Software-defined WAN (SD-WAN) technology has emerged to mitigate the performance and security issues associated with Internet connections while cost-effectively supporting the migration of enterprise applications to the cloud. “The main goal of SD-WAN technology is to deliver a business-class, secure, and simple cloud-enabled WAN connection with as much open and software-based technology as possible. This can be used to deliver basic WAN connectivity, or it can be used for premium business services such as VPN, WAN optimization, and application delivery controller (ADC).”

This brief describes enterprise cloud solutions using Citrix* SD-WAN and Citrix ADC products, which are based on technologies from Intel and are optimized to deliver the performance and scaling needed by businesses today.

**SD-WAN Overview**

The deployment of SD-WAN products is ramping up, partly because they simplify and automate the management and operation of a WAN by decoupling the networking hardware from its control mechanism. They also provide the overlay capabilities and functionality that allow branch offices to securely connect to the cloud without relying on expensive MPLS-based WANs.

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**Introduction**

Enterprises rely on wide area networks (WANs) to deliver business critical applications to employees in branch offices and other types of remote locations. When deploying a WAN, IT personnel typically deploy multiprotocol label switching (MPLS); Internet connections via broadband technologies, such as cable and DSL; or a hybrid of the two. MPLS provides reliable, fast, and consistent performance and secure data communications via a virtual private network (VPN), but it is relatively expensive with respect to both OpEx and CapEx. Internet connections are often less reliable and secure than MPLS, but are approximately 50 to 150 times less expensive on a price/bit basis.¹

Software-defined WAN (SD-WAN) technology has emerged to mitigate the performance and security issues associated with Internet connections while cost-effectively supporting the migration of enterprise applications to the cloud. “The main goal of SD-WAN technology is to deliver a business-class, secure, and simple cloud-enabled WAN connection with as much open and software-based technology as possible. This can be used to deliver basic WAN connectivity, or it can be used for premium business services such as VPN, WAN optimization, and application delivery controller (ADC).”²

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**Figure 1.** SD-WAN technology logically bonds multiple MPLS and broadband paths into a single logical path.
Figure 1 shows how SD-WAN appliances create a virtual network overlay with MPLS and broadband connections, and route data traffic streams to connections best suited for them. For instance, time-sensitive applications, like VoIP, can now be sent over high bandwidth connections while best-effort applications, like email and web browsing, are sent over less ideal connections.

To ensure high-priority applications perform well and the bandwidth on all connections is fully utilized, SD-WAN appliances implement quality of service (QoS) rules at both ends, path selection, and traffic shaping. In addition, the appliances measure latency, jitter, congestion, and packet loss in real time and in both directions to create a performance profile of all the connections.

Secure, Hybrid-Cloud Application Delivery

To deliver applications to their users, many enterprises are adopting hybrid cloud architectures consisting of on-premises infrastructure, and public-cloud-and Software-as-a Service (SaaS)-based environments, as shown in Figure 2. The increasing adoption of cloud-hosted applications, including the move to SaaS, is causing enterprise IT to evaluate alternatives to inefficient backhauling of Internet traffic over costly legacy WAN architecture. The ability to differentiate Internet traffic coming out from the branch is critical to delivering a more reliable, low-latency user experience. With an integrated database of over 4,000 applications and deep packet inspection technology for real-time discovery and classification of applications, Citrix SD-WAN can intelligently steer traffic from the branch to the Internet, cloud, or SaaS the connections.

Cloud-Based Security Services

In this example, branch office and data center SD-WAN appliances employ next-generation firewall from third-party, cloud-based security services that allow enterprises to establish regional, cloud-based firewalls to protect remote networks, mobile users, and the SD-WAN fabric with traffic inspection and threat prevention capabilities. Citrix has partnered with a number of vendors offering cloud-based security services, giving geographically dispersed customers reliable and secure connections to data centers and the cloud.

Citrix ADC and Gateway

The Citrix ADC serves as a software-enabled proxy for applications deployed either on premises or in the cloud to ensure availability and business continuity, and provide L4-7 optimization and security. Citrix ADC is built to provide cloud-native functionalities that include:

- High-performance virtual appliances, supporting up to 100 Gbps
- Templatized configurations for configuring and replicating ADC instances
- Cloud-ready ADC for DevOps, enabling containerized microservices infrastructures

Citrix Gateway and Gateway Service authenticate users and enable secure access with single sign-on (SSO) to virtual desktop infrastructure (VDI), SaaS, and web applications, regardless of whether they are deployed on premises or in the cloud.

Citrix End-to-End SD-WAN Solution

As a comprehensive WAN Edge platform, Citrix SD-WAN can help customers consolidate or eliminate networking infrastructure (router and firewall functionality) at the branch, saving costs and valuable manpower. The Citrix SD-WAN integrated edge solution combines SD-WAN capabilities with WAN optimization, routing, and security in a single appliance. This allows enterprises to choose which network functions they need for each branch without worrying about purchasing and managing separate appliances for each function.
Solution Brief SD-WAN

Solution Advantages

The combination of Citrix SD-WAN, ADC, and Gateway products provides enterprises with compelling networking capabilities and functionality, including:

**Innovative Software**
- Flexible deployment options: hardware, virtual appliance, or hypervisor/container-compatible code
- High-performance ADCs that support up to 100 gigabits per second (Gbps)
- Reliable, resilient, secure WAN connections from branches to the cloud

**Cloud Native**
- High-performance virtual appliances in Amazon Web Services* (AWS*) and Microsoft Azure*
- Automatic provisioning of new virtual machines (VMs) and AWS auto-scaling

**End-to-End Management and Visibility**
- Advanced analytics to detect server anomalies for pre-emptive remediation
- Centralized visibility into connections between branch, data center, and cloud, and zero-touch deployment

**User Experience**
- Single sign-on to all applications, including hosted, mobile, cloud, and SaaS applications
- Consistent application experience for in-network and out-of-network users
- Reduced latency with large application library, deep packet inspection, and intelligent traffic steering to enable direct egress from the branch to the cloud and SaaS

Citrix*-Optimized Performance on Intel Processors

Citrix ADC and SD-WAN software runs on the suite of Intel Atom® processors, Intel® Xeon® D processors, and Intel Xeon processor E5 families, which come in a variety of configurations, enabling Citrix to match processor core counts, frequencies, and power levels to their workload requirements. For very high performance equipment, the Intel Xeon processor E5 v4 family supports up to four DDR4 DIMM channels and 22 cores, capable of delivering throughput up to 200 Gbps with low Secure Sockets Layer (SSL) or 120 Gbps with high SSL.

ADC handling of data security and the management of critical workloads are also boosted by technologies integrated in Intel Xeon processor E5 families, such as database transactions and vector operations:

- Intel® Advanced Vector Extensions (Intel® AVX) accelerate floating point operations for increased support of mixed workloads.
- Intel® Advanced Encryption Standard New Instructions (Intel® AES-NI) dramatically speed up software-based encryption (by up to ten times in parallel modes), decryption, key generation, and matrix manipulation.
- Intel® Data Direct I/O Technology (Intel® DDIO) sends I/O packets directly to the processor cache to improve throughput and lower latency.
- Intel® Virtualization Technology for Directed I/O (Intel® VT-d) improves performance of input/output (I/O) devices in virtualized environments and enhances overall security and reliability.
- Intel® Hyper-Threading Technology (Intel® HT Technology) allows Citrix products to process different packets in each core for better performance and scalability.

Scalable SD-WAN Appliances

Figure 3 shows possible hardware and software configurations for different types of SD-WAN appliances. On the left side, the SD-WAN appliances are customer premises equipment (CPE) specified for small office/home office (SOHO) and small, medium, and large branches. They have a wide range of computing and networking requirements, which can be satisfied by scalable Intel® architecture processors and Intel® Ethernet products. Since these processors feature backward compatible instruction sets, developers can use a common software base, including virtual network functions (VNFs), across all these appliances.

On the right side of Figure 3, a data center SD-WAN appliance runs VNFs similar to a large branch, but its hardware platform requires more processor cores since it handles more traffic than a branch.
Processor Architecture Consistency

As pointed out in the previous section, one of the advantages of using the same processor architecture across different SD-WAN appliance types is the ability to reuse application software. Two other reasons to design in Intel architecture throughout an end-to-end SD-WAN deployment are to achieve higher performance and security consistency. This is because the choice of processor architecture also dictates different performance accelerators, security features, and software packages accompanying the CPU.

One example is the Data Plane Development Kit (DPDK), which is a set of libraries and network interface controller drivers that can increase fast packet processing on Intel architecture platforms by up to ten times. DPDK has been optimized for the family of Intel architecture processors, meaning packet processing software running on SD-WAN appliances – from SOHO to data center – can benefit from this performance acceleration. In contrast, if a CPE appliance is built with another CPU architecture, it may not be able to reap the same gains from DPDK, possibly resulting in lower performance.

Like DPDK, some other capabilities available across select Intel architecture processors are:

- **Intel® QuickAssist Technology (Intel® QAT)**: On-CPU hardware acceleration for security, authentication, and compression.
- **Hyperscan**: Open source regex matching library, optimized for Intel architecture and suitable for deep packet inspection (DPI), intrusion detection (IDS/IPS), and firewall applications.
- **Intel® Virtualization Technology (Intel® VT)**: Hardware assist for virtualization software, eliminating performance overheads; improving security; and reducing software size, cost, and complexity.
- **Intel® Platform Trust Technology (Intel® PTT)**: Integrated CPU capabilities that store keys, passwords, and digital certificates, and support Microsoft* firmware requirements for a discrete Trusted Platform Module (TPM 2.0).

Benefits from Processor Architecture Consistency

There are a variety of reasons to use the same processor architecture across an end-to-end SD-WAN deployment.

**Improved network response:** If different SD-WAN device types employ similar accelerators, they will likely work together better. For example, if all devices can perform the same compute-intensive cryptography functions in hardware (instead of software), then it is less likely one of the devices will be a major bottleneck for network traffic.

**Economies of scale:** When deploying new features and functions on more device types across SD-WANs, the financial cost benefit is likely to be higher. Likewise, the economics of developing software improves when it can be applied to more devices.

**Performance scaling:** With the trend towards edge computing, the ability to scale the performance of edge devices to meet workload requirements becomes increasingly important. Predictable performance scaling is aided by architecture consistency that
drives greater device platform synergy with respect to software, NIC features, virtualization technology, accelerators, etc.

Emerging use cases and mega changes, like 5G, are increasing the need to run enterprise edge workloads, both existing and new (e.g., IoT, analytics, and ADC), on SD-WAN appliances and other edge devices. Therefore, enterprises should deploy edge devices with sufficient computing headroom to accommodate upcoming requirements in order to avoid having to change or upgrade these devices in the future.

Common management and provisioning framework: Operations costs can be minimized when architecture consistency makes it possible to manage a variety of devices with similar procedures, such as to:

- Automate services provisioning, configuration, and overall orchestration
- Autonomously connect to the cloud
- Configure/reconfigure based on business requirements

Software consistency from edge to data center: The same software (e.g., firewall, intrusion prevention) that runs in the data center can also run at the edge when the same processor architecture is used throughout the network.

Simplified deployment: Deployment complexity is reduced when similar requirements (e.g., software and configuration) are shared by different device types.

Consistent and Scalable SD-WAN

SD-WAN technology provides branch office and data center connectivity using a relatively simple and cost-effective approach to more efficiently consume the rich base of applications and services hosted in the cloud. The technology can also help reduce the usage of expensive private circuits; provide greater flexibility and security to connect to private and public clouds; and enable rapid, elastic deployments.

Technologies from Intel and Citrix deliver the performance and economics needed to cost-effectively design and deploy a scalable SD-WAN solution. Enterprises will also benefit from fast network connections, a rich set of features and functionality, and a common management and provisioning framework. Together, Citrix SD-WAN and the Intel Xeon processor E5 families are the foundation for SD-WAN solutions that can increase business productivity and operational efficiency.

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2 sdxcentral.com, “What is Software-Defined WAN (or SD-WAN or SDWAN)?” https://www.sdxcentral.com/sd-wan/definitions/software-defined-sdn-wan/
4 Intel® Virtualization Technology requires a computer system with an enabled Intel® processor, BIOS, and virtual machine monitor (VMM). Functionality, performance or other benefits will vary depending on hardware and software configurations. Software applications may not be compatible with all operating systems. Consult your PC manufacturer. For more information, visit http://www.intel.com/go/virtualization.
6 https://01.org/hyperscan.
7 Intel® Virtualization Technology requires a computer system with an enabled Intel® processor, BIOS, and virtual machine monitor (VMM). Functionality, performance or other benefits will vary depending on hardware and software configurations. Software applications may not be compatible with all operating systems. Consult your PC manufacturer. For more information, visit http://www.intel.com/go/virtualization.