RESEARCH ARTICLE OPEN ACCESS

Enhancing Network Performance: A Comprehensive Review of Sd-Wan

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ABSTRACT

Software-Defined Wide Area Network (SD-WAN) technology has revolutionized network management by offering advanced capabilities to prioritize critical applications and traffic. Emerging around the mid-2010s as a response to the growing complexity of traditional WAN architectures, SD-WAN leverages software-based management to provide more agile and efficient network solutions. Unlike traditional WANs, which often rely on static configurations and costly MPLS circuits, SD-WAN allows for dynamic traffic steering and application-aware routing. This means that critical applications, such as real-time video conferencing or mission-critical enterprise applications, can be allocated the necessary bandwidth and low latency they require to function optimally. SD-WAN achieves this by continuously monitoring network performance and adjusting traffic flows in real-time based on predefined policies and application priorities. This evolution from rigid, hardware-centric networks to flexible, software-defined solutions reflects a significant leap forward in how enterprises manage and optimize their network resources, ensuring that high-priority traffic is always given the precedence it needs. The purpose of this review paper is to summarize the current state of knowledge on SD-WAN by evaluating and synthesizing published research papers.

Keywords - LTE, MPLS, SD-WAN Traffic, WAN.

I. INTRODUCTION

Software-Defined Wide Area Networks (SD-WAN) makes managing and running wide area networks (WANs) easier. By separating the networking hardware from its control system, it makes it possible to transfer data between sites more quickly. [1]

The usual WAN (wide-area network) function was to connect branch or campus users to applications stored on data center servers. Dedicated MPLS circuits were often used to increase connectivity security and dependability. As businesses seek fast, scalable, and adaptable connections across several network settings, software-defined WAN (SD-WAN) solutions have gained in popularity. They also want to lower the total cost of ownership (TCO) while boosting application performance. However, a faulty SD-WAN architecture can significantly hinder an organization's ability to respond swiftly to changing business demands, especially if it lacks integrated security. [1]

A network that spans great distances to link multiple local area networks (LANs) is known as a wide area network (WAN). WANs are often used by large companies to link their numerous branch offices and locations to the main corporate network. The software that controls the flow of traffic in traditional WANs. Usually, this hardware/software combo is acquired from a single networking vendor. [2] [7]

A more flexible WAN architecture that supports a wide range of hardware platforms and connectivity options is called a software-defined WAN (SD-WAN). All networking devices are compatible with the administration software. An SD-WAN can be implemented with off-the-shelf devices rather than expert equipment. For these reasons, SD-WANs are more affordable, adaptable, and scalable than traditional WANs. [2]

SD-WAN Capabilities

The issues that MPLS has with capacity, network cost, visibility, and speed are also issues that SD-WAN has. The system offers direct cloud access options and chooses dynamic routes across several data services (broadband, MPLS, and wireless LTE). Businesses benefit from flexibility provided by the pay-as-you-grow approach and on-demand provisioning, and clients may easily advertise by gaining access to the new links without changing their network or foundation. Customers can also adjust traffic volume by taking content kind or service priority into account. Furthermore, SD-WAN has the potential to significantly reduce MPLS costs. By employing software-based solutions to manage infrastructure and connectivity, businesses can increase automation to eliminate expensive routing hardware, reduce network overhead, and improve IT productivity. [15]

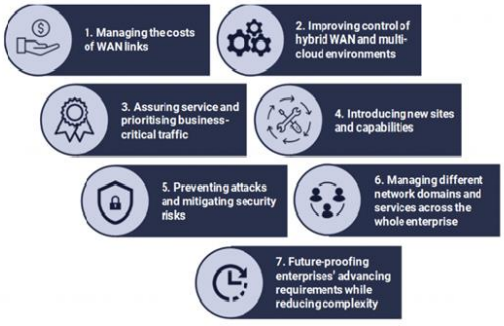

Fig. 1: SD-WAN enterprises with scalability and agility

(source: https://stlpartners.com/articles/network-innovation/sd-wan-providers/)

II. SD-WAN ARCHITECTURE

The basic purpose of SD-WAN is to connect end users and applications, independent of physical location. SD-WAN routes traffic according to the application's business requirements. These business criteria include the application's priority, obligatory security standards, and application performance requirements. Typically, critical mission applications receive the most attention. The networking strategy could vary from MPLS to broadband to 4G LTE. [4]

The SD WAN architecture (both the branch office/location router and the head office/data center router) can have'software defined', which means it can be configured in a variety of ways based on the scenario at any specific site. [5]

SD-WAN works by constructing a network of SD-WAN gadgets connected via encrypted tunnels. Each site on the WAN has its own SD-WAN appliance, through which all traffic goes. Because all equipment is managed centrally, consistent networking policies may be enforced throughout the organization. When traffic enters SD-WAN equipment, the appliance determines the type of application traffic and routes it to its destination depending on existing policies, evaluating the availability and performance of different network connections. [3]

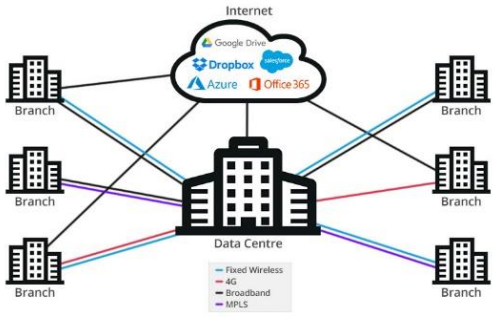

Fig. 2: SD-WAN Architecture

(source: https://www.apcsolutionsuk.com/wp-content/uploads/2021/02/SD-WAN-Diagram.jpg)

III. TYPES OF SD-WAN

In the SD-WAN market, there are numerous manufacturers, each with a distinct feature set and value proposition. Nonetheless, they fall into three broad SD-WAN categories:

A. Appliance-based SD-WAN

These SD-WAN appliances might be virtual or hardware-based. Appliance-based SD-WAN only provides overlay capability rather than an uptime SLA because it lacks an underlying network infrastructure. It is necessary to integrate enterprise-grade security capabilities, such as next-generation firewalls (NGFWs) and secure web gateways (SWGs), which are not built-in.

B. SD-WAN managed service

Regarding technology, appliance-based SD-WAN and managed SD-WAN are same. The two primary distinctions are that the provider oversees and maintains the solution, and the provider is typically a carrier offering a SLA-backed underlying transport technique.

C. Cloud-based SD-WAN

The core network and security processing architecture for cloud-based SD-WAN is hosted in the cloud. Global PoPs (points of presence) form a network backbone that offers a service-level agreement. Generally, appliances in the network-connected locations come equipped with enterprise-grade security features.

IV. SD-WAN V/S VPN

SD-WAN (Software Defined Wide Area Networks)

SD-WAN is the next-generation solution! It dynamically distributes traffic across multiple WAN lines (broadband, LTE, and MPLS), hence improving scalability, security, and performance. It is best suited for enterprises that use cloud services and require more agile, centralized network management. [9]

VPN (Virtual Private Network)

VPNs, which encrypt data, are an ideal way to establish safe connections over public networks. They are less adaptive to modern cloud-based programs and are commonly used for remote access to private networks, but they can have performance issues over long distances. [9]

Key differences:

Performance: SD-WAN dynamically prioritizes traffic, but VPNs can experience congestion and latency issues.

Cost: SD-WAN reduces costs by routing traffic via the most efficient path, whereas VPNs frequently rely on expensive MPLS lines.

Scalability: SD-WAN grows seamlessly across numerous locations and cloud applications, whereas VPNs require complex setups.

Security: Both provide encryption, but SD-WAN allows for more advanced security features such as firewalls and threat detection. [8]

SD-WAN can use multiple types of connectivity. The simpler encrypted tunnel to transmit data.

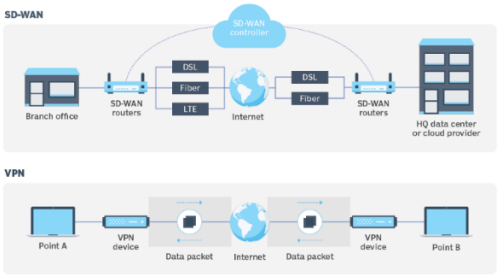

Fig. 3: SD-WAN V/S VPN

(Source: https://www.bitsinflight.com/content/images.png)

V. WAN V/S SD-WAN

WAN	SD-WAN
Scaling up and new setup take a very long time.	Scaling up and new setup require very little time.
Traditional network configuration calls for human interaction and is accomplished by experienced resources.	Without human assistance, SD WAN network configuration is completed automatically.
It doesn't offer fast and inexpensive connectivity.	It offers fast connectivity at a minimal cost.
It connects to an intermediary hub before reaching the cloud; it offers poor performance for the application. [19]	It has direct access to cloud-hosted apps; it offers high performance for the cloud application. [19]

TABLE 1: COMPARISON OF WAN AND SD-WAN

VI. EXCEPTIONAL USER EXPERIENCE

To provide an excellent user experience for programs like software as a service (SaaS), unified communication as a service (UCaaS), and other business-critical applications, an SD-WAN solution must provide crucial characteristics such as:

Accurate identification of applications and sub-applications is required in order to categorize, prioritize, and forward traffic based on application-specific business regulations. Application SLAs are measured by exploiting real-time application traffic, such as the number of transaction failures and application server response, as well as network SLAs such as jitter, packet loss, and latency. Provide application SLAs for both bookended and open-ended network architectures. Most significantly, the ideal SD-WAN system must leverage these features to provide optimal performance and user experience. [6]

SD-WAN can help enterprises compete more effectively and efficiently in today's global marketplace, but it is vital to understand what distinguishes a Secure SD-WAN solution from the more generic set of technologies and services known as SD-WAN. Secure SD-WAN combines advanced routing and security capabilities into a single, integrated system that is managed and orchestrated through a single interface. This gives a level of safety and flexibility that cannot be achieved when an IT team is forced to build security as an afterthought overlay on top of SD-WAN features.[10]

VII. CHALLENGES OF SD WAN

SD-WAN is a valuable tool for enterprises shifting to cloud-first architectures, providing cost savings, increased network agility, and easier management. However, SD-WAN will continue to confront a number of obstacles that may limit its acceptance and performance in enterprise networks. These challenges include:

1. Complexity in multi-cloud environments

As more enterprises implement multi-cloud strategies, SD-WAN must properly manage and optimize traffic across many public and private cloud providers. This can complicate efforts to ensure consistent performance, security, and reliability. Traditional SD-WAN systems, which excel in hybrid environments, may fail to orchestrate between disparate cloud platforms, causing issues with monitoring, management, and troubleshooting. [16]

2. Security and Data Privacy Issues

While SD-WAN automatically provides increased security through encryption and segmentation, the growth of cyber threats makes maintaining SD-WAN security a constant struggle. Attack vectors such as Distributed Denial of Service (DDoS), ransomware, and data breaches are becoming increasingly complex. Furthermore, SD-WAN's reliance on public internet pathways to connect branch offices creates worries about data protection, particularly as legislation such as GDPR and CCPA emerge. [14] [17]

3. Integration with Legacy Infrastructure

Many firms continue to rely on legacy network infrastructure, which may not be easily integrated with contemporary SD-WAN systems. The transition from existing MPLS and VPN systems to SD-WAN can be time-consuming, costly, and plagued with compatibility concerns. Ensure legacy systems are compatible with SD-WAN without disrupting business continuity is a major challenge.

4. Internet performance

While SD-WAN minimizes the need for expensive MPLS circuits by utilizing broadband internet, it also creates issues in maintaining continuous performance over public internet networks. Network latency, packet loss, and bandwidth unpredictability over the internet can have an influence on application performance, particularly for latency-sensitive services like VoIP or video conferencing. Organizations will require increasingly advanced analytics and AI-powered solutions to predict and manage performance issues in real time.

5. Scalability and Vendor Lock-in

As businesses expand, their SD-WAN systems must evolve to accommodate more branch sites, cloud apps, and connected devices. Scaling SD-WAN necessitates careful consideration of bandwidth, security, and configuration. Additionally, vendor lock-in is still a risk. Enterprises frequently experience issues when trying to transfer providers or combine SD-WAN with emerging technologies; many systems are deeply integrated with specialized hardware or cloud services. [18]

6. Increased operating costs

Despite the promise of cost reductions, deploying and administering SD-WAN can incur unanticipated operating expenditures. The ongoing management of SD-WAN infrastructure, network professional training, and the potential requirement for third-party assistance can all increase the total cost of ownership. The complexity of administering a hybrid network that includes SD-WAN and traditional systems might increase expenditures.

7. Evolving Technology and Standardization

As SD-WAN technology changes rapidly, enterprises must keep up with new capabilities, protocols, and standards. This rapid progress necessitates ongoing monitoring to avoid using old technology. Furthermore, the lack of defined, globally accepted SD-WAN standards might cause interoperability challenges between vendors and technologies.

The times have evolved. IT is recognizing that the user application experience is subpar as businesses embrace the utilization of infrastructure-as-a-service (IaaS) and software-as-a service (SaaS) applications across various clouds. This is a result of WANs built for an earlier period not being prepared for the unparalleled surge in WAN traffic that cloud adoption delivers. This traffic leads to data insecurity, unpredictable application performance, and complexity in management.

Increasing the enterprise's exposure to the Internet and cloud presents significant risks and compliance challenges. Protecting an organization's vital assets is very difficult when a diverse workforce, comprising partners, contractors, vendors, employees, and visitors, uses its applications. The security needs increase when broadband is enabled over wide area networks (WANs), posing issues for IT in striking a balance between complexity, security, and user experience.

VIII. NEXT-GEN SD-WAN

SD-WAN adoption will be encouraged and first-generation SD-WAN solutions will be updated by the trend of combining cloud-based security and networking utilizing the organization's secure access service edge (SASE) framework. Network-as-a-service (NaaS) and other new consumption models will be deployed more quickly. The increasing adoption of SaaS apps and enterprise multicloud strategies will require vendors to optimize. Artificial intelligence (AI), analytics, and troubleshooting capabilities will all grow in networking. Vendors will work to increase visibility and enforce policies from beginning to end. [11]

IX. SD-WAN GROWTH FORECASTS

The market for software-defined wide area networks, or SD-WANs, saw tremendous growth thanks to its centralized management and flexible architecture, which give enterprises better connection and agility. Optimized network performance, cost savings from effective resource use, and streamlined network operations are some of its advantages. As demand increases, SD-WAN is transforming networking, fostering creativity and giving businesses a competitive advantage. [13]

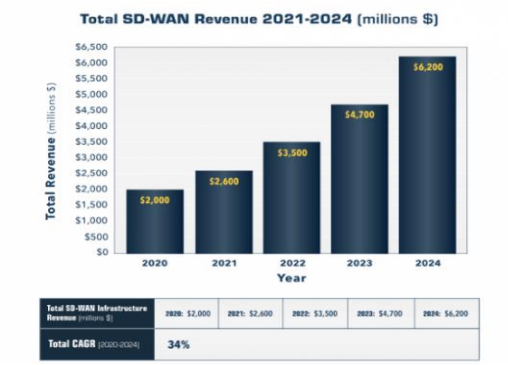

Fig. 4: SD-WAN Growth Forecasts

(source: https://www.futuriom.com/assets/_600xAUTO_crop_center-center_none/SD-WAN-Growth-2021.png)

X. CONCLUSION

SD-WAN transforms enterprise networking and gets around the drawbacks of traditional WANs. It improves the efficiency of cloud applications, gives priority to important traffic, and incorporates cutting-edge security measures, which makes networks more economical and flexible. Its development is being propelled by frameworks like SASE and despite obstacles in legacy integration and multi-cloud administration. SD-WAN is a key component of next-generation networking that enables companies to prosper in a cloud-first environment by providing flexibility, scalability, and strong security.

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