Energy Efficient Optical Networks for Cloud Computing using Software-Defined Provisioning

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***Abstract*— We present a demonstration of energy savings achieved through dynamic orchestration of networks within and between metropolitan area cloud data centers. Using open source management code which we developed based on industry standards, we virtualize an optical transport network to enable resource pooling. Further, each tenant segment of the virtual network can be managed using a different open source controller. Efficient bandwidth utilization avoids the need for over-provisioning and can result in significant energy savings. Dynamic provisioning also enables new functionality which would otherwise require higher energy consumption, such as avoiding storage controller timeouts due to traffic bursts. We illustrate this approach with an interactive demo using live VM migration and synchronous storage replication based on traffic monitoring from real world applications.**

Keywords-OpenFlow, Open Daylight, SDN, WDM, storage

I. Introduction

Network-based cloud computing is rapidly becoming a viable alternative to traditional enterprise data centers. It has been shown [1, 2] that energy consumption in transport and switching can account for a significant percentage of the total energy consumed in cloud computing applications. Recently, software defined networking (SDN) has emerged as a means to enable energy efficient, dynamic orchestration of network resources in cloud computing services, such as network-based storage and virtual machine (VM) live migration. Potential benefits include reducing direct energy consumption by server, storage, and networking equipment (including optical transport), corresponding reductions in data center cooling, and secondary reductions in energy and carbon footprint by avoiding dispatching service trucks to manually provision equipment which may be separated by hundreds of kilometers.

We will provide an interactive demonstration of energy savings through dynamic provisioning and orchestration of an end-to-end data communication network, spanning three data centers separated by 125 km of optical fiber. The demo includes automated, software-based orchestration of the optical transport network between data centers, as well as the networking between server and storage resources within each data center. Key elements of this demonstration include the following:

1) Using a software defined control plane for wavelength division multiplexing (WDM) equipment, we will virtualize the optical metropolitan area network (MAN) into independent "slices" which can be assigned to different tenants running different applications. A cloud service provider could use this approach to dynamically assign network resources to multiple clients without over-provisioning the optical network, resulting in energy savings from using fewer resources to accomplish the same tasks.

2) Each cloud tenant can use a different type of network controller to manage resources on their slice of the network. We demonstrate two slices running in parallel using different open source controllers (FloodLight and Open Daylight), although any other controllers should work as well. Each cloud tenant reduces their energy consumption, since they no longer need to over-provision network resources within their slice of the network.

3) Network management will be demonstrated using open source software which we have developed, based on industry standard OpenFlow protocols. Our management software includes a graphical user interface with single-click provisioning and a static flow pusher which can deploy pre-configured network profiles or schedule network configuration events. We also demonstrate the management interface using wireless devices, including an iPad tablet and an Android smart phone.

We will demonstrate the following independent use cases, running in parallel on two virtual slices of the optical transport network.

The first network slice demonstrates multi-site workload balancing for virtual network functions (VNFs). We chose to demonstrate this functionality using a video streaming application as the VNF, since video distribution accounts for about half of the Internet traffic in North America [3]. A video streaming application is hosted in a VM within one data center. Other applications may be running on different VMs in the same physical server as an energy saving measure. Using open source software including Ganglia [4], we monitor CPU utilization for the VM in real time. When CPU utilization exceeds a preset threshold (65%), we trigger an automated live VM migration across the optical network to a server in another data center with available capacity. This approach leads to more efficient utilization of resources across the metro optical ring, reducing overall energy consumption. Once a VM migration has been triggered, analytic models can be used to determine optimal placement of the VM, including considerations such as minimizing overall energy consumption. We provision a path for traffic within the source and target data centers, and across the MAN. Conventional MAN provisioning is a manual process, requiring several weeks [5] and includes dispatching service trucks with trained technicians to each point on the MAN. We demonstrate automation of this process, reducing the provisioning time to about a minute and eliminating the need for dispatching service trucks, with a corresponding savings on energy and greenhouse gas generation. Once VM migration is successfully complete, the network is programmed to automatically revert to its original configuration. We demonstrate that the video streaming application continues to run uninterrupted during this process, without pixilation or degradation of the video signal, and that we can continuously ping the VM during live migration.

The second network slice (running at the same time as the first slice) demonstrates dynamic provisioning for workload bursting in synchronous storage replication. Two data centers on the same MAN need to synchronously transfer large volumes of iSCSI storage data in near real time. The workload includes bursts of storage data which exceed typical utilization by 2-3 times, and which last 15-30 minutes. Data collected from network monitoring in an actual client application shows that static network provisioning is insufficient to prevent the storage application from timing out; this would normally require deploying additional network and/or storage resources with a corresponding increase in energy use. As an alternative, we demonstrate energy savings by dynamic provisioning bandwidth from a resource pool to compensate for bursts of storage traffic. Instead of monitoring the CPU as in the first use case, network traffic is monitored in near real time using an inexpensive hardware-based demarcation point integrated with the WDM optical transport equipment. When the traffic monitor detects that a storage burst is beginning, we trigger automated provisioning of additional optical network bandwidth. The re-provisioning is complete in less than a minute, making it rapid enough to compensate for storage spikes of 15-30 minutes duration. The traffic spike duration is known a priori (from network monitoring over a period of time), so the dynamic provisioning can be maintained long enough to ride through the spike before the network is automatically returned to its previous configuration. We note that this approach is applicable to other use cases, including data center migration, regulatory compliance testing, and business continuity/disaster recovery.

The design of our proof-of-concept test bed is shown in figure 1; it consists of three data centers connected by a 125 km ring of single-mode fiber and dense wavelength division multiplexing (WDM) equipment (Adva FSP 3000, nominal power consumption 200W per shelf)), operating at 10 Gbps/wavelength. Within each data center, a combination of IBM PureSystems, IBM System Z enterprise servers, NetApp storage, and IBM v7000 storage devices are connected by a 10 Gbps Ethernet network including four IBM G8264 switches and 4 Plexxi switches. All of the data center switches and WDM equipment (Layer 0-3) is orchestrated through a Floodlight or Open Daylight SDN controller running OpenFlow 1.3.1. We have created an open source management graphical user interface called Avior based on JavaScript, which controls the OpenFlow devices from a mobile device (tablet or smart phone). Avior monitors network statistics, configures traffic flows, and administers firewall properties. It incorporates a static flow pusher which can deploy pre-configured network profiles or schedule network configuration events. We also developed a second application (Advalanche) which is called by Avior to orchestrate the WDM equipment (this is a pre-standard implementation, since commercial optical transport equipment doesn't yet support OpenFlow 1.4). We illustrate examples of energy savings for each of these use cases, and quantify expected results based on comparing typical resource utilization with and without dynamic orchestration.

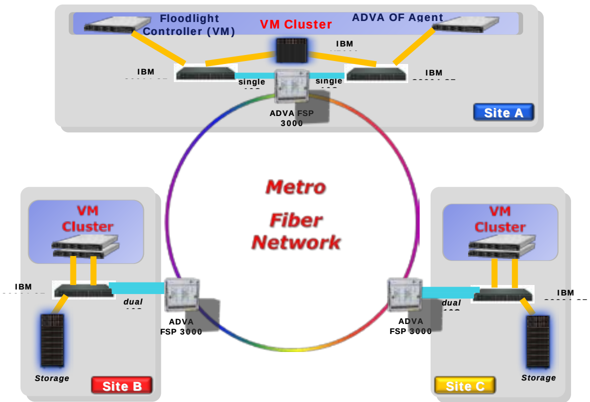

Figure 1 – SDN/VNF Dynamic Infrastructure Test Bed using 125 km Fiber Network

REFERENCES

[1] J. Baliga, R. Ayre, K. Hinton, and R. Tucker, "Green cloud computing: balancing energy in processing, storage, and transport", Proc. IEEE vol 99 no 1 p. 149-167 (January 2011)

[2] "Google Apps: energy efficiency in the cloud", Google white paper, http://static.googleusercontent.com/media/1.179.250.107/en/107/green/pdf/google-apps.pdf (last accessed Sept. 8, 2014)

[3] T. Campbell, "YouTube, Netflix take up half of Internet traffic", May 2013 www.iptv-news.com/2013 .(last accessed Sept. 8, 2014)

[4] M. Massie et.al., "Monitoring with Ganglia", O'Reilly Media, N.Y. 256 p. (November 2012)

[5] J. Manville, "The power of a programmable cloud", OFC 2012 annual meeting, Anaheim, CA, paper OM2D.2 (March 18-22, 2013)

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