MARKET FORECAST

APR 2016

Software-Defined Network Architectures Find High Customer Value When Applied to the WAN

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Networking has evolved rapidly in the last five years with the emergence of what is often called software-defined networking (SDN). Most recently, SDN concepts have begun to transform the enterprise wide-area network (WAN) – in many ways the most exciting software-defined transformation yet because of the clear and immediate benefits to the customer.

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Key Findings

Software-defined wide-area network (SD-WAN) solutions deliver significant and immediate customer benefits driven by the real need for more agile WAN management, improved WAN performance and the potential for significant WAN cost reduction.

These solutions are an excellent example of the value of overlay/underlay SDN architectures, where the existing transport network is preserved with a new layer of 'edge' networking that is centrally controlled.

SD-WAN solutions are enabled by other important network technology inflections, including networking as a virtualized software workload (rather than a dedicated appliance) and cloud-based networking that leverages the global on-demand public datacenters as a platform.

This technology is best seen as an adaptation and optimization of existing WAN systems rather than as a new approach that replaces those systems. There is a natural synergy between SD-WAN vendors and WAN service providers: The SD-WAN vendor gets access to the WAN service provider customers, while the WAN service provider is able to extend its capabilities by incorporating SD-WAN technology and systems.

Executive Summary

INTRODUCTION

Networking has evolved rapidly in the last five years with the emergence of what is often called software-defined networking (SDN). The SDN movement was based on the invention of OpenFlow, a revolutionary means of implementing network devices where the software of the device is replaced by use of a centralized controller in the network. OpenFlow was part of a broader movement to make networking more open and, by doing so, increase competition and enable broader innovation.

The initial focus of SDN was in the datacenter, where server virtualization created a clear need for improved networking so virtualized workloads could be addressed (the network just knew about the server, not the virtual machines running on it) and network provisioning could be accelerated to keep up with the greatly improved server provisioning agility that virtualization provided.

Recently, SDN concepts have begun to transform the enterprise wide-area network (WAN) – in many ways the most exciting software-defined transformation yet because of the clear and immediate benefits to the customer. The need for software-defined wide-area network (SD-WAN) systems must be understood in the context of how IT is changing as well as how networks are built.

First and foremost, the smartphone and public cloud are fundamentally changing IT. Mobile devices make IT services available almost anywhere in the modern world. Modern cloud computing lets services be built and provided globally with minimal investment in, or management of, physical resources. Mobile/cloud IT is revolutionary in what it offers users, and is completely disruptive to the existing IT ecology. The network is essential in mobile/cloud computing, but the networks involved are very different as users spend more time on cellular or public Wi-Fi networks and as applications are increasingly run in shared datacenters rather than private enterprise datacenters, with enterprise managed networks being displaced by independently managed networks and internet connectivity.

Independently, modern networking usage has evolved remarkably over the last 40 years. Many of the issues addressed by SDN are solutions to problems with or limitations of the original architecture and protocols, specifically problems that result from the autonomous operation of network devices: Once initialized, a network device (a router or switch) operates without ongoing human management or external automation. There is no global internet management system. This autonomous architecture served remarkably well to enable the growth and transformation of the internet but poses problems in modern networking precisely because the devices were not designed for collective management. SDN is first of all about improving network configuration automation and orchestration.

OpenFlow hasn't been a big winner – but while the SDN revolutionaries lost the battle, they are winning the war. SDN has transformed networking quite profoundly, but this has been accomplished largely through the adaptation of existing network products rather than by new OpenFlow-based products that replace them. The idea of pragmatic adaptation has led to an important category of SDN architectures in which a 'thin' layer of networking is added at the edge of the network, designed so that it can be managed by a central controller, while the legacy network remains in use as an underlying data transport. We call these networks 'overlay/underlay' architectures. This architecture is in common use in the datacenter: A centrally controlled software switch (the vSwitch) is added to each server at the hypervisor layer; a traditional network is used to send traffic between the virtualized servers and other destinations. The architecture leverages existing switches rather than requiring new OpenFlow switches. The new edge layer of networking (with central control) adds the new functionality required by virtualization, creates a control point for automation and enables much faster network provisioning agility.

METHODOLOGY

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1. Software-Defined Networking – Automation and Agility

SDN means many things to many people. For the discussion here, we focus on the customer benefits delivered by SDN solutions and stay away from the theology. SDN solutions improve network provisioning agility and automation, improve network instrumentation and visibility, and enable the creation of new network abstractions that are better suited to application development and use.

Network provisioning automation replaces manual network administration done through command-line interfaces, reducing opex, increasing reliability and improving agility. The benefits are the basic DevOps improvement: Automate where possible, therefore eliminating the delays and errors inherent in any human task.

One attempt to do this was OpenFlow, a network implementation model based on the use of a central controller rather than the distributed control logic in the autonomous devices. It created a great deal of investor and entrepreneur interest because it was seen as an opportunity to disrupt the established market positions in networking, an industry dominated by a few large vendors. But despite the early enthusiasm and investment, OpenFlow-centric SDN didn't accomplish its goals. The definition of OpenFlow became more problematic than expected when pressed into commercial use; re-implementing existing network functionality was a large task.

In the datacenter, motivated by the rapid growth of server virtualization, a different form of SDN took off, characterized by a new layer of networking implemented in server software that used the existing physical networking for data transport. This overlay/underlay architecture accomplished the goals of OpenFlow – the required improvements in orchestration and automation could be implemented in the new server software layer – and adoption was much easier because the investment in and existing functionality of the physical network could be maintained.

A virtual network – the network seen through an SDN interface – can but doesn't have to mimic a physical network. The thin layer of added software can create a new networking programming model or abstraction. In the datacenter a great example of how that can create value is what VMware markets as 'micro-segmentation.' Using NSX networking software, the network can be configured in an application-centric fashion and specified according to the application connectivity it provides rather than the myriad details needed to configure each of the switches correctly to accomplish that. Because the network can be specified at the application-connectivity level, it is easy to precisely define what connections are permitted between application pieces. This enables implementation of 'zero trust' networking, where anything that is not explicitly permitted is prohibited – i.e., micro-segmentation.

The overlay/underlay networking model that was adopted pragmatically in the datacenter is an architecture pattern that is now being reused in other areas with similar benefits, including the ability to make the network more manageable and agile while preserving investments in existing technology. When SDN is applied to the WAN, new network abstractions can provide high and clear value.

2. The Enterprise WAN

Enterprise networks can be categorized as datacenter, access, campus and wide area. Ten years ago IT was largely a headquarters and datacenter issue, and the WAN was the way to bring branch offices and travelers in as needed. In today's mobile/cloud IT, all of that is inverted. Every employee is more and more dependent on applications for their day-to-day jobs. Most employees are in the field, not at HQ. Increasingly the applications are executed from cloud datacenters or services. The WAN has become a critical asset, and the role of and requirements for it have evolved substantially.

Compared to the other categories of enterprise networks, the WAN has always been the most challenging to manage because it often incorporates a diversity of devices and services, and because some of those devices are remote and in unsupported locations. Administration and upgrade is complex; often access to WAN devices is most convenient via the WAN itself, so fixing any unrecoverable mistakes made during an upgrade may require access to the device itself. As a result of these difficulties, WANs are understandably often treated as fragile and touched as little as possible (in the tradition of "If it ain't broke, don't fix it!").

At the same time, there has never been a time when the need to evolve and transform the enterprise WAN was greater. Modes of application use and destinations are changing as more applications move out of enterprise datacenters and off enterprise managed networks; bandwidth demands are increasing rapidly as enterprises try to bring the home broadband experience into retail stores or branch offices; regulatory and security requirements are increasing and evolving; and new technologies have emerged that enterprises want to incorporate into WANs, including disruptively inexpensive consumer broadband internet connectivity (e.g., cable) and cellular wireless data links.

WHAT IS A SOFTWARE-DEFINED WAN?

Like the overlay/underlay datacenter network, with an SD-WAN the existing network is retained and used for data transport and new, centrally controlled networking software is added at the edge. The network is improved in terms of management agility by the centralized and automated management of the new edge networking layer.

There are many potential benefits of an SD-WAN architecture, including:

- **Automation of standard tasks:** Network administration is complex because it requires the correct provisioning of each device in the network in terms of the software revision level and protocols enabled, the correct configuration of each device once provisioned, and finally the correct and mutually consistent configuration of each link between devices. Historically, this has been done by the network vendor first developing and testing correct configurations, then training network engineers with respect to these best practices; finally, the actual network configuration – the mapping between the application requirements of the network and the specific configuration details – is done by those trained network engineers. An SDN system can bypass many of these steps by incorporating standard designs and best practices within the automation.
- **Optimization of physical resources:** Adding intelligence at the edge improves optimization of resource usage well beyond what is possible with existing networking capabilities such as performance-based routing because of the addition of a central controller that can aggregate and share performance information and more completely incorporate business priorities. For example, an inexpensive broadband link can be used rather than an MPLS link if the performance is adequate. An expensive mobile LTE link can be used when peak demand exceeds capacity and business policies and priorities dictate.
- **Ability to synthesize logical WAN links that are better than an individual physical link:** Data replication techniques such as forward error correction (introduced redundancy) can be used when link packet loss requires them. Traffic can be spread across multiple paths for higher throughput.

- **Handles regulatory requirements within the network:** Security and privacy regulations often dictate when and what encryption must be used to protect the transmission of sensitive data. In the past this often entailed binding applications and specific network resources – for example, requiring that sensitive data only be transmitted over specific, private links. With carefully designed SD-WAN software (the secure management of encryption is not simple), the issues of regulatory compliance can be largely managed within the network. A logical WAN link (the application-visible link) can be specified as, for example, PCI compliant, and then encryption can be brought to bear according to which physical links are required at any given moment.

THE ROLE OF THE CLOUD IN SD-WAN SOLUTIONS

The cloud is part of the SD-WAN challenge – enterprise traffic patterns are changing rapidly as more applications are run in the cloud. But it is also an important part of SD-WAN solutions because of the flexibility and capital efficiency it provides. Public (multi-tenant) cloud providers create a fascinating new platform for all forms of IT, including for the execution of network services that are packaged as virtualized software workloads and run on a virtualized server rather than embedded within network devices. The ability to deploy network functions packaged as VMs enables deployment on virtualized servers within branch offices as well as on diverse public and private cloud platforms.

The ability to deploy network functions as VMs also enables the broader use of 'dual-ended' WAN optimization technologies that require coordinated functions at each end of the optimized link (such as with Riverbed SteelHead appliances). Being able to package WAN optimization functions as a VM, rather than requiring that they be deployed embedded within a network device, creates opportunities to gain the benefits of these technologies, such as improved de-dupe and compression, that require keeping content-optimized compression catalogs at each end.

THE POTENTIAL VALUE OF NEW ABSTRACTIONS IN THE SD-WAN

Adding a layer of software enables the implementation of new abstractions, as noted earlier in the context of the datacenter. The benefits of new abstractions are potentially large, but often require a rethinking of how networks are managed and the role of network administrators and engineers.

Network virtualization is the separation of network use (application interfaces) from the specific details of the physical network underneath. While a physical network is managed by the network team, management of a virtual network can be delegated to the application team, a significant change in roles and responsibilities. Virtualization (of servers, networks or storage) requires organizational structures to evolve away from traditional silos. The addition of an SD-WAN system can be alternately viewed as either a valuable new tool for the network team or automation that replaces activities previously done by the networking team (i.e., a threat to and loss of control for the network team). The choice isn't simple: Networks are complex and benefit from skilled network engineers and administrators; at the same time, automation is generally a way to increase reliability and availability by minimizing the need for humans to be involved, and thus the potential for human errors. Ultimately, virtualized IT (virtualized servers, network and storage) requires that silo administration disappear, but these organizational changes can be the most difficult part of the transition.

The history of server virtualization suggests that network virtualization can be a win for both the application team and the network team. When a server is virtualized by the insertion of a hypervisor between the hardware and software workloads, both the user and the administrator benefit. For the server user, the new 'virtual server' abstraction is a clear improvement over the physical server: It can be created and provisioned in minutes (not weeks), the physical resources can be returned to a common pool when no longer needed, a known configuration can be replicated and duplicated on demand, a virtual server can be moved to a new location, the state of a virtual server can be saved for months and then restarted again later, and so on.

What's important and not necessarily obvious is that virtualization helps the server administrator as well. Previously, each application was tightly married to the specific hardware it ran on, and administrators were severely limited in how they could manage the hardware infrastructure. For example, refresh of the hardware required either the precise replication of the host server or application disruption when the application was rebuilt on a new server. With virtualization, the server team can actually manage the resources – select standard configurations (independently of the specifics of the application) and grow

and refresh those resources to be cost-effective and take advantage of advances in technology. Over time similar benefits will accrue to the network team in terms of the ability to select, manage and change WAN technology without detailed negotiation and planning with each application owner.

Virtualization in the sense of separation of use and resources was a necessary outcome with servers because the hypervisor was added to improve utilization, and abstraction came as an unplanned but highly valuable benefit. In the WAN, virtualization is optional – some of the SD-WAN implementations focus entirely on administration automation (which has high value by itself). We believe that creating new networking abstractions and separating use of resource management will be comparably valuable in the WAN and represent an important second attribute.

PUTTING THE SD-WAN INTO THE BROADER WAN CONTEXT

SD-WAN is best understood within the context of the existing and large WAN services market, valued at more than $10bn worldwide just for MPLS services. Network virtualization in the form of an SD-WAN is different from server virtualization, which rapidly transformed the server business. The impact of SD-WAN will be more evolutionary – it will optimize and improve existing WANs, but it won't replace them.

There are of course exceptions to this rule. For many new and small companies, consumer broadband and LTE mobile can be the basis for a very effective WAN. SD-WAN systems make the customer less dependent on an MPLS provider by making it much easier to integrate new technologies or new locations into the WAN. But conversely, SD-WAN technology enables a service provider to increase and extend an existing MPLS offering by making it possible to service new customer needs more quickly (using LTE) and more flexibly (e.g., with consumer broadband) than is possible within the MPLS system proper.

SD-WAN systems also don't displace the fundamental value of a trusted service provider partner. For most enterprises, the network is business-critical (if the network is down the business is down) and non-differentiating (they are not trying to beat competitors with better networking). Trying to manage the network themselves is more an opportunity to create problems than to solve them. For these reasons, networking is a perfect target for outsourcing to a competent and specialized partner. 'Software-defined' technology of any form changes the nature of management and administration from the siloed management of specific technology to the management of more complex and interacting systems. An SD-WAN is no different. Some of the mundane tasks are automated, but there is still a great opportunity for ongoing intelligent management as the load and the relative cost and availability of various networking technology changes.

3. Possible Benefits of SD-WAN Solutions

SD-WAN solutions offer many potential benefits, including:

- **Better use of internet technology to improve bandwidth and cost performance.** Modern consumer broadband technology is much higher-performing and dramatically less expensive than traditional enterprise branch connectivity. On top of that, consumer-facing enterprises (e.g., retail) are creating web-based user experiences that take advantage of home bandwidth and desire to make the same experience available within enterprise branches as well. Because internet traffic is broadly visible, care must be taken to use encryption as needed on private or sensitive data.
- **Better use of resources for internet access.** Historically, most enterprises backhauled all branch traffic to a corporate datacenter and then provided internet access from that point so that the desired security policies could be enforced, but this led to slow internet access from the branch (compared to what someone gets at home, for example) and congestion for enterprise traffic that needed to use the WAN link. Intelligent networking (policy- and destination-sensitive) combined with local (at the branch) internet connectivity can go a long way to improving things, provided that privacy, security and regulatory compliance can be ensured.
- **Optimized internet connectivity.** Modern internet usage was impossible to anticipate when the protocols were initially designed, and in many ways it is a miracle that the internet continues to function today (the initial ARPAnet backbone links were 56Kbps). 'Fixing' the many known problems isn't possible because of the millions of devices in use. Fortunately, many of the problems can be handled with edge intelligence. The internet operates on a packet-by-packet basis with each packet handled with best-effort (but not guaranteed) services. Adding end-to-end intelligence can offer marked benefits. The dynamic performance of available paths can be measured (latency, jitter and packet loss) and coupled with a clear view of application needs to optimize for application performance while at the same time sharing links intelligently – i.e., demanding connections can get as much capacity and priority as they need to meet the application SLA (e.g., a VoIP quality link), but no extra. Edge intelligence can be used to remediate observed problems: Use of forward error correcting codes (added redundancy) can make up for expected packet loss; higher-cost/quality links can be used sparingly but when needed to meet business goals; logical link traffic can be spread across multiple physical paths to achieve adequate application-level link capacity. Protocol transformation can be used (e.g., encapsulating IP within User Datagram Protocol) to avoid the latency-introduced delays in the basic flow control.
- **MPLS cost savings.** It is not uncommon for large enterprises to use two independent MPLS networks for robustness, with path choice done by simple routing. Adding intelligence at the edge allows the full available capacity to be used at any moment rather than simpler standby architectures. SD-WAN vendors report that for many large enterprises the opportunity to reduce MPLS costs is a key opportunity driver.
- **MPLS network enhancement.** An MPLS network can be improved by the addition of SD-WAN capabilities – for example, intelligence at the edge that can incorporate wired or LTE internet connectivity and that can make intelligent routing and path selection choices (whether to route traffic over the MPLS network or edge internet alternatives) based on policy, line quality and cost. Adding such capabilities can dramatically increase an MPLS provider's ability to offer higher bandwidth and quickly add new locations to the customer's network. In turn, the MPLS provider can be an invaluable go-to-market provider for the SD-WAN product because of existing customer relationships and service capabilities.
- **LTE cost optimization.** Modern 4G cellular technology and network coverage make wireless broadband a very real option, as consumers know from the fact that the bandwidth on their phones often exceeds bandwidth available in work locations. For most applications LTE connectivity is excessively expensive if used exclusively, but with intelligent network connectivity it can be used only when justified by application needs in a cost-optimized way. LTE can provide a great backup connection, only paid for if used, and then brought into the mix when business objectives and policies dictate. LTE also enables same-day network setup for new locations where LTE coverage suffices, with the possibility of substituting more cost-effective alternatives as soon as they can be installed.

- **Cloud system deployment.** Microsoft has done a brilliant job of moving existing Exchange customers to the Office 365 service rather than losing them to other cloud mail system providers. In doing so, it has provided two excellent examples of the potential value of SD-WAN technology. First, if an enterprise is using audio and video services from the cloud (one important aspect of Office 365), then consumer broadband connectivity to an office is excellent for providing cost-effective bandwidth, but inadequate in terms of availability and break-fix response assurance. However, it turns out that two consumer broadband systems that are connected in parallel and not subject to the same failure modes move connectivity availability up to acceptable levels and increase the total capacity in the branch office, and create a very cost-attractive alternative to the use of MPLS resources as a backup link. Second, SD-WAN technology in the form of selected use of special resources can be critical in terms of making the cloud system work in all branch offices (e.g., ability to use a specialized provider or service in a specific location and yet manage the network simply as a whole). One of the requirements of an IT transition like a move to Office 365 is that the benefit is only realized when the conversion is complete; as long as an enterprise is running two systems in parallel, it's clearly spending more money. A corporate cloud collaboration system like Office 365 doesn't work if it can't be used by a few locations. SD-WAN technology can be the key to the cost-effective implementation of a suitable WAN for all locations.
- **Optimization of cloud service traffic.** An SD-WAN system can incorporate knowledge about optimal connectivity to a cloud service, for example by measuring and monitoring access performance from the various nodes in the SDN and/or by using virtual nodes that have been installed on various public and private cloud platforms. Gathering, analyzing and using this data can achieve far better performance than use of the routes given by Border Gateway Protocol on the internet.

4. SD-WAN Solution Differentiators

SD-WAN offerings differ in technical approach but are often most differentiated by other factors including existing product lines, customer bases and specific customer WAN issues.

There are a variety of technologies that can play a role in an SD-WAN system:

- **Routing:** For maximum benefit, the SD-WAN system needs to control routing from the branch office in order to optimally balance application connectivity requirements with resource cost and utilization.
- **Internet access optimization:** SD-WAN systems enable intelligent, policy-driven use of local internet connectivity.
- **Cloud access optimization:** An SD-WAN system can optimize the path selected to access major cloud and SaaS services.
- **Internet transit optimization:** An SD-WAN system can optimize internet connectivity by incorporating performance data into route selection and thereby avoiding problematic parts of the internet.
- **WAN optimization:** This set of services is designed to maximize throughput on long (higher-latency) links. Technologies include de-duplication, forward error control, packet replication and various forms of protocol optimization.
- **Cloud-based networking:** Cloud platforms enable the construction and evolution of SD-WAN control systems. Over time more and more of the networking functionality will evolve to the use of software in the cloud as well.
- **Link bonding:** With intelligent edge networking, virtual links can be composed of multiple independent paths starting with the bonding of broadband links (e.g., multiple DSL connections as an alternative to less cost-effective links).
- **LTE and cellular networks:** Modern cellular networks can be an invaluable addition to an enterprise WAN but require knowledge of new providers and new technologies, including protocol optimization for cellular links.
- **Encryption and key management:** Encryption is an essential communications technology and a crucial element of most WAN networks. The SD-WAN system can either be a user of externally provided services (e.g., entitlement and key management) or provide integrated management and offload them from the enterprise network and IT teams.
- **Appliances/virtualized appliances/network functions virtualization (NFV):** Network functionality has always been largely implemented in software that is then embedded within and sold as a network device. For many reasons, more and more networking software is packaged as portable software (virtual machine or container). Understanding how to package and deploy networking as software requires new learning (e.g., hypervisor optimization), achieving performance comparable to a network device). NFV is a carrier-oriented initiative to create standards for software-packaged networking. Most SD-WAN systems won't need to be NFV-compliant, but the relationship is important for a vendor to understand.

Most of the prospects for SD-WAN systems are larger enterprises (because they have the larger WANs). A relationship with business partners that are already established in this market is an important, if not essential, asset for new, small market entrants. The major device vendors that sell into the branch are ideal partners, if not competitors (acquisition would be a likely outcome of partnership). For similar reasons, network service providers already serving those customers are potential go-to-market partners. Technology specialists such as LTE providers are also possibilities.

Some of the SD-WAN market participants (e.g., Cisco, Citrix, Riverbed, Silver Peak) have significant customer relationships and installed bases to leverage. And in some cases there are pretty direct links between existing products or services and SD-WAN opportunities, including MPLS technology and services, branch routing and service platforms, and WAN optimization technology.

5. Possible SD-WAN Business Models

There are many ways in which SD-WAN technology and systems can be packaged into a product offering:

- **Enterprise product offering:** An enterprise can buy a product (some combination of hardware and software appliances and a means of centralized control) and interpose it within its WAN, integrating it with existing links and services.
- **Enterprise product offering integrated with hardware line:** For a vendor with a related product line such as an edge router, the SD-WAN edge elements can be integrated with and sold as an option for those existing products and can leverage the installed base and existing platforms.
- **Co-marketing with WAN service provider:** Vendors can take advantage of a complementary and potentially synergistic relationship with existing WAN service providers.
- **Integrated with network service provider/relationship to NFV:** The network service provider market as a whole is being transformed by NFV, building much more agile and flexible technical infrastructures in hopes of becoming a more agile business. SD-WAN can also be viewed as an NFV-like offering for those providers, even if they aren't the customer's WAN provider.
- **Integrated with mega-scale cloud provider:** The most profound change in modern enterprise IT is the growth in use of mega-scale public cloud platforms, including Amazon Web Services (AWS), Google and Microsoft Azure in the US. An SD-WAN system can be imagined as an extension outward from those resources (rather than from the enterprise branches), although to date none of those platforms have developed such capabilities.
- **New intermediary service provider:** Finally, we can imagine new service providers emerging to manage SD-WAN services that integrate with the enterprise network and existing WAN links and service providers (a managed SD-WAN service, but separate from existing WAN services).

6. Market Forecast

The emerging SD-WAN market consists of a number of startups and a few larger publicly traded technology firms, neither category of which publicly discloses or breaks out revenue directly attributable to the focus of this report. In addition, as the market is still nascent, the solutions can be hardware-based, software-based, cloud-based or any number of combinations. Finally, a number of companies have just launched their respective offerings, making sizing their potential growth highly uncertain. This first forecast of the SD-WAN market is based on both written and verbal conversations with each of the vendors included, and represents what we believe to be a conservative estimate of the overall SD-WAN market in 2016 and beyond.

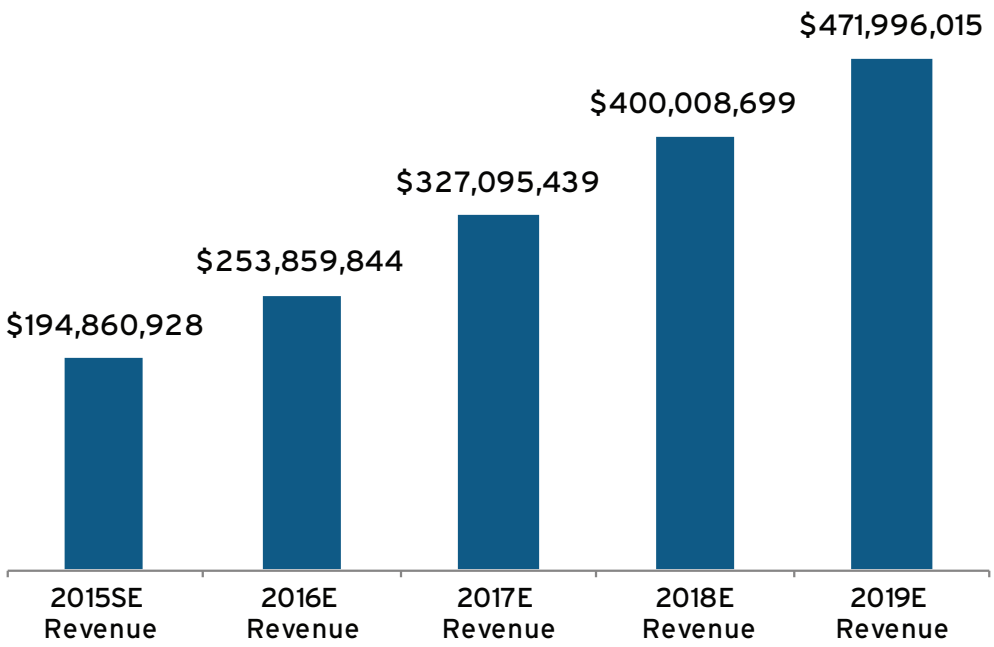
A number of market 'earthquakes' could occur, as they have occurred in prior market disruptions, that could increase the rate of adoption assumed in this forecast. These include: faster-than-anticipated adoption by carriers and other service providers in response to pressure from over-the-top service providers that wish to commoditize carrier WAN infrastructure; the inclusion of key SD-WAN abstraction technologies as a feature in the core operating system of mainstream networking equipment; and carriers continuing to price and market MPLS at current levels (margin preservation) versus competing aggressively against this new market threat.

In this initial forecast, we have included nine companies: Aryaka, Cisco, Citrix, CloudGenix, Cradlepoint, Silver Peak, Talari, VeloCloud and Viptela. While these companies differ widely in their respective approaches to the segment, we have included them in an aggregate bottoms-up market size (combined estimated revenues). By definition, this approach does not include 100% of the market participants and substitute functionality to SD-WAN in the market. We chose to use this approach in contrast to a 'percent cannibalization of legacy MPLS revenue' because we believe that SD-WAN is partially cannibalistic but also partially incremental to MPLS WANs.

By our measurement, the aggregate SD-WAN revenue generated by the nine companies we have included in this analysis totaled approximately $195m in 2015, and we expect that number to grow at a CAGR of 19.36% to just over $470m in 2019 (see Figure 1).

Figure 1: Total Market Revenue and Projection to 2019 ($US)

Source: 451 Research, 2016



Figures 2 and 3 provide vendor characteristics and vendor distribution by 2015 revenue for the SD-WAN space. Some high-level takeaways include:

- Two of the nine vendors included in this report are publicly traded, with the remaining seven being private firms. Public vendors represented only 19% of total 2015 estimated market revenue. The market is still too early to indicate that any vendor has exceeded $100m in annual revenue directly derived from SD-WAN product and services sales.
- The market is currently segmented into substitute but indirect functionality being provided by the networking incumbent (Cisco), larger (originally) WAN optimization companies that have made the leap to SD-WAN, and a number of challenger startups that are approaching the market from differing angles. We anticipate substitute functionality to expand from traditional networking vendors in response to the competitive challenge that SD-WAN represents to 'front-ending' branch and aggregation routers and the perceived loss of control that represents.

Figure 2: 2015 SD-WAN Market Statistics

Source: 451 Research, 2016

SUMMARY		VENDOR STATISTICS BY REVENUE TIER	
2015E Revenue ($M)	$194.8	# Vendors $30-100m	2
2019E Revenue	$471	*% of total*	*22%*
CAGR	19.36%	Total 2015E Revenue	$85M
Total Vendors	9	*% of total*	*44%*
PUBLIC/PRIVATE SPLIT		# Vendors $15-30M	5
Public Vendors	2	*% of total*	*56%*
% of total	22%	Total 2015E Revenue	$97.8M
Public Vendor 2015E Revenue	$36M	*% of total*	*50%*
% of total	19%	# Vendors $1-15M	2
Private Vendors	7	*% of total*	*33%*
% of total	81%	Total 2015E Revenue	$11.7M
Private Vendor 2013E Revenue	$158.5M	*% of total*	*6%*
% of total	81%		

Figure 3: SD-WAN Vendors by Revenue Tier, 2015

Source: 451 Research, 2016

$30-100M	Aryaka, Silver Peak
$15-30M	Cisco, Citrix, Talari, VeloCoud, Viptela
$1-15M	CloudGenix, Cradlepoint

7. Virtual WAN Vendor Profiles

The emerging virtual WAN vendors have a number of things in common (physical WAN abstraction, central point of orchestration); however, different vendors achieve these ends via different mechanisms. Although the market is too nascent to strictly compartmentalize into different 'camps' of approaches, there is early speciation among vendors that are building hardware-based solutions, services, software-only approaches or a combination of the above.

The software-only approach varies from vendor to vendor, with virtual customer premises equipment (CPE)/router approaches (e.g., CloudGenix) contrasting with end-user device-centric approaches (e.g., Cradlepoint). Hardware-based approaches (although each vendor downplays the hardware component in favor of the software component) have either evolved from legacy WAN optimization products and proxies (e.g., Cisco, Silver Peak) or are 'placeholder' x86 CPE that can sit alongside existing branch routers or as a substitute for the routers themselves (e.g., Viptela). Finally, there are cloud-based solutions that range from centralized WAN orchestration from a cloud service (e.g., VeloCloud) to a private WAN outside the internet that incorporates SD-WAN technologies (e.g., Aryaka).

The companies profiled in this report by no means constitute an exhaustive and complete list of all active vendors in this space. The segment is still being defined and a number of WAN optimization technologies, such as those from Riverbed and others, provide functionality that overlaps with the companies profiled. For the purposes of this initial market estimate, we have chosen to include companies that self-identify as SD-WAN or virtual WAN companies. This number is likely to grow as the market becomes better defined and its percent of overall WAN spending increases. In addition to the nine companies included in our 2015 market sizing above, we have also included profiles of Juniper, which has acquired SD-WAN capabilities, and Versa, which launched out of stealth at the end of 2015.

ARYAKA (PRIVATE)	
Headquarters: Milpitas, CA	aryaka
CEO: Shawn Farshchi	
FUNDING RAISED (ROUNDS)	$88m (6)
ESTIMATED REVENUE RANGE (BANDED)	$30-100m
PEERS	Citrix, Dell, Juniper, Riverbed, Silver Peak, VeloCloud, Viptela, Virtela
PARTNERSHIPS	21Vianet, Internet Binat, KDDI, Microsoft Azure, Sejong Telecom, SK Broadband
DIFFERENTIATION	Operates a proprietary 'virtual' network where the customer connects to a nearby Aryaka PoP that optimizes traffic across the Internet and inserts WANOP improvements as well.
Aryaka was one of the first vendors in the SD-WAN market and has built an extensive private virtual network that incorporates private links as well as selecting between backbone carriers and other internet connectivity options in addition to routing traffic over the public internet. It sells exclusively to enterprise customers. While Aryaka sees benefits from carrier adoption of SD-WAN capabilities, on balance it competes with carrier offerings in nature compared to companies such as Viptela and VeloCloud, which target carriers as a channel to market. In February, Aryaka announced private connections to Microsoft Azure via ExpressRoute, providing enterprise customers faster and more reliable connections to Office 365.	

CISCO (NASDAQ: CSCO)	
Headquarters: San Jose, CA CEO: Chuck Robbins	
MARKET CAPITALIZATION	$140bn (as of March 2016)
REVENUE (FROM EARNINGS REPORT)	$49.1bn (FY 2015)
PEERS	Citrix, Talari, VeloCloud, Viptela
PARTNERSHIPS	Akamai, Glue Networks, LiveAction
DIFFERENTIATION	Cisco is the leading enterprise network equipment vendor and the leading provider of edge routing devices. Its ACI is a leading policy-driven SDN solution in the datacenter and a precursor to Cisco policy-driven WAN offerings.
Cisco's approach to SDN has been the slow and steady adaptation of existing products. Cisco is a leading provider of existing WAN router technology and has made incremental improvements to edge routing (e.g., intelligent WAN). The company has also recently partnered with Akamai for joint solutions that integrate with Cisco's ISR routers. Recently, Cisco made significant SD-WAN announcements that incorporate use of its SDN controller (APIC-EM), the packaging of existing network functionality as virtual network functions, and the potential for replacing an edge router with a UCS or generic x86 server and a virtual ISR router. The Cisco ONE enterprise licensing program lets customers transfer licenses between physical and virtual devices during as SDN transformation. Partner Glue Networks offers cloud-based WAN orchestration of Cisco routers in customer environments. Partner LiveAction monitors and reports on network health and status while also managing QoS policy configuration.	

CITRIX (NASDAQ: CTXS)	
Headquarters: Ft. Lauderdale, FL CEO: Kirill Tatarinov	
MARKET CAPITALIZATION	$11.87bn (as of March 2016)
REVENUE (FROM EARNINGS REPORT)	$3.27bn (FY 2015)
PEERS	Cisco, Talari, VeloCloud, Viptela
PARTNERSHIPS	Zscaler
DIFFERENTIATION	Citrix is a long-term market and technology leader in the remote delivery of applications over the network (XenApp) and in the optimization of traffic for large web systems (NetScaler). Its networking approach has always been software-based. Citrix has a valuable enterprise customer base.
Citrix CloudBridge is a packet-by-packet traffic steering solution that is offered in virtual, physical and (recently) an AWS instance. CloudBridge also utilizes link bonding of multiple WAN connections, as well as optional multi-pathing of traffic to improve performance of VoIP and/or other application sessions, a common use case for WAN optimization and SD-WAN. Citrix provides the option of integrated WAN optimization features as well. The CloudBridge controller orchestrates 'data plane elements' with policies that can operate autonomously in the event that the data plane devices/virtual machines are disconnected from the controller.	

CLOUDGENIX (PRIVATE)	
Headquarters: Santa Clara, CA	CLOUDGENIX NETWORKS WITHOUT NETWORKING
CEO: Kumar Ramachandran	
FUNDING RAISED (ROUNDS)	$34m (2)
ESTIMATED REVENUE RANGE (BANDED)	$1-15m
PEERS	Aryaka, Cisco, Cradlepoint, Juniper (just SD-WAN)
PARTNERSHIPS	VMware
DIFFERENTIATION	CloudGenix is an SD-WAN pure-play startup with plans to bring a comprehensive WAN solution to medium to large enterprises.
CloudGenix markets both appliance-packaged and software-only versions of its SD-WAN solution. The company does not take a packet-by-packet traffic steering approach (as used by Silver Peak and Talari, for example) but rather handles traffic by application at the session level. The company achieves this without modifying existing router configurations, choosing to sit alongside a branch router, shortening the time to deployment.	

CRADLEPOINT TECHNOLOGY (PRIVATE)	
Headquarters: Boise, ID	cradlepoint Global Leader in 4G LTE Network Solutions
CEO: George Mulhern	
FUNDING RAISED (ROUNDS)	$73.13m (6)
ESTIMATED REVENUE RANGE (BANDED)	$30-100m
PEERS	Cisco
PARTNERSHIPS	Trend Micro, Zscaler
DIFFERENTIATION	Cradlepoint is a pioneer and market leader in the use of LTE technology for data networks. LTE coverage and performance makes it an attractive addition to many SD-WAN solutions because of its use as a Day 1 deployment technology, as a high-bandwidth backup technology, and as an additional technology to utilize as needed to meet dynamic capacity requirements.
Cradlepoint provides software-defined routers for SMBs and enterprises in 4G LTE, broadband and MPLS WANs, along with an enterprise cloud management platform. It provides platforms for fixed locations, vehicles and machine-to-machine (M2M) devices such as kiosks and digital signage. While the company has offered networking solutions since its inception, its acquisition of Pertino in December 2015 enabled it to leverage Pertino's cloud platform and create its SDN portfolio. Part of the reason for the acquisition was Cradlepoint's push to provide enhanced networking solutions for the Internet of Things (IoT), which increasingly requires greater levels of 4G LTE bandwidth. Pertino's portfolio helps in Cradlepoint's effort to provide wireless virtual networks in a secure manner for IoT products.	

JUNIPER (NYSE:JNPR)	
Headquarters: Sunnyvale, CA CEO: Rami Rahim	
MARKET CAPITALIZATION	$9.7bn (as of March 2016)
REVENUE (FROM EARNINGS REPORT)	$4.9bn (FY 2015)
PEERS	CloudGenix, Cradlepoint
PARTNERSHIPS	CloudScaling Technology, Nutanix, ThousandEyes
DIFFERENTIATION	Juniper has always emphasized both software and silicon technology as key to effective network solutions. The company acquired Contrail Networks, an early datacenter SDN pure play and has a comprehensive routing, switching and security portfolio.
The underlying optimization technology from the $60m acquisition of WANDL in 2013 is a key component of the current Juniper SD-WAN offering, the NorthStar Controller. The NorthStar Controller is a traffic optimization WAN SDN controller that automates the creation of traffic-engineering paths across the network for increased network utilization and customized programmable networking. Together with the company's Junos operating system, WANDL optimization algorithms and transport abstraction, the NorthStar Controller enables efficient design for control and visibility. Additionally, Juniper's open source SDN option is Contrail Networking, which automates and orchestrates the creation of highly scalable virtual networks and has brought about partnerships with the likes of Cloudscaling Technology, Sonus Networks and Silver Peak. The company also offers a cloud CPE product based on a combination of hardware and software components.	

SILVER PEAK (PRIVATE)	
Headquarters: Santa Clara, CA CEO: David Hughes	
FUNDING RAISED (ROUNDS)	$68.9m (10)
ESTIMATED REVENUE RANGE (BANDED)	$30-100m
PEERS	Aryaka, CloudGenix, VeloCloud, Viptela
PARTNERSHIPS	Avaya, Ciena, Dell, HP, Juniper, Infoblox, Nutanix, VMware, Zscaler
DIFFERENTIATION	Silver Peak was a late WANOP market entrant. As a result, the company aggressively adapted its solutions with new technology and market inflections, including specifically software-packaged networking and SD-WAN solutions.
Silver Peak's virtual WAN solution, Unity EdgeConnect, originated from the company's roots in WAN optimization. The company offers virtual, physical and cloud instances of its SD-WAN offerings, which are managed from a centralized orchestrator (controller). The company began with session-level traffic steering and added packet-by-packet steering in subsequent releases. Silver Peak adopted an intent-based provisioning model, which optimizes traffic by dynamically mapping business requirements to physical links based on capacity and performance (packet loss, jitter) and aggregates and disaggregates links (bonding) as needed.	

TALARI (PRIVATE)	
Headquarters: San Jose, CA	
CEO: Mark Masur	
FUNDING RAISED (ROUNDS)	$45m (6)
ESTIMATED REVENUE RANGE (BANDED)	$15-30m
PEERS	Cisco, Citrix, VeloCloud, Viptela
PARTNERSHIPS	Axial Systems Limited, Zycko
DIFFERENTIATION	Talari is a long-term participant in the WAN optimization market, having developed proprietary technology for bonding multiple DSL connections together as an alternative to higher-capacity but costlier MPLS links. This early business gave Talari a significant installed base of WAN-sensitive customers that form the basis for Talari's entrance into the SD-WAN market.
Talari claims to have more than 200 customers in over 40 countries after pivoting into SD-WAN over the past two years. Talari appliances are built for datacenters, headquarters and branch offices. The CT800 software appliance can be deployed with an application in AWS and VT500 is hosted on a local virtualized server, useful for branch offices. Major management changes in March 2016 included Mark Masur stepping in as CEO and cofounder John Dickey moving from CTO to president and COO.	

VELOCLOUD (PRIVATE)	
Headquarters: Mountain View, CA	
CEO: Sanjay Uppal	
FUNDING RAISED (ROUNDS)	$49m (2)
ESTIMATED REVENUE RANGE (BANDED)	$1-15m
PEERS	Cisco, Citrix, Talari, Viptela
PARTNERSHIPS	AWS, Console, Equinix, Forcepoint, HP, Intel, Microsoft Azure, VMware, Zscaler
DIFFERENTIATION	VeloCloud began with a midmarket internet/cloud focus and a solution that included an inexpensive but powerful edge appliance orchestrated and coordinated by a cloud system.
VeloCloud separates itself from other vendors in the segment by claiming it is the only purely cloud-delivered SD-WAN, leveraging its system of gateways residing in POPs around the globe within close proximity of cloud services (SaaS, IaaS, storage, security, etc.). Like Silver Peak, VeloCloud points to its sub-second application steering as a competitive differentiator, allowing it to steer traffic through the best links based on application type and near-real-time route congestion and performance. Unlike other vendors, it remediates network impairments by steering data plane traffic via its multi-tenant gateways or using its on-premises edge appliances.	

VERSA (PRIVATE)	
Headquarters: San Jose, CA	
CEO: Amir Khan	
FUNDING RAISED (ROUNDS)	$43m (2)
ESTIMATED REVENUE RANGE (BANDED)	$1-15m
PEERS	Cisco, VeloCloud, Viptela
PARTNERSHIPS	Ciena, EMC, RAD, VMware
DIFFERENTIATION	Versa started as an NFV pure-play startup with a comprehensive architecture for secure, multi-tenant, performance-optimized NFV solutions. After initial market testing, Versa decided to position itself as a next-generation branch communications and security solution and SD-WAN offering.
After three years of stealth development, Versa formally launched its branch office and WAN network offering last November, with an eye to the service provider and larger enterprise markets. The company focuses on specific SD-WAN, vCPE and branch security use cases rather than restructuring of a carrier or mobile operator's infrastructure. Versa recently unveiled plans for major European channel expansion, as well as new security capabilities to layer onto its SD-WAN solution.	

VIPTELA (PRIVATE)	
Headquarters: San Jose, CA	
CEO: Amir Khan	
FUNDING RAISED (ROUNDS)	$33.5m (1)
ESTIMATED REVENUE RANGE (BANDED)	$15-30m
PEERS	Cisco, Citrix, Talari, VeloCloud
PARTNERSHIPS	CA Technologies, EMC, SevOne, SolarWinds, Splunk, Verizon, Zenoss, Zscaler
DIFFERENTIATION	Viptela started with a focus on providing secure SD-WAN solutions that could incorporate diverse transport technologies that include the public internet, suitable for highly regulated industries. The solution includes a secure router and a distributed key management solution than runs on the router platform.
Viptela has been targeting carriers with what it characterizes as its secure overlay technology, and as such, does not actively advocate for the rip-and-replacement of MPLS networks (an approach that would likely alienate its target customers). While carriers represent a high-growth area for the company, it is also active in large enterprise, specifically retail, where the value proposition of SD-WAN technologies is demonstrable.	

8. Further Reading

Versa bulks up virtual branch security, signs RAD as a partner, April 2016

Shell games for SD WAN: Dispersive Technologies makes data hard to find, April 2016

Versa Networks exits stealth mode, launches with focus on branch-office use cases, January 2016

Cradlepoint delivers all-in-one routing for small branch offices, August 2015

9. Index of Companies