Software-Defined Wide Area Network Architectures and itseffect in improvement of Network Application Performance

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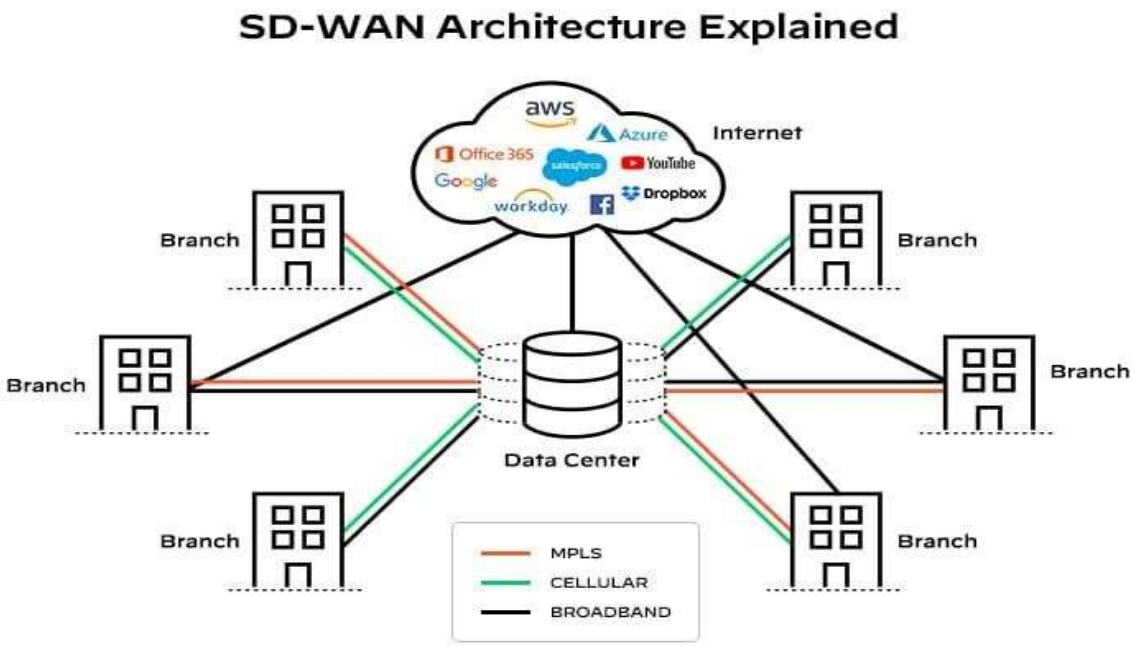
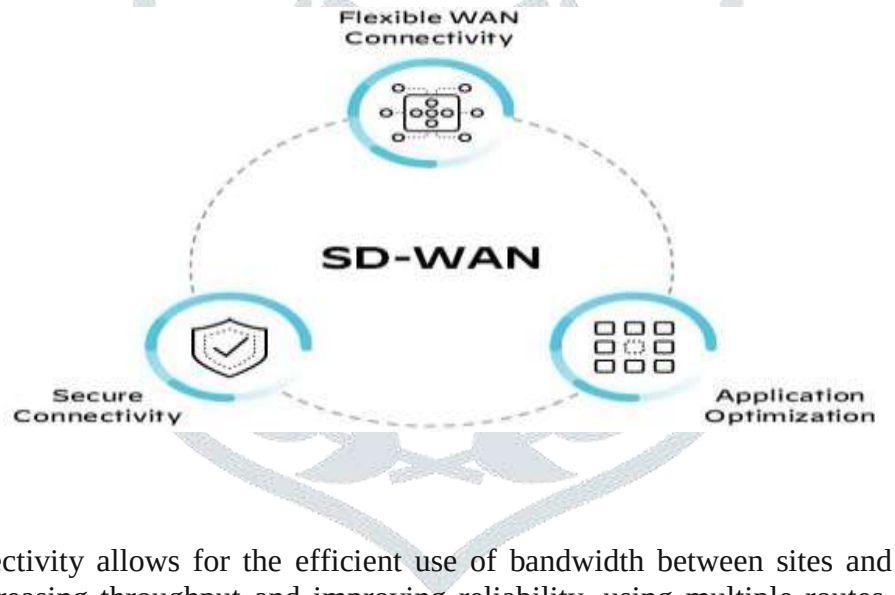
Abstract- WAN (software-defined wide area network) is a type of networking technology that uses software-defined networking (SDN) principles to manage and optimize the performance of wide area networks (WANs). It enables organizations to securely connect users, applications and data across multiple locations while providing improved performance, reliability and scalability. SD-WAN also simplifies the management of WANs by providing centralized control and visibility over the entire network. However, implementation or test bed results is very hard. That's why some of these actual research works just to provide theoretical software defined networking. New research illustrates that software-defined WANs (SDWANs) improve QoS, facilitate network control, and connect branch offices to a main group network, or connect data centers isolated by intervals. SDW AN helps the network to provide consistent and unified security to all our networks. In this study, we come to an overview of Software-defined Wide Area Network (SDWAN) architectures and how it works, a qualitative comparison in terms of features such as virtualization and programmability. As well as, a Software-defined Wide Area Network (SDWAN) benefits from Internet-based wide area networks (WANs) to enable multi-service networks and VPN services.
Keywords: Network, SDWAN, SaaS, QoS.

I. Introduction: SD-WAN is a virtualized service that connects and extends enterprise networks over large geographical distances. WANs use links such as multiprotocol label switching (MPLS), wireless, broadband, virtual private networks (VPNs) and the internet to give users in branch and remote offices access to corporate applications, services and resources, allowing them to work regardless of location. SD-WAN also monitors the performance of WAN connections and manages traffic in an effort to maintain high speeds and optimize connectivity. Traditional WANs use legacy routers to connect remote users to applications hosted in data centers. A router is mostly command line interface (CLI) driven. To define where and how the data egresses a branch network utilizing traditional WAN, network engineers and administrators must manually write rules andpolicies. Such procedures are frequently time-consuming and error-prone.SD-WAN is designed to solve the multiple challenges associated with traditional WAN, allowing networking professionals a simpler way to optimize and secure WAN connectivity. SD-WAN is based on software rather than hardware and is configured to handle different kinds of traffic and conditions in real-time. It can adapt quickly to changing situations and offer better security and reliability than traditional WANs.

SD-WAN uses a centralized control plane to route traffic, allowing administrators to write rules and policies and deploy them across an entire network at once.Control is detached from the hardware to simplify network management and enhance service delivery. SD-WAN appliances obey operational regulations passed downfrom the central SD-WAN controller. This significantly reduces or eliminates the need to manage gateways and routers individually. SD-WAN gateways support hybrid WAN, which means that each branch appliance can support multiple connections via various means of transport, such as MPLS, broadband internet, LTE and so on. For security reasons, a virtual private network (VPN) is typically installed across each WAN connection.



By allowing the WAN to use a variety of different connection types (including LTE, MPLS, and broadband internet) interchangeably, network bandwidth is increased, as is performance and redundancy, allowing for centralized management and administration. Individual gateway and router management is greatly reduced or eliminated when operational policies and rules are passed down across an entire network at the same time.



Flexible WAN connectivity allows for the efficient use of bandwidth between sites and the data center by reducing latency, increasing throughput and improving reliability, using multiple routes—all of which help reduce costs. This allows companies to access their network from anywhere using any device or operating system with an internet connection. If you're away from your office or on the road and need access to your company's servers or databases, SD-WAN will help you do so securely.

Application optimization is a key component of SD-WAN. This feature enables you to optimize applications that have been identified as being sensitive to latency and packet loss. For example, if you're running a VoIP call over the internet, application optimization can help ensure that your calls are always connected and clear.

Application optimization ensures that applications can run smoothly even when they need more bandwidth thannormal. That way, users won't experience any issues while they're working remotely from home or while traveling abroad on business trips because their connection isn't reliable enough to handle their needs without slowing down or dropping out altogether. With application optimization, you can choose whether to optimize all applications or just those that have been identified as sensitive to latency and packet loss. If you choose the latter option, then only those applications will be optimized. Businesses that prioritize the cloud can employ an SD-WAN to give users a better application quality of experience (QoEx). While making sure that apps get the QoS and security policies they require, an SD-WAN gives WAN connections insight. With the greatest

levels of cloud performance, secure access to cloud resources is made possible by a working local internet breakout of IaaS and SaaS application traffic from the branch office. While doing so, enterprise networks are kept safe.

SD-WAN technology is ideal for small and mid-size businesses with limited budgets, allowing for access to all of the benefits of a large enterprise network without having to pay top dollar. SD-WAN also offers a number of benefits to large distributed organizations with branch offices located all over the world.Because each device is centrally managed, with routing based on application policies, network administrators can create and update security rules in real time as network requirements change. By combining SD-WAN with zero-touch provisioning — which helps automate deployment and configuration processes — organizations can further reduce the complexity, resources and opex required to stand up new sites.SD-WAN allows for use of multiple internet service providers (ISPs) depending on where you are located or the best price available at the time. You can also choose which ISP you want to use in each location, so if one goes down or has problems connecting, your network won't be affected.Network administrators can scale up or down their WAN connections based on actual demand. Network administrators can supplement or substitute expensive MPLS with broadband connectivity options. This also reduces the amount of capital expenditure required by eliminating unused capacity at any given time. Because it's easier to manage than traditional networks (since it requires less configuration), there are fewer ongoing costs associated with maintenance and support.

With software-defined networking, you can protect your network from external threats like DDoS attacks and malware. You can also prevent internal threats like hacking or data theft by only allowing authorized devices onto your network. This means that if someone tries to get into your system from an unapproved location, they'll just be blocked out automatically. With SD-WAN, you can ensure that all of your data stays connected regardless of internet connectivity or physical location. Your employees will always have access to their datano matter what happens with their internet connection or cellular service — and they'll never have to worry about missing important emails or calls because they forgot their phone at home!SD-WAN is transforming network architectures and is also playing a crucial role in the growing ecosystem of Internet of Things (IoT). SD-WAN benefits IoT in the following ways:

Better Performance: SD-WAN uses a centralized control function to intelligently direct traffic across the WAN.

Improved Security: SD-WAN can enhance security by segmenting the network.

Scalability: As businesses deploy more IoT devices, SD-WAN can easily accommodate increased traffic and moredevices.

Cost-Effectiveness: With SD-WAN, businesses can use a combination of network services (like MPLS, 4G/5G, orbroadband) based on their needs.

Simplified Management: SD-WAN simplifies the task of network management.

Quality of Service (QoS): SD-WAN allows for policies to prioritize certain types of traffic over others.

Better Visibility: SD-WAN provides improved visibility into network performance and traffic patterns.

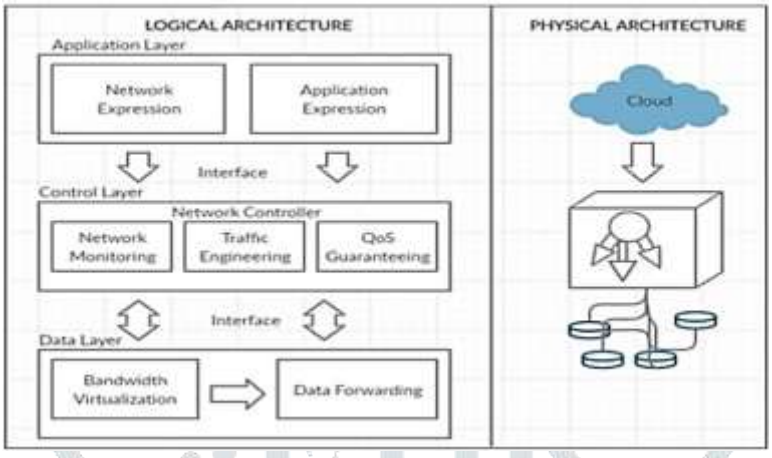
SD-WAN provides a flexible, scalable, and secure solution for managing the increased network traffic and complexity that comes with IoT. By improving performance and visibility, while also reducing costs, SD-WANis an essential tool for businesses looking to leverage the power of IoT.

Take a deep dive into how SD-WAN can leverage the power of IoT by reading our article,Because MPLS networks are private networks built for one given organization, they are considered reliable andsecure, but they are expensive. Moreover, MPLS is not designed to handle the high volumes of WAN traffic that result from software-as-a-service (SaaS) applications and cloud adoption.

Compared to traditional WANs, SD-WANs can manage multiple types of connections, including MPLS, broadband, LTE and others, as well as support applications hosted in data centers, public and private clouds, and SaaS services. SD-WAN can route application traffic over the best path in real-time. In the case of cloud, SD-WAN can forward internet- and cloud-bound traffic directly out to the branch without backhauling.

II) ARCHITECTURE OF SD-WAN:

The architectures of the underlying WAN's are inappropriate to cooperate with new era's more vibrant networking courses and adhere to the requirements for QoE and current users. SD-WAN is being extensively considered to substitute the existing network. The central concept of SD-WAN to clarify Internet services in Wide Area Networks, optimize the internet network superintendence and advanced reform and acceptability as corresponded to old architectures of WAN [3]. In this, we give a study of the physical and logical flow structures of the SD-WAN. Fig. 1: Logical Flow Architecture and physical architecture of SD-WAN



A. Logical Flow Architecture of SD-WAN:

Starting from the base to the topmost layer, the SD-WAN is divided into three layers, and this includes the data layer, control layer and the application layer as shown in Figure 1. The purposes of the data layer are for bandwidth virtualization and data forwarding [3]. Commonly, a Wide Area Network contains various kinds of networks like switching fabric, 4G, and Internet multiple protocol labels [9]. To appropriate the resources of bandwidth thoroughly, virtualization of bandwidth consolidates different network sections supporting one volume into a resource pool that is available for all applications and services [4]. Forwarding of data contains a different assemblage of network forwarding components that is mainly switched in forwarding packets order utilizing the bandwidth provided by virtualization of bandwidth. Both of them receive directions from the controller of the top layer network with the help of interface protocols such as Open Flow. Control layer contains many network functions. These functions of the network are managed and achieved autonomously [8]. These features allow internet operators to develop, modify, remove irrational, and debug at a moderate expense without affecting others. The extension of operating individually, system roles can be combined or connected mutually to perform numerous assistances and enhance the acceptability of SD-WAN [5]. For instance, internet monitoring gives an overall traffic avenue to network planning, by the help of these results, the optimal scheduling analysis to accomplish in the network is estimated. Quality of Service holds the assessment of gratifying software requirements at the time of transmission of data. The layer of Application allows the developers of the Application and the providers of the internet services to demonstrate their necessary system demands for the system within the representation of Application and network composition can render specifications of high level stated around in straightforward language within acquiescent configuration of networks. As an increase in a lot of more dimensional requirements of applications, that is essential to customize designs of the network while catching the narrative of properties of software [5]. For instance, to satisfy users, it is required to have a high bitrate and low latency in the live video streaming services. Developers of Application may demonstrate the policies regarding managing some unyielding conditions plus reducing them in a WAN [5]. Comparable to the representation of applications, network composition is intended to summarize fundamentals of the network, just like networking with multi objects and also networking with cost-productive manners [12]. The layer of Application facilitates developers of applications and internet providers to be further concerned regulating the internet network.

B. Physical Architecture of SD-WAN:

Multiple factions of switches of SDN are connected to each other by physical links in the layer of data [3]. The controller of the network is the administrator of these systems. Generally, the controller of the network is a batch or a server that depends upon the capacity of bandwidth. The controller of the network instructs various network functions [6]. The internet service provider and software developers can verbalize the conditions to the controller of the system, and then the controller of the network will persuade them toward policies

and configurations [7]. Commonly, in different places, there are more numerous controllers of the network distributed, in which one of them is elected as the central controller as master and the rest of the others as controllers for backup So that when the main controller master crashes, immediately it will be taken over by a controller from the backup [3].

The primary goal of every organizational network is to offer fast, frictionless networking that optimizes productivity and minimal network stress. But with virtualization, there is increased use of third-party platforms like cloud, hosted applications, and big data analytics, which stresses networks. Productivity and, eventually, profitability are impacted by poor networking. A single solution that has come to resolve all of these pain pointsis SD Wan technology.

Software Defined-Wide Area Network (SD-WAN) is a centralized software application running a virtual network over the hardware. It is a hybrid technology that combines software-defined networking(SDN) with Wide Area Networking (WAN). SD-WAN uses multiple potential transport links over traditional dedicated circuits and currently has become the most efficient networking solution for cloud computing.

Hence, globally, sd wan technology adoption has been rapid at a CAGR of 21.64 between 2020 and 2026. The revenue forecast for SD-WAN is expected to exceed USD 8 billion by 2026 and achieve USD 2.7 billion in North America by the end of 2022.

Improving network performance SD-WAN solutions:

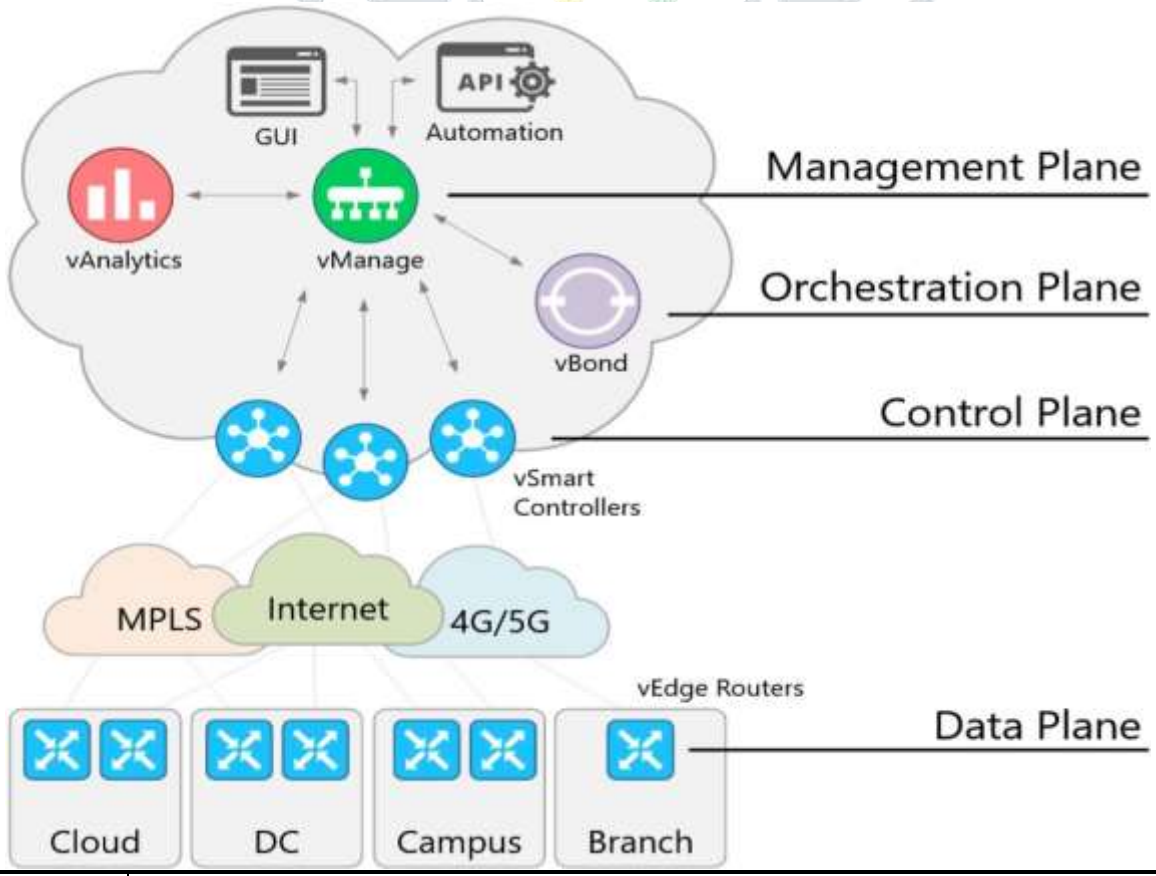
The SD-WAN solution consists of four isolated planes: Orchestration, Management, Control, and Data Plane. Every plane has its own work and responsibilities and is isolated far from the other planes when compared with the traditional WAN; in traditional WAN, each device shares in the data plane (packets forwarding), in the control plane and in the management plane [3]. SD-WAN's parts can be explained as follows:

vManage controller is responsible for the Management Plane in the SD-WAN system. It works for gathering network data, turns on analytic controller, and warns on critical events in the SD-WAN fabric paradigm. Additionally, vManage controller is the tool used in creating device templates, push configurations, and is used to do traffic engineering.

***vBond* controller** is the Orchestration Plane of the SD-WAN system. It is responsible for the authentication, authorisation and whitelisting of vEdge routers and control/management information distribution.

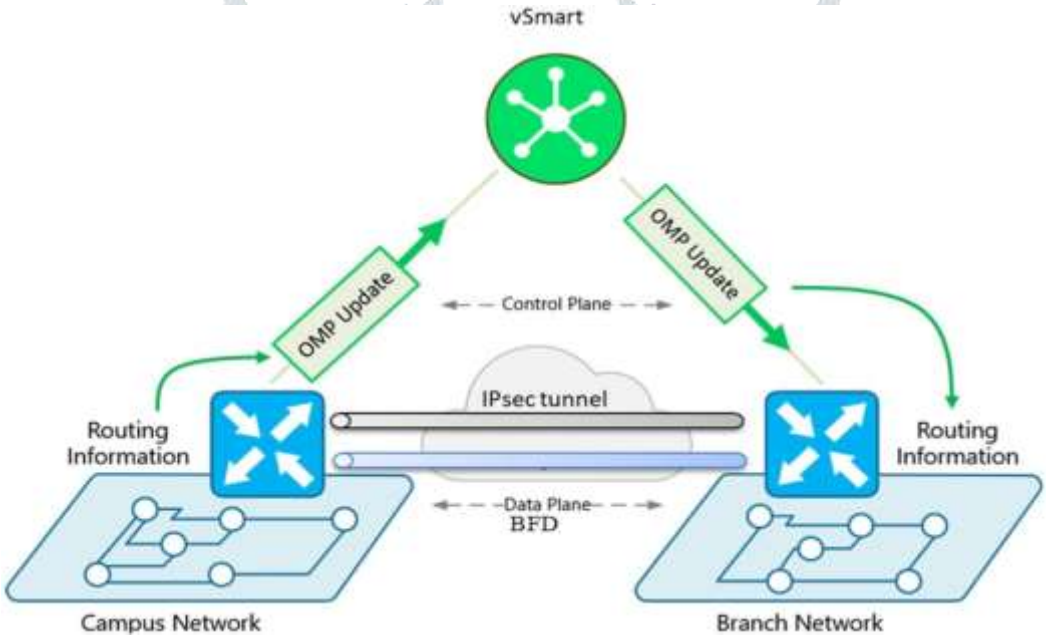
vSmart controller works in the Control Plane of the SD-WAN fabric. It is the intelligence part in the SD-WAN system. It advertises routing, policies, and security. Noting that the vSmart controller is not part of the Data Plane additionally, it does not share in packet forwarding.

vEdge *routers* act in the Data Plane of the SD-WAN fabric. They locate at the WAN border and form the network build and are responsible for establishing network fabric and forwarding traffic.



The SD-WAN controller creates the forward decision upon global network vision and pushes it to the vEdge router. Then, the vEdge router can process all packets into the flow based on the decision [3]. Figure 5 explains,in detail, the sequence of operations in the router [3] as follows:

- ***IP Destination Lookup*** The main function of the routers in the data layer is to route data based on the decisions of the controller in the control layer, so the data forwarding process starts with the IP destination lookup step.
- ***Ingress Interface (access control list [ACL])*** Localised policies are usually utilised to make ACLs and attach them to vEdge router interfaces. These policies are used for filtering, marking, and traffic policing.
- ***Application-Aware Routing*** It means it makes a routing decision based on the specified service level agreementcharacteristics such as packet loss, latency, jitter, load, cost, and bandwidth of a transporter.
- ***Centralised Data Policy*** The centralised data policy is estimated after the previous step and is able to override the AAR forwarding process.
- ***Forwarding*** In this step, the destination IP is matched with the routing table, and the output interface is determined.
- ***Security Policy*** If there are security services attached to the WAN edge node, they are processed in the following sequence: Firewall, intrusion prevention system, URL-Filtering, and Advanced Malware Protection. The necessary tunnel encapsulations are performed and virtual private network (VPN) labels are inserted.
- ***Egress Interface ACL*** Local policy creates ACLs and applies on egress as well. If the egress ACL reject or manipulate traffic, the modification will be done before the packet is forwarded
- ***Queueing and Scheduling*** Egress traffic queueing services such as Low-Latency queuing and Weighted RoundRobin queueing are implemented before the packet leaves.



Some of the ways in which the software-defined wide area network can improve the performance of a businessare as follows:

Improves Speed and availability

Traditional wide area networks are known to use backup circuits but are in passive mode and opted for only when the primary circuit fails, choking critical applications like VoIP and unified communications that are lag-sensitive and bandwidth-intensive[7]. However, WAN can be optimized by using sd wan solutions. It increases visibility and flexibility and moves voice packets to the top of the priority list; sometimes, hybrid deployments are also adopted for rapid shifts in traffic for connections relying on public internet and MPLS.

Prioritizes load balancing

Given that networks use applications that use different levels of services, SD Wan solutions offer flexible pathways per the application. Hence, performance-intensive applications can no longer congest networks and

impact latency-sensitive applications with sd wan technologies. It resolves congestion by diverting traffic to channels that offer easy flow. Thus, data flow becomes reliable, and networks no longer experience vulnerabilities due to dropped data packets or blocked or lost data.

Affordable Flexibility

The biggest challenge with WAN and optimization is using expensive, branded routers at every site. For IT ecosystems with multiple locations, local or overseas networking becomes very expensive. Additionally, making changes or expanding the network also becomes very challenging. With SD wan solutions, businesses can run on any connection type, and most sites can be up and running in the shortest turnaround time. Investment in router infrastructure for sd wan solutions is typically not up-front and is on a use-basis, helping companies quickly transition to enhanced networking solutions. Additionally, no maintenance contracts or professional service providers are needed to set up the network. SD-WAN's most significant advantage is that configuring and deploying networks and hardware profiles is simplified, as all WAN allocation is automaticallyhandled remotely on SD-WAN[8].

Overcome Low latency with SD Wan solutions

One of the essential points of using SD wan solution is to improve any unstable links that rely on local broadband. This technology uses path conditioning techniques to improve low-quality internet to deliver high-performance networks. It improves resource utilization, lowers bandwidth costs, enhances customer experience, and improves productivity. This is mainly in the case of VoIP applications. Many vendors use forward error correction or packet order correction, so they don't have to re-transmit packets. A forward error correction injection and Packet Order Correction packets are resequenced. Hence, SD Wan will lower the retransmission packets and ensure call quality even when connections are prolonged and unreliable.

SD-WAN for class of service over the internet

The most significant advantage of using the software-defined wide area network is that there are exact details of the end-to-end tunnels that an SD wan device supports at every site. Hence there is automated control in managing the data that these devices send. On a traditional WAN, a Class of Service is defined for the router, but it is ignorant of the loads and data handling at other devices. With SD-WAN Business Intent Overlays, the performance of applications can be maintained easily. No prioritization is applied when the network is not congested and the Service Level Agreements (SLA) are met. However, when the network is congested, Business Intent Overlays prioritize the application on other network devices, which will minimize their traffic to handle priority.

Enhance cloud application performance

The primary advantage of using an SD-WAN solution is enhancing the cloud application performance. This is because the solution identifies the easiest or the best route. The remote side can directly connect over the internet using the SD-WAN solution. It provides the shortest route to the application and hence improves performance.

Appropriate security and routing recognized apps

Traditional WAN is known to send external traffic defended by corporate firewalls. However, the increase in the number of applications on the internet has impacted performance. With SD-WAN solutions, known applications can set up SLA requirements for trusted applications, like Microsoft 365, to be routed directly or toweb proxy to lower latency[9].

SaaS and IaaS performance improves with virtual devices

SD-WAN vendors are known to improve the performance of cloud applications by enabling the license deployment in the form of an Infrastructure allowing the application connections at both ends to be treated as one.

Secure connections in comparison to IPSec

SD Wan allows controlling rotation of keys, whereas traditional WAN uses only IPSec to configure hub devices leading to human errors. Automated configuration of the hub device on SD-WAN ensures optimized secure connections[10].

Moreover, SD-WAN can use the public Internet to securely interconnect branch offices with distributed resources, while ensuring high performance for latency-sensitive and business-critical applications. SD-WAN solutions can support these functions through flexible and reliable connection methods, expansion of advanced routing functions, and load balancing across the organization's mesh VPN overlay, and provide a complete integrated security suite that can be end-to-end protected Data and progresses. In Hand`s upcoming SaaS cloud service platform is equipped with the latest SD-WAN technology to empower enterprises. It not only has intelligent flow rate limiting based on QoS to achieve precise control of uplink flow, but also has intelligent routing functions, support link backup and load balancing, and ensures the stability of the network.

IV. CONCLUSION:

The Software Defined Wide Area Network is reliable for analyzing, and it's also the one of significant concern regarding the new generation Wide Area Network. By this paper analysis, we presented some difficulties of the traditional WAN as SD-WAN is considered as the assuring structure of new engendering purpose of the WAN, as impersonated the architectures of physical and logical structures. The representational advances conceived are examined to promote it. Analysis presented in this paper supports encouragement of the SD-WAN ahead. Optimizing WAN is the networking solution that every organization needs for application acceleration. This can be in the form of software-as-a-service(SaaS) or Infrastructure-as-a-service (IaaS). Spectra's SD wan device and solutions improve productivity, unlock innovation and, strengthen security, spur growth, leading to competitive advantage.

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