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"Develop A Hybrid Software-Defined Wide Area Network Application Model by using Eve-Ng in Cloud Computing": A Case Study of World Vision International Rwanda

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Subject Area: software-defined networking

Abstract:- Enterprises with multiple offices in different locations can connect their corporate headquarters with remote branches by using SD-WAN. This might be a global corporation with offices all over the world or a chain of sites scattered throughout a city. Since SD-WAN is carrier independent, you may configure your bandwidth for each site, in contrast to MPLS, which mandates the usage of a single telecom across all locations. For instance, a company in one nation that has satellite offices in several places might need to operate apps that function well across many locations. They will be able to achieve this easily and affordably with the help of SD-WAN and/or MPLS as hybrid. The team could easily connect the new office with the existing one via SD-WAN and/or MPLS if they decided to create another site in a different city. Both MPLS and SD-WAN use various technologies to guarantee service quality. With its approach to network packet routing, MPLS is a network technology that guarantees users' end-to-end service. However, SD-WAN ensures a comprehensive picture of the complete network and centralized management, making it simple to configure or swap out the current configuration system. By configuring and simulating these two network technologies as hybrid in the software program called EVE-NG Emulated Virtual Environment Next Generation and Wireshark, this research will concentrate on their examination such as Savings, Method of Deployment, Greater Internet Stability. The study will draw on a review of the relevant literature and standards with the goal of offering a thorough analysis with applications for both MPLS and SD-WAN and Hybrid SD-WAN. The fundamental ideas of hybrid SD-WAN will be explained in this study, along with how it stacks up against competitors like MPLS and VPN.

I. INTRODUCTION

Wide area networks - WANs are made up of one or more local area network - LANs, and one popular technique for connecting these LANs is Multi-protocol Label Switching (MPLS). MPLS enhances the standard operation of the Internet by routing packets through specific network paths utilizing specialized routers. These predefined network channels can be used as the structural underpinning of a WAN, allowing numerous virtual WANs to coexist on the same network backbone. However, they require a contractual service from a carrier or telecommunications business, take a long time to set up, and can be expensive. A software-defined WAN (SD-WAN) is a large network that connects LANs with software rather than hardware. In SD-WANs, no specialized equipment is required for routing. Because they use the ordinary Internet, they are simpler to implement than alternative networking solutions. Although MPLS is one of the networking strategies that can be utilized in an SD-WAN. However, SD-WANs are usually more versatile and cost-effective than MPLS.

Hybrid SD-WAN is a design methodology that employs both MPLS and 'direct-to-internet' WAN connectivity to deliver a diversified and seamless WAN service. This enables each link (whether MPLS or 'direct-to-internet') to be closely monitored in real time for current consumption, latency, packet loss, and faults. If a line fails, suffers from latency, or suffers from packet loss, the other lines might take over the burden.

II. PROBLEM STATEMENT

Most of institution, public and private have offices in different location across the globe. Accessing services like VoIP, Central monitoring in those offices become challenging and costly. Internet stability and deployment method either MPLS or SD-WAN for those office is also a problem when interconnecting offices in different locations.

The goal of this study is to develop a hybrid SD-WAN technology solution and their effects on the WAN market for various institutions, public and private enterprises. To demonstrate to the reader the benefits and drawbacks of the SD-WAN and MPLS technology, a comparison with alternative WAN options, such as MPLS VPN, will be made. The analysis will highlight the existing position of this new technology on the WAN market and act as a springboard for further investigation into the development of WANs. How does a hybrid SD-WAN technology compare to the software-defined wide-area networking technology and MPLS? How SD-WAN solution will be deployed compared to MPLS solution? The main question that this research will attempt to address is what the results mean. The solution will be offered following analysis and comparison of the hybrid SD-WAN, SD-WAN and MPLS technologies using EVE-NG and Wireshark.

III. METHODOLOGY

A. *Research design*

Qualitative methodologies should produce the desired findings for this research project. In actuality, through interviews and observation, qualitative research attempts to comprehend a phenomenon in its natural environment. A research design is a strategy or blueprint that outlines how the data needed to address the issue the researcher will concentrate on, as well as the steps and techniques for gathering and analyzing the data, will address the study questions. Accordingly, the researcher would use a descriptive design in the current study to describe the characteristics of a population under investigation and closely examine the use of EVE-NG to compare and analyze the cloud computing applications for SD-WAN and MPLS. (A Queirós, D Faria, & F Almeida, 2017).

B. *Survey*

Surveys are one of the most commonly used methods, as they allow for the collection of large amounts of data from a broad range of participants.

C. *Observation*

Observation is another useful method, as it enables researchers to observe how system is used, and how people interact with it, in a natural setting.

D. *Experimentation*

Experimentation is an important tool for exploring the effects of different system / technology designs, as it allows researchers to measure and compare the performance of different designs and configurations. Taken together, these data collection techniques provide researchers with a range of powerful tools for gaining a deeper understanding of the topics they are studying.

E. *EVE-NG*

EVE-NG, an emulation platform, is a network emulator that provides a virtual environment for network devices such as routers, switches, firewalls, load balancers, and more. It allows users to simulate and test various network scenarios without relying on physical hardware (E Ng, 2017). EVE-NG is designed to be used in a variety of scenarios, from research and development to educational training. It can be used to simulate large networks or to build small laboratory environments. EVE-NG's platform-independent architecture allows it to run on a wide variety of operating systems, including Windows, Linux, and Mac OS. The platform is highly configurable, allowing users to customize the number, type, and configuration of network devices to suit their needs. EVE-NG is a powerful and versatile platform, providing users with a wide range of features and capabilities to meet their needs (E Ng, 2017).

F. *Wireshark*

Wireshark is a powerful network protocol analyzer. It is used by network administrators to troubleshoot network protocols and analyze traffic on their networks (Sanders, 2017). It provides detailed information about every packet that traverses the network, including source and destination addresses, protocol type, and port numbers. It also provides information on the time the packet was sent and received, and the size of the packet. Wireshark can be used to analyze the performance of networks and identify security issues such as malicious traffic. It can also be used to debug applications and detect network errors

IV. RESULTS

The research was guided by specific objectives; and whose research findings are analyzed and interpreted respectively; Objectives are, namely:

- To develop a low-cost schema of a company or institution can gain once they choose SD-WAN solutions and/or MPLS solution in WAN environment.
- To apply deployment method of SD-WAN and MPLS solutions depending on what institution will choose.
- To demonstrate internet stability when SD-WAN and MPLS solutions are used.

A. *Cost for MPLS with VPN*

This shows that the total bandwidth for broadband for one month is 140Mbps, this include 40Mbps for Headquarters and 10Mbps for each field office. Note that World Vision International Rwanda has 10 field offices and here the cost of VPN (40Mbps) must be added

Per month, World Vision International Rwanda used the following bandwidth:

HQ: 40Mbps
10 field offices: 10Mbps * 10 = 100 Mbps
VPN: 40 Mbps

Total bandwidth is 180Mbps per month (This is composed by 140 Mbps for broadband and 40 Mbps for VPN).

1 Mbps costs 106,200 Frw for brodband
1 Mbps costs 88,500 Frw for VPN

Thus, the total amount the institution pays is [(106,200 * 140) +(88,500 * 40)] = 18,408,000 Frw

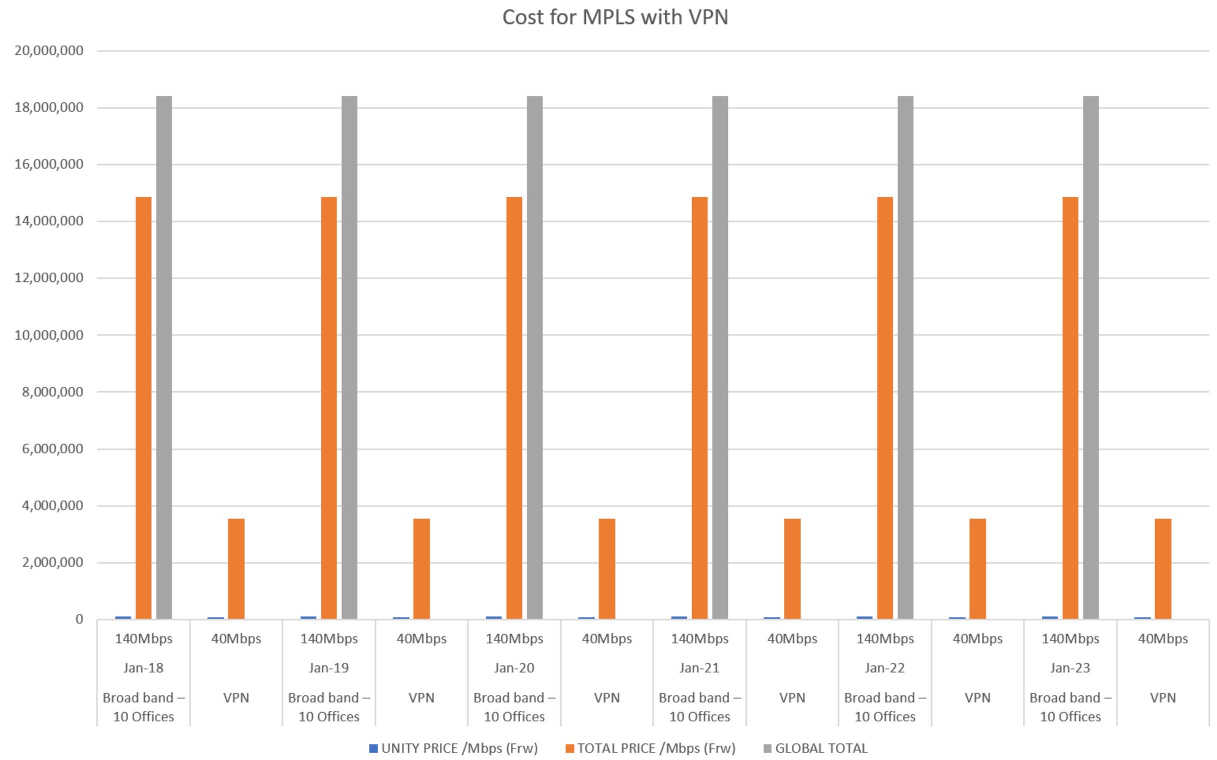

Fig. 1: Cost for MPLS with VPN

B. Cost with SD-WAN Appliances

With the appliances with SD-WAN capabilities, the following illustrates the cost for one month. Note that with SD-WAN, the cost of VPN is eliminated due to the feature called auto-vpn that SD-WAN enabled appliances have

HQ: 80Mbps
10 field offices: 10Mbps * 10 = 100 Mbps

Total bandwidth is 180Mbps per month (This is composed by 80 Mbps broadband for HQ and 100 Mbps broadband for field officed).

1 Mbps costs 55,647 Frw for brodband

Thus, the total amount the institution pays is (55,647 * 180) = 10,016,460 Frw

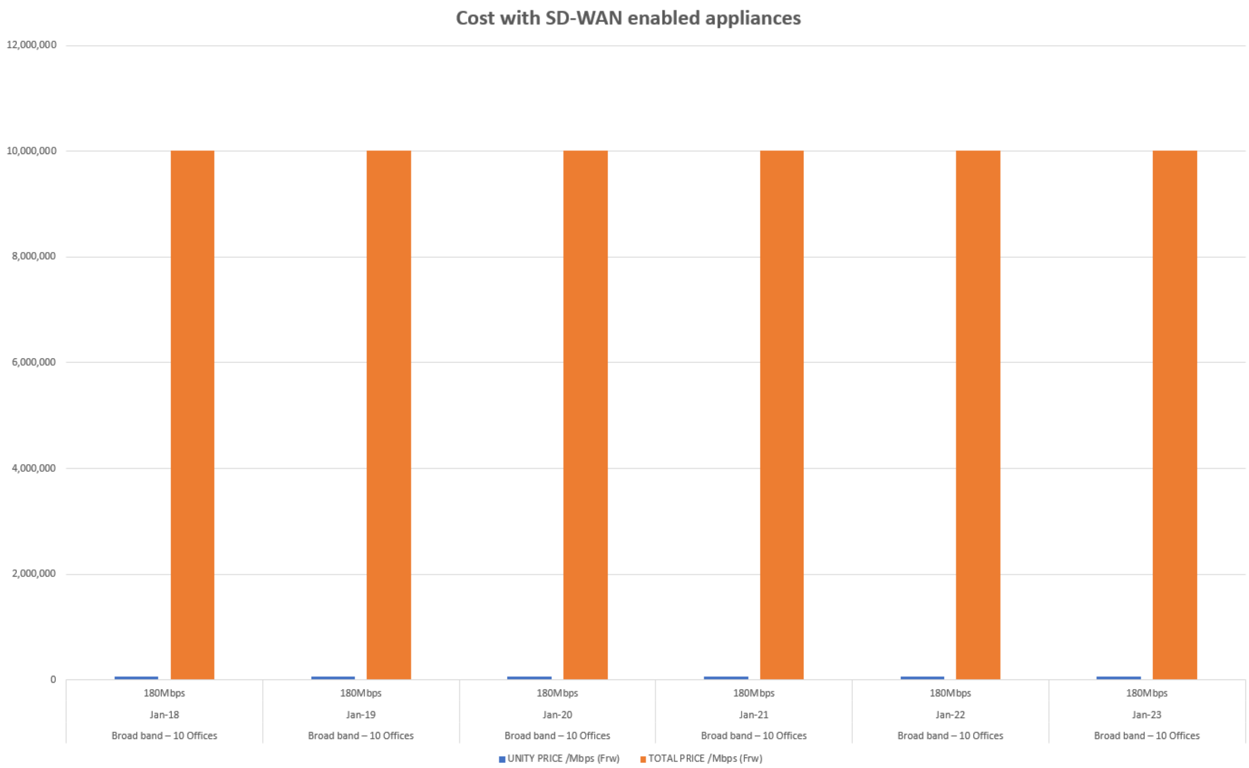

Fig. 2: Cost with SD-WAN enabled appliances

➢ *Saving schema analysis*

The analysis shows that there is a huge saving when shifting from MPLS to SD-WAN as illustrated here bellow:

- The saving per month: 18,408,000 - 10,016,460 = 8,391,540 Frw
- The saving per year will be 12 * 8,391,540 = 100,698,480 Frw

ITEM	YEAR	CAPACITY (Mbps)	TOTAL PRICE /Mbps (Frw)- for MPLS	TOTAL PRICE /Mbps (Frw)- for SD-WAN	SAVINGS
Broad band – 10 Offices	18-Jan	180Mbps	18,408,000	10,016,460	8,391,540

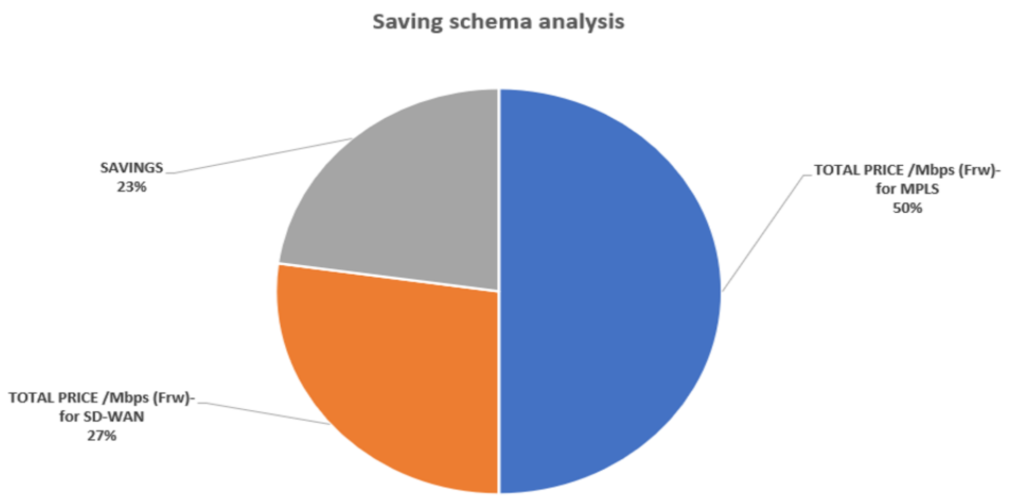

Fig. 3: Saving schema analysis

➢ *Deployment method of hybrid SD-WAN and MPLS solutions depending on what institution will choose.*

Because MPLS connections must be configured in physical routers in the neighboring network, businesses must utilize the same carrier at all WAN-connected sites. SD-WAN connections use the standard Internet; therefore, any ISP can support them.

There are just a few fundamental methods for how an SD-WAN solution is supplied to the end user when selecting to adopt one for your company. The strategy you choose should be based on a thorough examination of your requirements. Is your company limited to a single location? Are there several branch offices in the same city? Or is your company genuinely global, with key assets spread across multiple continents? Obviously, these use cases have very distinct networking implications, and hence varied deployment methodologies are to be expected. SD-WAN can be deployed in a variety of ways by businesses. Do-it-yourself (DIY), managed SD-WAN, and working with a managed service provider (MSP) are the key alternatives.

C. DIY - Do-It-Yourself

Organizations can create their own SD-WAN architecture by deploying SD-WAN solutions at each corporate network site and connecting them via available network lines.

D. Managed SD-WAN

Managed SD-WAN or SD-WAN as a Service is provided by several service providers. Some of the advantages of SD-WAN as a Service installations are as follows: Simple Deployment, Improved Infrastructure, and a Consumption-Based Model.

E. MSP - Managed Service Provider

SD-WAN is frequently offered as part of the portfolio of telecoms and other managed service providers (MSP). Among the benefits of MSP SD-WAN implementations are: Managed Deployment and Service-Level Agreements (SLAs) are two terms used interchangeably.

➢ *To demonstrate internet stability when hybrid SD-WAN and MPLS solutions are used.*

Two simulations are being used here:

- For MPLS, Internet Access VRF Aware NAT is simulated
- For hybrid SD-WAN, DIA – Direct Internet Access for guest users is simulate

F. Internet Access VRF Aware NAT for MPLS

For this scenario, we have 3 customers named CustomerA-Site1, CustomerA-Site2, CustomerB-Site1, CustomerB-Site2 and CustomerC-Site1, CustomerC-Site2. All these customers need to access to the internet. For this reason, CE routers are not NAT enabled, the service provider should give the service of NAT through internet router as illustrated bellow:

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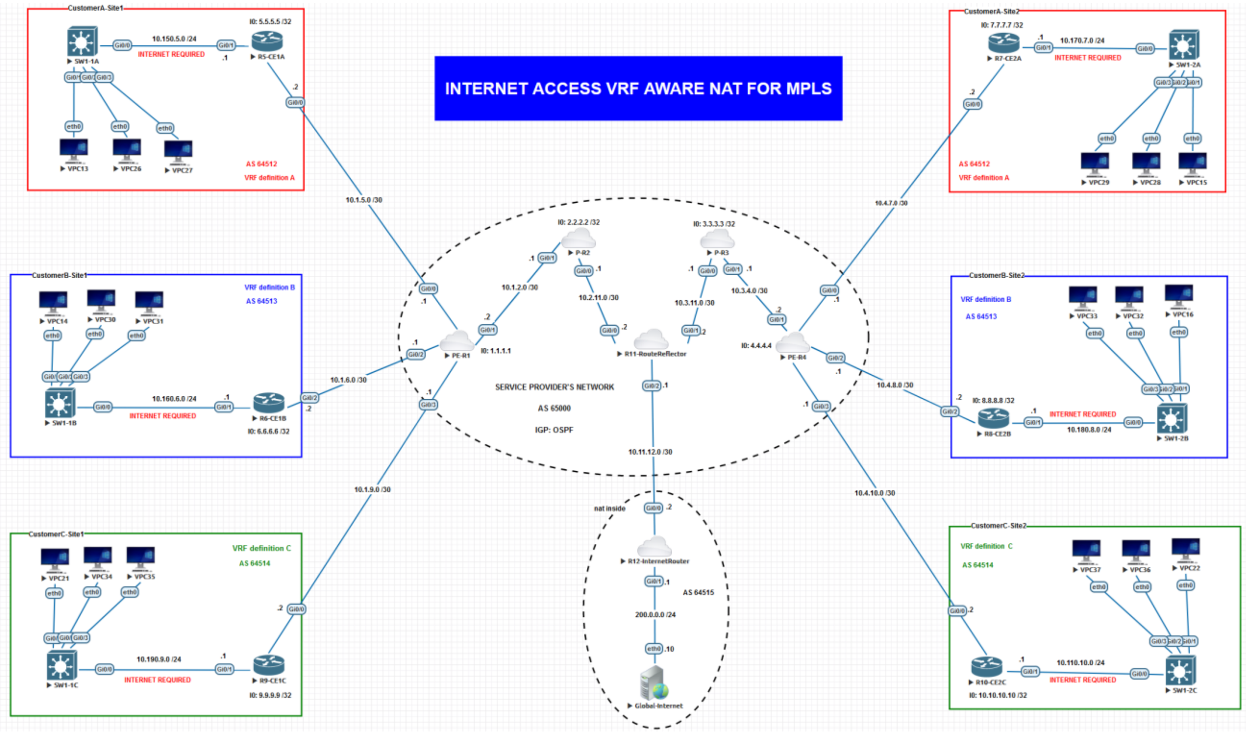

Fig. 4: Internet Access VRF Aware NAT for MPLS

In this scenario, VPC13, VPC14, VPC15, VPC16, VPC21 and VPC22 can get to the internet here referred as "Global-Internet" with IP address of 200.0.0.10/24 as illustrated bellow:

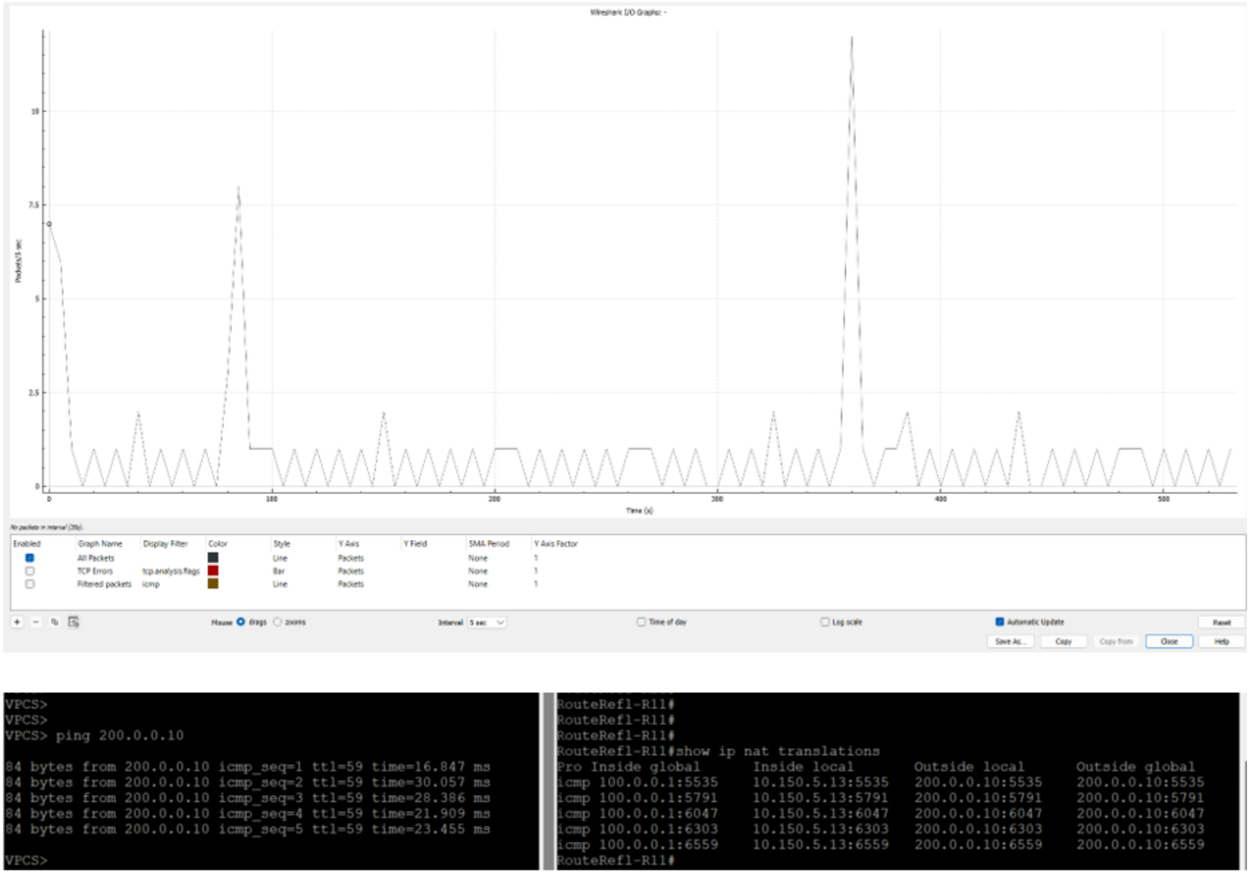

Fig. 5: Ping results from clients to internet with I/O graph in Wireshark

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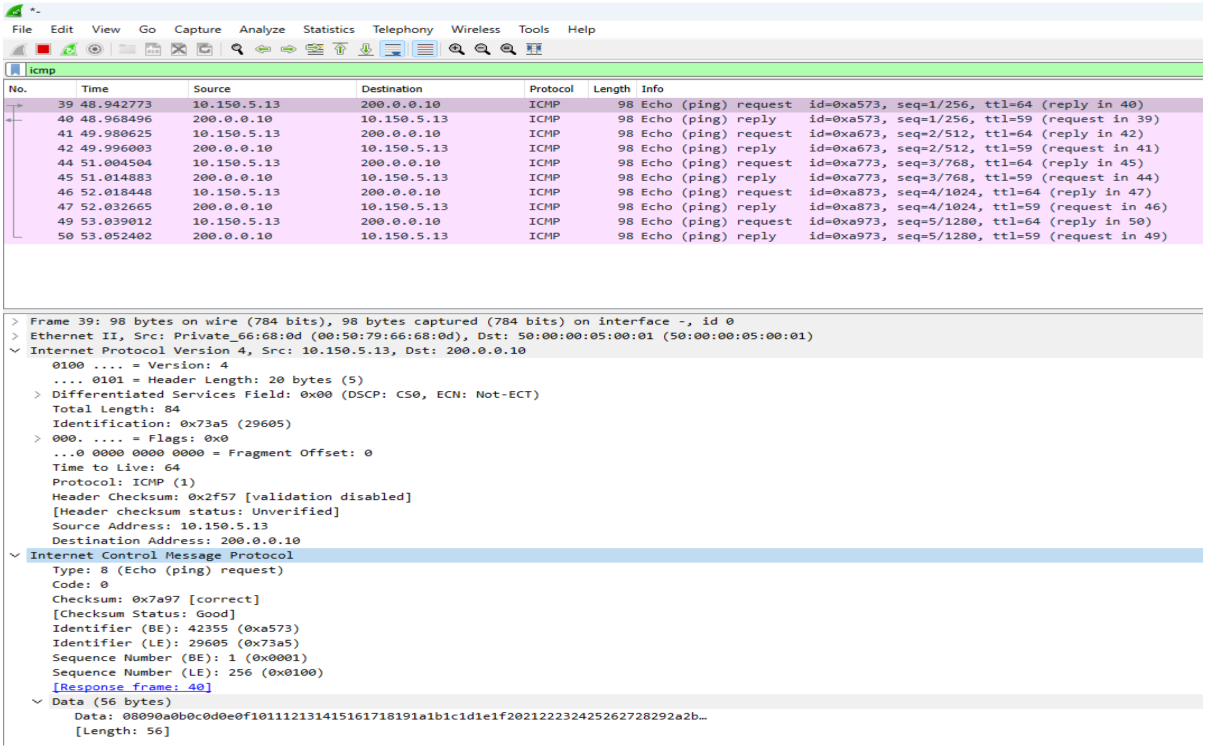

Fig. 6: ICMP packet capture in Wireshark

G. Direct Internet Access for guest and corporate users in hybrid SD-WAN

DIA is an SD-WAN architecture component that allows Internet-bound traffic from branches to be routed directly to the Internet via local ISPs, avoiding the inefficiencies of traffic backhauling to a data center or a regional hub. Local Internet breakout at remote branches has several significant advantages over the datacenter-centric approach:

- DIA increases application performance by removing the latency caused by backhauling traffic to and from the data center.
- It reduces bandwidth utilization at the data center's WAN lines, lowering WAN costs.
- It enables us to partition Internet access per VPN, allowing us to separate guest and corporate traffic.
- The end result is a better application experience for customers and corporate at branch locations.

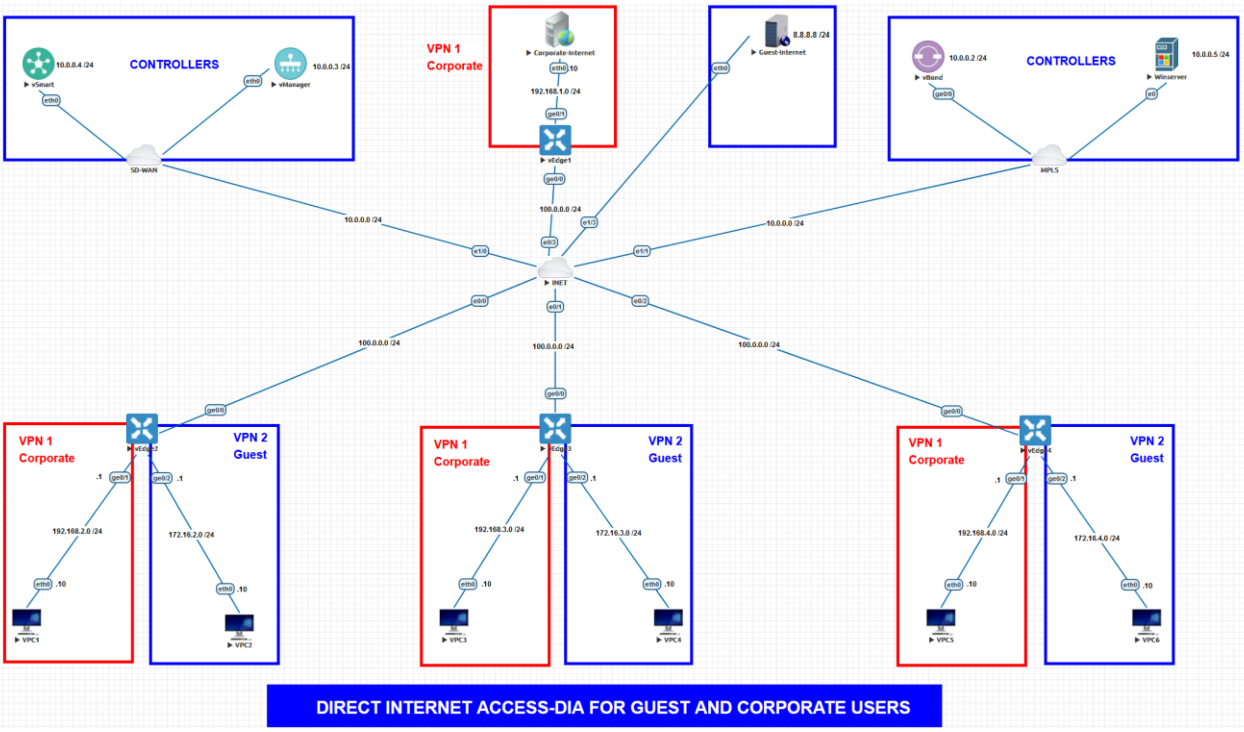

Fig. 7: Direct Internet Access for guest and corporate users in hybrid SD-WAN

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In this scenario, through feature templates, VPC1, VPC3, and VPC5 are communicating because they all belong to corporate vpn1 but they cannot communicate to VPC2, VPC4 and VPC6 because they are belonging to guest vpn2. In contrast VPC2, VPC4 and VPC6 can communicate each other. Also:

- VPC1, VPC3, and VPC5 can reach corporate Internet

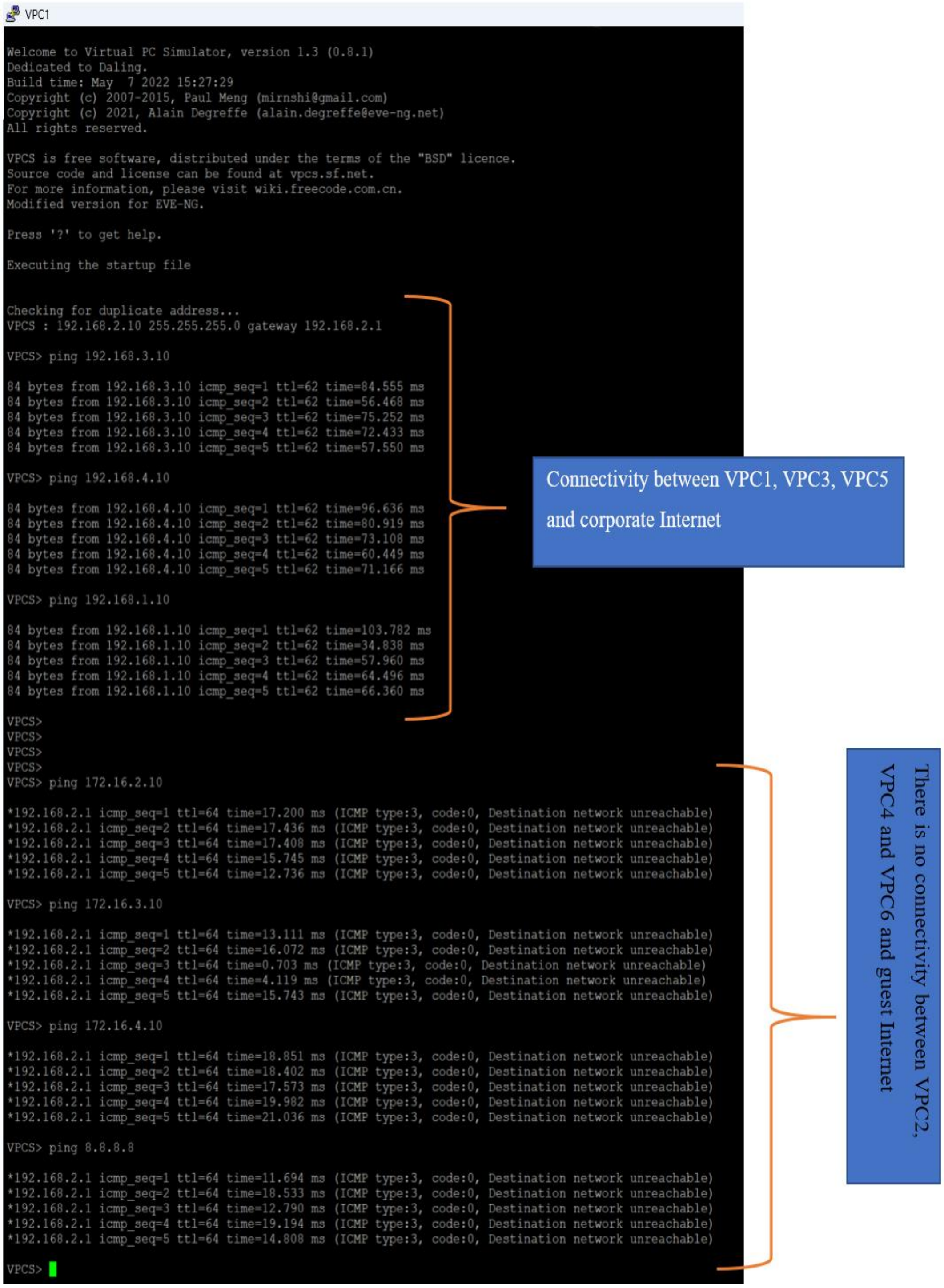

Fig. 8: Connectivity between VPC1, VPC3, VPC5 and corporate internet

- VPC2, VPC4 and VPC6 can reach guest Internet

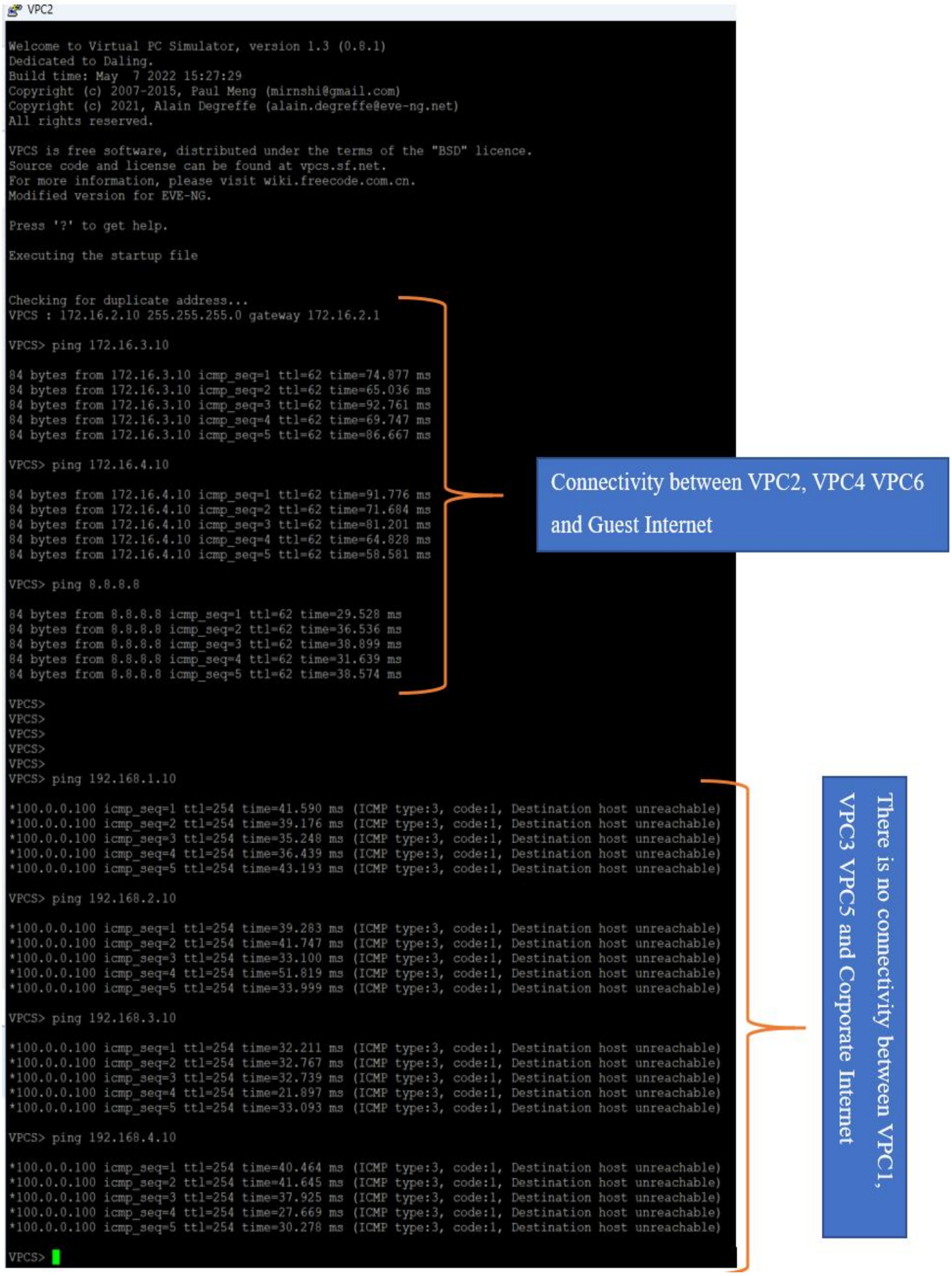

Fig. 9: Connectivity between VPC2, VPC4, VPC6 and guest internet

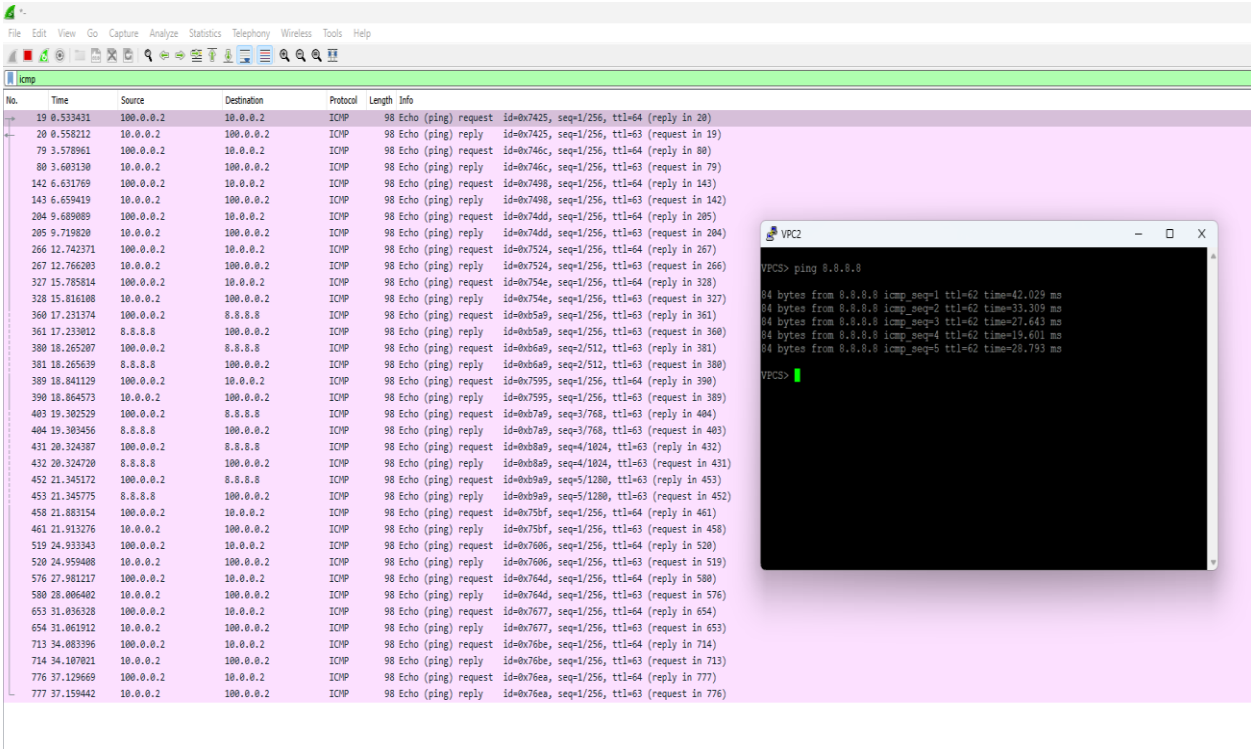

Fig. 10: Packet capture when guest client pings internet

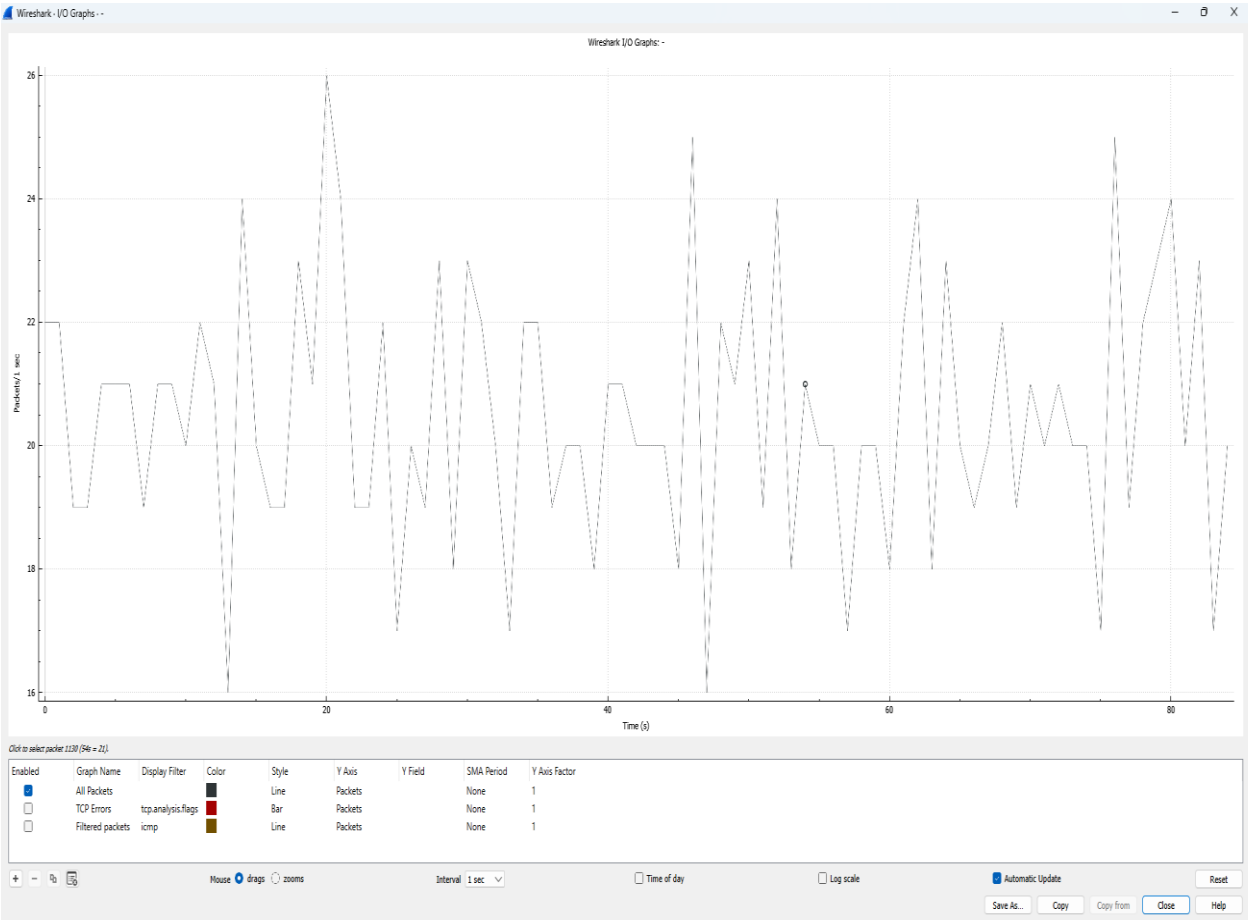

Fig. 11: Wireshark graph when guest pings internet

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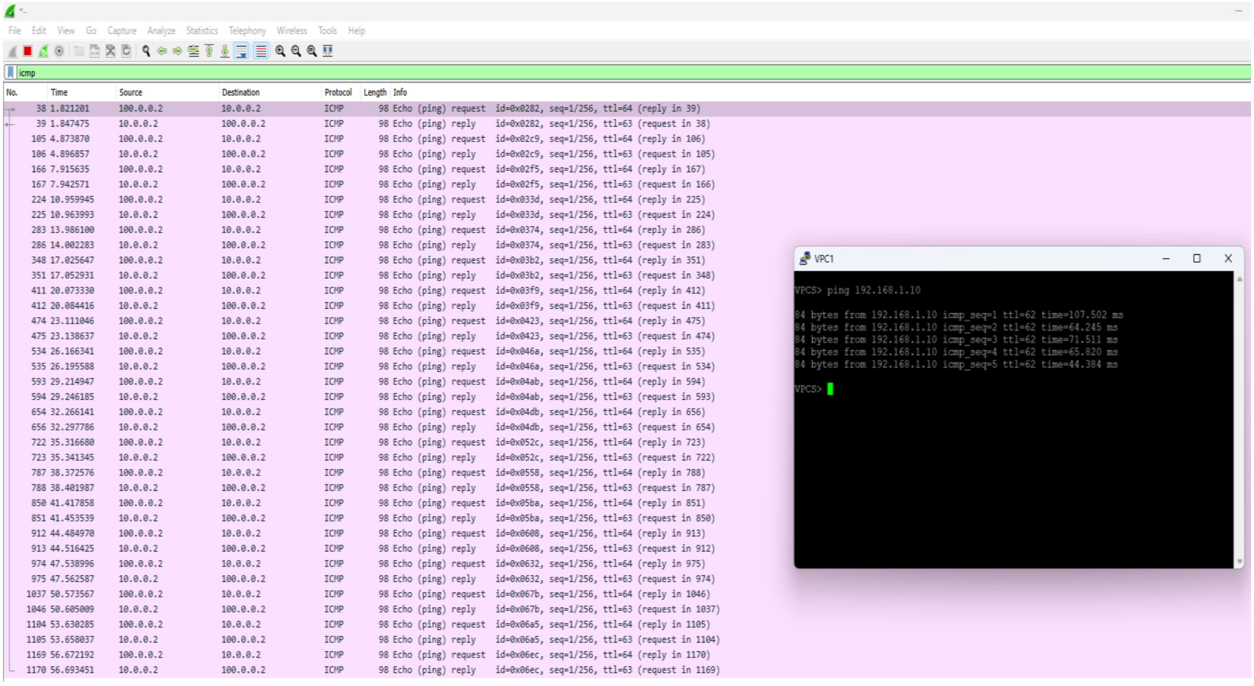

Fig. 12: Packet capture when corporate client pings internet

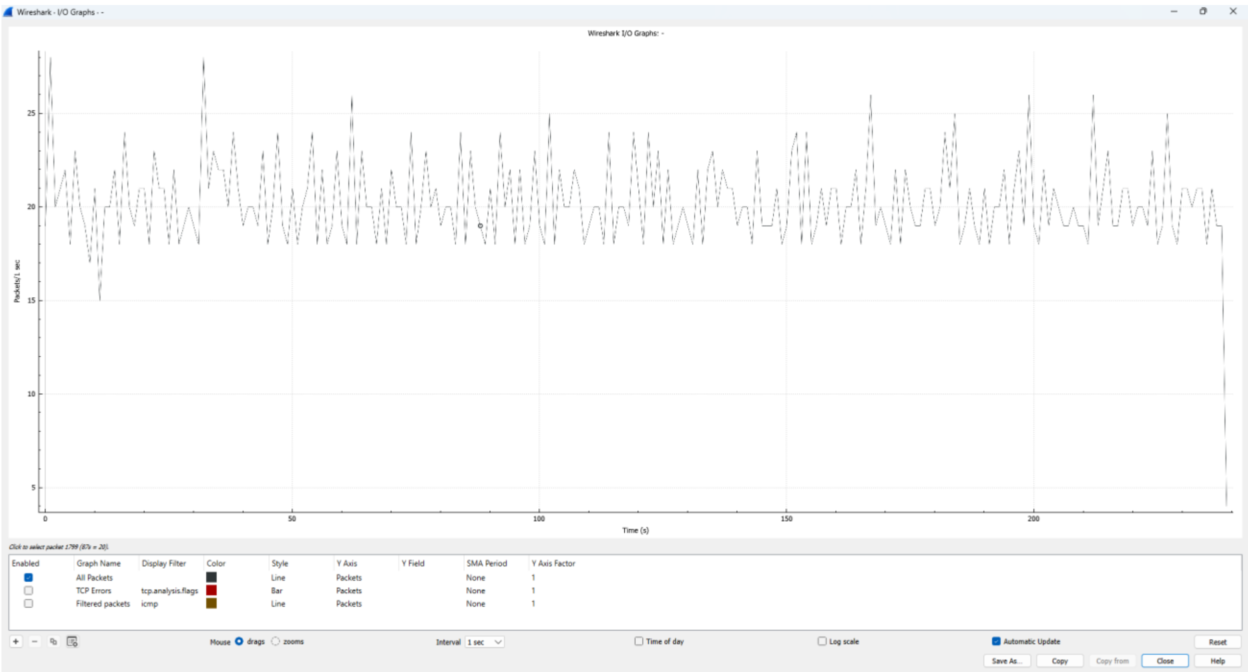

Fig. 13: Wireshark graph when corporate user pings internet

Table 1: MPLS vs hybrid SD-WAN: Time to reach Internet

For MPLS	For hybrid SD-WAN
Average of time to reach internet: (16.847+30.057+28.386+21.909+23.455) ms /5= **24.1308 ms.** Hence ability to provide Quality of Service compared to SD-WAN	Average of time to reach internet: (107.502+64.245+71.511+65.820+44.384) ms /5 = **70.6924 ms.** Hence SD-WAN doesn't fix bad or unreliable internet connections

Table 2: Hybrid SD-WAN vs MPLS (Percentage of Time in ms)

	MPLS (Time in ms)	SD-WAN (Time in ms)
Time in ms	24.1308	70.6924
in %	25.45%	74.55%

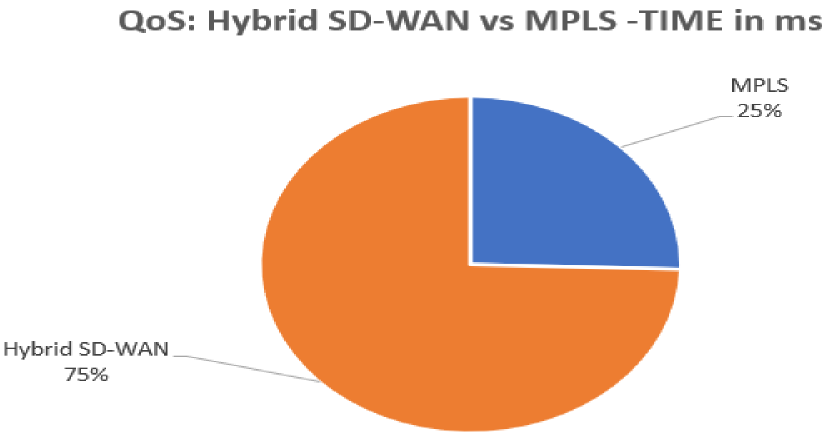

Fig. 14: Hybrid SD-WAN vs MPLS (Percentage of Time in ms)

V. CONCLUSION

SD-WAN can be used by multi-location firms to connect their headquarters with outlying branches. This might be an organization with offices all over the world, or it could be a merchant with a few locations in a city. Unlike MPLS, which necessitates the usage of a single telecom provider across all locations, SD-WAN allows you to configure your bandwidth per site.

World vision gain the saving of 23% of the total cost (For the bandwidth) when they prefer using SD-WAN over MPLS.

SD-WAN uses more one deployment method such as Do-it-yourself (DIY), managed SD-WAN, and managed service provider (MSP) compared to MPLS Because MPLS connections must be configured in physical routers in the neighboring network, businesses must utilize the same carrier at all WAN-connected sites.

For MPLS, it provides 25.45% of QoS compared to 74.55% for SD-WAN Hence MPLS has ability to provide Quality of Service compared to SD-WAN.

Hence here are some reasons to choose hybrid SD-WAN over MPLS and SD-WAN for business continuity:

- Applications requiring a low latency can use the MPLS line.
- The MPLS line can be used by services that need a SLA for compliance.
- The Direct-to-Internet connection is used for web hosting services and Internet connectivity to reduce latency.
- Both MPLS and Direct-to-Internet traffic flows can be managed using SD-WAN, which can also select the best route for that traffic.
- Less reliant on a single WAN provider
- Low latency traffic can take use of the MPLS link, which offers improved performance SLAs.
- The more secure MPLS line can be used for sensitive on-net communications.
- Bulk download traffic might take advantage of the less expensive Higher Bandwidth SD-WAN link.
- Service can be maintained even if a total site SD-WAN or MPLS failure occurs.

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