Virtualizing Service Infrastructure with Hardware Gateway in Data Center

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Abstract: Service providers have been struggling with service infrastructure management in their data centers like taking care of excess or shortage of physical resources. To solve the issue, we propose virtualization of service infrastructure by connecting physical resources with hardware gateway and virtualize network traffic among physical resources. With this approach, service providers can make their service infrastructure more flexible and dynamically change service infrastructure configuration like adding or removing physical resources on demand.

1 INTRODUCTION

As more and more enterprise companies and organizations have been using IT services like cloud computing service, service providers have been facing challenges to achieve higher resource utilization and scalability in their data centers to make them competitive in the service market.

However their data centers are becoming "siloed" environment where resources are physically divided into service infrastructures (silos) rather than a single flat resource pool. This is because scalability limitations of components used in each service infrastructure (silo), like specification maximums of server virtualization software, network and storage system. As a result, service providers are struggling to improve resource utilization and scalability.

To mitigate this situation, network virtualization has been tried in service providers' data centers in the last several years so that service users' network can be expanded among different silos. But silos still exist and their sizing, configuration changes and operation are still tough problems.

To solve these problems caused by silos, we propose virtualizing silos themselves by using hardware gateway. Virtualizing silos and using server virtualization inside silos could cause management complexity. We introduce the 2 layered hierarchy where each can focus on user service and resource service respectively.

2 OVERVIEW OF CHALLENGES OF CURRENT DATA CENTER

2.1 Overview of Data Center Network

In the IaaS (Infrastructure as a Service) service infrastructure, server virtualization software has been widely used where the server virtualization manager software manages hypervisor software on physical servers (hypervisor host), deploys Virtual Machines (VM) on hypervisor hosts and moves VMs among hypervisor hosts (live migration). The logical network separation technology like VLAN (Virtual LAN) is used to isolate VM network traffic for multi-tenancy and shared storage system is used to store VM images so that VMs can be moved among hypervisor hosts. There are commercial and open source server virtualization and IaaS software like VMware vSphere, Microsoft Hyper-V, OpenStack and so forth (see the Reference Section).

In such an environment, service infrastructure cannot scale well and has to be divided into silos because there are scalability limitations in server virtualization software, network and shared storage system. For example, server virtualization software has configuration maximums based on software specification. Some of them are explicit and documented, but some are not and realized only in real practice. Even different versions of the same server virtualization software sometimes cannot

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work together and a service provider has to manage different versions respectively. When a service provider has a multi-vendor policy and uses different types of server virtualization software to avoid vendor lock-in, it is likely that they cause inter-connectivity problem as well. Even if a service provider tries to make homogeneous infrastructure, technology and software evolve and change day by day and result in heterogeneous infrastructure. Network also has its scalability limitation like the maximum number of VLANs. Share storage system has I/O maximum as well. Even worse, when a service provider tries to provide a wide variety of services like IaaS, managed service, PaaS (Platform as a Service) and SaaS(Software as a Service), they often have to separate each service infrastructure because of difference among service requirements.

As a result, service provider data center in a real environment is not a flat resource pool. It is divided into many silos as shown in Figure 1. In this example, a service provider data center consists of 3 silos where two of them provide IaaS but use different versions of server virtualization software, and one of them provides bare metal service and does not use server virtualization. Sometimes a silo is called a zone, an island and so forth. In a large data center, there might be even hierarchy among silos. A silo can be a rack or multiple racks.

As service users increase or decrease, service providers have to take care of shortage or excess of resources in a silo. And as services grow or decline, service providers have to take care of expansion or shutdown of a silo as well. However, service providers cannot easily change silo configuration because a silo is a group of physical resources like servers. Changing the size of a silo, creating and destroying a silo require a lot of cost.

In these situations, service providers need workarounds. For example, they need to expand a user system to a different silo in case of resource shortage. They also need to migrate a user system from an outdated old silo to a new one. And they might have to expand a user system across different service silos to meet user's requirements. Because silos are problems in service infrastructure behind the scene, service providers cannot enforce their users to change network configuration like IP addresses when users' system have to go beyond a silo. So, extending user network across silos in Layer2 (L2) has been required so that users don't have to change network configuration (L2 extension). To realize L2 extension, user network virtualization has been tried in the last couple of years (Ben Pfaff et al., 2009).

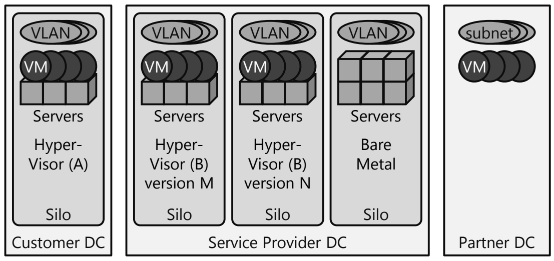

Figure 1: Overview of Data Center.

2.2 User Network Virtualization

An overlay network virtualization technology like VXLAN (Virtual eXtensible LAN), NVGRE (Network Virtualization using Generic Routing Encapsulation) and STT (Stateless Transport Tunneling) has emerged in the market in the last couple of years to realize user network virtualization. The overlay network virtualization uses encapsulation of L2 traffic among virtualization endpoints called VTEP (Virtual Tunnel End Point) as shown in Figure 2. In this example, each VTEP is placed on different L2 network (e.g., VLAN) domain. VTEPs are connected via existing L3 network, and encapsulates L2 network and transfers them to other VTEPs. Because the overlay network virtualization is based on L2 over Layer3 (L3), a large L2 inter-silo network is not required and thus inter-silo network can be flexible. And it can connect multiple silos using multicast or meshed tunnels.

In the market, software-based overlay network virtualization is popular that implements a VTEP function in a virtual switch on a hypervisor host as shown in Figure 3. In this example, virtual switch software with VTEP function is on each hypervisor host, encapsulate L2 traffic of VMs and transfers them to other virtual switches. When it comes to connectivity between a software-based overlay network virtualization environment and a legacy non-virtualized environment, hardware gateway can be used. Some hardware gateway products like a VXLAN Gateway are already available in the market. The software-based implementation is likely to be integrated with server virtualization. With this tight integration, software-based implementation can deploy virtual networks along with VMs deployment.

The user network virtualization using the overlay network virtualization allows service providers to realize L2 extension among silos. However, it is just a workaround in case of resource shortage and user system migration. And it works only for silos that use the same server and network virtualization software. Service providers still have to take care of situations like excess of resources in a silo, and expansion or shutdown of a silo. It is difficult for service providers to forecast service demand and estimate how many resources would be necessary in advance. In case excess of resources happens in a silo, it directly affects service providers' cost. And even though another silo is running out of resources, user network virtualization might be impossible because another silo is not using the same server and network virtualization software. In that case, moving resources from one silo to the other is costly, time-consuming and might cause miss-operation because resources are physical.

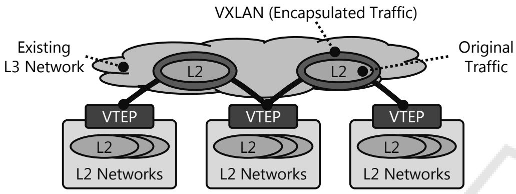

Figure 2: Overlay Network Virtualization.

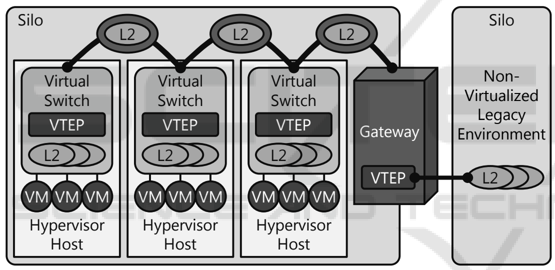

Figure 3: Software-based Overlay Network Virtualization.

3 SILO VIRTUALIZATION

3.1 Gateway-based Silo Virtualization

To solve problems caused by silos, we propose virtualization of an entire silo. We cannot eliminate silos because service infrastructure components like server virtualization software, network and storage system have scalability limitations. However, we can solve problems by virtualizing silos and thus making silos flexible.

Because a silo is a group of physical resources, we cannot use software-based approach like server virtualization or software-based overlay network virtualization. Instead, we connect physical resources each other using a hardware gateway like a VXLAN Gateway and virtualize network traffic among those physical resources as shown in Figure 4. In this example, physical resources like servers are connected to VXLAN Gateways. Each VXLAN Gateway encapsulates L2 traffic of physical resources and transfers them to other VXLAN Gateways. Even if a silo uses multiple VLANs, those VLANs are virtualized using VXLAN and connected among physical resources that belong to the same silo. In case a silo uses software-based overlay network virtualization, it is just L3 traffic from the gateway perspective and can be virtualized among physical servers that belong to the same silo.

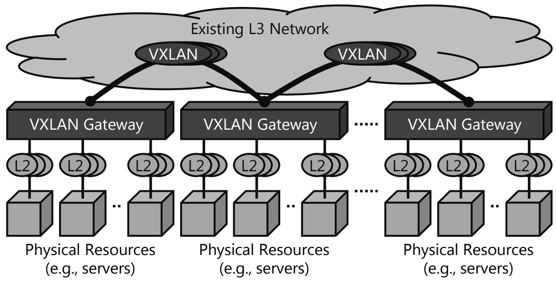

Figure 4: Connecting Physical Resources via Gateway.

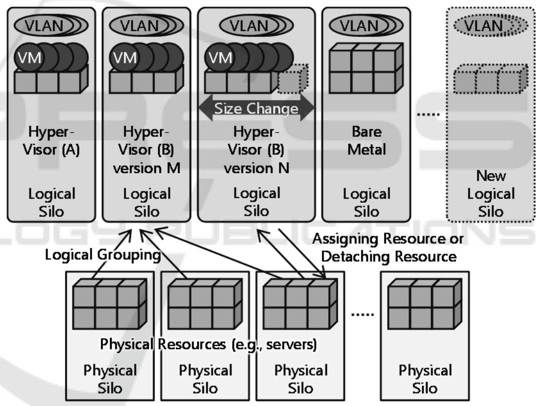

Figure 5: Silo Virtualization.

With this approach, a silo is still a group of physical resources but the grouping becomes logical. We can define a silo using physical resources that are not necessarily placed next to each other. For example, we can have a silo from physical servers from different racks. This allows service providers to dynamically change the size of silos, create a new silo, destroy an old silo and thus, make silos flexible as shown in Figure 5. In this example, a physical silo is a rack, multiple racks, a floor or a data center, and contains multiple physical resources like servers. Each logical silo is defined as a logical group of physical resources from different physical silos. When service in a logical silo grows and needs more physical resources, those physical resources are chosen from different physical silos and assigned to the logical silo by changing VXLAN Gateway configurations. When service in a logical silo does not go well as expected and does not need physical resources any more, those physical resources are detached from the logical silo and returned to physical silos. Thus, service infrastructure become flexible and service providers do not have to precisely estimate sizing of service infrastructure.

3.2 Hierarchical Architecture

Silo virtualization could cause management complexity. For example, there might be software-based server virtualization and overlay network virtualization in a virtualized silo. To mitigate the management complexity in a data center, we use a 2 layered hierarchical architecture as shown in Figure 6. The upper layer is "User Service" layer where service providers provide services to users using virtualized silos. The lower layer is "Resource Service" layer where resource provider provides physical resources to service providers in the upper layer. We set the resource service interface between them. When a user service provider has excess or shortage of physical resources, starts a new service, or shutdown an existing service, the user service provider can request the resource service provider to give or return physical resources through the resource service interface. Based on those requests, the resource service provider can manually or automatically change silo configuration only by changing connectivity among physical resources with VXLAN Gateways. This allows user service providers to focus on their services for users, the resource service provider to focus on managing physical resources that are independent from software used by user service providers.

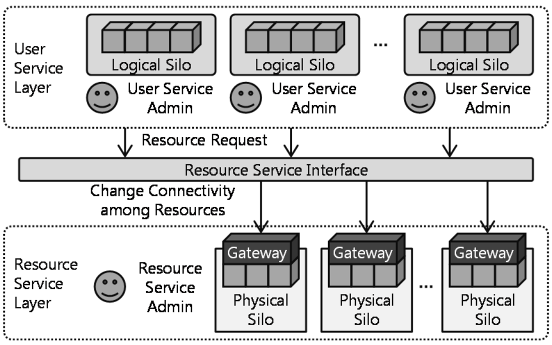

Figure 6: Hierarchical Architecture.

4 CONCLUSIONS

We proposed virtualization of service infrastructure (silo) in data center. A basic prototype system has been developed based on our approach using commercial hardware VXLAN gateways where a couple of physical silos are connected through gateways. And we are evaluating the effectiveness and drawbacks on our approach.

Our approach can help service providers deal with situations like excess or shortage of resources, and expansion or shutdown of a silo. And this also allows service providers to make their data centers more flexible with hierarchical architecture.

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