Applying the Software Defined Networking Paradigm to MSO Commercial networks

Nagesh Nandiraju , Ph.D. and Sebnem Ozer, Ph.D.
Arris Inc.

Abstract

Today, a growing number of enterprises and SMBs are adopting cloud infrastructure for data storage, computation and services, which is driving increased traffic in unpredictable patterns. Enterprises are seeking greater flexibility from the access network infrastructure to effectively address demands, such as dynamic bandwidth and ad hoc services, from these new cloud services.

To successfully compete and lead in this market, MSOs need to evolve their current infrastructure into a more agile network that is capable of launching new services with much shorter lead times. An overarching common control and management layer is required to address the needs in a timely and cost effective way.

Software defined networking (SDN) presents an interesting concept of decoupling the control and data planes. As traditional, and even more modern, network architectures struggle to cope with dynamic applications and services, applying SDN paradigms will lend towards an effective solution to solve the operators' challenges. This paper highlights how SDN principles can be operationalized to result in a network infrastructure platform that is easy to manage and also presents new opportunities to monetize from the network.

INTRODUCTION

Over the past few years Multiple Service Operators (MSOs) have made successful strides in the business services segment by competing against incumbent players. Just as they are feeling comfortable by optimizing their in-house operations teams for provisioning and delivering the services, new challenges are arising. With the rise of data centers and maturity of services over cloud infrastructure, a growing number of enterprises and SMBs are migrating towards a public or private cloud infrastructure, consolidating their server rooms (see Figure 1). This presents a change in the network traffic patterns where its not only a North-South traffic (Server-Client) but a lot of East-West traffic between sites or branches and between branches and data centers.

To successfully lead in this market, MSOs can present a differentiating point by offering a seamless interface for the customers to dynamically control the bandwidth needle of their network pipes. Furthermore, while some MSOs have been deploying, others are considering new business models such as mobile backhaul, managed services and wholesale service models. They are also expanding their services beyond SMBs to serve large enterprise customers. Larger enterprises generally have multiple business locations geographically dispersed and span across different service providers' footprint.

In this paper, we will first describe the objectives and requirements for the new dynamic business services from the enterprise customer's and service provider's point of view. We then present a couple of approaches that can be used to achieve the desired flexibility. One way to address these new service models would be by integrating the DOCSIS backoffice with the core network provisioning tools and publishing the noth-bound APIs that 3rd party or in-house software tools can utilize to present a friendly interface to the customers. Another approach is to adopt the SDN paradigm. SDN presents an attractive concept of being able to virtualize the network and can control, configure and program the network (and all network elements) as and when needed. A deeper look into SDN and methods of adopting SDN principles can prepare the MSOs to transform today's network into a future network that is very agile, extremely easy to manage and capable of launching new services with much shorter lead times. As networks continue to evolve, we will provide some insights into how hybrid approaches and adopting SDN incrementally will ease the transformation of today's networks into more flexible and capable networks.

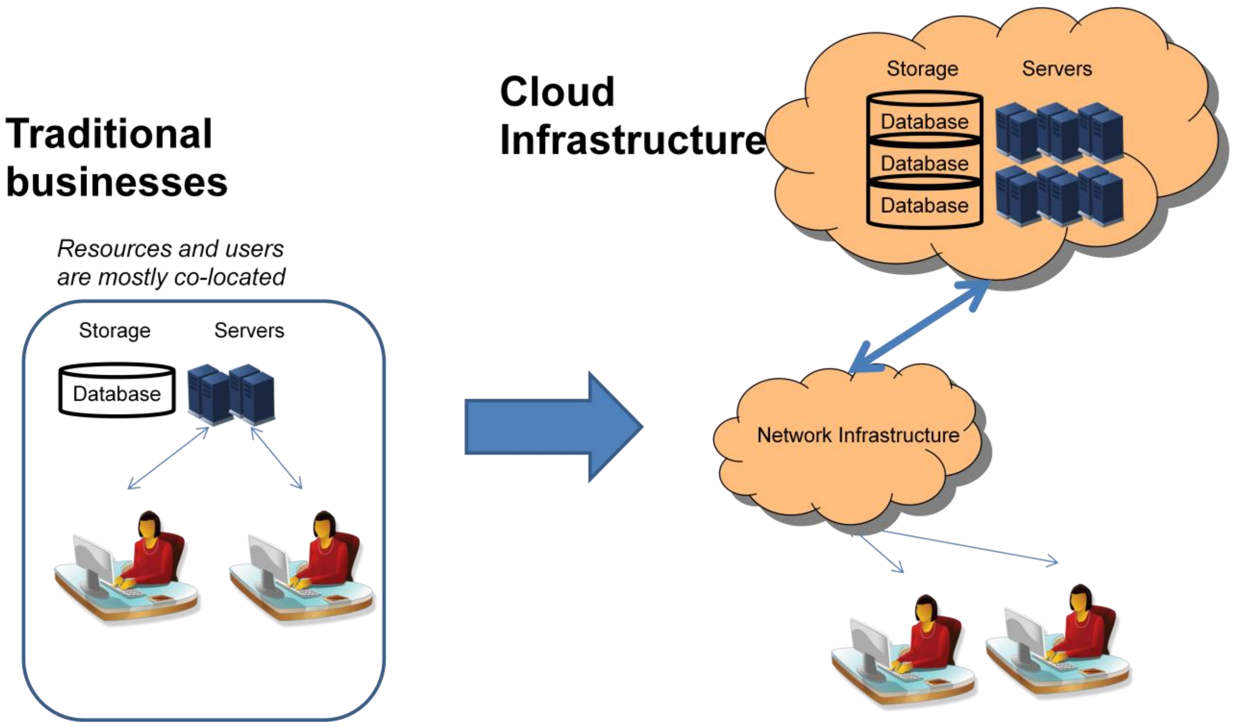

Figure 1. Enterprise Infrastructures migrating to Cloud

BUSINESS SERVICES BY MSOs

Cable operators have been providing residential services for many decades while their business services are relatively new and their current market share is smaller but steadily increasing. Cable operators started to sell their residential triple plays services to small to medium business customers, mostly companies with one location and few employees, local government, healthcare and education. However, increasing revenues and even bigger market opportunities have been a big motivation for cable operators to extend their business services segment. Cloud based services, advanced data services, mobile backhaul, increasing video and mobile (including Cable Wi-Fi and small cells) traffic, managed services and wholesale models and larger business customers offer new revenue areas. To successfully compete in this market requires new network architectures with higher consistency in service and that support dynamic bandwidth services.

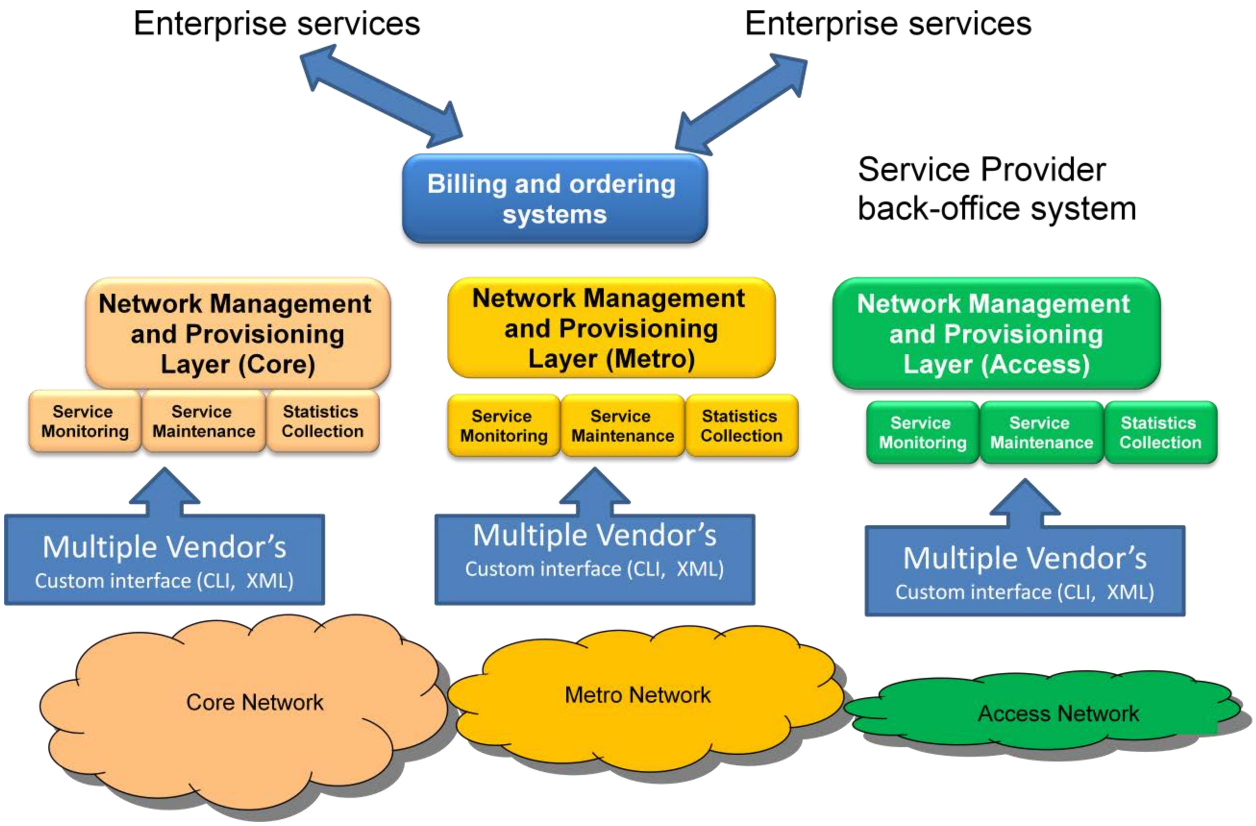

Figure 2. Segmented Network Infrastructure

While there is a common consensus on potential revenue opportunities for MSOs from video, mobile, cloud and backhaul services, a key question to be answered is "How can MSOs decrease their mean time to derive revenue while evolving to future proof systems?". To answer this question, we have to analyze current and future business services and their requirements (i.e. enterprise customer's perspective) and current and future network and system architectures with their performance and cost characteristics (i.e. service provider's perspective). The analysis should lead to evolutionary steps for Greenfield deployments and leveraging existing technology while incrementally adopting software defined and virtualized networks that may be deployed for Brownfield deployments.

In current network deployments, to provision dynamic services with end-to-end service guarantees and ensuring a SLA is not straight forward. Figure 2 shows a typical service provider network infrastructure. The current network infrastructure is divided into separate segments (Core, Metro and Access networks); each of these networks segments are controlled and managed by customized interfaces and tools. Often multiple vendor network elements and dedicated EMS/NMS systems are connected to the OSS/BSS system.

Lack of a common network control layer makes it hard to obtain a global consistent network topological view and cause the inability to instantaneously evaluate the capability of the network. Without this information it is extremely difficult to support dynamic services in a timely manner. Typically, the network has to be traffic engineered and often times there are multiple touch points (i.e. network elements) involved

– each of which need to be carefully configured and tested for inconsistencies. It involves coordination among multiple teams from these silos which is very hard to pull off in a short time period. This implies a huge cost and longer lead times that may not meet the customers' desired flexibility.

To support rolling out dynamic backhaul services to these customers requires a global network topological view and ability to evaluate the capability of the network to ensure a guaranteed service. Seamless network monitoring and performance measurement tools are required. While there are many tools and protocols, such as IEEE 802.1ag and ITU Y.1731, defined to achieve this functionality, they are non-existent in many parts of the network. This makes it extremely challenging for the operators to offer these services over today's network infrastructure.

Evolving commercial services, new business models and larger scale services impose new requirements both on network management and physical network infrastructure. For instance, network management should be flexible to support rapid service integration, dynamic bandwidth control and end-to-end SLA visibility. The underlying network infrastructure should support elastic bandwidth requirements and the scale of these new cloud based applications. There are several new standards and emerging industry groups' initiatives on providing solutions to achieve these requirements, namely Software Defined Networking (SDN) and Network Functionality Virtualization (NFV). Most of these standards originated to solve the problems in data centers and cloud infrastructure. While the network elements in data centers are quickly becoming all software defined and virtualized, service provider's networks and systems have differences that require a more evolutionary strategy.

In the next two sections, we compare the enterprise and service provider's point of views and the challenges in fulfilling the emerging requirements.

Enterprise Customer's Perspective

With the increasing adoption of Cloud for compute and storage by enterprises and businesses, application development teams have overcome many resource challenges and it has become a norm to roll out new iterations of their applications fairly frequently (reduced from weeks to days and some cases hours). Since most of these applications are based on cloud resources, they need the bandwidth and some level of QoS for their services. The IT teams in these Enterprises and SMBs are challenged to provide the necessary resources in a relatively short time period while ensuring these new applications do not have any detrimental effect on the already running critical and daily traffic.

These services along with projects that require temporary network usage, data back-ups and upgrades demand dynamic network solutions. Increasing traffic and unpredictable patterns are challenging the CIOs and IT network architects to accurately forecast the capacity requirements for the backhaul pipe. Usually a WAN service that has enough data rate capacity to satisfy the near term demands is ordered. This increases the total cost of operation for the business and often results in poor utilization of their subscribed static pipes.

These customers are actively seeking backhaul services that can be controlled dynamically instead of a static services that are either inflexible or take days to change. In addition to dynamic bandwidth changes, some enterprises are also considering more granular service options where a new business application can be deployed as a new service with end-to-end SLA visibility, monitoring and business analytics.

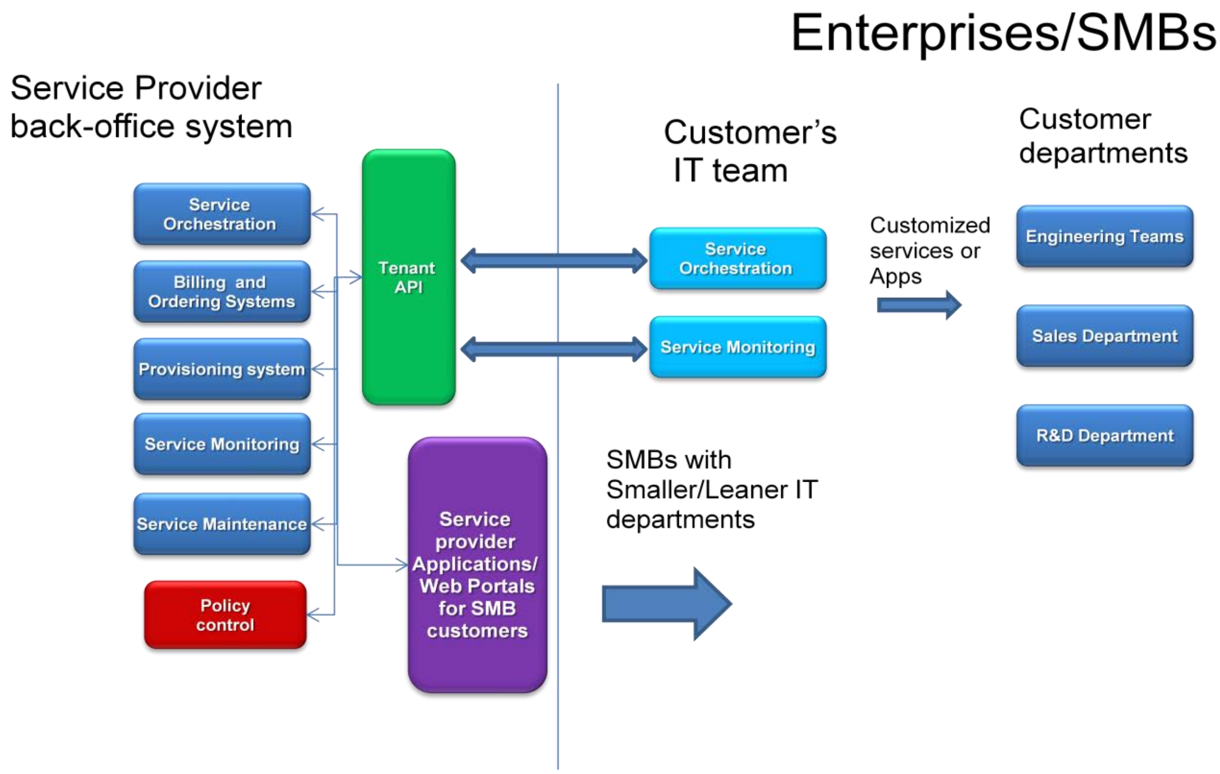

Figure 3. Exposing control to customers - Tenant API

To meet these new fast paced requirements, these customers are seeking turnkey solutions that include both technology and professional services for cloud based services; communication services including Voip, virtual PBX, video/web conferencing and other business video applications, resource and data management; managed mobile services, BYOD (bring your own device); and related security technology and services.

Figure 3 presents an ideal view of an Enterprise or SMB's IT team vision. Having the visibility, control and interface to build their own applications such as Service Orchtestration, Service Monitoring, using an open API (e.g. Tenant API as shown in Figure 3) increases the flexibility for the customers. Some SMBs and Enterprises with leaner IT teams, MSOs can offer canned applications or web portals that can be customized.

Service Provider's Perspective

Today, most of the backhaul connections in the access and the core network are either static and involves manual provisioning or pseudo automated provisioning. Typically the enterprise or SMB's IT team estimates the bandwidth required for each branch office and negotiate a service with the desired data capacity, SLAs and QoS requirements (e.g. 2 EVCs, CIR1 = 50Mbps, EIR1 = 15Mbps and CIR2 = 10Mbps, EIR2 = 0 etc.) from their service providers. If the customers need to upgrade the pipe capability, it requires a lot of manual intervention from both the customer and service provider. The provisioning and billing team from the service provider have to communicate and provisioning involves a lot of touch points. Unfortunately, this whole effort is in the order of days if not weeks.

Service Providers have to offer enterprise communications and managed services with the dynamic and flexible solutions as described in previous section. Other revenue opportunities such as mobile backhaul and wholesale models demand dynamic bandwidth management and end-to-end service visibility as well.

MSOs are exploring different solutions to meet high bandwidth demand by extending HFC networks (e.g. Docsis 3.1) and Carrier Ethernet and EPON networks (e.g. DPoE). In addition to physical network infrastructure, backoffice and customer management software solutions should enable flexible and dynamic service integration, control and management. Multiple MSOs should be able to serve a big enterprise with multiple locations. While supporting dynamic bandwidth requests, the new management systems should maintain high network utilization. The system provisioning, service integration and control should be simplified and independent of specific network components provided from multiple vendors as interoperability is desired.

The time scale for service introduction and bandwidth contol should be `comparable to computing and storage programmability of data centers, which may be achieved by service and network virtualization.

SOFTWARE DEFINED NETWORKING (SDN)

Software defined networking presents an interesting concept of abstracting the network infrastructure from the applications by decoupling the control and data planes. Figure 4 shows a typical SDN. Network control intelligence and state of network elements are consolidated into a centralized software server. Conceptually this software controller can be hosted on any elastic cloud infrastructure and thus can be scaled based on the demand.

SDN has emerged primarily to solve many new problems in the data center space such as provisioning and managing thousands of end points (virtual machines) that dynamically move. Data center interconnectivity requires high-capacity, low latency links that can dynamically scale based on need. The East-West communications between data centers (Inter-Data-Center) of several data intensive companies, such as Google, Facebook etc., have demanded a more configurable network that is efficient in both cost and performance. On the other hand an Intra-Data-center is characterized by highly dynamic end-points (VMs). To increase efficiencies and maintain low cost of operations, VMs are often migrated from one host to another resulting in a dynamic logical network.

OpenFlow [1] is one major attempt to radically abstract many of the networking functions. It presents a programmable interface with well defined instruction set to control and program a network. A centralized controller application can use this programming interface to configure and manipulate the network elements dynamically. Applications can use this interface to respond and adapt the underlying networking infrastructure to tackle these new challenges. A consistent and centralized logical view of the network can be obtained relatively easily.

In [3], several attributes are discussed to define SDN. Below we list the relevant attributes and show how they can help MSOs to achieve their business service objectives. Some of these attributes may be achieved by extending current technologies, leading to hybrid solutions towards the evolution of pure software defined and virtualized networks.

Logically centralized and separated control plane:

Separation of control (and management plane) from data plane enables controlling the data flow in software (without specific hardware) and control becomes logically centralized with full view of network. Today, most of the network elements in a service provider network has data and control plane in the same appliance although management plane is

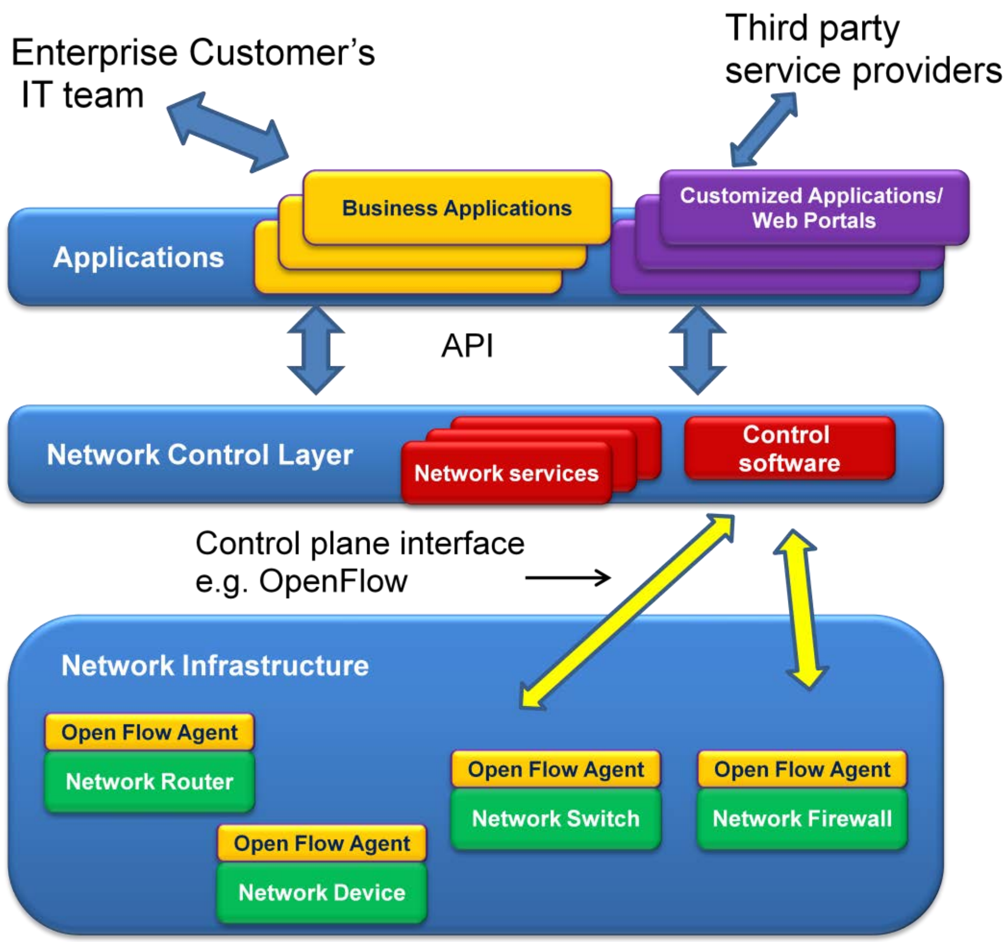

Figure 4. Typical Software Defined Network (SDN)

mostly separated. The notion of remote control is well established but appliance dependency and distributed nature are the main differences compared to logically centralized and separated control plane of SDN networks In an SP network, control of network elements may include packet, wavelengths, TDM etc. and depending on the technology the decision should be made on the control elements to be centralized. The ultimate goal for a SP is to have a modular single logical entity that is abstracted from appliances and controllable for service, subscriber and policy management.

Programmability of network and service features:

What makes it different than today's programmable and configurable attributes of SP's network and service elements is the time scale of dynamic change. The time scale is expected to improve over evolution of the networks. For example, a new service creation and deployment should take hours compared to weeks and be automated without dependency on a specific appliance. Programmability provides business agility by enabling enterprise customers to request dynamic changes in their services.

Network and Service Virtualization:

The feature corresponds to the abstraction of network and service attributes that can be changed dynamically through software control and dynamic programmability of the network and services. Virtual networks and services such as VPN, VLAN, VPLS, Virtual Access Points etc. help service providers to serve multiple customers and services over a single network. However, both virtualization and programmability enable automation and finer time scale compared to what virtual networks can provide today.

In addition to Open Networking Foundation (ONF), IETF, ITU's Network Funtions Virtualization (NFV [5]), Open Daylight, MEF [2] and TMFORUM [4] has ongoing efforts on providing SPs with interoperable mechanisms to extend Carrier Ethernet networks for new services. MEF introduced CE 2.0 which enables multi-CoS. (e.g. differentiating best effort Internet vs. high QoS voice for enterprise and MBH services). E-Access element provides end-to-end SLAs and management control enabling multiple cable operators to serve a big enterprise with multiple locations. E-Access also enhances wholesale Ethernet services e.g. selling to multiple wireless customers with one carrier Ethernet service. Manageability is enhanced with fault tolerance and other tools. MEF's CE4Cloud project with Dynamic Responsive Ethernet (DRE) proposal corresponds to programmability of SDN environments towards controllable software components. It addresses elastic Ethernet service attributes, including dynamic change of EVC or UNI attributes for a time period (e.g. increasing CIR of existing EVC, adding or removing UNI endpoints) and on-demand and reservation models.

ENABLING SDN and NFV

SDN and Network Functions Virtualization (NFV [5]) enable MSOs to have enhanced and dynamic service integration and management, reduce provisioning and deployment cost and time. SPs can orchestrate their network and services in an end-to-end manner from a logically centralized control with simplified provisioning and management, including dynamic service management, traffic engineering (dynamic bandwidth and load distribution), full view monitoring, fault management and business intelligenc. It provides enterprise customer and wireless service provider end-to-end SLA visibility and business intelligence analytics. Virtualization and programmability increases resource utilization.

For service providers the objective is to have both service and network virtualization. Network virtualization helps the SPs to see the network as a one entity to control and manage while service virtualization enable SP to manage, programme and automate services over the network. Virtualization does not require SDN and vice versa. Centralized control, programmability and virtualization enable the network to be movable (e.g. bandwidth allocation can be moved).

Benefits of SDN

Centralizing the intelligence and control is not a new concept for operators. This is how most of the networking has evolved over the past few decades. What SDN does differently is abstraction and consolidation of the intelligence and control portion into a centralized controller thereby simplifying and potentially eliminating the control and intelligence portion from the network elements. This offers several benefits to the operators resulting in lower OPEX and CAPEX.

With this abstraction and consolidation, hardware dependence can be eliminated and the benefits of a cloud based controller can be realized. The controller is a software module that can potentially run on a cloud environment and can be elastic and scalable as needed.

The NEs become more focused on forwarding rules and only act on the ACLs set by the controller. This can dramatically reduce the cost of these network elements.
Service providers can also achieve better efficiencies from the network

- build and maintain logical mesh networks (both in core and access) much more easily and control
- dynamic load balancing for efficiency improvements and
- network resilience can be easily achieved

A common centralized controller presents a potential for improved network provisioning, management and monitoring of the entire network

- Automated provisioing and fault correlation can bring lower operational costs.
- End to end flows, SLAs can be easily monitored.
- Statistics can be viewed internally and external access to customers can also be arranged through the API.

Time to market can be dramatically brought down yielding in quick revenue, resource optimization (virtualization, dynamic control, statistical utilization), better overall performance. (service and network planning, SLA assurance, opertational orchestration, unified billing)

A logical topology view along with the control state and intelligence at a central controller can greatly benefit the operators. Operators can obtain a global state of the network with a granular view of each flow or traffic on any link fairly easily. Adding a new service becomes a mere point and click model. Of course this assumes all the network elements support a standard protocol and present an open API for configuring. OpenFlow or similar protocol can be agreed by all vendors.

Why should MSOs care about SDN?

SDN makes a lot of sense in an environment where changes are rapid and require dynamic network reconfiguration. As can be noted from the discussions in previous sections, many IT organizations will sooner or later need to offer dynamic services to their clients. SDN will help reduce the complexity of provisioning and any manual intervention by abstracting the underlying infrastructure as new applications are deployed. This also enables the network infrastructure to be agile and highly scalable to accommodate dynamic application deployments. Another motivation to the Enterprise's IT organizations is to avoid the complex network engineering tasks (often manual planning) and leverage the toolset of SDN to simplify the QoS provisioning, ACL rule setup and dynamic monitoring of the services.

Service providers do not have to change every switch or router with Openflow (or bgp-te; PCE; IETF SDNP; ALTO) enabled virtual swicthes and neither their OSS/BSS systems have to be replaced with SDN orchestrated systems to achieve the objectives listed herein. Overlay models and intermediate control modules can be extended by examining which features are implemented in hardware and their performance and impact on service and network control. One important aspect is simplification of provisioning and operations of the system. Simplification will enable to have open APIs for automated control at both service provider and enterprise customer sites. The services and applications may be requested from the enterprise customer or application (data center/cloud) center.

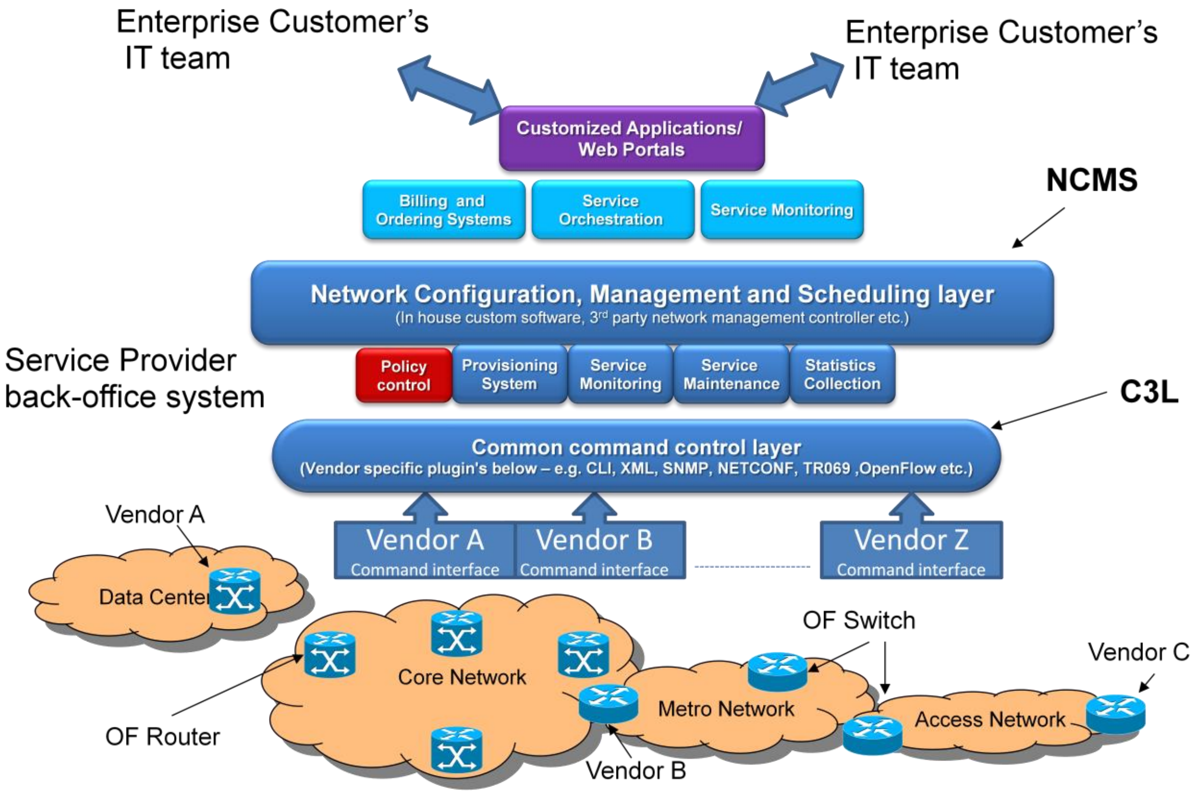

Figure 5. Provisioning Dynamic BW Services on MSOs current Infrastructure

<u>PROVISIONING DYNAMIC BANDWIDTH SERVICES</u>

This section looks at an approach of delivering dynamic services by building an overarching control layer over the existing physical network infrastructure. Figure 5 presents a high level architecture overview of the potential solution.

Accomplishing these new services such as dynamic service scheduling, providing seamless control to customers is challenging with today's network infrastructure because of lack of a common language that can be interpreted by the multi-vendor systems with various non-standard control interfaces. SNMP provides a standard configuration interface but does not completely solve the problem. Many vendors only support monitoring part of the SNMP and do not implement the configuration part of SNMP.

This can be solved by building a common command control layer (C3L) that integrates the configuration (CLI, SNMP, custom APIs) of all the vendor network elements. In this approach, vendors provide plug-in modules that integrate into the (C3L).

The abstraction in the form of NCMS vastly improves the capabilities of the operator's networks. Specifically new services can be provisioned with point and click modes even with today's network infrastructure. With this approach billing capabilities are also enhanced. As NCMS has the full view of the network, end-to-end capacity analysis may be done per customer and service. This information can be shared with the customer as available resources for dynamic service requests (e.g. using Tenant API as described below).

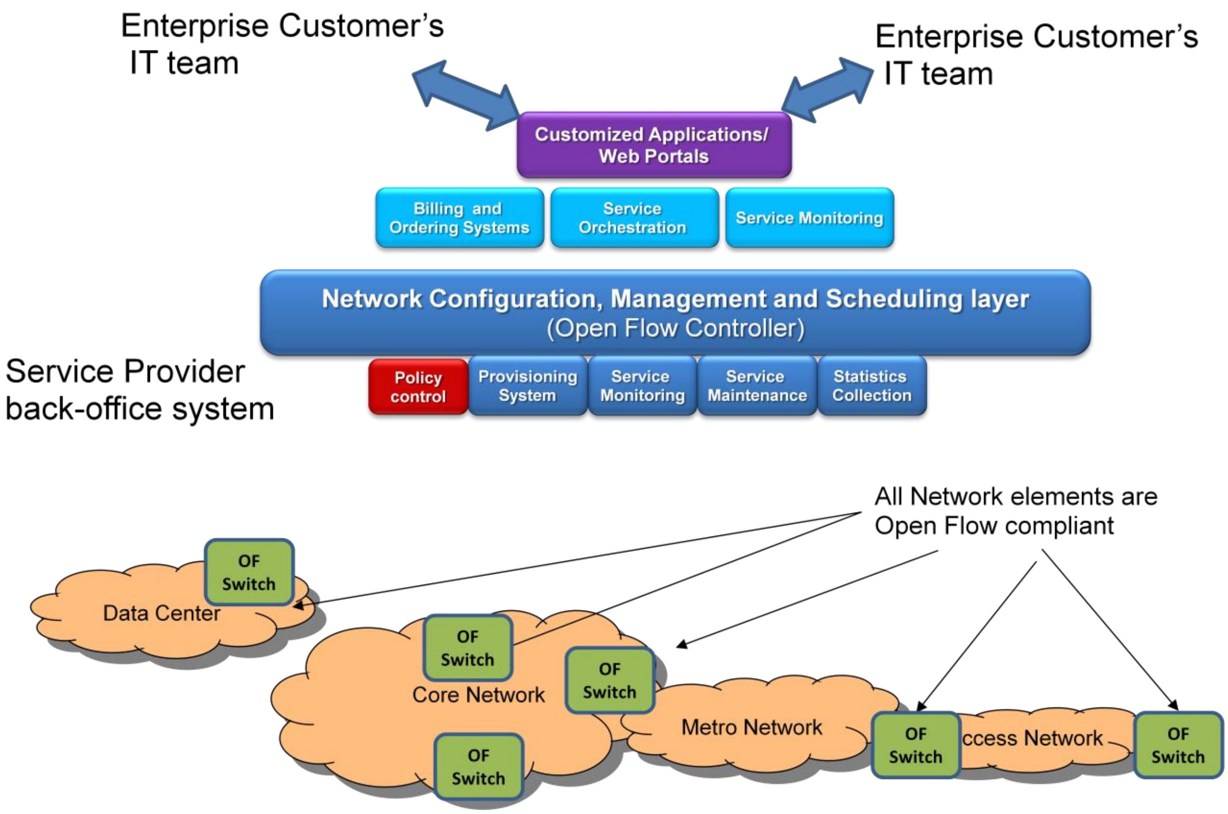

Figure 6. Pure SDN Approach

Pure SDN Approach

Ideally if all the network elements can be replaced with a OpenFlow or a similar protocol, NCMS implementation can be further simplified. OpenFlow can help by providing a standard forwarding instruction set that can configure the network elements. If all vendors adopt a common configuration control protocol then network management and control becomes a lot easier. A centralized controller requires to interface and interpret in only one language.

In addition to the advantages gained with from the approach specified in previous section, this network is much more powerful and reconfigurable. Because of the native support of an OpenFlow instruction set, all network elements can be completely controlled by the NCMS.

Furthermore, as the network elements implement OpenFlow, elimination of the complex control modules in the NEs can drive the costs of the NEs significantly down.

However, this can be very challenging and time taking effort to enable the change as it involves significant investment of resources from both the MSOs and vendor community.

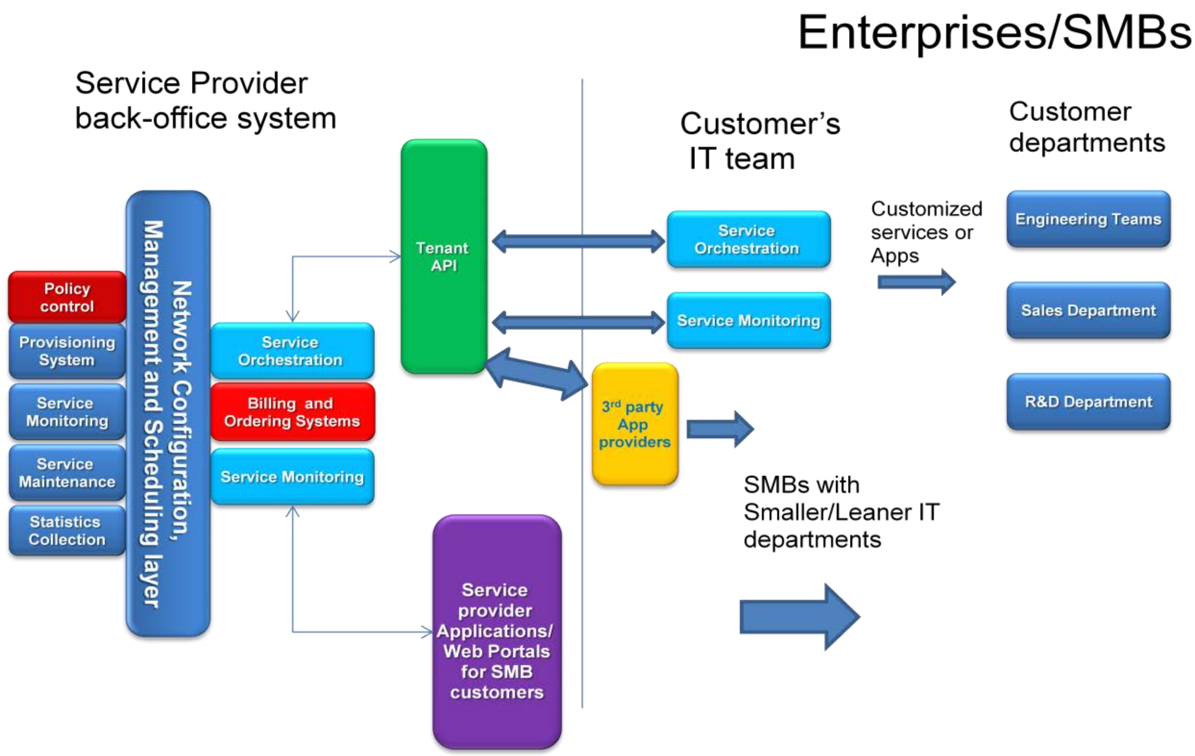

Figure 7. Tenant API: Empowering the Customers

Tenant API: Empowering the Customers

The Tenant API could allow the customers to orchestrate new services and change the data rates of existing services dynamically. Enabling this feature by the MSOs becomes easier with the NCMS abstraction layer. Background checks are made to ensure the SLAs are met and the customer can be billed appropriately for the services.

As shown in Figure 7, IT departments at larger enterprises can build their own internal applications (or buy 3rd part applications) using the Tenant API for orchestrating the services to internal teams or departments. This way they don't have to completely reveal their internal application structure or corporate details to the service providers.

In smaller or medium businesses which typically run leaner IT departments can use the applications or web portals provided by the service providers. These web portals or applications help the customers to demand customized services, control existing services and the applications will orchestrate accordingly.

With these new service orchestration, billing has to be very granular and many innovative techniques could be used to drive up the revenue from the services satisfying both the customers and service providers.

In addition to the service orchestration, service performance monitoring and maintenance features can also be provided for detailed reports on a periodic basis. These statistics can help the customers make informed decisions on future growth predictions and demand patterns. Service providers on the other hand can use this information for improving their utilization and offer services that are cost effective to the customers. This enables the customers to provision and prioritize the traffic dynamically and change over time. For example during day time certain services could be assigned high priority and during night time a different set of services are assigned with high priority.

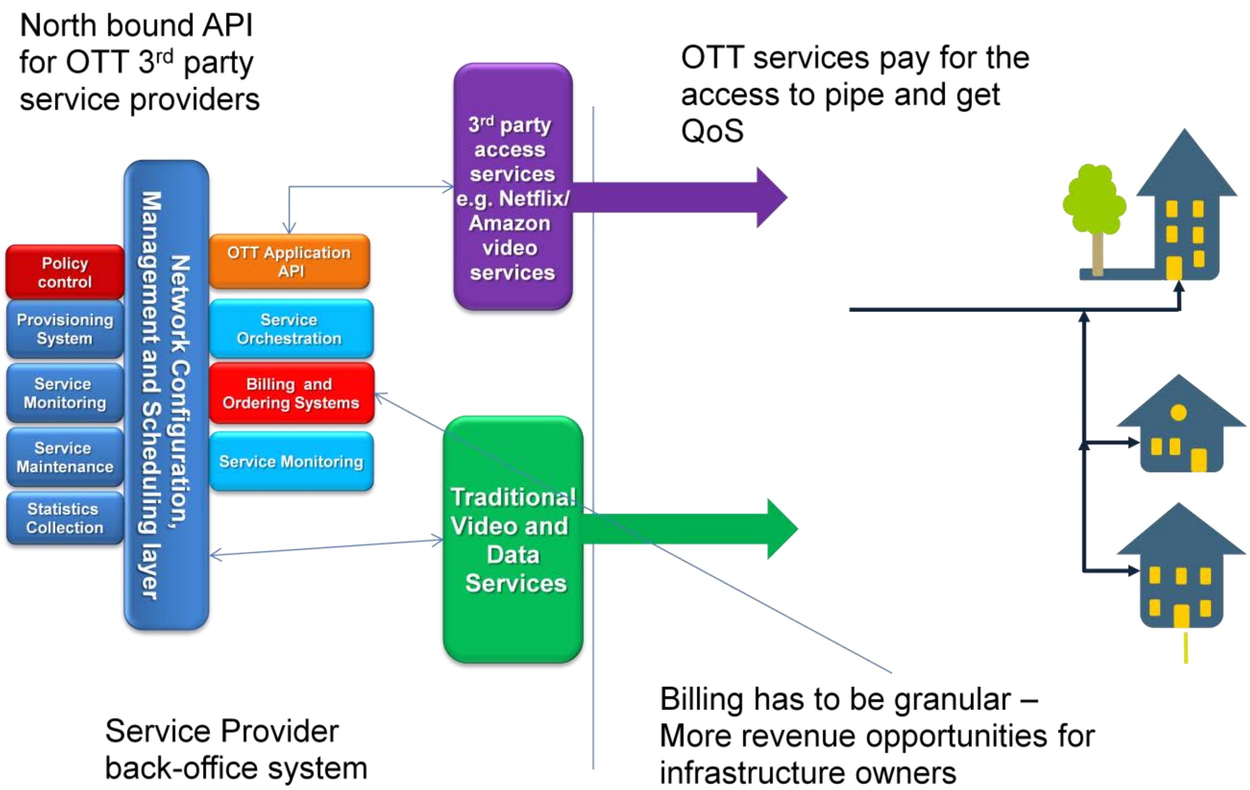

Figure 8. Virtualizing the Network Pipe

VIRTUALIZING THE ACCESS PIPE

Virtualization of anything and __ as a service is becoming has been the trend and are being embraced by many customers. Brand new business models like Network-as-a-Service (similar to Amazon's IaaS) can be explored by the MSOs. Network and Service virtualization can be defined in different ways. The existing network elements can continue to host the control plane intelligence but present Open API support to control the behavior from remote controller elements. This sort of control already exists in many devices, primarily through proprietary interfaces or by standard tunneling methods (e.g. VLANs, GRE) where the controller device sends policies to the network elements. But most of the API is either limited or closed to the vendors. Third party application developers have limited access and due to the proprietary API, development usually does not scale well. Presenting a standard API interfaces like adopting Openflow standard would present a better option for innovation.

Once a NCMS layer is built, virtualizing the current network infrastructure is straight forward. As shown in the Figure 8 an Over the Top (OTT) API can be defined that interacts with the NCMS, the service orchestration, billing and ordering systems, and service monitoring modules. The OTT API lets third party service providers to orchestrate services by requesting and reserving resources to obtain a desired QoS. The billing and ordering systems can appropriately turn on relevant counters for accounting and get paid for the services. New granular billing lets the operators to come up with innovative ways to improve the revenue opportunities.

SUMMARY

A significant number of businesses are adopting cloud infrastructure for compute and storage and application services. This has stirred the growth of new era of applications that communicate and exchange lot of data, and are deployed rapidly for testing. IT teams in these enterprises are trying to keep up with the requirements of nimble and faster response times. Soon the access network infrastructure will need to be nimble enough to match the agility of cloud data center based services and support dynamic network reconfiguration and features like multi-CoS features at a more dynamic time scale.

To address these needs, an overarching control and configuration layer is required on top of the existing physical infrastructure.

As operators make new investments into physical infrastructure, an intelligent network with dynamically reconfigurable network elements should be considered. OpenFlow appears to have a great potential with its well defined forwarding instruction set. Vendors and Service providers can start this as reference point to drive the industry to a common and intelligence control plane which can reinvigorate the network to meet the new challenges presented by the cloud based application services. This also presents a several new benefits for the service providers. First, an evolution of today's network into a virtual network can help in building new business models that monetize by selling services to third party access providers A common control and intelligence plane can help in improving the billing granularity. Services that exceed the fair use bandwidth could get fair treatment and pay for those services.

Furthermore, a network with a common network control layer will significantly reduce the time to market and will be capable of delivering new services with efficient management and streamlined operations.

REFERENCES

[1] OpenFlow [www.opennetworking.org]
[2] MEF [www.metroethernetforum.org]
[3] http://www.metanoia-inc.com/blog/
[4] TMFORUM
[5] ETSI NFV [http://portal.etsi.org/portal/server.pt/community/NFV/367]