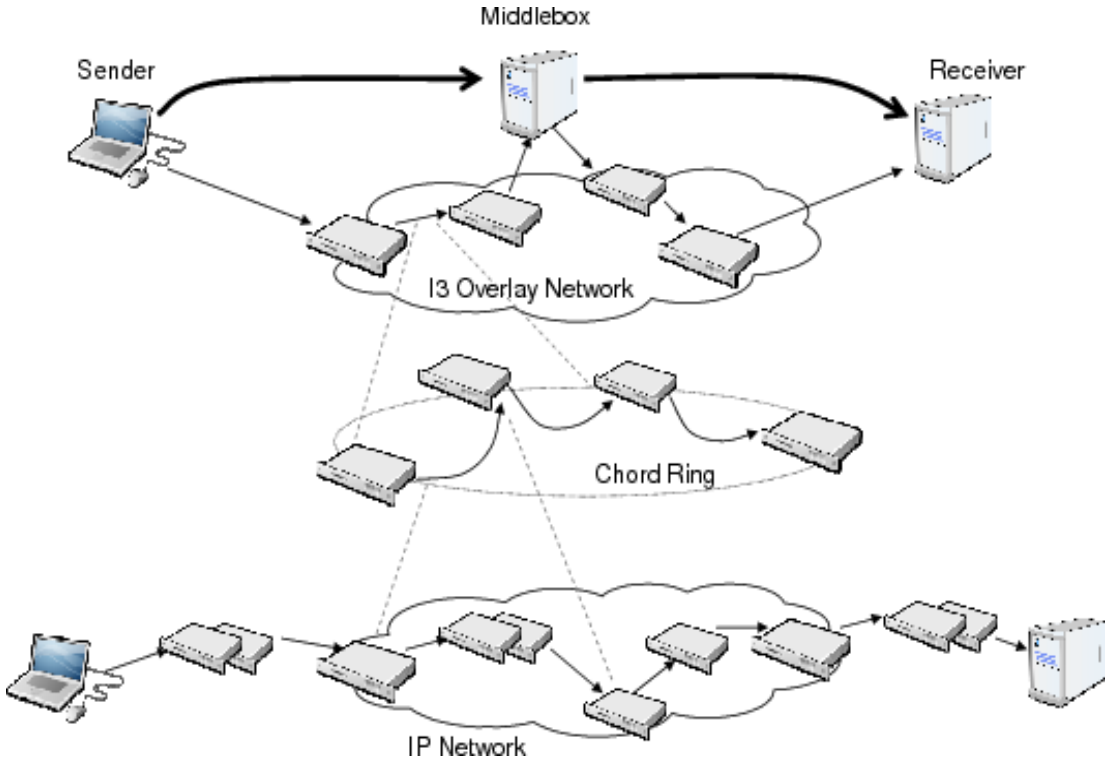

Figure 25: Example of Overlay Networks built on top of IP Core [7]

3. PRESENT & FUTURE VIRTUALIZATION TECHNIQUES

In the present, day we see Virtualization at a whole new level. Extensive features and services are provided with centralized and distributed implementations. Here we will discuss some the state of the art virtualization techniques.

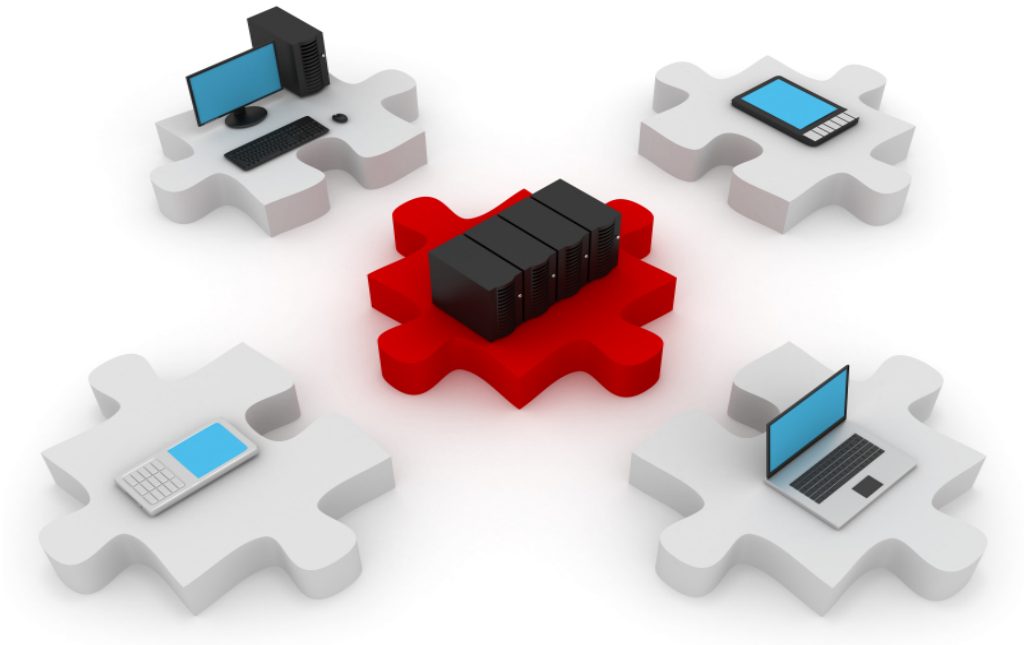

Figure 26: Generalized concepts of Cloud computing & Virtual Data Centers [8]

3.1 Cloud Computing

Cloud Computing is basically a set of services or resources being delivered to Users over an infrastructure, typically over any network. Usually the internet is the base for the provision of such services. A user can use any service such as office, storage space, any software or any feature online on the Cloud without having to install and configure software. On a generic level, cloud implementation is viewed as a single abstract cloud from the user perspective; however, from a network professional's perspective it contains number of routers, switches, servers and many other nodes.

The concept of cloud computing dates back to the early 1950s when many universities were equipped with large-scale mainframes which were accessed by thin client (Dumb terminals having no/less capabilities) to perform heavy/complex functions on their own. In 1960s John McCarthy said that in the future computation will be organized centrally as a Public Utility. In 1966, Douglass Parkhill's book "The Challenge of the Computer Utility", explained many modern day cloud computing features. He explained the ideas of elastic provision, online, illusion of infinite supply and many other ideas. Similarly, cloud computing concepts were also explained by numerous other scientists dating back to the 1950s and until now [9].

After the dot-com bubble, Amazon developed their data centers and ware houses and enhanced the concepts of cloud computing. After much research, in 2006, Amazon launched a commercial product to the end users under the name of Amazon Web Service (AWS) on a utility computing basis. In 2008 Eucalyptus became the first open source platform for deploying private clouds. Similarly, in the same year OpenNebula became the first open source software to implement and offer private as well as hybrid clouds. In the Mid 2008, the patch between the providers of IT Services via cloud and the end users was filled by Gartner. And presently we have evolved to a new era of Smarter Computing which was announced by IBM on March 1st, 2011. It is basically a framework that supports Smarter Planet which contains all concepts relating to Cloud Computing. Smarter Computing is a copy right IBM Specific name for the provision of cloud computing services for enterprise companies for Business use. They offer service via private, public and hybrid cloud delivery method as required.

Public cloud computing are of various types which include, Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS), Storage as a Service (STaaS), Security as a Service (SECaaS), Data as a Service (DaaS), Database as a Service (DBaaS) and Desktop Virtualization.

Figure 27: Example of Cloud Computing with all services centralized [26]

3.2 Virtual Data Centers

Data Centers are places where computer systems, telecommunication systems and other related equipments are housed. Such centers are redundant in any type of service they provide. Heavy storage and backup systems are deployed to provide non-stop service to consumers. Data centers can be as large as taking up the space of an entire building. Data centers consume loads of electrical. Backup power systems such as battery banks and backup generators are installed to provide 24/7 Service Availability. Large scale air conditioning is required to cool the equipment installed. Redundant links are installed to avoid faults causing services outage.

Data Center concept dates back to the old times when we use to have main frame systems and servers. With the dawn of the micro-processor industry, personal computing become very much popular and advances in centralized computing or data center halted. With the introduction of client-server computing in the early 1990s, computers started finding their way into old computer rooms. Data center technology observed a boom during the dot-com bubble period. Many companies started deploying heavy equipment in data centers and started providing industries, vendors and operators with unified services and solutions. With the introduction of cloud computing data centers started to get regularized and standardized. Proper data center requirements, designing and safety procedures were published.

Data Centers are categorized into four tiers, which are based on their functionality and availability. For Example, tier 1 is just a mere Server Room housing small scale computing equipment. This server room is non-redundant and offers expected availability of 99.671%. Tier

2 meets all the requirements of Tier 1 but provided redundancy and offers expected availability of 99.741%. Tier 3 meets all the requirements for Tier 1 and 2 with extra specification of dual power sourced and independent connectivity to the IT Room and expected 99.982% availability. Tier 4 is the most crucial mission sensitive level which fulfills requirements of all lower tiers plus all equipment being dual powered HVAC systems and offers 99.995% availability. All these specifications are standardized [10].

All solutions and services being offered by Data Centers are effectively virtualized and all the end users can access and utilize these services 24/7 from any geographical location. Virtualization in data centers are effectively divided into five levels of degrees. Degree 1 is the virtualization of a specific application or a specific task of a company's array of services and solutions and Degree 5 being the Virtualization and Automation of the entire services platform. All the degrees in between these two extremes offer and follow a hierarchical pattern. Virtualization of services and application is much cheaper than the actual real life replica of the same services. We can achieve 10 times the processing power with 1/3rd of the cost of actual implementation by including and deploying such a system in the virtualized space [11].

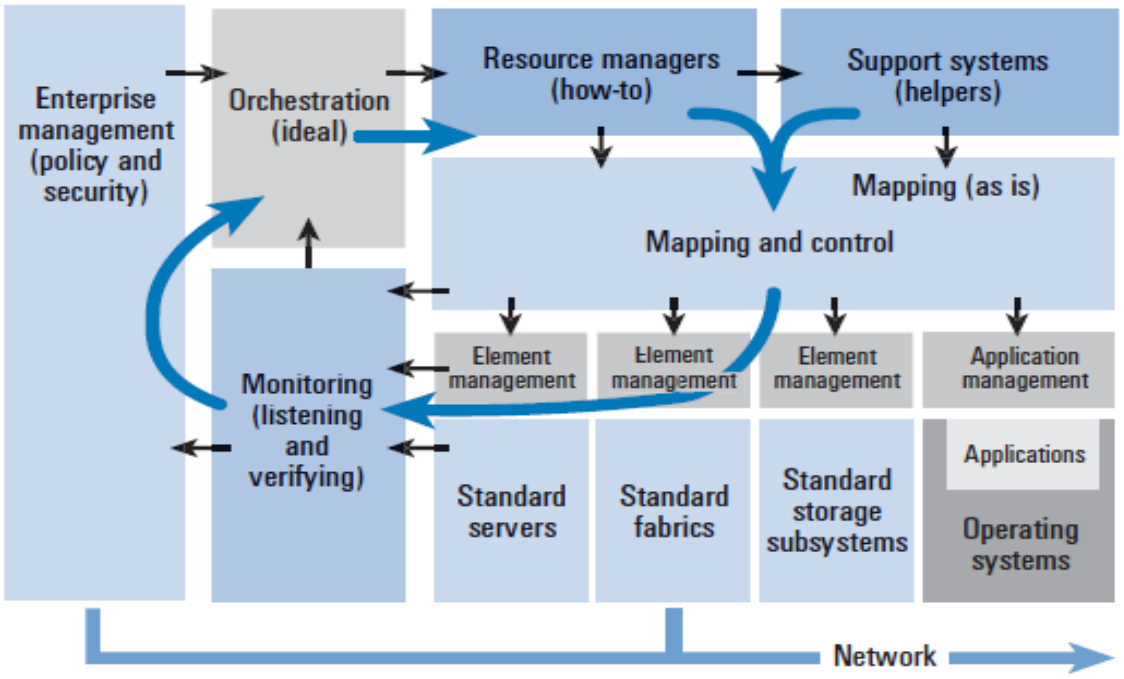

Figure 28: Example of Implementation of a Virtual Data Center [7]

3.3 Software Defined Networking

Software defined networking is an architecture specifically designed for the networking domain. This architecture is based upon the segregation of the control and data plane in networks. The control plane is implemented in software away from the networking equipment

installed at different locations. The data plane is however implemented in the network equipment such as router and switches. SDNs offer many new features which include simplified management and configuration, optimization of routing policies and protocols, remote access to network equipment and much more. SDN implementation breaks the barriers of vendor specific implantation and works over all equipments of various vendors. The most popular specification for implementing SDN is the Open Flow standard.

This technique is very useful for network administrators as it simplifies networking and managing the traffic. Administrators can block users, change switching policies, prioritize packets and even block packets at granular level. This architecture is very much useful in Cloud Computing, Virtualization and management of VPNs. There are various deployment strategies for software defined networking implementation. Some techniques include Symmetric vs Asymmetric information handling, floodless vs flood based and host based vs Network-centric models. Administrators can access and configure different aspects of any network by using or logging onto a centralized console at the virtualized data center via VPNs or virtual tunnel techniques.

The motivation behind the implementation of software defined networking is fairly simple. Management of large networks which are deployed globally was very difficult task. Access to remote sites was not present which in case of an outage or fault caused a lot of time for rectification. SDN can be implemented in Data centers at any severity degree level and at any tier as per requirement.

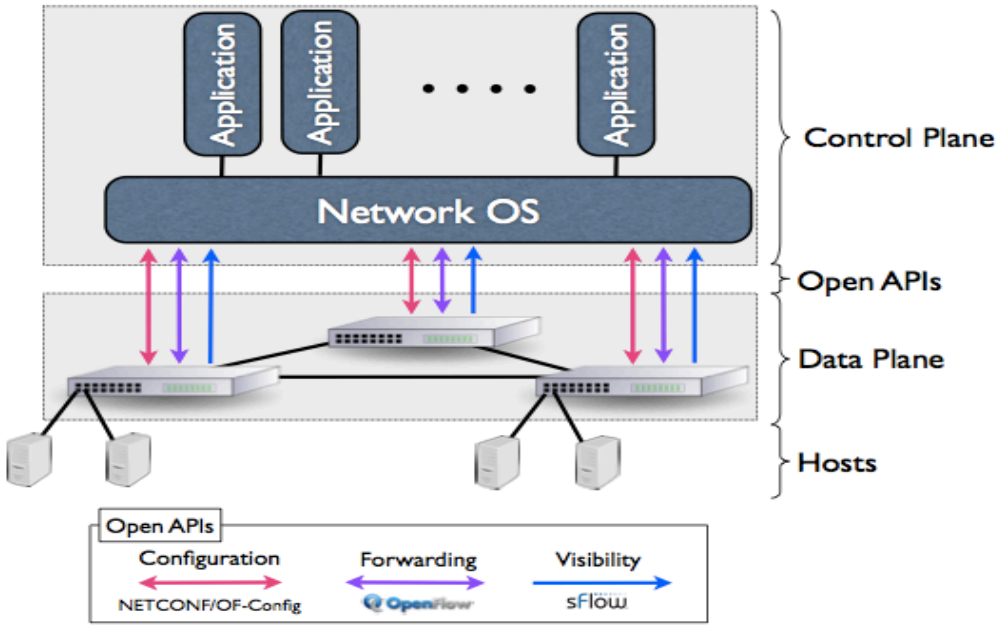

Figure 29: Example of Implementation of SDN [12]

4. CHALLENGES

There are a lot of challenges that have to be dealt with while vitalizing some enterprise environment. Virtualization of applications and software on a single server may be questioned to be as a single point of failure. Dependence on a single server may be considered as risky. This challenge is reduced with the implementation of a redundant server and redundant links. Redundant servers can run in any configuration, such as Hot Standby, Dual Homing or in a load balancing configuration. This solution comes with an increase in cost. Servers are high end computing machines and costs a lot. Another challenge that deployment specialist face is that they have to ensure that the deployment is fault tolerant and avoid network outages at all costs. Servers and systems should be self-sustaining and should have the capabilities to self-recover after any sort of failure.

Resource Starvation is also considered to be an important aspect of virtualization. Running several instances of virtualization or virtual machines can significantly increase hardware resource utilization and choke resources. It burdens the infrastructure causing delays, decreased performance and resource/service availability. I/O bottlenecks can be observed if several resources are being used from the same network interface card or any other I/O equipment. Experts have solved this problem by offloading such extensive I/O hungry operations on a separate device dedicate to perform only a specified task. This will only increase the cost by a small amount but it avoids bottlenecks which is a critical to consumers and service providers.

On many occasions it has been observed that, implementation engineers virtualized the OS itself on a server while the applications are not virtualized which can cause the application to not respond to a large number of requests. Applications have separate I/O, memory and storage requirements which are very different from the requirements of the OS itself. So when large number of users tries to access the application, it can cause the server hardware to overload and cause service outage. Engineers must ensure the resource and other requirements of all the applications being virtualized by the OS, so as to avoid unnecessary after implementation costs and outages [13].

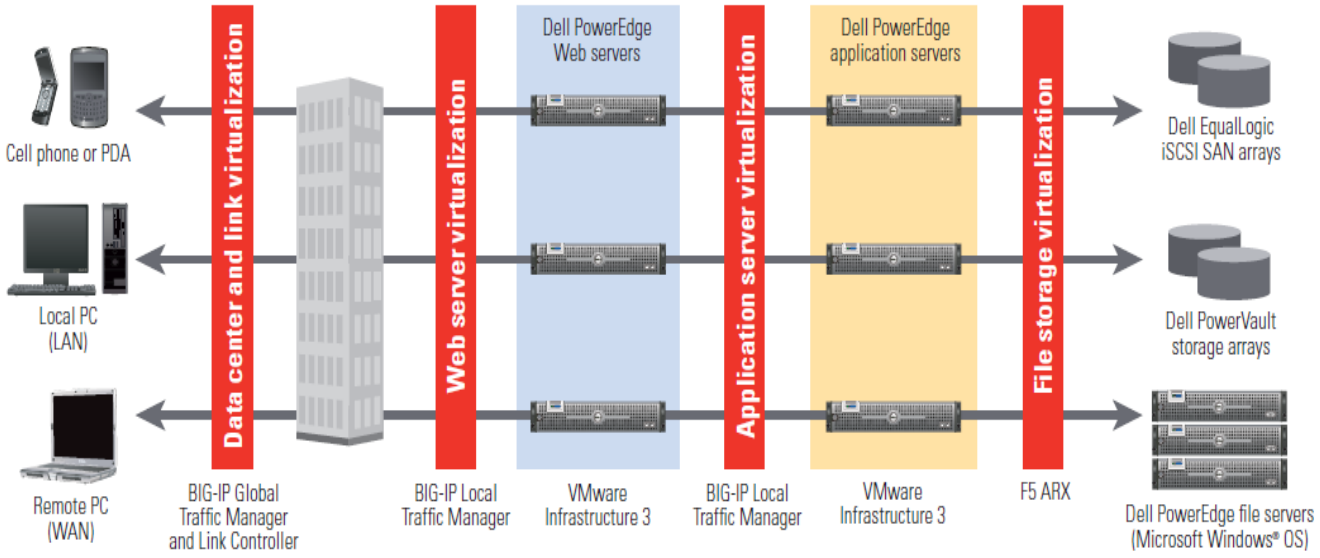

Figure 30: Different Types of virtualization at different stages [8]

Virtualization is implemented to reduce data center costs, minimizing power consumption and increase business productivity. In some cases, unanticipated costs can reduce the above mentioned objectives. Ineffective planning and incomplete design can cause the service provider to offload services or to increase physical servers to cater for the growing requirements of the service. Virtualizations of Operating systems need to run many instances of virtual machines causing large storage requirements for storing and running Virtual instances of OS and applications. Same is the case when the server is not being used to its intended purpose causing resource wastage and ineffective allocation of resources causing many problems. Storage requirements can increase over time as OS can occupy over hundred giga bytes of space after virtualization on shared file sharing servers [14].

Management of a virtualized environment can often turn into a complex and difficult task. Management terminals and interface can give us an insight to virtualized features, their usability, resource utilization, load information and many other performance metrics but will not provide an insight on the data center as a whole. For this administrators have to use many other utilities to manage every aspect of the data center which increases complexity, cost and time to manage a virtualized environment. The implementation, as mentioned before should be self-sustaining. Decision should be based upon data being received from different nodes and monitors should monitor difference performance metrics and deciding to offload, balance or notify for a hardware capacity increase if the limit is reached. Modern techniques and experts cater for all these challenges at the time of deployment and leave ample space for fault tolerance and scalability keeping in view the exponential nature of growth of users over the internet.

5. NETWORK VIRTUALIZATION PROJECTS

Many projects have been introduced that offer different services and platforms related to VPNs, cloud computing and Virtual Data Centers. Some of the projects are worth mentioning here. These projects are differentiated by their characteristics and features. They vary on the basis of Network Technology, layer of virtualization, Level of Virtualization and Architectural Domain [15].

Table 6: Comparison of various network Virtualization projects

Project	Architectural Domain	Networking Technology	Layer of Virtualization	Level Of Virtualization
VNRMS [16]	Virtual network management	ATM/IP		Node/Link
Tempest [16]	Enabling alternate control architecture	ATM	Link	
NetScript [17]	Dynamic composition if services	IP	Network	Node
Genesis [13]	Spawning virtual network architectures		Network	Node/Link
VNET [18]	Virtual machine grid computing		Link	Node
VIOLON [19]	Deploying on-demand value added services on IP overlays	IP	Application	Node
X-Bone [16]	Automating deployment of IP overlaps	IP	Network	Node/Link
PlanetLab [17]	Deployment and management of overlay-based test beds	IP	Application	Node
UCLP	Dynamic provisioning and reconfiguration of light paths	SONET	Physical	Link
AGAVE [12]	End to end QoS aware services provisioning	IP	Network	
GENI	Creating customized virtual network test beds	Heterogeneous		
VINI [21]	Evaluating Protocols and services in a realistic enjoinment		Link	
CABO [11]	Deploying value added end to end services on shared infra structure	Heterogeneous		Full

6. CONCLUSION

Following from the beginning of the internet to the modern day version of the internet it is evident that Virtualization has been the corner stone for development in the IT Infrastructure. Many forms of virtualization have been seen over the course of time. Each instance and version was designed to address a specific issue faced at that time. The computing trend varied from being Centralized to distributed and then back to being centralized as we see nowadays which is the basis of Virtualized data centers and data ware houses. Virtualization allows businessmen, professionals, policemen, doctors to stay connected with crucial applications and resources on the go 24/7. Virtualization has reached every scope of life with a new twist to every deployment. It has made the life of administrators simpler and easier.

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