A COORDINATED VIRTUAL INFRASTRUCTURE FOR SDN IN ENTERPRISE NETWORKS

SOFTWARE DEFINED NETWORKING (SDN), OPENFLOW AND APPLICATION FLUENT PROGRAMMABLE NETWORKS

STRATEGIC WHITE PAPER

Increasing agility and automation in the data center to optimize application delivery requires a complete, end-to-end, coordinated virtual infrastructure. This infrastructure will allow applications and the physical network to collaborate, thereby providing a high quality experience for users and enabling optimization of resources. The ideal solution should follow a Software Defined Networking (SDN) approach. This will allow it to bridge the gap between the network world and the newly virtualized compute world by defining a framework that uses standardized interfaces between applications and networks. Likewise, it should be flexible enough to leverage multiple methods, including OpenFlow, to provide direct access to all virtual and physical objects in the data center and enable manipulation of the forwarding plane of physical and virtual network devices, such as switches and routers.

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INCREASING AGILITY AND AUTOMATION IN THE DATA CENTER

A completely disruptive technology has been introduced to data center computing over the last decade. Virtualization has provided enormous flexibility, including the ability to dynamically optimize resource utilization based on workloads. As a result, application architectures have evolved. Applications can now be decomposed into components that run in their own virtual machine containers while sharing the same physical server. Virtual machines delivering a single application can be spread across multiple servers in the data center (or even between data centers) and moved rapidly between servers to optimize delivery performance. In effect, virtualization has enabled significant automation and cost reduction in the data center.

Unfortunately, this new found flexibility at the data center computing level has not been matched by an equivalent capability within the physical network. Today's data center network has very little awareness of the applications that are generating traffic and, conversely, the new virtual application control systems are unaware of the conditions prevailing within the network. Thus the network and the applications are operating in silos and any attempt by the network or the application controllers — the hypervisor — to improve network resource utilization usually leads to sub-optimal results.

With automation and the ability to rapidly shift workloads between servers in the data center come new requirements that the network and network management systems were never designed to handle.

All nodes in the network of today possess a limited view of the global state of the network because they operate solely by distributed control schemes. This results in a very robust solution for delivering highly available networks. But optimizing delivery performance for applications that are spread across several servers, rather than deployed on a single server, requires a global view of the conditions prevailing within the network. In many cases, time-intensive and error-prone manual intervention on the part of the network team is required when a virtual machine is moved. In other cases, network teams have been able to deploy maintenance intensive in-house solutions using scripting tools. This effectively defeats the intended goal of rapid compute workload optimization.

Increasing agility and automation in the data center to optimize application delivery can best be achieved with a complete, end-to-end, coordinated virtual infrastructure. This infrastructure will allow applications and the network to collaborate to provide a high quality experience for users and enable optimization of resources. To support this architecture the network must be equipped with:

- **Programmability,** which will provide a link between the application control and network control layer. This will enable an orchestrated capability to optimize application delivery performance and increase visibility.
- **Application fluency,** which will allow the network to automatically identify and provision applications and react to any subsequent movement of compute resources, such as virtual machines. This will unleash the workload optimization capabilities now available for computing and enable the network to dynamically adjust to application traffic flows, thereby tuning the network to provide a high quality user experience.
- **Global control view,** which will be maintained by the network to provide application and network control systems a global view of network conditions. This can be used

to improve local decisions made by individual network nodes on how to treat traffic streams of a particular application, as well as improve decisions made by application control systems concerning placement of virtual machines.

This paper outlines a practical approach to delivering a Software Defined Network (SDN) for enterprises with a coordinated virtual infrastructure. It provides an overview of SDN and OpenFlow to de-mystify these terms. And it outlines the Alcatel-Lucent Enterprise perspective on how programmability, application fluency and a global control view can be achieved for an enterprise with smaller scale computing needs than those in service provider or Web scale data centers.

SOFTWARE DEFINED NETWORKING (SDN) AND OPENFLOW

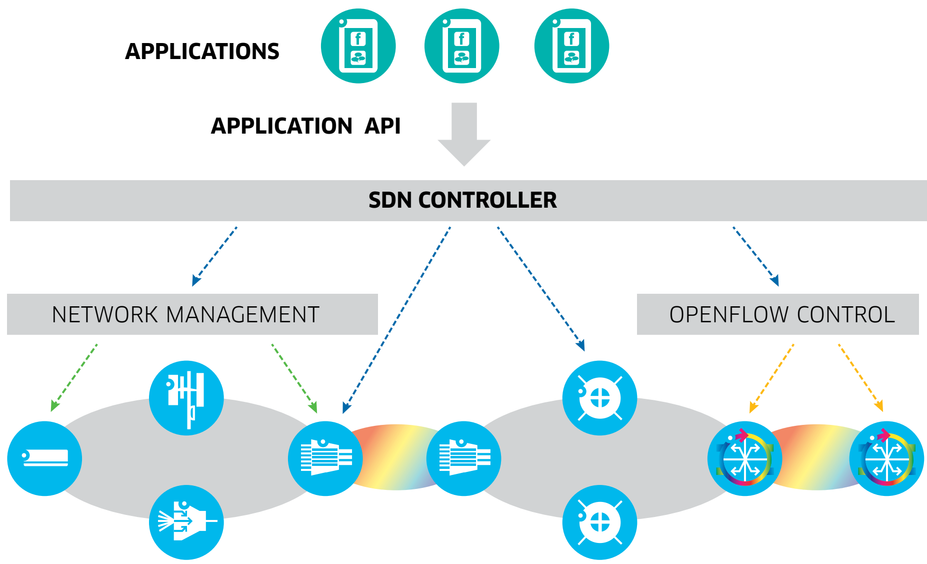
SDN and OpenFlow have been introduced to the networking world in an attempt to automate configuration changes in data center networks. To date, these new network additions have been used in very large scale computing environments, such as public clouds and web scale data centers. SDN and OpenFlow are quite different and should not be referred to interchangeably.

What is SDN?

SDN is an approach to bridging the gap between the network world and the newly virtualized compute world by defining a framework that uses standardized interfaces between applications and networks. Currently, industry attention is focused on southbound Application Programming Interfaces (APIs) that detail how an SDN framework interacts with the network. A number of communication protocols and interfaces, including existing protocols such as NetConf and Simple Network Management Protocol (SNMP), as well as new approaches based on web services, such as Representational State Transfer (RESTful) and Simple Object Access Protocol (SOAP) APIs are being discussed and can be used to realize this. OpenFlow is another such protocol.

SDN also implies developing an understanding of a global control view for the network and managing the network as a single unified abstraction. With the introduction of APIs and a global control view, SDN makes the network control plane remotely accessible and modifiable via applications that leverage open protocols. Network control and decision making can become partially centralized in SDN controllers, which maintain a global view of the network. As a result, the network appears to the virtualized application control layer as a single, logical switch (Figure 1).

Figure 1. Software-Defined Network Architecture



At the time of writing, it was not clear if this new centralized control view should be maintained as a separate SDN controller or become a function of the network provided by an existing network element for enterprises where the scale requirements are less than that of public cloud providers or providers of web scale applications.

What is OpenFlow?

OpenFlow is a technology. More specifically, it is a protocol being standardized by the Open Networking Forum. It provides direct access to and manipulation of the forwarding plane of network devices, such as switches and routers, over a network. This includes both physical devices and virtual switches. In this way, it allows the path of network packets through network switches to be determined by software running on multiple routers.

The OpenFlow protocol is based on a completely centralized control plane that is separated from the forwarding plane of the network nodes, unlike the networks of today where control and forwarding planes are both distributed in each network node. This centralization of control enables more sophisticated traffic management than is feasible using access control lists (ACLs) and routing protocols at each individual switch.

An SDN controller can use the OpenFlow protocol if it is realized on both the SDN controller and network nodes implementing the forwarding plane. OpenFlow allows the SDN controller to adjust the operation of the forwarding plane on a per flow basis.

At the moment, OpenFlow is primarily focused on data center and isolated enterprise network implementations. Google® is deploying an intra-D.C. network with OpenFlow, where the protocol is used as a traffic engineering tool, similarly to what Multi-Protocol Label Switching (MPLS) has been used for so far. Other implementations are focused on network virtualization in cloud computing environments where OpenFlow is used to control overlay networks. At present, potential service provider use-cases are around traffic-steering and hybrid-cloud/cloud-bursting, although there is no clear view on whether existing network features/protocols can be re-used or a new set of control and forwarding toolkits must be defined.

SDN and OpenFlow

SDN is an approach, OpenFlow is a technology and they are complementary.

The goal of SDN is to enable existing networks to become more adaptable to applications. More importantly, it can be used to bridge the gap between application control and network control elements, thereby allowing a coordinated effort to optimize application delivery performance. It can also provide an evolutionary path to complete network programmability by application control platforms. In addition, it can provide the means to add application level programmability to existing networks, as well as OpenFlow-enabled networks.

OpenFlow is one of several mechanisms that can be used to enable control of the forwarding behavior of network nodes by external elements. It is certainly one of the potential building blocks that can be used to deliver SDN. It provides a basic mechanism to program flow entries in a network node from an external controller. But it should be noted that several other methods already exist to achieve the same functions. OpenFlow alone is not sufficient to realize SDN, but SDN can be realized without OpenFlow. OpenFlow is focused initially on the interaction between the network control plane and forwarding plane. It leaves "northbound" APIs to application control platforms for later versions. OpenFlow assumes all control capabilities are removed from network nodes, providing forwarding without offering a sufficient scalability model for the newly proposed network architecture. Also, OpenFlow does not define mechanisms for interacting with existing control planes in today's network elements, a necessity for environments that must have backwards compatibility with existing network infrastructures. In addition, OpenFlow does not consider how the new SDN control plane should interact with current network management platforms.

BUILDING A COORDINATED VIRTUAL INFRASTRUCTURE IN ENTERPRISE NETWORKS

Defining the requirements

To build a coordinated enterprise virtual infrastructure, one must first consider the scale of the network in question, as well as desirable properties of current networks that should be maintained. For example, an enterprise network infrastructure is highly resilient and provides high performance in terms of bandwidth and ability to monitor application flows. This infrastructure, based on standard protocols, provides a resilient distributed control capability with a high degree of scalability and rapid recovery times upon failures. Therefore, any new solution that follows an SDN approach to deliver increased automation and coordination between the network and the applications should capitalize on existing capabilities and enhance them with additional functionality.

Understanding the limitations of current approaches

Efforts to date to realize SDN using OpenFlow and orchestration platforms, such as Open Stack and Cloud Stack, which have been focused on very large scale data centers have required large teams of experts to deliver the final solution. There are significant limitations to these solutions when the requirements of a typical enterprise are taken into account:

- A completely centralized control model as proposed with OpenFlow is not scalable, especially from the perspective of monitoring application flows.
- Smaller enterprises typically require simpler solutions with higher levels of automation built-in.

- There is no model for deployment alongside existing networks, which implies a "rip and replace" strategy is required for conversion of existing networks.
- There is a limited model for how OpenFlow-enabled networks interface with existing network management platforms and troubleshooting tools.

All of these issues must be addressed in a complete solution that can be successfully deployed in today's enterprises.

Desirable properties for a coordinated virtual Infrastructure

The ideal way to deliver automation to the network following an SDN approach is to provide programmability, application fluency, and a global control view, which will make it easier to virtualize the network and establish a control model that parallels the one established for applications. This solution should make use of standardized interfaces between applications and networks, as they become available, and provide a "plug-and-play" environment with a single pane of glass for management across applications and the network.

Programmability

Programmability will enable an orchestrated capability to optimize application delivery performance and provide increased application performance visibility for both the network and application control platforms, thereby removing the current division between applications and the network.

Increased programmability will require a rich set of capabilities from the network to link with application control platforms to share a global view of network status derived from information collected at each network node. And it will require the application control platform to issue requests to the network. These links can be delivered by network management platforms or from one of the network nodes, such as a core switch within a data center network in smaller enterprises or a separate network element in larger enterprises.

Application Fluency

Application fluency will allow the network to automatically react to the movement of compute resources, such as virtual machines, to unleash the workload optimization capabilities now available for computing and dynamically adjust to application traffic flows to provide a high quality user experience

An application fluent network benefits from increased autonomous decision making capabilities of network nodes making use of a rich feature set for user, device, virtual machine and application profiling. Profiles allow the network to collect and act upon information on the types of users, devices, virtual machines and applications that connect across the network to ensure a high quality experience. The profiles should provide the network with provisioning information, the security profile required by each user or device, the quality of service (QoS) requirements, and the priority of each user or device within the network.

By using profiles, the network can recognize users, devices, virtual machines and applications to automatically bind them to a profile, and to take autonomous action based upon the perceived state of an application. The network is also able to automatically discover the location of a user or device by monitoring traffic on a specific switch port. It can automatically provision the user and device on that switch port, including security and initial QoS parameters. And it can designate conversations initiated by a particular user on a specific device that are to be measured for actual QoS received.

Global Control View

A global control view will improve local decisions made by individual network nodes on how to treat traffic streams of a particular application, as well as improve decisions made by application control systems concerning placement of virtual machines.

Providing a global control view requires a continued migration to a model for network control that should follow a hybrid approach, while maintaining a degree of autonomy and distributed control within each network node. This is in contrast to a completely centralized control model. The global control view will be assembled by collecting event information at each network node and assembling an abstract view of end-to-end network status. This view can be shared with each network node to improve local decision making and via standard APIs to application control platforms.

THE ALCATEL-LUCENT COORDINATED VIRTUAL INFRASTRUCTURE

For some time now, Alcatel-Lucent has recognized the need for enterprise networks to be more aware of the applications that they transport. It has developed an Application Fluent Programmable Network optimized to provide programmability, application fluency, and a global control view for enterprise scale networks.

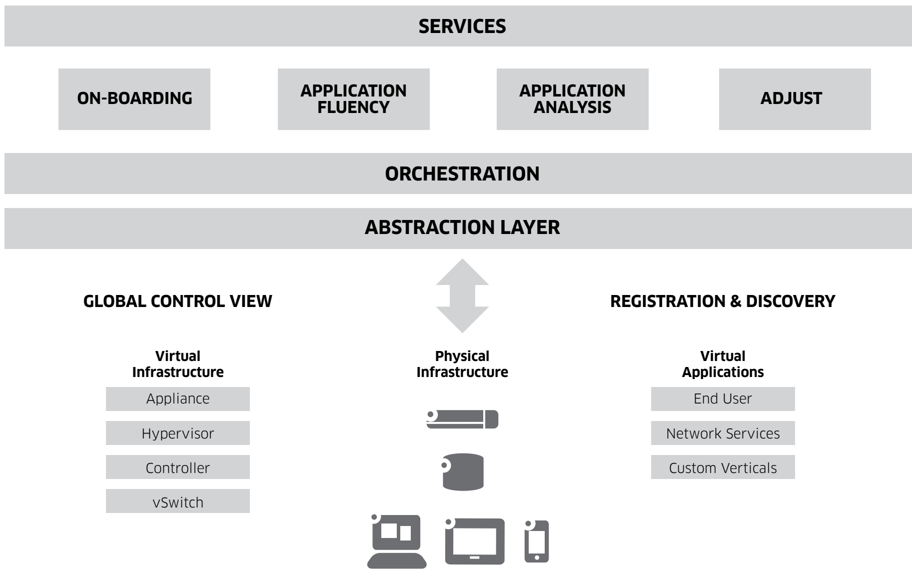
The Alcatel-Lucent solution follows an application fluent approach that:

- Increases embedded information on the types of users, devices and applications that connect across a network through embedded network profiles: User Network Profile (uNP) and Virtual Network Profile (vNP)
- Improves the ability of each network node to take autonomous action based upon the perceived state of the application through:
    - Automatic binding of devices and users upon network access to a uNP to support automatic assignment of security and QoS policy
    - Automatic binding of vNPs to virtual machines in the data center to support automatic provisioning, assignment of security and QoS policy with the network to allow the network to automatically adapt to virtual machine movement
- Enables links between existing network management platforms and application control platforms for improved visibility on virtual machine location and movement with the Alcatel-Lucent OmniVista™ Virtual Machine Manager (VMM).

The Alcatel-Lucent framework for delivering a coordinated virtual infrastructure is shown in Figure 2. Three types of operational elements are located in the data center:

- Virtual infrastructure, which is comprised of appliances, such as WAN optimization, hypervisors, controllers, such as OpenFlow controllers, and virtual switches
- Physical infrastructure, which is comprised of servers and switches
- Virtual applications, which is comprised of end user applications, such as unified communications and virtual desktop, services, such as security, and vertical specific applications, such as media control

Figure 2. One coordinated virtual infrastructure



Network capabilities specific to delivering a coordinated virtual infrastructure include:

- An abstraction layer that removes detail from upper layers of the framework concerning the interfaces of each element in the data center and the programmable capabilities that each element possesses. Each element in the data center can either be discovered or will register itself with the fabric establishing a two way communication with the fabric.
- An orchestration layer that controls the delivery of SDN like applications.
- A services layer that can be expanded as new SDN use cases relevant to the enterprise are discovered. The initial service categories that support current SDN use cases include:
  - On-boarding, which are services targeted to bring into service all the elements in the data center, such as boot services, Dynamic Host Configuration Protocol (DHCP), IP address management and Domain Name System (DNS)
  - Application fluency, which are services that discover context (user, device, business priority of the conversation) for each application using the network and direct how to fine tune the network to provide a high quality end user experience
  - Application analysis, which are services that measure and make visible actual service levels provided to applications using the network
  - Adjust, which are services that tune how the traffic flow of a specific application is treated by the network

Finally, when considering the entire physical infrastructure for application delivery, the end user devices must also be included, as shown in Figure 2.

The Alcatel-Lucent approach encompasses the goals of SDN while resolving the capability gaps that exist in current approaches. It envisions a role for SDN in enterprise networks that extends beyond the data center to include the entire corporate network. It also goes past simply automated configuration of network elements to focus on the entire user experience. With this approach:

- The scalability of current networks is maintained because individual network elements can continue to operate and make autonomous decisions on how to handle application traffic — even if the global control view becomes unavailable
- Enterprises that do not have teams of skilled programmers can benefit from a solution that is designed for their current size, leveraging existing management platforms and switches with additional automation built-in
- Existing network architectures, physical elements and management platforms can be easily and cost-effectively leveraged through an evolutionary approach to network development, rather than a revolutionary approach

CONCLUSION

Today's data center network has very little awareness of the applications that are generating traffic and, conversely, the new virtual application control systems are unaware of the conditions prevailing within the network. Thus the network and the applications are operating in silos and any attempt by the network or the application controllers to improve resource utilization usually leads to sub-optimal results.

To date, SDN has been used primarily on service provider and web-scale data centers to bring automation to the network for configuration. But there are limitations to current approaches to implement SDN, such as scalability and compatibility with existing networks. These limitations often make current solutions not applicable for a typical enterprise network.

The ideal solution to delivering automation to an enterprise network using an SDN approach is to provide programmability, application fluency, and a global control view. This will allow the network to be virtualized and establish a control model for the network that parallels the control model established for applications. This solution should make use of standardized interfaces between applications and networks, as they become available, and provide a "plug-and-play" environment for the network with a single pane of glass for management across applications and the network.

Alcatel-Lucent has recognized the need for enterprise networks to be more aware of the applications that they transport and has developed an Application Fluent Programmable Network optimized to provide programmability, application fluency, and a global control view. The Alcatel-Lucent approach to application fluent network infrastructures encompasses the goals of SDN while resolving the capability gaps that exist in the current approaches to SDN. In addition, the Alcatel-Lucent vision for SDN in enterprise networks extends beyond the data center to include the entire corporate network. It goes past simply automated configuration of network elements to focus on the entire user experience.

ACRONYMS

Term	Definition
ACL	Access Control List
API	Application Programming Interface
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
MPLS	Multi-Protocol Label Switching
RESTful	Representational State Transfer
SDN	Software Defined Networking
SOAP	Simple Object Access Protocol
SNMP	Simple Network Management Protocol
QoS	quality of service
uNP	user network profile
vNP	virtual network profile

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Alcatel-Lucent SDN-OpenFlow Position Statement – May 2012-07-26

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