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A Survey on Software Defined Wide Area Network

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Abstract: With the rate of an increasing number of devices connected to the internet and rapidly increasing traffic demands, there is a need to develop a mechanism that should be able to cope with the challenges currently being faced by various Wide Area Network (WAN). SD-WAN (Software-Defined- Wide Area Network) is a new WAN technology that incorporates the features of Software Defined Networking (SDN). With its enormous benefits and simple working principle of separating the control plane and data, the plane produces many new opportunities that further diminish the various limitations of traditional WAN technologies such as flexibility, cost, and inefficiencies. This paper aims to provide an overview of SD-WAN research and technologies by comparing it with traditional methods of WAN technologies. It will help various researchers and industrialists to have an overview of this new technology which is an area of high interest over the upcoming year.

Keywords: Software defined networks; data plane; control plane; wide area network.

1. Introduction

SDN can be considered as a key technology through which various kinds of the different network are all working together [1-2]. It makes the networks agile, flexible and scalable. The basic functionality behind its success is the separation of control plane and data plane [3-4]. Control plane defines the intelligence of the network (decisions to be taken for the network) whereas data plane can be defined as the underlying network hardware used such as switches, routers, etc. In SDN with the help of centralized network provisioning complexity and manageability of the network becomes easy [5]. The key technologies are functional separation, network virtualization, and automation through programmability [6-8].

In recent years the exponential growth of network traffic, adoption of IoT (Internet of Things) and Multi-Cloud technologies have forced to look after the control over various WAN technologies [9]. These technologies have a great impact in terms of using bandwidth [10]. It is also expected that WAN bandwidth is increasing 20 percent every year [11]. Traditional WAN technologies are incapable of handling the enormous amountof data and increased bandwidth [12]. Therefore, there is a need for such WAN technology which is reliable, secure and possesses high performance [13-15].

SD-WAN is the new WAN technology which is making the use of its basic principle. Instead of installing dedicated hardware or specialized WAN technology SDN has made it easy to make use of open virtual switches and configurable API's [16]. SD-WAN is a specific use of SDN development associated with WAN relationship, for instance, broadband web, 4G, LTE, or MPLS. It interfaces undertaking frameworks — including branch working environments and different server farms over enormous geographic detachments [17]. WAN might be used, for example, to interface branch working environments to a central corporate framework, or to relate server farms detached by partition. Beforehand, WAN affiliations normally used development that required unprecedented prohibitive gear [18].

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SD-WAN, on the other hand, utilize the web or cloud-nearby private frameworks [19]. SD-WAN decouple the framework from the organization plane and separate the traffic the load up and checking limits from system equipment [20].

The main contribution of this paper is to provide:

- An overview of SD-WAN which is one of the hottest technologies in the IT infrastructure market.
- Background and traditional WAN technologies /protocols working.
- Comparison of SD-WAN with MPLS.
- Various advantages, challenges and future of SD-WAN.

The remainder of the paper is divided into various sections. Section 2 is comprised of the background and various previously used WAN technologies. Section 3 is constituted with essentials of SD-WAN architecture, advantages, options, and various benefits. SD- WAN vs. MPLS: The Pros and Cons of both technologies are discussed in section 4. In section 5, challenges in SD-WAN are illustrated and finally, section 6 constitutes the conclusion.

2. Background

Before we investigate how SD-WAN came into existence and become a need to support today's real-time applications, we need to have a look at how traditional WAN technology works.

Traditionally WAN was created using switching techniques; such as circuit switching, packet switching [21]. In-circuit switching technique WAN was created. Integrated Service Digital Network (ISDN) [22] as shown in Figure 1 is an example of a circuit- switched network, where the transmission of data, voice, video and other network services can travel simultaneously. This technology fails because it suffers from many limitations [23]. In this technique as soon as two parties are establishing a link to communicate, it establishes a dedicated link for these parties and when either party disconnects or the circuit is broken, the data which travels from one end to another is also lost [24-25]. Therefore, this technique makes it less efficient to create a WAN.

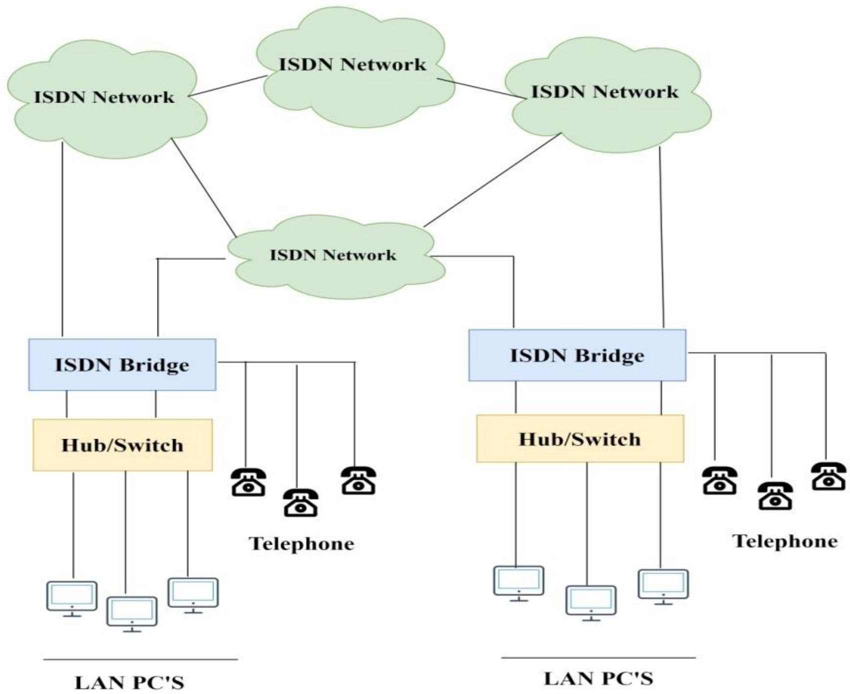

Figure 1. ISDN Network for WAN.

To overcome the situation another switching technique was introduced in order to create the WAN i.e. Packet switching. In this technique first of all, a digital network is established then suitable blocks of data are created [26]. These data blocks are known as packets. These packets are assigned with source addresses and destination addresses [27]. This information is used by the packets while changing the different routes or path from one to another [28]. The data which transmits from one end to another end travels in the form of bit rate which is varied. There is a formulation of sequence of packets over the network when the data bits travels [29]. The delay in any packet is directly dependent upon the load of traffic over the network. There are some protocols such as X.25 which was used to create this type of WAN's [30-32]. Creating WAN by using packet switching with its functionality is shown in Figure 2. While making use of packet switching technique for creating WAN, packets may get lost while changing the route or path so sequence numbers are require identifying missing packets [33-35].

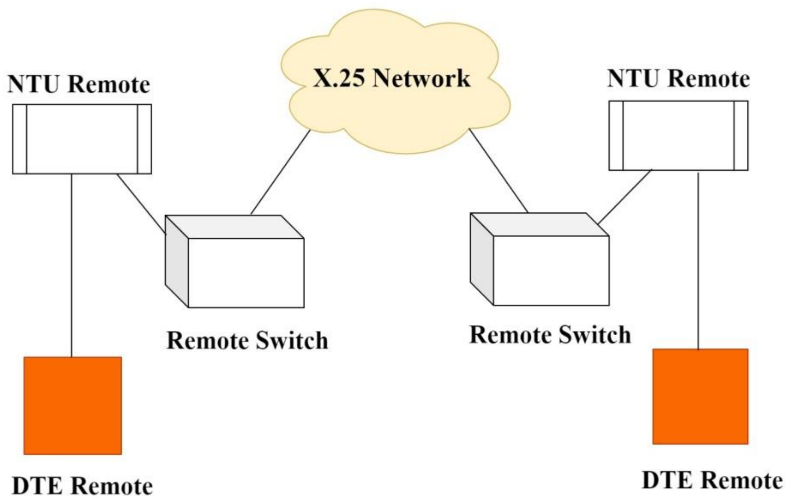

Figure 2. X.25 Network.

Another technology for WAN was Frame relay which was developed to overcome the shortcomings of X.25 packet switching. The main objective is to reduce network delays, protocol overheads and equipment cost [36-40]. There exist some limitations in Frame relay as well [41- 42]. Some of the major drawbacks of Frame relay are unreliable delivery of packets, a different sequence of packets at the sending end, packets which possess errors are discarded, there is no provision of maintaining the flow control among the data, etc.[43- 46].

Asynchronous Transfer Mode (ATM) was another technology which was developed after Frame relay [47-48]. In ATM the packets are divided into a fixed-sized block of packets which are called as cells. These cells are having a size of 53 bytes which further consists a header of 5 bytes. ATM cell format is shown in Figure 3. ATM technology sometimes is also known as cell relay [49-50]. Overhead of a cell header, not cost- effective, congestion may cause cell losses, etc. are some of the limitations of ATM technology [51-57].

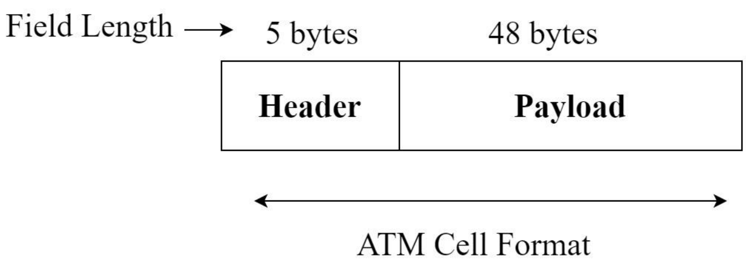

Figure 3. ATM Cell Format.

ATM was used to provide private WAN networks to enterprises over dedicated hardware [58]. It was replaced when IP/MPLS came out and could provide the same functionality over shared hardware [59-63]. In MPLS, parcels are coordinated through the system dependent on an allotted name. The name is related to a foreordained way through the system, which permits a more elevated amount of control than in packets exchanged systems [64-66]. MPLS [67] directing permits varying Quality of Service (QoS) attributes and needs to be allocated to specific information streams, and administrators can foreordain fallback ways in the occasion that traffic must be rerouted [68-76]. It is sometimes also known as layer 2.5 protocol because it is intermediate between layer 2 (Data link layer) and layer 3 (Network Layer) headers as shown in Figure 4.

The need for more bandwidth is increasing day by day because customers are making use of applications such as videos, AR/VR, etc.[77]. The limitation of MPLS network was bandwidth cost and no support for built-in data protection and other network vulnerabilities. Dissimilar to MPLS, SD-WAN accompanies no punishment for data transfer capacity in this way clients can update effectively by including new connections, without any progressions important to the foundation or system [78]. Maybe the best selling point for SD-WAN is the capacity to cost-successfully blend and match system connections as per substance type or need [79].

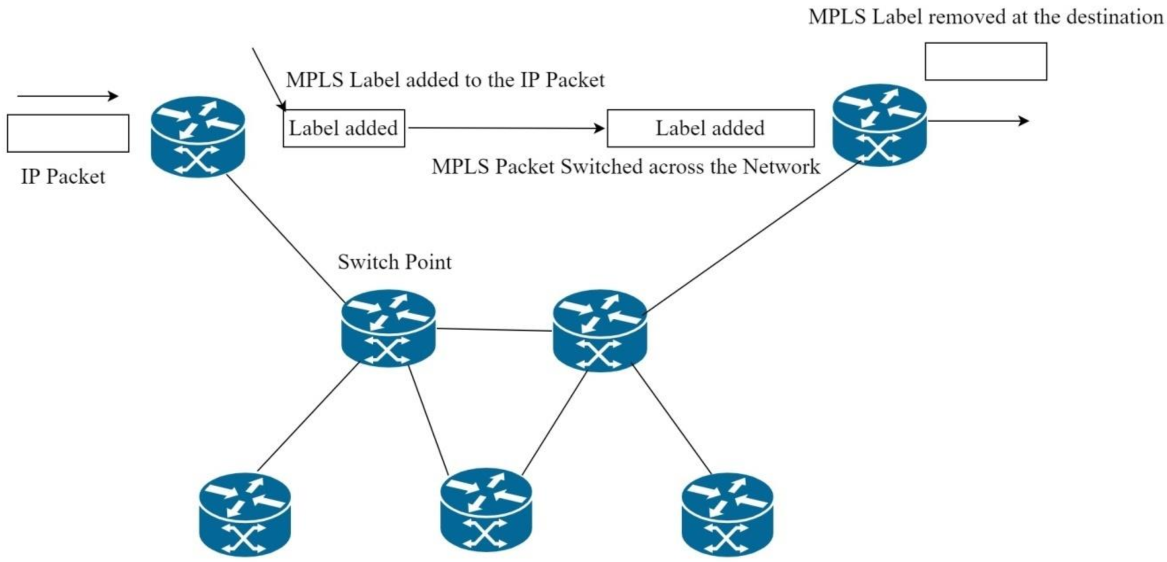

Figure 4. MPLS Network.

3. SD-WAN

Old techniques for WAN were suffering from multiple limitations as they have a connection which is limited between enterprises, branches and data center [80]. Nowadays as the IT, the industry is adopting for various cloud-based application services which are using service models such as SaaS (Software as a Service) and IaaS (Infrastructure as a Service) [81]. Most of these enterprises use the WAN architecture which is very complex as they are using the propriety hardware which is vendor-specific inflexible and very costly to buy and therefore the WAN architecture of these WAN technologies are very complex [82-85].

SD-WAN is a new approach which is based on the basic principle of SDN, designed to manage the WAN [86]. With SD-WAN, IT can deliver routing, threat protection, efficient offloading of expensive circuits and simplification of WAN network management [87].

3.1 The Architecture of the SD-WAN

SD-WAN is a new automated and flexible architecture for WAN. It has diminished the various cons of previously used WAN technologies [88]. It provides all the advantages of SDN into it. SD-WAN design is especially gainful to situations isolated by separation for instance between fundamental workplaces and branch workplaces [89]. Though conventional WAN can be costly and complex, SD-WAN engineering diminishes repeating system costs, offers arrange wide control and visibility, and improves the innovation with the zero-contact organization and incorporated administration. Key to the SD-WAN engineering is that it can speak with all system endpoints without the requirement for outside instruments or extra conventions [90].

The architecture of SD-WAN can be divided into two types:

(1) On premises: An "on-prem-just" SD-WAN design is actually similar to it sounds. Any organization/endeavor/association has a SD-WAN box (basically an attachment and play switch), performing continuous traffic forming at each site as appeared in Figure 5.

Benefits:

- Lower or zero month to month SD-WAN cloud-enablement transmission capacity costs.
- Multi-circuit/ISP load-adjusting.
- Real-Time traffic forming, improving the presentation of all WAN applications.
- Improved fiasco recuperation (DR), by having better network reinforcement.

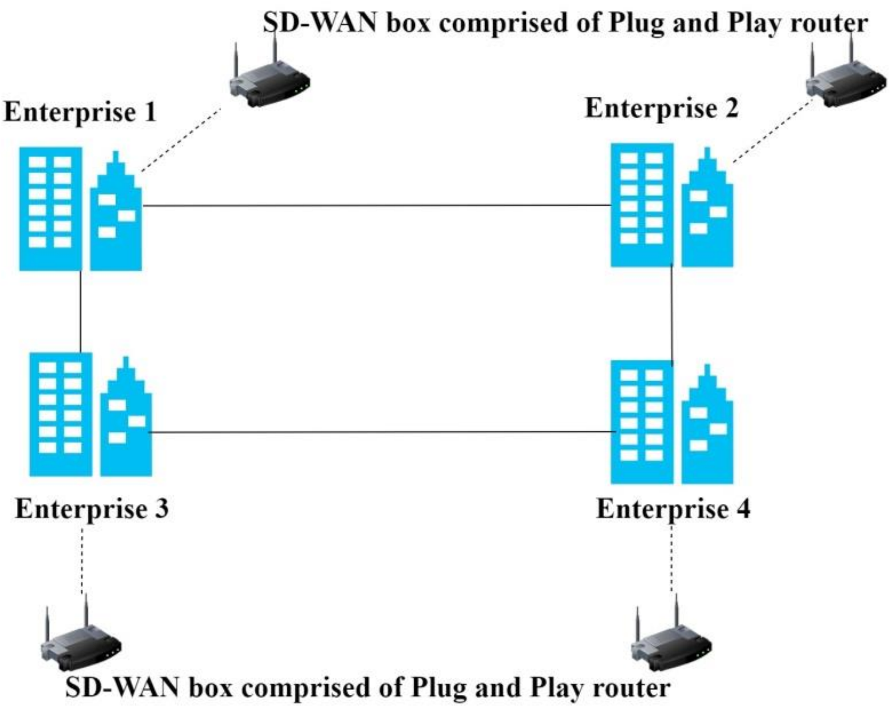

Figure 5. On premises SD-WAN architecture.

(2) Cloud Enabled: This is another kind of SD-WAN design in a cloud- empowered SD-WAN engineering, the arrangement offers an on location SD- WAN box associating with a cloud (virtual) portal as appeared in Figure 6. With this engineering, an organization gets the advantages of an on-prem-just design (for example continuous traffic forming and multi-circuit burden adjusting/failover), in addition to expanded execution and unwavering quality of any cloud applications [91-92]. The cloud passage is arranged legitimately to the real cloud suppliers (for example Office 365, AWS, Salesforce, and so forth.), which results in a general improvement in the exhibition of the cloud applications [91]. What's more, if an organization's Internet circuit comes up short while utilizing a cloud application, the door can keep a cloud session dynamic (while the circuit folds). In the event that any organization has another Internet circuit, the SD-WAN can re-course any cloud application promptly to any organization's other Internet circuit, averting interference of a solitary session [93].

Benefits:

- Cloud gateways, improving the performance and reliability of cloud applications.
- Multi-circuit/ISP load-balancing.
- Real-Time traffic molding, improving the exhibition of all WAN applications.
- Improved DR by having better network reinforcement.

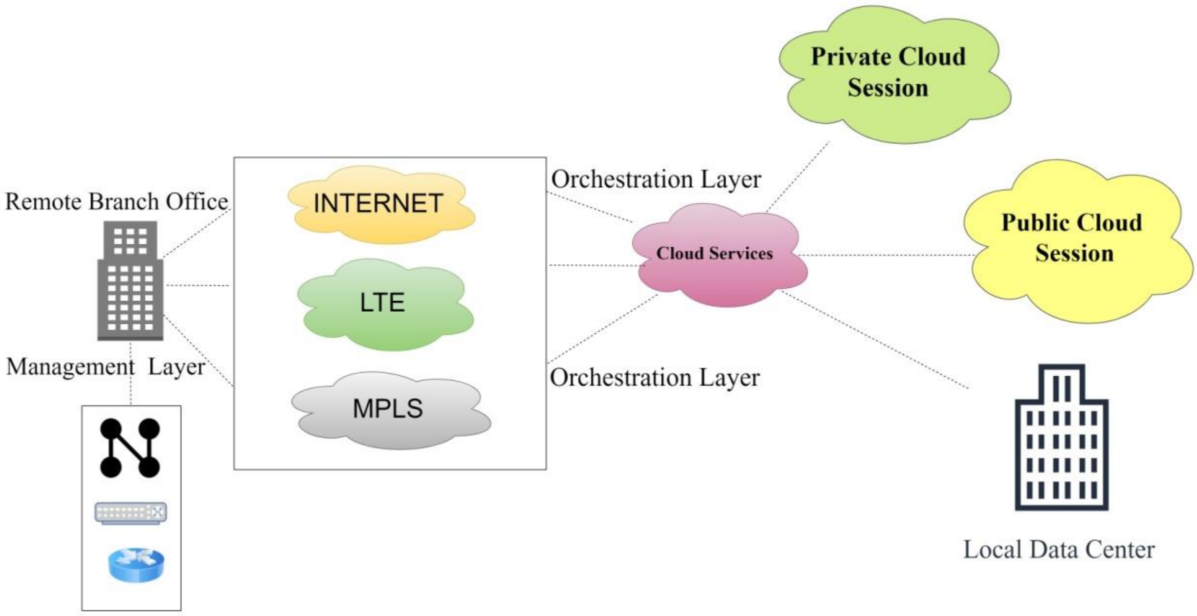

Figure 6. SD-WAN architecture.

4. SD-WAN VS. MPLS

As stated in section 2 that before SD-WAN there was MPLS which is a protocol mainly used for efficient network traffic flow between two or more locations [94-95]. MPLS suffers from a large number of limitations and to overcome all of them SD-WAN come into existence. Table 1 depicts the difference between MPLS and SD-WAN on the basis of some parameters.

Table1.MPLS vs. SD-WAN.

Parameters	MPLS	SD-WAN
Packet Loss	• Only one circuit • Carrier grade connection • Packet loss< 0.1 % • SLA assurance available	• Availability of two circuits • One carrier grade connection • One cable broadband • Public Internet packet loss=1.0%ormore • SLA assurance nominal • Two or more connections required
Application Prioritization	• Higher performance guarantees	• More tools for monitoring and control • May offer dozens of levels application prioritization mapping • Auto-Identification of common application for easy setup • Analytics provide actionable performance insights
Reliability	• BGP based failover • VPN to connect to MPLS	• Uses multiple links • Self-aware fail over mechanism • Priority applications router over best connection • Session based apps uninterrupted
Security	• Private packet addressing • Single service provider	• VPN based secure tunnel (IPsec) • Multiple active path increases security • Support additional security layers

4.1 Will MPLS be replaced by SD-WAN?

SD-WAN is better than MPLS on the following parameters [96]:

- **More availability of Bandwidth**
  With MPLS, in the event that you need 100M+ data transmission, month to month circuit costs will regularly make the things remains on-end [97]. Now and again it's the switch costs and some of the time it's simply the circuits yet the fact of the matter is, high-transfer speed MPLS is normally pricy. SD-WAN, in any case, enable the organization to use different, high-transmission capacity, modest Internet associations, all the while (for example business-class link, fiber, 4G, and so forth.). By accumulating various associations, the organization will experience quick Internet speed requiring little to no effort.
- **Better Performance**
  SD-WAN will throttle low-need traffic on-the-fly and (on the off chance that you have different ISP associations), dependably send the traffic over the Internet circuit with the quickest course. MPLS won't perform both of these activities. With MPLS, there is just one system association and you're Class of Service (CoS) settings are static, without the capacity to alter on-the-fly [98].
- **Increment in Uptime**
  By enabling the organization to total various ISP Internet and WAN associations at a solitary website, the organization will have consistent circuit repetition for the WAN, over numerous circuit types and specialist co-op systems. MPLS suppliers now and then have a failover to an auxiliary Internet association however it's normally not momentary and it's never ready to have a third alternative [99].

- **Increased performance at small, remote or international sites**
  Almost every organization has locales which are not a solid match for their MPLS arrange on the grounds that they are either excessively little (and can't legitimize the mind- boggling the expense of an MPLS circuit), or they are not workable by their MPLS supplier (since they are in a remote or global area where their MPLS supplier does not have arranged). In these areas, organizations with MPLS are ordinarily compelled to endure not exactly alluring execution as they run all traffic over an IPsec VPN. Despite what might be expected, SD-WAN is supplier freethinker and will convey similar advantages, regardless of which basic ISP organization is utilizing [98,100].
- **No longer imprisoned by any ISP**
  With MPLS, you should have the equivalent MPLS specialist organization at all locales, making it a win big or bust relationship [99]. Therefore, it takes a ton of motivations to make you need to experience the issue of exchanging the organization's MPLS supplier. With SD-WAN being ISP rationalist, any organization is never stuck in ISP jail and can include and evacuate ISP's at any site, whenever, effortlessly [100].

5. Challenges in SD-WAN

- **Processes in Operational Cost –** The principle issue for huge environments is the management of processes. The procedure assumes a key job in controlling the client experience [101]. As we move from conventional physical systems to a crossbreed condition—with physical and virtual resources, changes ought to be foreseen in the vast majority of these operational procedures [102]. A portion of these foreseen changes include: observing changes that move far from SNMP (Simple Network Management Protocol) and toward those that are telemetry- based; orchestrator-encouraged changes rather than inconvenient contents or manual intercession; and moving far from manual investigating of issues with WAN transport and toward robotized changing of traffic starting with one circuit then onto the next [103-105].
- **Requirement of Technical Skills –** Customarily, IT workforce specialists are prepared to line up with innovative designs, for example, arrange frameworks, risk avoidance andappraisal, and server farm servers and virtualization. Be that as it may, this restricted specialization is not true anymore [106]. With these innovations meeting on a solitary machine with VNFs (virtual system capacities) running on top, activities experts require aptitudes that range different specialized areas, however, they likewise need involvement with programming the board and investigating, composing Yang models and creating applications to exploit arrange programmability. Discovering this skill in one specialized proficient is troublesome, also, preparing somebody to address every one of these innovations [107].
- **Structure of Organization –**With systems administration and server farm innovations meeting onto single boxes with virtualized arrangements, separated innovation storehouses ought to vanish after some time [108]. Also, with controllers facilitated in a telco cloud or open cloud condition, the entire stack should be overseen by singly-bound together group. The genuine inquiry turns out to be, how does this affect hierarchical structures? Also, in the event that regardless you look after storehouses, who claims the issue if blackouts happen? Every one of these issues needs to investigate and tended to fittingly, which will drive change and advancement of hierarchical structures and operational exercises [109].

- **Various used Operational tools –** A "one size fits all" the approach doesn't make a difference for SD-WAN as various sections, contingent upon their size as well as industries is at various purposes of the SD-WAN voyage and in this manner have various needs. MSPs may settle on numerous arrangements from the equivalent or different sellers [110]. For each arrangement, there might be a need to make critical tooling speculations to coordinate with merchant frameworks to give a solitary sheet of glass (however much as could reasonably be expected), from checking to ticketing to change and execution/limit the board [111]. This is an extravagant recommendation regardless of what you look like at it.
- **Shift in Culture** –Administrators getting on board with the SD-WAN fleeting trend are understanding that "Half and half WAN ain't no walk in the park", as revealed by Light Reading. SDN/NFV all in all, and SD-WAN specifically, are troublesome by its very nature, as the system is changing from customary equipment boxes to programming, programmability, mechanization, and united models [112]. In addition, the "requirement for speed" is determined to keep up or gain the focused edge and keep conveying a similar predominant client experience while all the while experiencing the change procedure. So as to be fruitful, an alternate outlook is fundamental, in overseeing the traditional systems. Tasks groups will require huge preparing and hands-on understanding before they become OK with this better approach for overseeing half and a half and united activities.

6. Conclusion

It is believed that with the advancements of SDN in various fields, the benefits are growing at an exponential rate. While we are still before all else periods of research around there, we see extensive space for the development of wide-area arrange execution, dependability, and adaptability through SDN innovations. SD-WAN is one such technology that is emerging nowadays. Expanding perceivability in WANs through observing and telemetry advances just as the mix of the control planes of the bundle and optical (transport) layers of WANs may have significant sway on the future activity of networks in a wide area. In this paper, we gave an overview of SD-WAN along with thecomparison of various other technologies.

Advantages and disadvantages of all WAN technologies and how these technologies have shifted towards SD-WAN are being presented. As SD-WAN is still an emerging field, therefore, it is gaining a lot of interest from both industry and academia a lot of researchers are currently working on it.

In the future SD-WAN can be used for securing the networks. Many such applications which require the secure remote access such as Amazon Web Service (AWS), Cloud Based Office 365 and many others requires a good security mechanism against various security threats. Many critical traffic jams in the network can be divided into small chunks and saved against the multiple vulnerabilities for different enterprises. Within the enterprises SD-WAN is going to be beneficial for securing the networking from external threats and attacks.

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