The 2012 Cloud Networking Report

Part 3: Software Defined Networks

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Software Defined Networks

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Executive Summary

The 2012 Cloud Networking Report (The Report) will be published both in its entirety and in a serial fashion. This is the third of the serial publications. The first publication in the series described the changes that are occurring in terms of how cloud computing is being adopted, with a focus on how those changes are impacting networking. The second publication in the series focused on data center LANs. This publication will discuss Software Defined Networks (SDNs) and will include the results of a survey that was done in conjunction with Information Week. Throughout this publication, the IT professionals who responded to the SDN survey will be referred to as the Information Week Respondents.

As is discussed in this publication, SDN is a new approach to networking that aims to make data networks more flexible, easier to operate and manage, and better able to respond to the changing demands of applications and network conditions. The initial definition of SDN focused on the decoupling of the network control plane from the network forwarding plane and the centralization of the control functionality in a controller, which could be an appliance, a virtual machine (VM) or a physical server. The early discussions of SDN also tended to focus on the physical network elements that comprised the network layers (e.g., Layer 2 and Layer 3) of the OSI model.

As is typical of emerging technologies and new approaches to networking, there is currently somewhat of a broad definition relative to how the industry, particularly vendors, define SDN. The emerging definition of SDN keeps a focus on Layer 2 and Layer 3 functionality. It does, however, add a focus on Layer 4 through Layer 7 functionality and it also adds a focus on supporting not just network equipment that is physical, but also virtual. That shift in definition is more than just semantics; it shows a change in the perceived value of SDN. In the emerging view of SDN, the value stems not just from separating the network control and forwarding planes, but from replacing a manual interface into networking equipment with a programmatic interface and that value occurs across the entire IT infrastructure. Over the last few months there has also been more discussion in the industry on the most important question related to SDN, a question that is expanded upon in this publication. That question is “What is the real value that SDN provides to enterprise IT organizations.”

The focus of the subsequent publications of The Report will be:

- Wide Area Networking
- Management

The Report will also be published in its entirety and there will be a separate executive summary that covers the totality of The Report.
The Definition of Software Defined Networking (SDN)

In the current environment vendors tend to have different definitions of SDN. The three most common ways that vendors use the phrase software defined networks are discussed below.

1. **Programmability of switch control planes whether or not the control plane is segregated and centralized**

   This approach to SDN is based on having direct programmatic interfaces into network devices, which are broadly defined to include all L2 - L7 functionality. In this approach, the control and forwarding planes are not separated, nor is the control plane centralized. Providing direct programmatic interfaces into networking devices is not new, as multiple vendors have supported this functionality for several years.

   One advantage of this approach is that it enables very detailed access into, and control over, network elements. However, it doesn't provide a central point of control and is vendor specific. While some network service providers may adopt the approach of directly accessing network platforms, it is unlikely to gain much traction in the enterprise market in at least the near term.

2. **Distributed Virtual Switching with segregation of control and data planes**

   In this approach to SDN the control and forwarding planes are separated. This approach is based on leveraging a virtual switch (vSwitch) and having the vSwitch function as a forwarding engine that is programmed by a device that is separate from the vSwitch. This functionality is used as part of an overlay network that rides on top of the existing network infrastructure using protocols such as VXLAN or NVGRE. As was the case with the approach to SDN discussed above, multiple vendors have supported this approach to SDN for several years.

3. **An architecture similar to the one shown in Figure 1**

   This is the most common way that vendors define SDN. Based on this definition, SDN is positioned as an emerging network paradigm that is based on multiple levels of abstraction. These levels of abstraction allow network services to be defined, programmatically implemented, and managed centrally without requiring network operations personnel to interface directly with the control and management planes of each individual network element that is involved in delivering the service. Instead, the SDN operator can deal with a pool of devices as a single entity.

   There are a couple of important options for how the architecture shown in Figure 1 could be implemented. One key option is the protocol that is used to communicate between the switch and the controller. The most commonly discussed such protocol is OpenFlow, which is described in a subsequent section of this document. Alternative ways to communicate between the controller and the switch include the Extensible Messaging and Presence Protocol, the Network Configuration Protocol and OpenStack. The other key option is the amount of intelligence in the switch. In one alternative, referred to as a pure SDN switch, the intelligence in the SDN switch is limited to just what is needed for data plane packet forwarding. In the other alternative, referred to as a hybrid SDN switch, some of the traditional control plane functionality may be centralized and the remaining functionality
remains distributed within switches. Depending upon how much control functionality is centralized, this scenario may not result in switches with significantly less functionality and in fact may result in switches that require additional functionality.

Unless specifically mentioned, throughout the rest of this publication the definition of SDN that will be used is the third one in the preceding list. In addition, unless specifically mentioned, it will be assumed that OpenFlow is used to communicate between the controller and the switch and that the only intelligence in the switch is just what is needed for data plane packet forwarding.

With this definition of SDN, network flows are controlled at the level of the global network abstraction with the aid of the OpenFlow protocol, rather than at the level of the individual devices. Global control of the network is achieved by logical centralization of the control plane function. Based on these characteristics, a well-designed SDN offers the potential advantage of greatly improved flexibility, highly reduced operational complexity, and a high degree of agility in responding to dynamic changes in the demand for network resources.

Another aspect of SDN that is of interest for cloud computing is the automated provisioning of networks as a complement to the automated provisioning of servers and storage. An SDN can provide this capability via interfaces with cloud controller orchestration software, such as the open source OpenStack controller and its "Quantum" virtual network interface.

Most of the networking industry that supports the SDN movement believes that SDNs should be based on industry standards and open source code to the degree possible. The open development model is the preferred model for timely adoption of new SDN standards that support multi-vendor interoperability and the creation of a large ecosystem of vendors providing a range of SDN components and functionality needed to span a variety of SDN use cases.
The SDN Network Architecture

A layered architecture for SDN is shown in Figure 1. In Figure 1, the control plane function is centralized in SDN Controller software that is installed on a server or on a redundant cluster of servers for higher availability and performance.

<table>
<thead>
<tr>
<th>Figure 1: Software Defined Network Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Services</td>
</tr>
<tr>
<td>Global Network APIs</td>
</tr>
<tr>
<td>SDN Controller OS</td>
</tr>
<tr>
<td>Native Switch Driver</td>
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<td>vSwitch/Edge Virtualization Driver</td>
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<td>Network Virtualization Overlay Driver</td>
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<tr>
<td>OpenFlow Driver</td>
</tr>
<tr>
<td>Data Center Networked Elements</td>
</tr>
</tbody>
</table>

Below is a description of the primary components of the network model in Figure 1.

- **Network Services**
  These are written to a set of Global Network APIs provided by the SDN Controller’s operating system (OS). Network Services might include SAN services, Security services, Multi-tenant services, and Multi-path load balancing services provided by the SDN Controller vendor, as well as other services provided by an eco-system of ISVs and third parties writing applications to a set of published APIs.

- **The SDN Controller’s Operating System**
  This supports a number of drivers that distribute state in order to control the behavior of the underlying network elements so that the network will provide the desired network services. Below is an overview of these lower level control elements.

- **Virtual Switch /Edge Virtualization Drivers**
  These enable SDNs to address some of the special networking requirements imposed by server virtualization, including control of the edge virtualization capabilities of hypervisor-based distributed virtual switches (DVSs) and/or access switches. With standards-based edge virtualization both the hypervisor DVS and the access switch can support the IEEE 802.1Qbg standard\(^1\), which enables edge virtual bridging.

\(^1\) [http://www.ieee802.org/1/pages/802.1bg.html](http://www.ieee802.org/1/pages/802.1bg.html)
• **Network Virtualization Overlay Drivers**
  These interface with edge switches to provide network virtualization by overlaying a virtual Layer 2 Ethernet network over a Layer 2/ Layer 3 physical network. The overlay is generally implemented using some form of encapsulation/ tunneling that may be performed by an SDN controlled vSwitch, virtual appliance, or physical access switch.

• **OpenFlow Networking Drivers**
  These interface with OpenFlow-enabled switches.

At the present time, there are a number of OpenFlow switches and SDN controllers available in the marketplace. In addition, a number of vendors, including controller vendors, switch vendors and application delivery controller vendors, have announced network services that are layered on the controller.
Open Networking Foundation

The Open Networking Foundation (ONF) was launched in 2011 and has as its vision to make OpenFlow-based SDN the new norm for networks. To help achieve that vision, the ONF has taken on the responsibility to drive the standardization of the OpenFlow protocol. Unlike most IT standards groups or industry consortiums, the ONF was not by founded by suppliers of the underlying technologies, but by Deutsche Telekom, Facebook, Google, Microsoft, Verizon, and Yahoo! As such, the ONF is one of the very few IT standards groups or industry consortiums that were launched by potential users of the technologies on which the consortium focused.

As part of their stewardship of the OpenFlow protocol, in March 2012 the ONF sponsored an interoperability event that was open to all of the members of the ONF\(^2\). A total of fourteen companies and two research institutions participated in the event which focused on the OpenFlow v1.0 standard. According to the ONF, the majority of its members have implemented v1.0. The ONF has also stated that many of its members are not going to implement v1.1 but will move forward and implement v1.2 and v1.3.

The interoperability event tested the following capabilities:

1. Discovering the network using the Link Layer Discovery Protocol (LLDP)
2. Dynamically provisioning point-to-point Layer 2 paths across an OpenFlow network
3. Learning the Layer 3 (IP) network and responding to a failed link
4. Performing load balancing on flows
5. Slicing the network with FlowVisor, which is a special purpose OpenFlow controller that acts as a transparent proxy between OpenFlow switches and multiple OpenFlow controllers

Additional information on the testing and the lessons learned can be found at ONF Interoperability Event White Paper\(^3\).

One of the criticisms of the ONF is that it is focused just on OpenFlow-based SDNs and that as previously mentioned in this report; there are other ways to implement an SDN. While there is some validity to that criticism, one of the other approaches to implementing an SDN, providing direct access to switches and routers, is by its nature vendor specific and hence not subject to standardization by the ONF or any other organization. The other approach, the use of vSwitches and overlay networks, encroaches on the domain of the IETF, which is currently working on overlay protocols including VXLAN and NVGRE.

Another criticism is that the ONF has been too focused on enabling L2 and L3 functionality and has had too little focus on enabling L4 – L7 functionality. There is also some validity to that criticism. However, the success of either developing or adopting a new technology is predicated in part on being able to have a broad enough scope so that the technology does indeed add significant value, but not so broad as to cause undue delay or organizational barriers. For example, a network organization that is considering implementing SDN could advocate that by so doing, it would improve L2 and L3 networking functions and would also significantly improve L4 – L7 functions such as load balancing and security. The problem with taking that broad of an approach to SDN deployment is that it will likely mean that multiple groups within the IT

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\(^2\) The ONF sponsored a similar event in October 2012, the results of which were not made public prior to the publication of this document.

\(^3\) [https://www.opennetworking.org/membership/onf-documents](https://www.opennetworking.org/membership/onf-documents)
organization would all have to agree to the deployment of SDN and that a level of consensus would have to be reached relative to how it would be deployed. In most IT organizations, getting the participation and buy-in from multiple groups prior to the deployment of SDN would result in a significant delay in the implementation of the technology. An approach that is more likely to succeed is for the networking organization to implement SDN for purely networking reasons and hence not need the approval and buy-in of other groups in the IT organization. Then, at some appropriate time in the future, the network organization can encourage other IT groups to leverage their SDN deployment. A related consideration is that over time the deployment of SDN may encourage significant changes in the roles, culture and structure of IT organization. However, in the vast majority of cases, any approach to SDN deployment that requires significant changes in the roles, culture and structure of IT organization prior to implementation is DOA. Similar to the need for network organizations to focus initially on L2 and L3 functionality, if the ONF had adopted too broad of a focus early on, it ran the risk of making little if any progress.

In August 2012 the ONF announced four new initiatives that have less of a focus on OpenFlow than has been typical of past ONF initiatives. These four new initiatives, which are described below, have the potential to significantly accelerate SDN adoption. These new initiatives are:

1. **Architecture and Framework**
   This initiative will look at upper layer orchestration of the network with the goal of exposing the various interfaces and elements of an SDN and identifying how these interfaces and elements relate both to each other and to legacy networking. To the degree that this initiative is successful, it will mitigate one of the challenges that is associated with the adoption of SDN, which is how to integrate an SDN into an existing production network. This initiative is also intended to develop what the ONF refers to as “network solution elements”, which refers to entities such as APIs and data models, and to enable these network solution elements to “work well together”. While the ONF did not define what they meant by “work well together”, the goal is to foster greater automation of the network and reduce the amount of manual tasks that are currently required.

2. **New Transport**
   The ONF new transport initiative is intended to accelerate the deployment of OpenFlow and SDN in carrier networks, optical networks, and wireless networks by defining the requirements and use cases necessary to deploy SDN. According to the ONF, the initiative will investigate how to use OpenFlow and switches not just between Ethernet ports, but also between fibers, wavelengths, wireless channels and circuits. The goal of this initiative is for network operators and users to gain both economies of scale and more system-wide consistency in applying policy and security across a broader reach.

3. **Northbound API**
   This initiative will survey and catalog the APIs that exist, define how to characterize them, outline what they are intended to be used for, and how they interact with the network. The ONF stated their belief that cataloging and characterizing the APIs will offer a clear understanding of what functions the market views as important and the common thread for application scenarios. They also stated their belief that this work will aid software developers to better program and virtualize the network, and enable network operators to translate network capabilities into lucrative services.
4. **Forwarding Abstractions**
   The forwarding abstractions initiative will focus on the development of next generation forwarding plane models, with a particular interest in terms of how to exploit and differentiate the capabilities of OpenFlow based hardware switches. The ONF stated their belief that one of the key benefits of SDN is the ability to take advantage of merchant silicon to drive better price and performance in the data center. The ONF also stated their belief that this initiative will foster a competitive marketplace for high performance hardware that meets the needs of demanding customers and that network operators, including enterprises, will be able to reap the benefits of OpenFlow in the core of their networks, not just the edge.
OpenFlow

OpenFlow is an open protocol between a central SDN/OpenFlow controller and an OpenFlow switch that can be used to program the forwarding behavior of the switch. Using pure OpenFlow switches, a single central controller can program all the physical and virtual switches in the network. All of the control functions of a traditional switch (e.g. routing protocols that are used to build forwarding information bases (FIBs)) are run in the central controller. As a result, the switching functionality of the OpenFlow switch is restricted entirely to the data plane.

Most modern Ethernet switches and routers contain flow-tables, typically supported by TCAMs that run at line-rate to perform forwarding functions based on Layer 2, 3, and 4 packet headers. While each vendor’s flow-table is different, there is a common set of functions supported by a wide variety of switches and routers. It is this common set of functions that is exploited by the OpenFlow protocol.

Many existing high functionality Layer 2/3 switches can be converted to be OpenFlow-hybrid switches by the relatively simple addition of an OpenFlow agent in firmware supported by the native switch Network Operating System (NOS). As previously discussed, an alternative to adapting an existing switch to support OpenFlow would be to build an OpenFlow-only switch that, by definition, is dedicated to supporting only OpenFlow forwarding. In theory at least, an OpenFlow-only switch would be extremely simple and inexpensive to build because it would have very little resident software and would not require a powerful CPU or large memory to support the extensive control functionality typically packaged in a traditional network operating system (NOS). The ability to build a highly scalable, low cost, OpenFlow-only switch is currently limited by the ability of the merchant silicon vendors to supply the necessary functionality. That is a large part of the motivation for the previously discussed ONF initiative on forwarding abstractions.

The basic elements of an OpenFlow V1.0 network are shown on the left hand side of Figure 2. Most existing Open Flow Switches have been built to the V1.0 spec (12/2009). This spec has been enhanced three times in V1.1 (2/2011), V1.2 (12/2011), and V1.3 (6/2012) to add functionality including additional components as indicated on the right hand side of the figure.

As shown in Figure 2, the central controller communicates with the switch’s OpenFlow agent over a secure TLS channel. This channel could be either in-band or out-of-band. The OpenFlow agent on the switch populates the flow table as directed by the controller.
The data path of an OpenFlow V1.0 switch is comprised of two entities. One entity is a single Flow Table that includes the rules for matching flows to table entries. The second entity consists of counters that record the number of packets and bytes received per flow and other port and table statistics. Figure 3 shows the 12-tuple of header fields that are used to match flows in the flow table.

OpenFlow switches are required to support two basic types of actions: Forward and Drop. Forwarding is either directed to a physical port or to one of the following virtual ports:

- **ALL**: Send the packet out all interfaces, not including the incoming interface.
- **CONTROLLER**: Encapsulate and send the packet to the controller.
- **LOCAL**: Send the packet to the switch’s local networking stack.
- **TABLE**: Perform actions in the flow table. Applies for only packet-out messages.
- **IN PORT**: Send the packet out the input port.

For OpenFlow V1.0 there are also a number of optional/recommended actions:

- **NORMAL**: Process the packet using the traditional forwarding path supported by the switch (for OpenFlow-hybrid switches)
- **FLOOD**: Flood the packet along the spanning tree.
- **ENQUEUE**: Forward a packet through a specific port queue to provide QoS.
• MODIFY FIELD: Change the content of header fields, including set VLAN ID and priority, strip VLAN, modify Ethernet or IPV4 source and destination addresses, modify IPV4 TOS, modify transport source and destination ports.

When a packet arrives at the OpenFlow V1.0 switch, the header fields are compared to flow table entries. If a match is found, the packet is either forwarded to specified port(s) or dropped depending on the action stored in the flow table. When an OpenFlow Switch receives a packet that does not match the flow table entries, it encapsulates the packet and sends it to the controller. The controller then decides how the packet should be handled and notifies the switch to either drop the packet or make a new entry in the flow table to support the new flow.

Over the last year and a half extensive enhancements have been made to the OpenFlow specification under of the auspices of the Open Networking Foundation. A complete listing of the enhancements included in OpenFlow V1.1-V1.3 is beyond the scope of this document. However, some of the major changes include:

• Additional components of a flow entry in the flow table. In addition to the match fields, the following fields are included in the entry:
  ▪ PRIORITY: matching precedence of the flow entry
  ▪ COUNTERS: to update for matching packets
  ▪ INSTRUCTIONS: to modify the action set or pipeline processing
  ▪ TIMEOUTS: maximum amount of time or idle time before flow expiration
  ▪ COOKIE: opaque data value chosen and used by the controller to process flows

• Flexible pipeline processing through multiple flow tables, as shown in the right hand side of Figure 2. As a packet is processed through the pipeline, it is associated with a set of accumulating actions and metadata. The action set is resolved and applied at the end of the pipeline. The metadata allows a limited amount of state to be passed down the pipeline.

• The new group table abstraction and group action enable OpenFlow to represent a set of ports as a single entity for forwarding packets. Different types of groups are provided, to represent different forwarding abstractions, such as multicasting or multi-pathing.

• Improved tag handling includes support for Q-in-Q plus adding, modifying and removing VLAN headers and MPLS shim headers.

• Support for virtual ports, which can represent complex forwarding abstractions such as LAGs or tunnels.

• OpenFlow Extensible Match (OXM) uses a TLV (Type Link Value) structure to give a unique type to each header field increasing the flexibility of the match process.

• Basic support for IPv6 match and header rewrite has been added, via OXM.

• Support for multiple controllers to improve reliability.
Potential Benefits of OpenFlow

There are a number of possible ways for the control centralization, programmability, and flow forwarding characteristics of OpenFlow to be exploited by innovative users and vendors of network devices and software. This includes:

- **Centralized FIB**
  One of the primary benefits of OpenFlow is the centralized nature of the Forwarding Information Base (FIB). Centralization allows optimum routes to be calculated deterministically for each flow leveraging a complete model of the end-to-end topology of the network. This model can be built using a discovery protocol, such as the Link Layer Discovery Protocol (LLDP). Based on an understanding of the service levels required for each type of flow, the centralized OpenFlow controller can apply traffic engineering principles to ensure each flow is properly serviced. The result can be much better utilization of the network without sacrificing service quality. Centralized route processing also allows the pre-computation of a set of fail-over routes for each possible link or node failure. Centralized processing also can take advantage of virtually unlimited processing power or multi-core processors and cluster computing for calculating routes and processing new flows.

- **The Google G-Scale WAN Backbone**
  This is the WAN that links Google’s various global data centers. As is mentioned below, the most common discussion of implementing SDN focuses on the data center. However, the G-Scale WAN is a prime example of a production OpenFlow Layer 3 WAN that is realizing the benefits of FIB centralization. The G-Scale control plane is based on BGP and IS-to-IS and the OpenFlow-only switches are very simple 128 port 10 GbE switches that were built by Google using merchant silicon. It is important to note that when Google built these switches, 128 port 10 GbE switches had not yet been introduced in the commercial market. The Google G-Scale WAN is discussed in more detail in the next section of The Report.

- **OpenFlow Virtual Networking**
  As described in a preceding section of The Report, there are a number of approaches to network virtualization including simple VLANs and network overlays based on various MAC-in-MAC, MAC-in-IP or UDP encapsulations. Future versions of OpenFlow specs will undoubtedly support standards-based overlays. In the interim, OpenFlow can potentially provide another type of virtualization for isolating network traffic based on segregating flows. One very simple way to do this is to isolate sets of MAC addresses without relying on VLANs by adding a filtering layer to the OpenFlow controller. This type of functionality is available in v0.85 of the Floodlight controller. Floodlight’s VirtualNetworkFilter module also implements the OpenStack Quantum API. This provides the option of automatically provisioning OpenFlow virtual networks from the OpenStack cloud management system in conjunction with provisioning virtual servers and storage resources via the OpenStack Nova and Swift capabilities.

- **OpenFlow Multi-Pathing**
  Most networking vendors offer data center fabric solutions featuring some form of Layer 2 multi-pathing to improve the network’s capacity to handle “east-west” traffic flow which is characteristic of server virtualization, converged storage networking, and cluster computing. OpenFlow offers another approach to multi-pathing that does not rely on
standards such as TRILL or SPB. As noted earlier, the OpenFlow Controller (OFC) can use LLDP to discover the entire network topology via discovering switches and switch adjacencies. Using this topological model, the OFC can compute all the parallel physical paths, including paths that share some network nodes and other paths that are entirely disjoint - and therefore offer higher reliability. The OFC can then assign each flow across the network fabric to a specific path and configure the OpenFlow switches’ flow tables accordingly. The OFC can then offer shared and disjoint multi-pathing as network services that can be delivered to applications. With appropriate processing power, the OFC can support very large-scale networks and high availability via path redundancy and fast convergence following link or node failures.

- **OpenFlow Firewalls and Load Balancers**  
  By virtue of Layer 2-4 flow matching capability OpenFlow access switches can perform filtering of packets as they enter the network, acting as simple firewalls at the edge. With OpenFlow switches that support modification of packet headers, the SDN/OF Controller will also be able to have the switch redirect certain suspicious traffic flows to higher-layer security controls, such as IDS/IPS systems, application firewalls, and Data Loss Prevention (DLP) devices. Another possible security application of OpenFlow would be in Network Access Control (NAC).

  OpenFlow with packet header modification will also allow the switch to function as a simple, cost-effective load-balancing device. With modification functionality, a new flow can result in a new flow table entry that includes an action to modify the destination MAC and IP addresses. The modified address can be used to direct traffic to the server selected by the controller.
The Marketplace Reality

In July and August of 2012, Ashton, Metzler & Associates and Information Week conducted extensive market research into SDN. This included a survey that was completed by 250 qualified Information Week subscribers. It also included interviews that were conducted with both enterprise IT organizations as well as with vendors. This sub-section of The Report will discuss some of the key findings of that market research.

One key finding was that:

*Most enterprise IT organizations have little if any knowledge of SDN.*

That conclusion follows because over a third of the 393 IT professionals who received the screener for the SDN survey indicated that they had no familiarity with SDN and roughly half of the respondents who did have some familiarity with SDN indicated that they were only somewhat familiar with it.

Of the Information Week Respondents who were familiar with SDN, there was a high degree of familiarity with OpenFlow. However, in spite of the fact that, as previously mentioned, it is possible to implement an SDN and not use OpenFlow:

*The vast majority of IT organizations believe that OpenFlow is an important component of an SDN.*

The fact that OpenFlow is perceived as being so important to SDN could be another indication that the overall awareness of what SDN somewhat lags the reality. Alternatively, it could reflect a feeling on the part of IT organizations that while there are other ways to create an SDN, that OpenFlow provides distinct advantages that they deem to be critical.

Relative to the question of whether or not SDN switches will be just dumb forwarding engines or more highly functional hybrid SDN switches, the Information Week Respondents were asked “Do you believe that SDN will relegate switches and routers to being just relatively dumb forwarding engines?” They were given three possible answers: Yes; No; Don’t Know. The 250 responses were almost equally split across the three answers:

*There is not a consensus amongst IT organizations about whether or not SDN will relegate switches and routers to be just dumb forwarding engines.*

While SDN can be applied in a variety of places within the network, including the WAN, most of the current discussion of SDN focuses on implementing SDN in the data center LAN. With that in mind, the Information Week Respondents were given a set of fourteen challenges that are associated with data center LANs. They were asked to indicate which three challenges they thought SDN would be most helpful in resolving. Their responses are shown in Table 1.
### Table 1: LAN Challenges Mitigated by SDN

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Percentage of Respondents</th>
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</thead>
<tbody>
<tr>
<td>Improve network utilization and efficiency</td>
<td>42%</td>
</tr>
<tr>
<td>Automate more provisioning and management</td>
<td>35%</td>
</tr>
<tr>
<td>Improve security</td>
<td>32%</td>
</tr>
<tr>
<td>Implement network-wide policies</td>
<td>31%</td>
</tr>
<tr>
<td>Reduce cost</td>
<td>29%</td>
</tr>
<tr>
<td>Get more visibility into applications that are using the network</td>
<td>25%</td>
</tr>
<tr>
<td>Reduce complexity</td>
<td>23%</td>
</tr>
<tr>
<td>Increase scalability</td>
<td>20%</td>
</tr>
<tr>
<td>Reduce reliance on proprietary protocols or proprietary extensions of standards-based protocols</td>
<td>12%</td>
</tr>
<tr>
<td>Support creation of a private or hybrid cloud</td>
<td>10%</td>
</tr>
<tr>
<td>Support creation and dynamic movement of virtual machines</td>
<td>8%</td>
</tr>
<tr>
<td>Reduce reliance on vendor’s product life cycles</td>
<td>4%</td>
</tr>
<tr>
<td>Support more east-west traffic</td>
<td>1%</td>
</tr>
<tr>
<td>Other</td>
<td>1%</td>
</tr>
</tbody>
</table>

*Source: Information Week and AM&A*

The top five rows in Table 1 demonstrate that:

*IT organizations believe the primary value that SDN offers in the data center is that it can help IT organizations to reduce costs, automate management, and enforce security policies.*

When discussing SDN, it is common for the trade press and industry analysts to talk about the ability of an SDN to better support the adoption of private and/or hybrid cloud computing. The data in Table 1 indicates that that capability is not currently a strong driver of enterprise adoption of SDN.

It is common to have technology adoption driven by different factors at different points in the adoption cycle. For example, the initial driver of server virtualization was cost savings. However, once IT organizations began to implement server virtualization, most of them found that the agility that virtualized servers provided became as important to them as the cost savings. In similar fashion, IT organizations may well implement a SDN initially for cost savings or added security and later expand that implementation because it provides other capabilities, such as making it easier to support cloud computing.
As previously mentioned, a number of vendors, including controller vendors, switch vendors and application delivery controller vendors, have announced network services that are layered on the controller. Those network services include:

- Network virtualization
- Load balancing
- Firewalls
- DDOS prevention
- Traffic engineering
- Disaster recovery
- Application acceleration via techniques such as SSL offload
- Web optimization
- Network analysis whereby management data is filtered from network elements and sent to a central site for analysis.

In the near term, SDN applications will come primarily from current infrastructure players. While infrastructure players will likely continue to develop SDN applications:

*One of the key promises of SDN is that developer communities will be created and that these communities will develop a wide range of applications.*

While cost savings can drive the adoption of technology or new ways of implementing technology, a key factor that needs to be considered is how those changes impact security. The Information Week Respondents were asked about the impact of SDN on security. Their answers indicated that only a small minority of IT organizations thinks that implementing SDN will make networks less secure. In contrast:

*The majority of IT organizations believe that implementing SDN will make networks more secure.*

A previous section discussed some of the ways that SDN could provide more security functionality; e.g., by providing simple firewalls at the edge of the network. The primary ways that The Information Week Respondents believe that SDN will increase security is that it will:

- Make it easier to apply a unified security policy
- Make it easier to encrypt data
- Enable access control that is more granular and more integrated
- Provide additional points where security controls can be placed
- Make it easier to inspect and firewall VM to VM traffic on the same physical server

In order to understand the resistance to implementing SDN, the Information Week Respondents were given a set of fourteen potential impediments to SDN adoption. They were asked to indicate which the three top impediments to their company adopting SDN in the next two years. Their responses are shown in Table 2.
The data in Table 2 demonstrates that:

**The primary inhibitor to SDN adoption is the overall confusion in the market and the immaturity of products and vendor strategies.**

The Information Week Respondents were asked when they expected to have SDN in production. Their answers are shown in Table 3.

### Table 2: Inhibitors to SDN Deployment

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Percentage of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immaturity of current products</td>
<td>41%</td>
</tr>
<tr>
<td>Confusion and lack of definition in terms of vendor’s strategies</td>
<td>32%</td>
</tr>
<tr>
<td>Immaturity of enabling technologies</td>
<td>25%</td>
</tr>
<tr>
<td>Other technology or business priorities</td>
<td>24%</td>
</tr>
<tr>
<td>Lack of resources to evaluate SDN</td>
<td>23%</td>
</tr>
<tr>
<td>Concern that the technology will not scale to support enterprise-class networks</td>
<td>22%</td>
</tr>
<tr>
<td>Worry that the cost to implement will exceed ROI</td>
<td>18%</td>
</tr>
<tr>
<td>We don’t see a compelling value proposition</td>
<td>18%</td>
</tr>
<tr>
<td>Lack of a critical mass of organizations that have deployed SDN</td>
<td>14%</td>
</tr>
<tr>
<td>Concern that major networking vendors will derail SDN by adding proprietary features</td>
<td>13%</td>
</tr>
<tr>
<td>Not scheduled to have a technology refresh in that time frame</td>
<td>11%</td>
</tr>
<tr>
<td>No inhibitors to implementing SDN</td>
<td>4%</td>
</tr>
<tr>
<td>We’ve already implemented SDN</td>
<td>2%</td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
</tr>
</tbody>
</table>

*Source: Information Week and AM&A*

### Table 3: SDN Production Timeline

<table>
<thead>
<tr>
<th>Timeframe for Production</th>
<th>Percentage of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDN in production now</td>
<td>4%</td>
</tr>
<tr>
<td>Less than six months</td>
<td>5%</td>
</tr>
<tr>
<td>Six to twelve months</td>
<td>9%</td>
</tr>
<tr>
<td>More than twelve months but less than twenty four months</td>
<td>17%</td>
</tr>
<tr>
<td>More than twenty four months</td>
<td>11%</td>
</tr>
<tr>
<td>No plans to implement SDN</td>
<td>37%</td>
</tr>
<tr>
<td>Don’t know</td>
<td>17%</td>
</tr>
</tbody>
</table>

*Source: Information Week and AM&A*
As shown in **Table 3**, currently 4% of IT organizations have SDN already in production networks and an additional 14% expect that they will within a year. If that data is completely accurate, then 18% of IT organizations will have SDN in production within the next year. However, survey data about the planned deployment of technology is seldom completely accurate. For example, an IT organization that indicates that it has no plans to implement a new technology in the next year is more likely accurate than one that says they do. That follows because if the IT organization has not yet started the planning and lined up the resources to test and implement the technology, it is highly unlikely that they will be able to turn that around and implement the technology in the next six to twelve months. However, a company may have every intention of trialing and implementing a new technology in the next six to twelve months, but priorities can change in that time frame. As a result, it is highly likely that somewhat less than 18% of IT organizations will have implemented SDN in a production network within the next year.
Crossing the Chasm

In 1991 Geoffrey Moore wrote *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*. In the book, Moore argues that there is a chasm (Figure 4) between the early adopters of a technology and the early majority of pragmatists and that these two groups approach the adoption of technology very differently. For example, the early adopters of a technology are typically the organizations who identify the primary use cases of a technology and who have both the capability and the orientation to work through the issues that are associated with implementing early stage technologies. In contrast, the early majority typically adopts a technology once the use cases have been identified and validated and once the solutions are stable. While there is a chasm, or discontinuity, between the early adopters and the mainstream adopters, there is typically a continuum of risks and rewards that then separates the early majority from the late majority from the laggards.

At the current point in time, SDN is appropriate only for early adopters. The market research previously presented indicates that 18% of IT organizations intend to have SDN in production within a year. Some market adoption studies\(^4\) indicate that the innovators and early adopters are roughly 16% of the total number of companies. Hence, if that market research is close to 100% accurate, then one could argue that SDN will cross the chasm and become a mainstream approach to networking in roughly a year. However, as was previously discussed, survey respondents tend to be optimistic relative to their adoption of technology. In addition, below is a list of factors that will influence the rate of adoption of SDN and hence will either increase or decrease the amount of time it will take for SDN to cross the chasm and become a mainstream approach to networking.

- The development and validation of compelling use cases.
- The stability of the OpenFlow protocol.
- The stability of the north bound APIs.
- Broad interoperability of products.
- The creation of an application developer community.
- The development of strong partnerships amongst members of the SDN ecosystem.
- Ongoing mergers and acquisitions.
- The lack of a major issue such as the inability of SDN solutions to scale or a major security incident that was the result of deploying SDN.

The bottom line is that SDN will likely cross the chasm in the next year or two.

A Plan for SDN

Given that there is a high probability that SDN will have a major positive impact on networking, IT organizations need to break through the cloud of confusion that surrounds SDN in order to better understand it and to establish an SDN strategy – even if that strategy ends up being that the IT organization decides to do nothing relative to SDN for the foreseeable future. Some of the components of that strategy are:

- A firm definition of what SDN means to the organization. This includes taking a position relative to whether or not they want to implement an SDN that features:
  - The direct programmability of switches and routers, which in most cases will be accomplished by leveraging software created by a third party.
  - The separation of the control and forwarding planes and use OpenFlow for communications between them.
  - The separation of the control and forwarding planes and use something other than OpenFlow for communications between them.
  - An overlay network.
  - Other approaches and technologies.

- The use cases that justify deploying SDN, whether that is to solve problems or to add value. Included in this component of the strategy is an analysis of alternative ways to solve those problems or add that value and the recognition that the use cases may change over time.

- An ongoing analysis of the progress that SDN is making relative to crossing the chasm. This includes analyzing the items mentioned in the preceding section; e.g., the stability of OpenFlow and of the northbound APIs.

- The identification of how extensive the implementation of SDN will be both initially and over the first couple of years of deployment. For example, will the implementation just include top of rack switches or will it also include some core switches? Will it include L4 – L7 functionality, such as load balancing or protection against DOS attacks?

- A decision on whether any of the control functions that have historically been done in switches and routers will be done in SDN controllers.

- An analysis of how the deployment of SDN fits in with both the existing infrastructure as well as with other IT initiatives that are in progress.

- An analysis of the SDN strategies and offerings of various vendors and the identification of one or more viable SDN designs. This includes an analysis of the risks and rewards of acquiring pieces of the SDN from disparate vendors vs. trying to acquire all or most of the solution from a single vendor.

- The identification as to whether or not the IT organization will write applications itself to take advantage of SDN and if so, what has to happen within the organization to enable that capability.
• The identification and analysis of the commercially available applications that take advantage of SDN.

• An evaluation of the availability and scalability characteristics of the particular SDN designs that are under consideration.

• An analysis how the IT organization can provide a sufficient level of security for the controllers.

• Assuming that the IT organization is interested in OpenFlow: An analysis of whether to implement OpenFlow only switches or hybrid switches that support OpenFlow and traditional networking.

• The identification of how the IT organization will manage and troubleshoot their SDN deployment.

• An evaluation of the publicly available reports on interoperability testing.

• A plan for testing the SDN designs and use cases that are under consideration.

• An analysis of how the intended implementation of SDN would impact the current networks.

• A plan for how the IT organization will minimize and mitigate the risks that are associated with implementing SDN.

• A program for getting management buy-in. This includes getting funding as well as the buy-in from any other organization that will be directly impacted by the deployment of SDN.
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Simplify and Accelerate Private Cloud Deployments with Cisco’s Virtual Networking Portfolio

Cisco and a Multi-Vendor Ecosystem Provide Cloud-ready Network Solutions

<table>
<thead>
<tr>
<th>ROLE OF THE NETWORK PLATFORM IN CLOUD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Access to Critical Data, Services, Resources and People</strong></td>
</tr>
<tr>
<td>• Core fabric connects resources within the data center and data centers to each other</td>
</tr>
<tr>
<td>• Pervasive connectivity links users and devices to resources and each other</td>
</tr>
<tr>
<td>• Network provides identity- and context-based access to data, services, resources and people</td>
</tr>
<tr>
<td><strong>Granular Control of Risk, Performance and Cost</strong></td>
</tr>
<tr>
<td>• Manages and enforces policies to help ensure security, control, reliability, and compliance</td>
</tr>
<tr>
<td>• Manages and enforces SLAs and consistent QoS within and between clouds, enabling hybrid models and workload portability</td>
</tr>
<tr>
<td>• Meters resources and utilization to provide transparency for cost and performance</td>
</tr>
<tr>
<td><strong>Robustness and Resilience</strong></td>
</tr>
<tr>
<td>• Supports self-healing, automatic redirection of workload and transparent rollover</td>
</tr>
<tr>
<td>• Provides scalability, enabling on-demand, elastic computing power through dynamic configuration</td>
</tr>
<tr>
<td><strong>Innovation in Cloud-specific Services</strong></td>
</tr>
<tr>
<td>• Context-aware services understand identity, location, proximity, presence, and device</td>
</tr>
<tr>
<td>• Resource-aware services discover, allocate, and pre-position services and resources</td>
</tr>
<tr>
<td>• Comprehensive insight accesses and reports on all data that flows in the cloud</td>
</tr>
</tbody>
</table>

The Power of Cloud for the Enterprise

Business and IT executives are confronted daily by conflicting and exaggerated claims of how cloud will transform their industries, but the lure of transformative efficiency and agility is hard to ignore. Understanding the objectives and obstacles to cloud, as well as the solutions to overcome those obstacles is the key to achieving cloud-readiness.

Defining Cloud

In the simplest terms, cloud is IT delivered as a service over the network. Going a level deeper, cloud is a model in which IT resources and services are abstracted from the underlying infrastructure and provided on demand and at scale in a multi-tenant environment.

- **On demand** means that resources can be provisioned immediately when needed, released when no longer required, and billed only when used.
- **At scale** means the service provides the experience of infinite resource availability to meet whatever demands are made on it.
- **Multi-tenant environment** means that the resources are provided to many consumers - for example, business units - from a single physical infrastructure.

Note that the physical location of resources (on or off premises) is not a part of this statement. From the perspective here, that aspect has more to do with the way the cloud is sourced than with what the cloud does.
Barriers to Adoption

While most enterprises have recognized the potential benefits of cloud, practical concerns and perceived challenges have hampered the widespread adoption of cloud technologies and services. Many of these barriers can be understood as questions of trust: Can the cloud be trusted to deliver the same capabilities at the same service levels in the same controlled way as traditional IT?

- **Security**: Can the same security available to applications be applied in the cloud?
- **Compliance**: Can applications in the cloud meet the same regulatory compliance requirements?
- **Reliability and quality of service (QoS)**: Can the same service-level agreements (SLAs) for reliability and QoS be met in the cloud, especially given the multi-tenant use of the underlying IT infrastructure?
- **Control**: Can application owners still have the same amount of control over their applications and the infrastructure supporting them in the cloud?
- **Fear of vendor lock-in**: Will use of a particular vendor for cloud services or infrastructure prevent use of a different one in the future, or will the enterprise’s data and applications be tightly locked into a particular model?

These concerns represent questions of technology and governance, but do not address any potential organizational friction that might arise from adopting cloud. For example, who will manage which part of the cloud or who will determine which applications to migrate to the cloud. Cisco believes that all these concerns can be met with the right technology, architecture, and approach.

Practical Solutions for Cloud-ready Virtual Networks and Infrastructure

The Cisco Virtualized Multi-Tenant Data Center (VMDC) architecture provides an end-to-end architecture and design for a complete private cloud providing IaaS capabilities. VMDC consists of several components of a cloud design, from the IT infrastructure building blocks to all the components that complete the solution, including orchestration for automation and configuration management. The building blocks are based on stacks of integrated infrastructure components that can be combined and scaled: Vblock™ Infrastructure Packages from the VCE coalition developed in partnership with EMC and VMware and the Secure Multi-Tenancy (SMT) stack developed in partnership with NetApp and VMware. Workload management and infrastructure automation is achieved using BMC Cloud Lifecycle Management (CLM). Clouds built on VMDC can also be interconnected or connected to service provider clouds with Cisco DCI technologies. This solution is built on a service delivery framework that can
be used to host other services besides IaaS on the same infrastructure: for example, a virtual desktop infrastructure VDI).

These solutions for building private clouds are also being used by service providers to build cloud infrastructures on which to provide public, hybrid, and virtual private clouds to their enterprise customers. With service providers and enterprises, Cisco is developing an ecosystem of cloud providers, builders, and consumers. This ecosystem will be able to take advantage of common approaches to cloud technology, management, interconnection, and operation.

Where to Begin Your Cloud Journey

Cisco is working with its broad ecosystem of partners to assist some of the world’s leading institutions in their initial cloud deployments. Cisco will have a central role in the unique journeys of enterprises, small and medium-sized businesses (SMBs), public-sector organizations, and service providers as they move to cloud.

When the topic of cloud comes up, the conversation often focuses on the newest technologies and the latest service provider offerings. However, Cisco believes that every conversation needs to begin with an understanding of the expected business outcomes. Is the goal lower total cost of ownership (TCO) or greater agility and innovation, or some blend of the two? The journey to cloud has many paths; starting the journey without a clear understanding of the destination can lead to disappointing results.

Enterprises should start the journey to cloud by answering some basic questions:

- What is the expected impact of cloud on my business?
- Which applications can and should I move to the cloud?
- What cloud deployment model is best suited for each of my applications?
- How do I maintain security and policy compliance in the cloud?
- How do I transition my organization to best take advantage of cloud?

The answers to these questions will fundamentally shape your cloud strategy. We are helping customers define and implement a pragmatic approach to cloud. We deliver solutions that address our customers’ unique business architecture and needs, align with regulatory constraints, and are optimized according to the customer’s individual preferences for performance, cost, and risk.

For More Information

As you begin your own journey to the cloud, we invite you to discuss the right approach for your organization with your Cisco account manager, channel partners, and other IT advisors. For additional information about cloud, please visit: http://www.cisco.com/go/cloud.