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Design and Performance Analysis for Small to Medium Enterprise's Networks: A Case Study-Jaber Ibn Hayyan Medical University (JMU)

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Abstract: This study suggests the best infrastructure network design based on the analysis of the performance and the type of protocol used. The infrastructure is built using Cisco components and Jaber Ibn Hayyan Medical University has been taken as case study for this purpose. The suggested network has the ability to address the common networks's drawbacks happening in reliability, security, speed (throughput) and manageability. To show these issues, the project is implemented by employing the Virtual LAN (VLAN) concept, airfibre (Fiber performance over wireless links) ASA and OSPF. The chosen network design for Jaber Ibn Hayyan Medical University has been built based on the existence requirements in every campus according to the basic of the needs and future vision compared to standardization included in the Cisco design. The project uses VLAN to solve the broadcast and management problems. It also emulates airfibre concept to provide flexibility and cost effective method of connection that could be deployed as the main network branches connections or backup paths. In addition, the design compares the OSPF (Open Shortest Path First) routing protocol with RIP protocol to find the better network performance as experimented and illustrated in the study results study. This network is considered as an efficient and a affordable cost to build a campus network, specifically is customized for Jaber Ibn Hayyan Medical University. The reason is because the university is newly opened and it lacks the presence of such a type of fully-service data center network. All the outcomes and the design have been conducted using simulation platform provided by Cisco called Packet Tracer (PT)*. Moreover, for backbone parts of the suggested network, actual comparison tests are done utilizing University of Kufa current Cisco platform infrastructure for more accurate results.

Key words: Packet tracer, network, VLAN, router, switch, Cisco, OSPF

INTRODUCTION

Today's data center may contain a huge number of devices with critical total data transfer capacity requirements (Anonymous, 1941). To provide well-performed data center for small to medium enterprise, network infrastructure plays a major role in this data center performance. Electing the most recent routers and switches with affordable cost is crucial to achieve such a data center network. The best utilization of the configuration employing the supported network mechanisms in the routers and switches produces the high performed network and data center accordingly. The idea of the project began from an official edifice of Ibn Hayyan University that it lacks of existence of a fully serviced network to manages its services, storage data, facilitate the research (database for employee, student, information recording).

Networks must support a wide range of applications and services as well as operate over many different types of cables and devices making up the physical infrastructure. VLAN concept is utilized to reduce broadcast which negatively affects network's speed and its performance. VLAN has been used to make network management more secure. That is network partitions do the same research as isolated networks using separate switches, so that, data is exchanged privately (Anonymous, 2017c).

In such a type of networks, it must be taken into account data transfer speed which is built on many standards. The moderate and costly affordable method is introducing the airfibre concept to ensure that the data transferred as fast as possible by implementing optics fiber over wireless to reduce the cost and speed up the network comparing with the pure wireless based networks (Anonymous, 2017b). A solid network must contain

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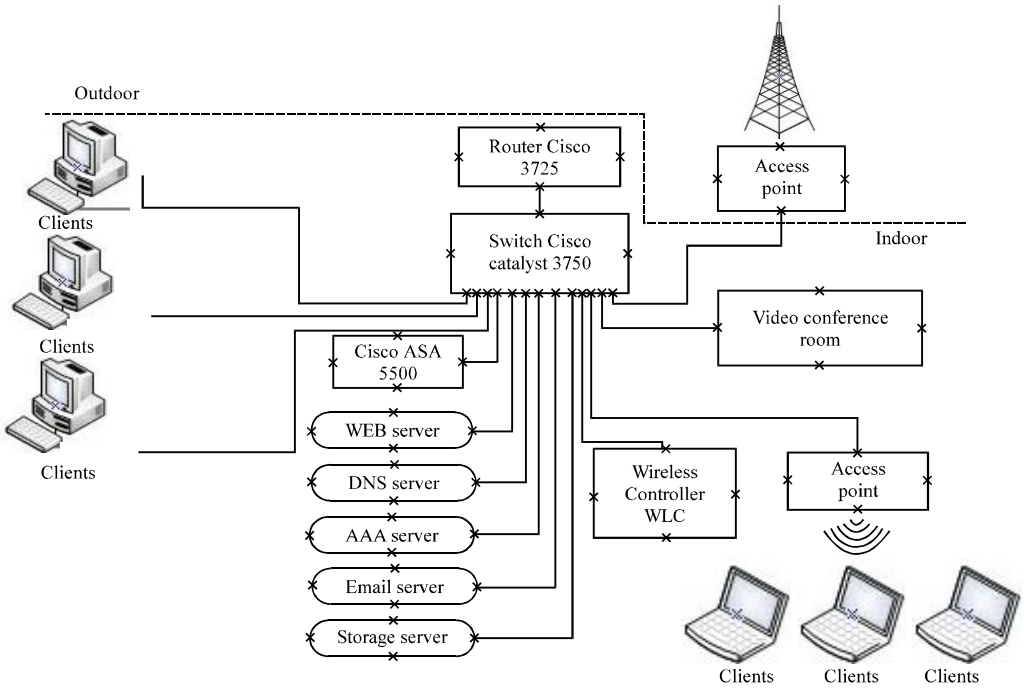

Fig. 1: The proposed core layer of (JMU)

security system to protect the network data from permeation and hackers by using many ways such as hardware or software, so that, ASA is mostly used (Anonymous, 2011).

Subnetting using Variable Length Subnet Mask (VLSM) was designed to maximize addressing efficiency to reduce the number of lost IPs in a network (Anonymous, 2005). In general, standardization network design is consist of three network layers based on the function of each layer as in the following study.

Standard form for network: Cisco has defined a hierarchical model known as the hierarchical internetworking model. This model simplifies the task of building a reliable, scalable and less expensive hierarchical internetwork because rather than focusing on packet construction (Anonymous, 2017b) it focuses on the three functional areas or layers of the networks.

Core layer: This layer is considered the backbone of the network and includes the high-end switches and high-speed cables such as fiber cables.

Distribution layer: This layer includes LAN-based routers and layer 3 switches. This layer ensures that packets are properly routed between subnets and VLANs in your enterprise.

Access layer: This layer is also called the desktop layer because it focuses on connecting client nodes such as research stations to the network. This layer ensures that packets are delivered to end user computers (Fig. 1).

MATERIALS AND METHODS

The main design of the network was built using the packet tracer program and based on the geographical location of Jabir Ibn Hayyan University. The project is started by regularly location visits for the university to gather the information about the departments and the requirements. After analyzing the data provided by the university's different departments, main physical locations of the university have been highlighted on the map, so that, the three aforementioned network layers will be built based on the locations and the discussed functions. The consideration of the cost has been taken, so that, the suggested network will be affordable to be implemented. The recommended devices are shown in Table 1 that are both available in the market place and cost-efficient with best functionality. To avoid disconnection and to provide fully reliable network, a mesh network is used to provide redundant path if the main paths are failed. In addition, two methods of connections are proposed. The wireless network using the towers that support microwave signals. The other approach is the optical fiber in the core and main links mixed with wireless network in the disturbing and access layers. A comparison between the purely wireless and mixed with fiber has been conducted in this study as explained in the results study.

Table 1: Recommended network devices and intermediate nodes for the designed data center JMU

Name of devices	Types of devices	Reasons
Router	Cisco 3725 (Anonymous, 1941)	Supports fiber optics links/Affordable cost/supported by PT
Switch	Cisco catalyst 3750 48-port (Anonymous, 2017d)	Supports fiber optics links/Affordable cost/supported by PT
Firewall	Cisco ASA 5500 (Anonymous, 2011)	For security purpose/Reduces Router access lists tasks/Affordable cost/supported by PT
Access point (Outdoor)	Cisco 1530 (Anonymous, 2017b)	Affordable cost/Availability in the market/Testable/Recommended by Cisco engineers
Access point (Indoor)	Cisco 1130 (Anonymous, 1984)	Affordable cost/Availability in the market/Testable/Recommended by Cisco engineers
Server	Microsoft, Linux	Depends on skilled JMU staff

Table 2: Planned IP addresses for each network branches

Departments	Network address	Mask address	Default gateway	Broadcast address
Administration	10.10.11.0	255.255.255.0	10.10.11.1	255.255.255.255
Interior section	10.10.12.0	255.255.255.0	10.10.12.1	255.255.255.255
management	10.10.13.0	255.255.255.0	10.10.13.1	255.255.255.255
Computer center	10.10.14.0	255.255.255.0	10.10.14.1	255.255.255.255
Classes	10.10.15.0	255.255.255.0	10.10.15.1	255.255.255.255
Physiology	10.10.16.0	255.255.255.0	10.10.16.1	255.255.255.255
Presidency	10.10.17.0	255.255.255.0	10.10.17.1	255.255.255.255

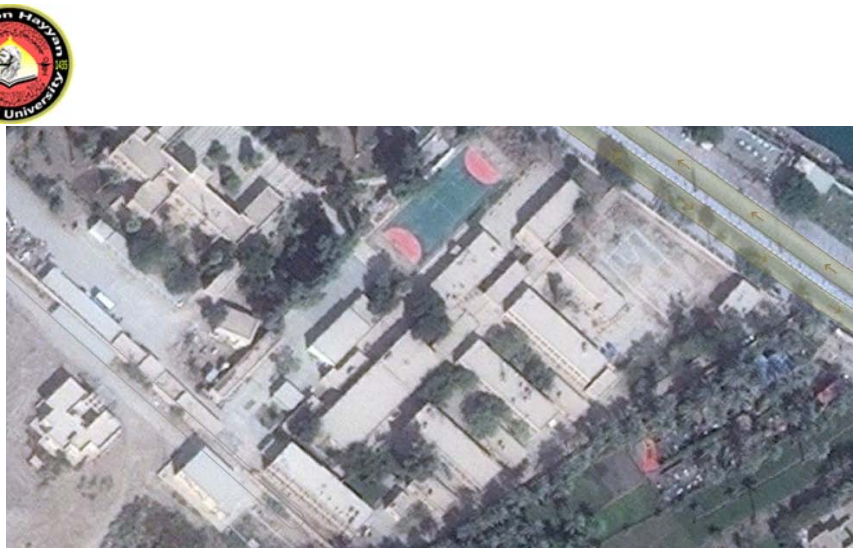

Fig. 2: Physical top view of the location (JMU)

Location of the case study of Jaber Ibn Hayyan Medical University. http://jmu.edu.iq/: The other main factor to be investigated is that the protocol type which plays vital role in the overall network performance. It has been adopted two routing protocols to be operating in the suggested network. With the fiber connection built network, another investigation has been made to show which protocol shows better performance. The IP addresses for routers, intermediate devices and end terminals have been designed and divided in a VLSM mechanism as shown in Table 2. The VLSM uses an adaptable prefix to define different subnetwork. This method ensures that as little lost as possible of IP addresses and it is considered the best design solution. On the other hand, network has been divided into various VLANs within Cisco switches to easily manage and separate network departments. Accordingly, ranges of IP addresses are utilized, so that, each study of the network has its own range for fully control and management. Each suggested routers and switches are explored online to meet the university requirements and to cover the future expansion if any. The main futures to be considered, they support Giga Ethernet, fiber connectors, reasonable cost and up-to-date framework and releases. DMZ servers are suggested based on the main campus network demands such as web server, AAA server, active directory, DNS server and e-Mail server. The project estimates the number of connected end users to the network according to the overall number of staff, employees, students and future needs (Fig. 2-4).

```
SW_Adminstration# configure terminal
SW_Adminstration(config)# int fa 0/1
SW_Adminstration(config-if) #switchport access vlan 10
SW_Adminstration(config-if) #switchport mode access
SW_Adminstration(config-if) #int fa 0/2
SW_Adminstration(config-if) #switchport access vlan 10
SW_Adminstration(config-if) #switchport mode access
SW_Adminstration(config-if) #exit
SW_Adminstration(config) #interface GigabitEtherneto/1
SW_Adminstration(config-if) #switchport mode trunk
SW_Adminstration(config-if) #exit
```

Fig. 3: One of the main parts of switch configuration piece of full configuration

```
R_Core(config) #ip dhcp pool Admin
R_Core(dhcp-config) #network 10.10.10.0 255.255.255.0
R_Core(dhcp-config) #default-router 10.10.11.1
R_Core(dhcp-config) #dns-server 10.10.11.10
R_Core(dhcp-config) #exit
R Core(config) #ip dhcp excluded-address 10.10.11.1
R Core(config) #ip dhcp excluded address 10.10.11.10
R Core(config) #exit
```

Fig. 4: One of the main parts of router configuration-piece of full configuration

RESULTS AND DISCUSSION

The main results of the project are a successful design and an efficient network in which the basic standards of networks have been achieved. Reliability in the delivery of information, security in data transfer and speed has led to better management of this network (Fig. 5).

Simulation results: The average overall system design in Cisco packet tracer is shown in Fig. 6. Comparing the backbone links fiber optics with pure wireless designs in the consideration of the system's throughputs (speeds) for the same simulation parameters is stated in Fig. 7 as experimented in PT and through actual test using available University of Kufa Cisco devices. As predicted based on theoretical, optical fiber link connected between all routers is better throughput than wireless link connection because optics fiber more speed than wireless and more security. As shown in ping test in Fig. 8 and 9 when the fiber optics is connected, the time to return reply is less than the time is spent with using wireless.

Another test using OSPF shown in Fig. 10 as a routing protocol in the network is conducted. The performance is superior than using RIP protocol. As demonstrated in Fig. 11 and 12 with OSPF protocol, the ICMP ping messages return much faster than the RIP ICMP messages.

Physical view of the design: As demonstrated in Fig. 13 (the distribution of main buildings in the JMU campus) where it is adopted in the design in terms of distribution of the equipments on each building/departments and according to their needs.

Racks: The following figures illustrate the main data center room (DMZ and core network) of Jaber Ibn Hayyan Medical University designed by PT.

Performance comparison, type of connection used: Figure 7 represents comparison the throughput "speed" for the same simulation parameters between pure wireless and wireless plus optical fiber connections to emulate the concept of (airfibre). The highlighted is showing the time in milli sec. It is obvious that using pure wireless is slower than utilizing fiber optics in the main connections in the suggested mesh network. Airfibre is recommended in this design to balance the cost over the performance (Anonymous, 2017a). Moreover, pure fiber optic for this case study needs costly civil efforts that could be compensated using recent microwave components for the main campu's links.

Performance comparison, type of protocol used: Similarly, taking the better outcomes which is the wireless with fiber optics in the contexts of throughput and delay, a comparison of the throughput "speed" for the same

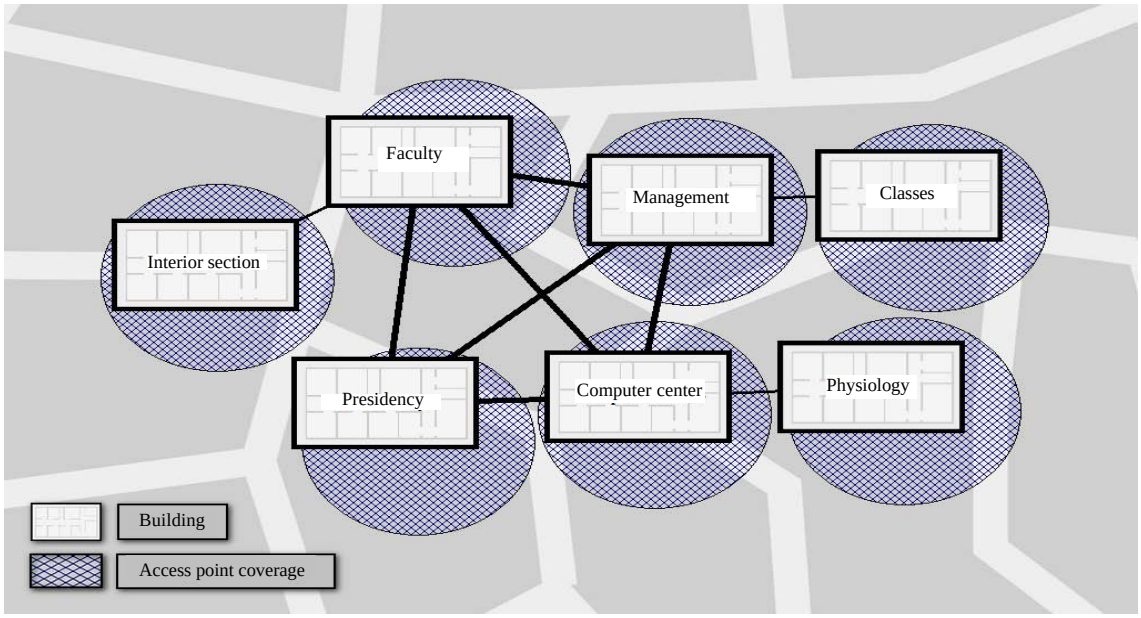

Fig. 5: Physical view of the suggested network design for Jaber Ibn Hayyan Medical University

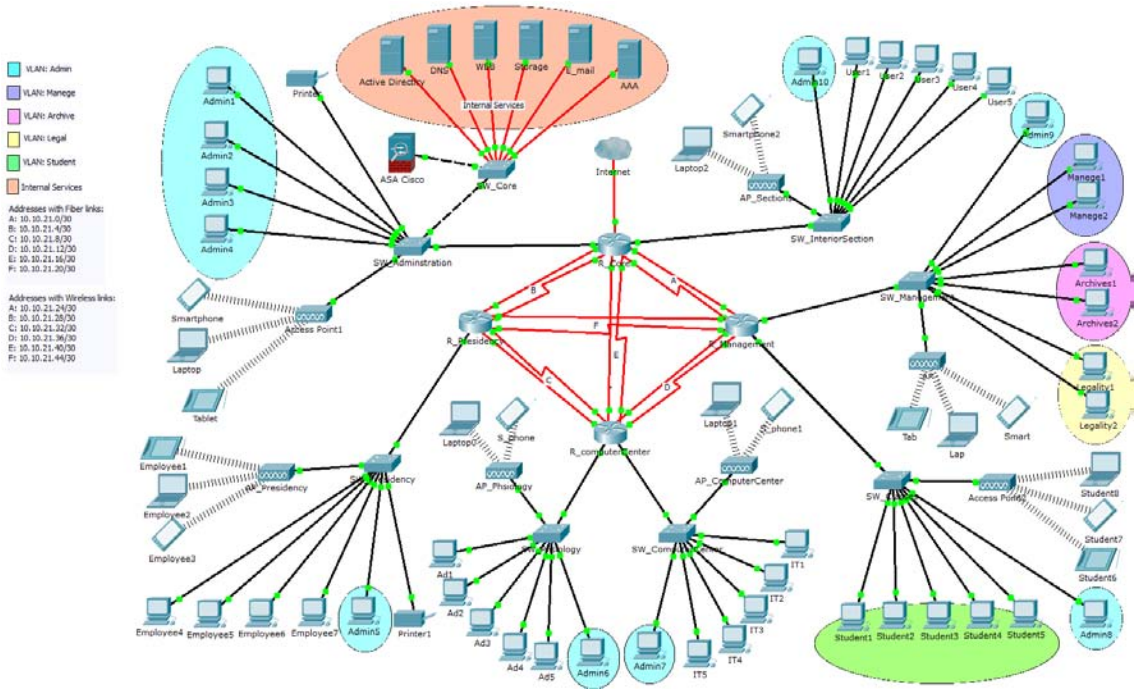

Fig. 6: Topology view of the suggested network design customized for Jaber Ibn Hayyan Medical University

simulation parameters between RIP and OSPF protocols shows that the OSPF is more speed than RIP as showed in Fig. 10.

As shown in the results study above the data center design is built on the base of an integrated network where the link between all routers is a mesh network. This is the most important characteristic that helps to sustain the research of the network. It also prevents errors occurring in the network paths as well as the occurrence of falling into any route. Another benefit of uing mesh is reducing the load on any loaded direction among the suggested main routers.

Fig. 7: a) Presidency rack and b) Main DMZ rack

On the other hand, the type of connection proposed in the design is the fiber optic which is an optimal solution in terms of delivering more secure and reliable information and preventing errors during the data transfer. However, the existence of another type of connectivity in some network branches is used which is the wireless, so that, microwave links were used for this purpose. Microwave links are used to connect the points that are considered far from the main core network in JMU campus. Fiber optics links for such distance is costly and hard to

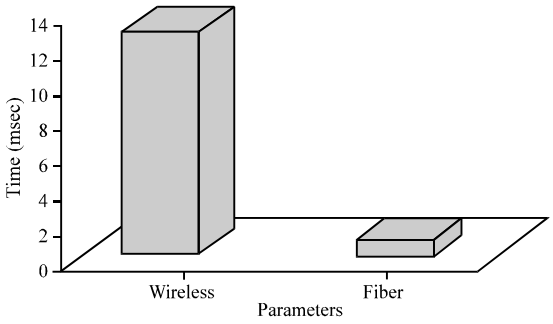

Fig. 8: Type of link speed comparison

```
PC>ping 10.10.12.3

Pinging 10.10.12.3 with 32 bytes of data:

Reply from 10.10.12.3: bytes=32 time=1ms TTL=127
Reply from 10.10.12.3: bytes=32 time=0ms TTL=127
Reply from 10.10.12.3: bytes=32 time=0ms TTL=127
Reply from 10.10.12.3: bytes=32 time=0ms TTL=127

Ping statistics for 10.10.12.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms
```

Fig. 9: Ping test to show the peformance

```
PC>ping 10.10.12.3

Pinging 10.10.12.3 with 32 bytes of data:

Reply from 10.10.12.3: bytes=32 time=1ms TTL=127
Reply from 10.10.12.3: bytes=32 time=0ms TTL=127
Reply from 10.10.12.3: bytes=32 time=0ms TTL=127
Reply from 10.10.12.3: bytes=32 time=0ms TTL=127

Ping statistics for 10.10.12.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 1ms, Average = 0ms
```

Fig. 10: Ping test to show the performance with using wireless

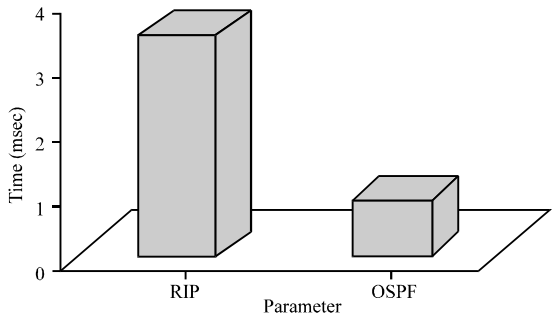

Fig. 11: Type of protocol speed comparison

```
PC>ping 10.10.12.3

Pinging 10.10.12.3 with 32 bytes of data:

Reply from 10.10.12.3: bytes=32 time=12ms TTL=127
Reply from 10.10.12.3: bytes=32 time=10ms TTL=127
Reply from 10.10.12.3: bytes=32 time=13ms TTL=127
Reply from 10.10.12.3: bytes=32 time=0ms TTL=127

Ping statistics for 10.10.12.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 13ms, Average = 8ms
```

Fig. 12: Ping test to show the speed using OSPE

```
PC>ping 10.10.12.3

Pinging 10.10.12.3 with 32 bytes of data:

Reply from 10.10.12.3: bytes=32 time=0ms TTL=127
Reply from 10.10.12.3: bytes=32 time=1ms TTL=127
Reply from 10.10.12.3: bytes=32 time=0ms TTL=127
Reply from 10.10.12.3: bytes=32 time=4ms TTL=127

Ping statistics for 10.10.12.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0%
loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 4ms, Average = 1ms
```

Fig. 13: Ping test to show the speed with using RIP

manage and maintain. As the test illustrates that while using fiber optics, the echo reply is 1 msec while the echo reply in wireless is 13 msec. That is obvious the fiber optics is much faster than the wireless back bone design. The fiber optic core network has been adopted in this project and to enhance the network farther, another vital parameter should be taken into consideration.

Routing protocol on the other hand is configured in the way that it chooses the best path to transfer data between department's networks. As the test shows the chosen OSPF is more efficient for several reasons. The inspected one is that OSPF and RIP are both using as a routing protocol. However, OSPF has a response time 1 msec lower than using RIP 4 msec. Hence, it shows faster network performance. While RIP using hop counts to calculate metric value, OSPF uses SPF (Shortest Path First) algorithm to select the best path. It is good to mention here that RIP uses lots of band width as it sends periodic updates but OSPF advertise only changes in a network and the Rip takes 30-60 sec to converge but OSPF converges immediately even in larger network. The design includes employing VLANs, so, instead of using many switches to each service represented by the network every switch divided into Virtual LANs (VLANs). Each VLAN research independently of the other, so, the broadcast aimed to a specific VLAN in the network is

lower overhead than a one segment network design. For example, switch in the management building in JMU network is divided into three VLANs one for the legal department, one for management department and the last VLAN for archive department.

CONCLUSION

The proposed network addresses the basic system problems occurring in small to medium size network designs such as reliability, security, speed and manageability. To overcome these issues, several concepts are employed. VLAN, airfibre (fiber performance over wireless link), ASA, OSPF and VLSM. The project utilizes VLAN to take care of communication and administration issues. Airfibre is deployed to give adaptability and cost effective method of main network connections or as a backup paths. In addition, ASA used for stopping attacks and hackers and OSPF as the routing protocol in a fiber optics environment for better network execution as tested and appearing in the result's study where the time spent to return replies using OSPF is less than the delay to return replies using RIP. Ultimately, VLSM mechanisms used to reduces the lost IPs in the network. Consequently, the case study of JUM network is one of the best network designs according to the standardizations considered in Cisco platforms.

RECOMMENDATION

Measure the performance of the DMZ room and develop the data room in terms of the services provided by the network.

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