OPEN NETWORKING
FOUNDATION

OpenFlow™-Enabled Cloud Backbone Networks Create Global Provider Data Centers

ONF Solution Brief
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OpenFlow-Enabled Software-Defined Networking

In a broad industry effort spearheaded by the Open Networking Foundation (ONF), Software-Defined Networking (SDN) is transforming outmoded WAN designs by decoupling the control and data planes, centralizing network intelligence and abstracting applications from the underlying network infrastructure using the OpenFlow standard.

As a result of this effort, data center operators and service providers will gain unprecedented network programmability, automation and control, enabling highly scalable and flexible WAN solutions that readily adapt to changing business needs.

Executive Summary

Traditional communication service provider networks are not well suited to supporting today's rapidly evolving cloud services and the emerging requirements of enterprise and wholesale customers.

Service providers of all types face pressure to increase capacity, deliver more dynamic and easily reconfigurable services, and reduce costs.

At the same time, networks have become more complex, more costly to scale, and more difficult to predictably plan and operate across all layers of the wide area network (WAN).

In recent years, advancements in data center server and storage virtualization have created a very dynamic environment, both within and among data centers. Operations such as workload balancing, and disaster or major data center outage pre-emption or recovery are increasing the traffic among service provider data centers.

The rising volumes of such traffic, coupled with its significantly transactional and time-variable character, are stressing network operations and creating

MARKET TRENDS

- Network becomes only one component of a larger, data-center based infrastructure, generating new imperatives on network services and limiting the value of existing network service paradigms

CHALLENGES

- Increasing stress on network capital and operational economics
- Increasing network complexity creates barriers to change, making service flexibility problematic
- Rising mismatch of existing network service modalities to inter-data center traffic types and dynamics

SOLUTIONS

- OpenFlow-based SDN allows networks and services interconnecting cloud provider data centers to be seamlessly integrated within the converged, data center-based service infrastructure

BENEFITS

- Improved capital and operational economics through improved network utilization and configuration automation
- Network services better adapted to application needs, enhancing their value to customers

escalating challenges in WAN utilization efficiency. Cloud backbone services must evolve to support more flexible and programmable service capabilities which better align all layers of the WAN with current and emerging cloud services requirements.

Trends Driving Change

The trend toward content- and compute-based services is affecting WAN traffic volumes, types and patterns. The inter-data center backbone is characterized by rapidly rising traffic volumes associated with database distribution and “synch” operations, and other data transfer operations in service contexts such as cloud computing.

Not only is the inter-data center traffic increasing, the variability of bandwidth requirements between peak and mean traffic rates is increasing. Solutions are required to:

- dynamically modify bandwidths among existing data center locations;
- activate new service connections on demand; and
- provide real-time feedback and visibility into the utilization of interconnection services for more efficient traffic loading by cloud applications.

Examples of some of the key infrastructure operations driving these requirements include:

- **Storage Migration** – transferring a copy of a data store from one data center to another, either as backup, or as a precursor to virtual machine migration or ongoing active-active replication.
- **Active-Active Storage Replication** – keeping a data store in two or more data centers consistently synchronized, by writing through cache simultaneously to both locations.
- **Virtual Machine Migration** – transferring the CPU state and memory image of one or more applications running on virtual machines, from a server in one data center to one in another data center, allowing dynamic server capacity expansion, improved business continuity or application failover.

On the one hand, the access/aggregation/metro network supports largely a user-to-provider data center traffic; while the metro and/or inter-metro “core” (regional, long haul, ultra-long haul/transoceanic) network increasingly supports a service provider inter-data center “cloud backbone” problem: see Figure 1.

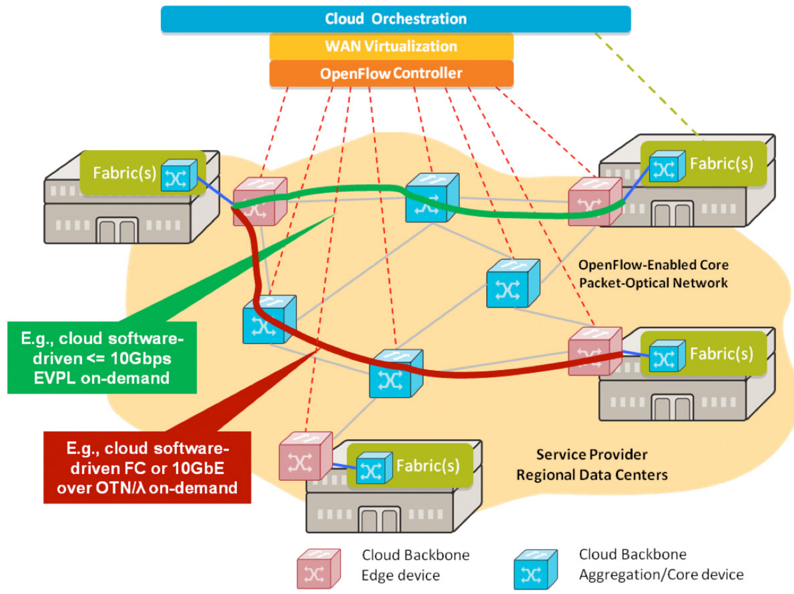

FIGURE 1
Content- and compute-centric service providers increasingly operate multi-data center architectures to support distributed services and user bases, to support high service availability and resiliency architectures, etc. Multi-layer WAN networks typically are used to service cloud data center interconnect needs.

Service providers of all stripes are looking to evolve their network and network service designs and offers to respond both functionally and economically to these trends.

Traditional network service providers may find both the nature of their existing services (e.g., long-term, parametrically fixed leased data, line and wave service paradigms) and their pricing attributes (vs. distance and bandwidth) to be ill-suited to supporting these trends going forward. The traditional static interconnect service model results in either over-provisioned, under-utilized service capacity, or under-provisioned, capacity-capped services.

Paying for over-provisioned, under-utilized interconnect resources places economic pressure on cloud service providers — who in turn will be driven to search for lower cost network service options.

Under-provisioned, capacity-capped interconnect services may result in protracted data transfer operations. Such limitations constrain the utility, performance and economics of the cloud infrastructure.

In most cases, carriers have limited their offers to static-capacity services. This is because the manually-managed, detailed configuration of traditional packet or circuit switched services, operating over one or more transport aggregation layer(s) and associated optical transport layers, has proven to be complex and operationally cumbersome. The prospect of opening up and sharing application interfaces or customer portals to allow customer- or application-driven provisioning or modification of these services has proven difficult to achieve.

This is particularly true when considering the multiple independent management and provisioning systems for each of the different products operating at different layers, from different vendors present in the network.

Factor in the historically-closed, proprietary nature of operational support systems, and the expense and difficulty of integrating with external systems and applications, and it becomes clear why innovation on this front has been slow to arrive.

For network service providers seeking to capture business from cloud service providers, this situation will increasingly lead to declining service margins, loss of business to self-builds employing new designs and methods, or both.

Fortunately, SDN was developed explicitly to address these types of issues and industry challenges. OpenFlow-based SDN provides a framework with which to address these challenges across the multiple potential categories of service providers addressing data center interconnect applications.

CLOUD-RELATED SERVICE PROVIDER CATEGORIES

- Provider may operate a fully-integrated cloud services infrastructure consisting of owned data centers and inter-connect networks
- Provider may operate a fully-integrated cloud services infrastructure consisting of owned data centers and interconnect services from network service providers
- Provider may operate managed data center inter-connect network services for cloud service provider customers

OpenFlow-Based SDN Resolves Multi-Layer Cloud Interconnectivity Challenges

SDN with OpenFlow provides the framework and tools to operate the provider inter-data center backbone network as a single fabric, under a centralized network control layer that maintains a global view of network resources and controls their allocation in response to evolving traffic demands.

SDN defines an architecture in three layers — see Figure 2.

- At the bottom, the infrastructure layer comprises network equipment. Network state, configuration and treatment of traffic flows in the infrastructure layer are determined in the control layer and "pushed" to the infrastructure layer over the control-data plane interface using OpenFlow and potentially other protocols.
- The control layer encompasses those functions — represented in Figure 2 by the generic label "network services" — that may be required to deal fully with the demands coming from business applications in the top layer.
- The application layer resides at the top and provides open API linkages with other applications, or systems.

DEMYSTIFYING MULTI-LAYER FABRICS

Fabrics are topologies often illustrated as a mesh due to the high density of connection paths required to ensure a set of connectivity characteristics among nodes. These characteristics include **determinism** — for pre-determined path selection prior to transmission; **multi-path** — where alternate paths are available; **self-healing** — where high failure rate paths drop to continuous test mode, and are restored automatically so that frame arrival is guaranteed; **low latency** — where transmission incurs the least delay; and so forth.

Originating with the crossbar switch fabric, Fibre Channel popularized the fabric moniker by meshing crossbar switches to provide the above characteristics on storage networks. In the case of the WAN, fabric technologies must address these capabilities for the packet services layer, a transparent circuit service layer to support storage area network technologies such as FC and others, and optical wavelengths.

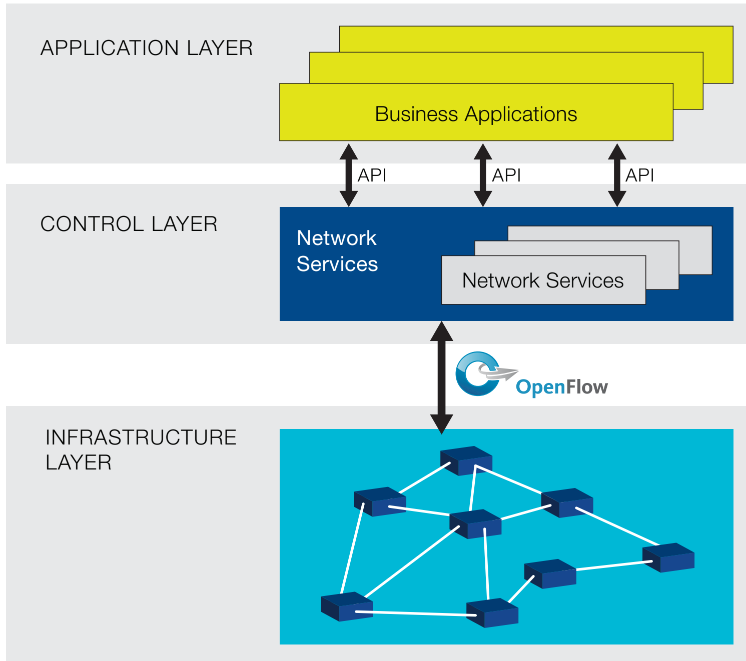

FIGURE 2
OpenFlow-based SDN architecture. An application layer communicates network needs to a control layer, which maintains a centralized and global view of network resources and utilization, hosts network service logic, and pushes network state, configuration and traffic treatment information to network devices in the infrastructure layer using OpenFlow.

In this example, the business application might be called a cloud orchestrator. In response to end user and application demands and needs, the cloud orchestrator links together virtual resources in the compute, storage and network domains — with the WAN constituting a resource domain in its own right.

The cloud orchestrator maintains a global view of traffic demands on the WAN and their operational resources. The orchestrator can control or modify some of those demands in response to WAN resource availability information provided by the network control layer.

The network control layer maintains a global view of network state, including network resource allocations against the various traffic flows, and actively controls these in response to demands from the cloud orchestrator — to which it effectively provides a virtualized view of the WAN.

A close mating of network demands to network resources is thus achieved — one that may be continuously updated as both demands and network resources may vary.

Because the demand and resource views maintained by the cloud orchestrator and network control layer respectively are global, both demands and use of network resources may be globally optimized. For example, the network control layer may “see” that concurrent major data transfers can be accommodated by sending each over a different network path, despite node or link saturation along “default” routes.

Similarly, global application demands sometimes may be modified to accommodate network resource or performance limitations. For example, some major data transfers might be deferred to later times in response to current or predicted network or path congestion that cannot be fully resolved by the network control layer.

OpenFlow standardization has focused to date on the packet infrastructure. Other layer networks may be supported in an SDN environment — i.e., one featuring a centralized control layer — through closed-system application of existing technologies. However, continued evolution of the OpenFlow standard may extend open interface support to those additional technology and infrastructure layers which are critical to the WAN. Such developments would extend the utility and benefits of OpenFlow-based SDN to the full suite of layer technologies and services associated with end-to-end cloud backbone interconnect services.

The use of OpenFlow-based SDN thus resolves the key market trend issues and network challenges identified earlier in this Solution Brief. Network services become continuously and automatically adapted to the evolving, real-time needs of the global set of cloud backbone traffic drivers, so that the size and therefore cost of the total network infrastructure may be constrained through improved average utilization.

The intrinsic and monetizable value of network services, and network service delivery economics, are both improved — benefitting both providers and consumers of cloud backbone network services. Further: increased automation of both the network and cloud infrastructure operations, means that operational complexities and costs are reduced, and implementation velocities improved, for both cloud backbone network providers and users.

Finally, since network provisioning becomes a software-driven affair, network configuration planning is more easily supported with software-based processes such as network simulations.

Key aspects of network service configuration — such as providing for network availability, survivability and restoration — can be examined through off-line simulation followed by direct porting of configuration templates to configure the physical network. Such use of software-based test and configuration may reduce errors and inaccuracies to further improve network service performance & value, and cost of operations.

Key Benefits

There are many general advantages to be realized by organizations that adopt OpenFlow-enabled SDN as the foundation for cloud backbone services interconnecting provider data centers.

A logically-centralized control layer provides a complete view of available network resources and their utilization. By coupling this control layer to the data center and cloud resources control environment, through the provision of an application interface for linking these systems, a comprehensive view of the entire cloud compute, storage and communication resources is generated that can efficiently support true optimization.

For Cloud Service Providers building their own data center interconnect networks, perhaps leasing dark fibers or wavelength services, SDN offers many compelling benefits:

- better alignment of network demands to network resources — minimizing peak interconnect traffic without impeding cloud operations performance
- better adaptation of network resources with cloud service needs via user- or application-activated service changes — without the complexity or delays of “swivel chair” processes
- better optimization of total network resources by correlating services and transport aggregates across multiple layers and technologies
- better network availability — with predetermined protection and reduced operational errors via software-driven provisioning across multi-vendor networks

For Network Service Providers, offering SDN-based network services provides the following additional benefits:

- more compelling and competitive services delivering higher value — justifying higher margins
- better utilization of network resources — reducing the effective cost of service delivery
- reduced operational complexity — reducing the cost of operations associated with service delivery
- a framework which is easily extensible to other services in other vertical market applications — extending the benefits to a wider range of customers and amortizing the cost of framework implementation

Conclusion

Cloud backbone WANs interconnecting service provider data centers pose challenges in terms of capital and operational costs, due largely to the transactional and time-variable nature of inter-data center traffic sources and flows, and the requirement to synchronize backbone network service configuration and traffic routing processes with data center-based infrastructure operations and demands. OpenFlow-based SDN provides an ideal means of coping with these challenges, achieving increased cost efficiencies through consistently better network utilization and operations automation, bending capital and operational cost curves downward and maximizing the value of network services to data center-based providers.

Contributors

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