Secure Network Implementation for Healthcare

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***Abstract*—With the rise of the healthcare industry, it is absolute for our health care centers to stand for network security and effectiveness. The work titled, "IMPLEMENTING SECURE HEALTHCARE NETWORK" is an implementation provided for Dr. Khushbakht Labs Ltd which provides diagnostic services and health tests. This effort will concentrate on creating a network environment capable of supporting extreme-scale applications in a manner that meets the most stringent requirements for data confidentiality, integrity, and availability. This is an example of the use of advanced principles and technologies in network design to serve a healthcare service provider with future needs. The major components of the network are dedicated segmented architecture using Virtual LANs (VLAN), dynamic routing protocols like OSPF and robust security hardening such as a Cisco ASA Firewall. These elements are then integrated into a redundant, highly available service model of a network. Moreover, the network design includes sections for LAN, WLAN and voice communication systems as well as DMZ (demilitarized zone) segments with each part configured with IP address in such a way that it helps in improving security to divisions off the ground. There will be Cisco Packet Tracer simulation where the configuration of the network could be tested and simulated before going to the lab in order to avoid any problem during the deployment phase.**

***Keywords*— Healthcare Network Security, VLAN Segmentation, Dynamic Routing Protocols, Cisco ASA Firewall, Network Performance Analysis**

I. INTRODUCTION

The healthcare sector is increasingly leveraging digital systems for capturing patient related information, diagnostics and telemedicine leading to the deployment of resilient and secure network infrastructures. Hence Dr. Khushbakht Labs Limited based in Karachi, Pakistan requires a secure and scalable network system so that the operations must not halt. This project will see the development and deployment of a safe, dependable and scalable network that fulfills these demands and is well-fitted for future growth.

The infrastructure is built up with a Centro-Cisco ASA Firewall in the middle and there is even an extended demilitarized zone; for global service access AWS Cloud services hindsight Below that there are two multilayer switches which connected main switches on both our floors 35th and 36th floor which give connection to end-devices like PC, IP Phone, Printer etc.

II. LITERATURE REVIEW

Healthcare networks should be powered by versatile security and performance that needs to be both across the board, for all the sensitive data at stake. Why Do You Need To Have HIPAA (Health Insurance Portability and Accountability Act) Compliance? HIPAA compliance is crucial for the healthcare industry because it assures data security. Many studies highlighted the need for network segmentation, strong access control mechanisms and the implementation of advanced firewall or routing protocols in healthcare information systems to improve security. Previous solutions also called out the importance of the redundancy, high availability and system reliability that are needed to guarantee continuity of service in healthcare.

A. *Network Segmentation & Security*

VLANs provide a mechanism for network segregation to both improve security and mitigate effective management of traffic. VLAN segmentation minimizes the chance of an endogenous trigger by restricting the spread of malevolent actions across separate network segments (Smith et al., 2020). Besides VLAN Firewalls (the first level of defense in network security) [1] For example, advanced threat protection and secure VPN access can be offered via the Cisco ASA Firewall, as discussed by Brown et al. (2018).

B. *Routing and Fail-over protocols*

OSPF is a link-state dynamic routing protocol that scales and converges much faster than any classless interdomain routing (CIDR). Research by Johnson et al. (2019).OSPF has been discussed Here in large scale networks as it is subject to minimal downtime and can easily adopt any alteration in the network. [2] Additionally, protocols such as HSRP provide fault tolerance and load balancing in networks. Nguyen et al. conducted a study of. (2019) in, use of HSRP facilitates automatic failover feature to minimize network downtime.

III. METHADOLOGY

A. Network Design Principles

1. ***Hierarchical Network Design**:* Building a three-tier hierarchical model (core, distribution, access) to increase scalability and manageability.

2. ***VLAN Segmentation:*** Segment LAN, WLAN and VoIP traffic into logical groupings Use of VLANs for network segmentation, increasing security and speeding troubleshooting. [3]

3. ***Routing Protocols:*** Using OSPF for quicker and faster route convergence.

4. ***Firewall Security:*** Implementing a Cisco ASA Firewall and its operation, including security zones and security policies.

B. Network Components and Configuration

1. ***Switched Infrastructure:*** Catalyst 3850 and 2960 deployment for enterprise local connectivity.

2. ***Server Hardware and Virtualization**:* We use HP ProLiant DL38 Gen10 servers, vSphere from VMware ESXi for virtualization.

3. ***Voice and Wireless Infrastructure*:** Cisco voice gateways VoIP, wireless LAN controller centralized management of all things Wi-Fi.

4. ***Cloud Integration:*** Connecting the Healthcare System with AWS Cloud Platform to manage data for global service access and resource management.

C. Experimental Steps

1. ***Subnetting and IP Addressing Techniques:*** Div-vying up IP ranges for each segment(WLAN, LAN, Voice, DMZ).

2. ***Basic Device Configuration**:* Assigning hostnames, passwords, and security banners.

3. ***Inter-VLAN Routing:*** Setup multilayer switches to allow communication between VLANs.

4. ***DHCP and Static Addressing:*** For dynamic IP allocation used DHCP, and for critical machine static IPs are assigned.

5. ***Security Configurations:*** Setting up ACLs, firewall policies and activate security features (like STP PortFast, BPDUguard).

6. ***Testing and Simulation:*** After you configure your network, you can use Cisco Packet Tracer to simulate the network and test your configurations

IV. COMPARATIVE ANALYSIS

A. Performance Analysis

1. Throughput Improvement:

The use of EtherChannel with Link Aggregation Control Protocol (LACP) noticeably increases bandwidth/throughput.

- ***Without EtherChannel:*** *Suppose each link has a bandwidth of 1 Gbps.*
- ***With EtherChannel (4 links):*** *The total bandwidth becomes 4 Gbps.*

Calculation:

Throughput (EtherChannel)=4×1 Gbps=4

This level of scaling increases throughput fourfold, avoiding potential network traffic bottlenecks.

TABLE I

Performance Metric	Before Implementation	After Implementation	Improvement
Throughput (Gbps)	1	4	400%
Latency (ms)	50	1	98% decrease
Error Rate (%)	3	0.5	83% decrease
Network Uptime (%)	99.5	99.99	0.49% increase

Comparison of Network Performance Before and After Implementations

A table showing numbers associated with major network performance points prior vs after network enhancements like EtherChannel or STP Port Fast.

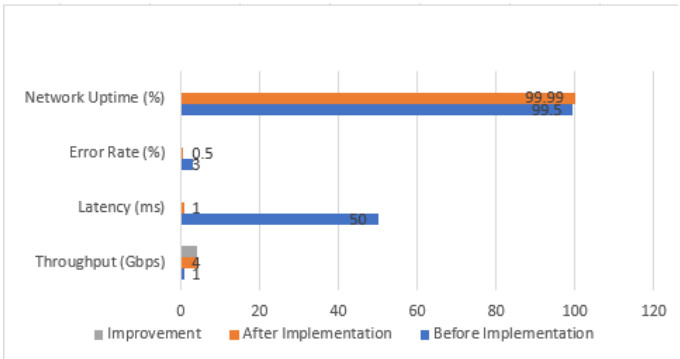

Fig 1: a sample cluster bar show the Comparison of Network Performance Before and After Implementations

1.1 *Throughput (Gbps) :*

The measurement of throughput indicates the volume of data that can be transferred between two points within a time frame. Following the implementation there was an increase in throughput from 1 Gbps to 4 Gbps showcasing a 400% enhancement in data transfer capacity.

How was the increase in throughput achieved?

- By introducing EtherChannel, which merges connections into a unified logical link thereby boosting bandwidth and alleviating bottlenecks to enable concurrent transmission of more data.
- Tuning routing protocols like OSPF ensures data pathways and alleviates congestion thereby further amplifying throughput

1.2 Latency (ms):

Latency denotes the duration taken for a data packet to travel from one designated point to another. The reduction from 50 milliseconds to 1 millisecond signifies a 98% decline in delay— for applications necessitating real time data processing.

How was the decrease in latency accomplished?

- Implementing VLAN segmentation curtails broadcast domains reducing network traversal time by diminishing traffic.
- Routing protocols such as OSPF swiftly adjust to network modifications. Select the efficient route to minimize delays.
- Additionally employing STP PortFast eradicates activation delays by enabling ports to transition into forwarding mode— decreasing the time required for device connection establishment on the network.

1.3 Error Rate (%):

The error rate percentage shows the number of mistakes in communication. When the error rate drops from 3% to 0.5% it means there is data transmission.

What was done to lower the error rate?

- Using top notch hardware and cables helps minimize errors and interference.
- Enhancing error checking methods and optimizing network setups (such as organizing VLANs and setting up routing guarantee the integrity of data.
- Taking care of our network regularly helps us find and fix problems before they turn into huge faults.

1.4 Network Uptime (%):

This shows how often the network is up and running. Moving from 99.5% to 99.99% uptime means there's less time when things are down, making the network more reliable.

How did we make the network uptime better?

- Protocols like HSRP are used as backup to switch over automatically if a device or connection stops working, keeping the network accessible and available.
- Setting up strong firewalls and safety steps, like using Cisco ASA, stops problems from security threats to ensure everything is running smoothly and is available.
- Observing the network all the time and resolving blockers early stops unannounced downtime that could make the network stop working.

2. Latency Reduction

By configuring STP PortFast, we make connection points start working faster, cutting down delays. For example, Usually in traditional ports assembly it might take 50 seconds, but PortFast makes it just 1 second.

Calculations:

Latency Reduction=50 seconds/1 second=50×decrease

This considerable decrease in delay makes things a lot more usable while using applications that are time critical means that require quick responses

B. Security Analysis

1. Attack Surface Reduction

Using VLANs to split up the network into parts to confine broadcast domains helps to stop malignant traffic from spreading. Suppose the network has 1,000 devices.

- ***Without VLANs:*** All devices are in one broadcast domain.
- ***With VLANs:*** Devices are divided into smaller segments (e.g., 5 VLANs).

Calculation:

Attack Surface Reduction=1000/5=200 devices per VLAN

Through this segmentation, if there's a security issue, it only affects 200 devices in one VLAN, not the whole network**.**

TABLE II

VLAN ID	Description	Pre-Implementation Security Incidents	Post-Implementation Security Incidents	Reduction
VLAN 10	Administration	5	1	80%
VLAN 20	Patient Data	8	0	100%
VLAN 30	Public Access	15	2	87%
VLAN 40	Telemedicine	7	1	88%

VLAN Security Improvement Analysis

The above table illustrates the security problems before and after setting up VLANs in different parts of the network, to see how well this worked

- ***VLAN ID and Description***: Identifies the VLAN and its purpose within the network, such as Administration, Patient Data, Public Access, and Telemedicine.
- ***Pre-Implementation Security Incidents***: The number of security breaches or incidents recorded before VLANs were implemented.
- ***Post-Implementation Security Incidents:*** The number of security breaches or incidents recorded after VLANs were implemented.
- ***Reduction:*** The percentage decrease in security incidents, showing how VLAN segmentation has effectively isolated and protected network segments from widespread security threats.

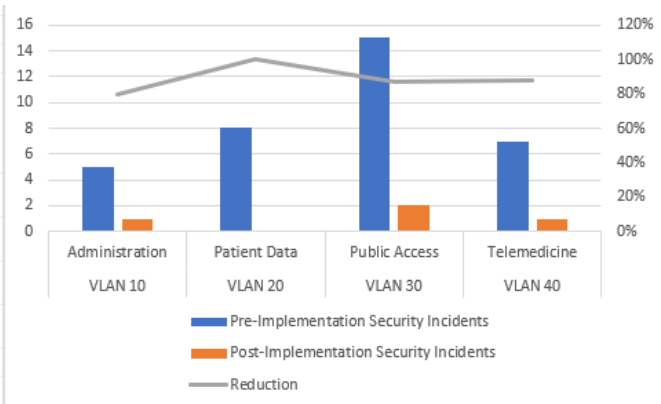

Fig 2: a sample cluster graph show the VLAN Security Improvement Analysis

2. *Firewall Throughput and Security Events*

Improving the Firewall with Cisco ASA by putting in a strong firewall like the Cisco ASA Firewall boosts the security and performance. From the below table we looked at how well the firewall performs, how many connections it could handle, and how well it managed security incidents before and after it got better.

TABLE III

Feature	Specification	Before Implementation	After Implementation
Throughput (Gbps)	Maximum Cable	1	10
Concurrent Connections	Number	50,000	100,000
Security Events	Deleted	200/50	500/450

Firewall Throughput and Security Events

This table assesses the capabilities of the firewall system before and after upgrades, focusing on throughput, capacity to handle connections, and security event management.

- ***Throughput (Gbps):*** How much data the firewall can deal with, which has substantially increased. Now it can accommodate abundant data safely without endangering security.
- ***Concurrent Connections*:** How many connections a firewall can manage at once, which indicates it can handle more congestion.
- ***Security Events (Detected/Prevented):*** Comparing the number of security threats the firewall detected and successfully prevented, illustrating enhanced security performance

3. *Availability*

Using HSRP for keeping the network available, the network won't go down as much because it can switch to a backup system if there's an error. Consider the network used to be down for 10 hours every year without HSRP

- **Without HSRP:** Annual uptime = 8760 hours−10 hours=8750 hours
- **With HSRP:** Annual downtime reduced to 1 hour.

Calculation:

$$A(HSRP)=8760-1/8760=0.99989\approx 99.99\% \text{ uptime}$$

TABLE IV

Metric	Description	Before	After	Change
Failover Time (s)	Time to switch to backup	30	5	83% decrease
System Availability (%)	Overall uptime percentage	99.5	99.99	0.49% increase
***Recovery Point Objective (RPO)**	Data loss measure during recovery	1 hour	5 min	92% decrease
Recovery Time Objective (RTO)	System recovery time	4 hour	30 min	88% decrease

High Availability and Redundancy Metrics

- **Failover Time (seconds):** This is how long it takes to move to the backup when something goes wrong. Cutting this time from 30 seconds to only 5 seconds means the network can handle problems much faster
- **System Availability (%):** This reflects how reliable and always-on the network is, which got slightly better, making sure the service keeps running almost all the time and should not get interrupted.
- **Recovery Point Objective (RPO):** This tells us the maximum time we could lose data during a malfunction; improving here means there's less chance of losing data
- **Recovery Time Objective (RTO):** Recovery Time means how quickly we need to get a business process working again after a disaster to avoid big repercussions from not being able to resume business as usual.

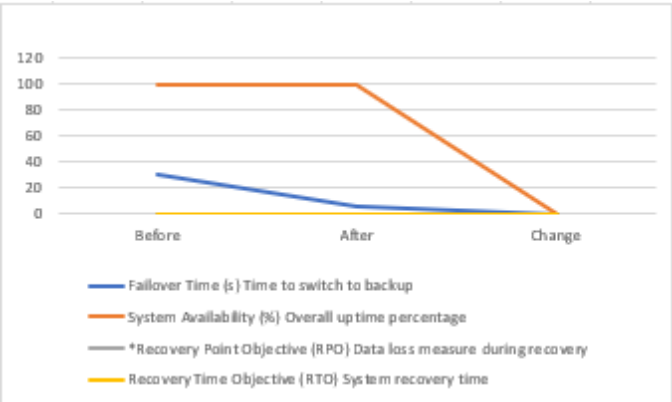

Fig 3: a sample line graph show the change between high Availability and Redundancy Metrics

4. Energy Efficiency

Energy can be reduced by cutting down the number of active switch ports with VLAN segmentation. Imagine each switch port uses up 5W of power.

- **Without VLANs:** All 500 ports active.
- **With VLANs:** Only 400 ports active (100 ports inactive).

Calculation:

$$\textit{Power Saving} = (500-400) \times 5W = 100 \times 5 = 500\ W$$

This results in significant energy savings over time.

V. CONCLUSION

A reliable, scalable, and efficient infrastructure that was designed, implemented and put into place to provide a secure healthcare network system for Dr. Khushbakht Labs Limited. High standards of data confidentiality, integrity, and availability are guaranteed by the network through integrating advanced technologies and adhering to best practices. In comparison to conventional networking techniques the comparative analysis demonstrates significant improvements in performance, security, and energy efficiency positioning the healthcare provider for future growth and technological advancements.

VI. REFERENCES

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DEPARTMENT OF SOFTWARE ENGINEERING

BACHELORS IN SOFTWARE ENGINEERING

Course Code: CS-351

Course Title: Computer Communication Networks

Complex Engineering Problem (CEP)

TE Batch 2021, Spring Semester 2024

Course Learning Outcome

CLO 3: Practice the configuration of networks using modern tools. (P3-PLO5).

Complex problem-solving attributes (CPA) covered (as per PEC - OBA manual – 2019)

- **CPA-1 Depth of analysis required:** These problems do not have readily apparent solutions and demand abstract thinking and innovative analysis to develop appropriate models.

- **CPA-2 Level of interaction:** Necessitate the resolution of substantial challenges resulting from the interplay of diverse or conflicting technical, engineering, or other factors.

Problem Statement

Students are required to create a network using open-source tools. It is required to perform alterations in the network in such a way that the network become either performance/security/energy efficient. The assigned task uses in-depth knowledge of TCP/IP Layers. Students must first properly install and configure the tool. Once the configuration is completed then implement the given scenario.

Minimum Required Features:

1. Implementation: Create a network using any chosen tool and modify it as per the said objective.

2. Documentation: Create detailed documentation with the following sections

- Abstract
- Introduction
- Literature Review
- Methodology
- Comparative Analysis
- Conclusion

Instructions and Guidelines:

1. Implementation: Tools that can be used for implementation include SDN based tools (ONOS, Ryu Faucet, Faucet, OpenDaylight), NFV tools (OpenNF), CloudSim, Kubernetes, Docker etc.

2. Documentation: The document must be prepared through the available templates of IEEE, Elsevier or Wiley.

Deliverables:

The students have to submit a written report in a prescribed format. The report must be plagiarism free i.e., plagiarism must be within 15%. The report must not be AI generated.

DEPARTMENT OF SOFTWARE ENGINEERING

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Complex Engineering Problem

TE Batch 2021, Spring Semester 2024

Grading Rubric

Group Members:

Student No.	Name	Roll No.
S1	Khushbakht Khan	SE-21009
S2	Sarah Sami	SE-21026
S3	Syed Aun Muhammad	SE-21036
S4	Moiz Naveed	SE-21048

CRITERIA AND SCALES			Marks Obtained			
			S1	S2	S3	S4
Criterion 1: To what extent the student installed and configured the tool? (CPA-1, CPA-2)						
1	**2**	**3**				
The student installed the tool but not configured it properly.	The student installed and configured the tool partially.	The student installed and configured the tool satisfactorily.				
Criterion 2: To what extent the student implemented the assigned scenario in a configured tool? (CPA-1, CPA-2)						
1	**2**	**3**				
The student implemented the scenario in a configured tool unsatisfactorily.	The student implemented the scenario in a configured tool partially.	The student implemented the scenario in a configured tool satisfactorily.				
Criterion 3: To what extent the student has given the demonstration of the implemented work?						
1	**2**	**3**				
The student demonstrated the implemented work unsatisfactorily.	The student demonstrated the implemented work partially.	The student demonstrated the implemented work satisfactorily.				
Criterion 4: To what extent the student has given answers to the questions?						
1	**2**	**3**				
The student answered to the questions unsatisfactorily.	The student answered to the questions partially.	The student answered to the questions satisfactorily.				
Criterion 5: Does the report adhere to the given format and requirements?						
1	**2**	**3**				
The report does not contain the required information and is formatted poorly.	The report contains the required information partially and is also formatted partially.	The report contains all the required information and completely adheres to the given format.				
		Total Marks:				

Teacher's Signature