



VAASAN AMMATTIKORKEAKOULU
VASA YRKESHÖGSKOLA
UNIVERSITY OF APPLIED SCIENCES

Rizwan Ahmad

UPGRADING THE CAMPUS NETWORK TO LAYER-3

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VAASAN AMMATTIKORKEAKOULU
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ABSTRACT

Author	Rizwan Ahmad
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The aim of this project is to upgrade the campus network of Vaasan ammattikorkeakoulu (VAMK), University of Applied Sciences. This project is divided into two parts, configuration of the VLAN subnets and configuration of the network routing.

This thesis focuses on configuration of VLANs, configuration of DHCP scopes for subnets, configuration and implementation of network routing such as static and dynamic routing (RIP). The theoretical part explains the basic network fundamentals and provides enough comprehensive background about the network routing. A major part of theory is devoted to the explanation of VLAN concept and routing protocols.

During the implementation, VLAN subnets are created. DHCP scopes are configured for each subnet to get IP addresses and finally static and dynamic routing is configured to fulfil the network demands. After the completion of implementation, tests have been made to verify the practical work. All the tests were successfully completed and a detailed report is in the results & analysis.

After the implementation, VAMK campus network is changed to Layer 3 network. Even access layer switches are configured to do the routing. Implementation of the routing at the edge of the network provides greater security, scalability, control and bandwidth conservation.

Keywords	IP Routing, Static Routing, Dynamic Routing, RIP Routing, VLAN, IEEE802.1Q
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Rizwan Ahmad

ABBREVIATIONS

ARP	Address Resolution Protocol
ARPANET	Advanced Research Projects Agency Network
BOOTP	Bootstrap Protocol
CIDR	Classless Inter-Domain Routing
CLI	Command Line Interface
DHCP	Dynamic Host Configuration Protocol
EIGRP	Enhanced Interior Routing Protocol
ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPTV	Internet Protocol Television
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
IRDP	ICMP Router Discovery Protocol
IS-IS	Integrated Intermediate System To Intermediate System
LAN	Local Area Network
MAC	Media Access Control
OSPF	Open Shortest Path First
QoS	Quality of Service

RFC	Request for Comments
RIP	Routing Information Protocol
SNTP	Simple Network Time Protocol
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
VAMK	Vaasan ammattikorkeakoulu
VLAN	Virtual Local Area Network
VLSM	Variable Length Subnet Mask
VoIP	Voice over Internet Protocol

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1 INTRODUCTION

The aim of this project is to upgrade campus network for supporting new technologies, provide greater security, high data connectivity. The rapidly growing demand for high data rate communication system requires network upgrading with time. The goal is to upgrade campus Layer 2 network into Layer 3 network architecture, to provide high speed data connectivity, reliable and efficient network performance. Layer 3 architecture limits the broadcast domains, is easier to manage, allows greater scalability, supports routing protocols, IP services, bandwidth usage, software tools to check network performance troubleshooting and configuration. /10/

Nowadays, everyone is familiar with computer and internet. Communication is a major activity around everyone's daily life. Besides, the new and innovative technologies are arising to fulfil the daily varying demands. Each network requires high bandwidth, secure and fast communication for network to provide greater Quality of Services to delay-sensitive devices or applications such as VoIP, IPTV and video conferencing. Since the demands for real time applications (VoIP, IPTV) are increasing, it is significant to make network not only respond quickly but needs to provide Quality of Services (QoS) as well.

This project will describe the configuration of the Layer 3 network framework implementation, basic configuration of routing switch HP Procurve 2910-al, creating, assigning and configuring VLANs for each subnet, configuring IP routing and DHCP server to allocate IP addresses for new subnets.

2 BACKGROUND & GOALS OF THE PROJECT

2.1 Background Information

Now, the world is in a new era, rapidly growing and high demands with many different types of networks have directed the implementation of the campus network into a new design. The new design is scalable and meets all the current demands of the network requirements.

Before this project, Vaasa University of Applied Sciences had Layer 2 (Data-Link Layer) network, all the routing has been done on the main routing switch. Each VLAN traffic forwards toward the routing switch for routing and subnet assignments that makes router performance lower and increases the bandwidth usage. The Layer 2 switches in the classrooms did not support routing and configured to forward all the traffic that needs to be routed towards the routing switch.

2.2 Working environment of the project

This project was implemented in Vaasa University of Applied Sciences. Vaasa University of Applied Sciences located at Vaasa, Finland (Western Finland). Vaasa is one of the largest student cities with more than 12000 students. Vaasa provides work for a diversified range of experts as well. There are many employers in Vaasa like Wärtsilä, ABB and Vacon.

University of Applied Sciences, Vaasan ammattikorkeakoulu (VAMK), started its operation on August 1, 1996 with the degree programs in Technology and Communication, Business Economics and Tourism and Health Care and Social Services. VAMK has collaborative universities all over the world. In addition to the international co-operation mainly in Europe, the student exchange has also been active. VAMK has 350 foreign degree and exchange students from about 40 countries. /2/

VAMK has two campuses, Wolffintie and Raastuvankatu. The Wolffintie campus provides the Information Technology studies and Raastuvankatu campus provides

International business, Catering and nursing studies. The project work has done in Wolffintie campus.

2.3 Purpose of the project

Today's technologies are developing day by day. Organizations are upgrading their networks and services to adopt new technologies. Organizations need a single network infrastructure that can provide all the demanding services like high data transmission, greater security, scalability, supporting for new technologies, routing protocols and other IP services instead of many different networks. All the companies want to reduce their cost and efforts. Since the demand for these kind of applications are increasing, it is vital that a better communication network is implemented, which provides the solution for real time applications and take care of data flow as well. This project will produce a network with faster data transfer speeds, reliability, increased security and the ability to meet the future demands of the campus community.

2.4 Objectives of the project

This project has the following objectives:

- Higher data transfer speeds (up to 1GigaBit to each workstation)
- Minimize broadcast domains
- IP Routing
- Static Routing
- RIP Routing
- Configuration of VLANs
- Configuration of DHCP

3 PROJECT DESCRIPTION

3.1 IP Routing

The IP routing in the IP network is the set of tasks required to move an IP packet from router to router to its destination, as specified in the IP header field /4, 1-2/. IP routing is the most important task in an IP network. Two types of IP routing exist in an IP network:

- Static Routing
- Dynamic Routing

3.1.1 Static Routing

The most basic and simplest routing method is called static routing. In static routing, the routing table is constructed manually. All the routes are fixed and network administrator has to manually create, modify or delete route from the routing table whenever network changes occurred. Well, static routing is easy to configure, gives more control for network administrator to control the network and the network path between two destinations always known precisely. But static routing is used only in small network to get better performance. /5, 317-319/

3.1.2 Dynamic Routing

Dynamic routing performs the same function as static routing except it is more robust. In dynamic routing, routing tables are created automatically in such a way that adjacent routers exchange routes with each other. Each router calculates its own best route using metrics and rules. The selection of best route is based on the metrics such as number of hops, delay, bandwidth, link cost and these values are updated by using protocols. Dynamic routing protocols can change the routing table in the router if possible routes are changed. Dynamic routing has capability to update the routing table automatically, so it does not consume the network administrator time but if it's not configured properly, it can create diverse problems such as routing loops. Dynamic routing is supported by several protocols: /5, 320/

- Routing Information Protocol (RIP)Ver.1
- Routing Information Protocol (RIP)Ver.2
- Open Shortest Path First (OSPF)
- Enhanced Interior Gateway Routing Protocol (EIGP)
- Integrated Intermediate System To Intermediate System(IS-IS)

Since this thesis is only focusing in Routing Information Protocol (RIP), we will not focus on other protocols.

3.1.3 Routing Information Protocol (RIP) Ver.1

Routing Information Protocol (RIP) was originally used by ARPANET and was designed to work with small sized networks. RIP ver.1 is a classful, distance vector routing protocol that does not support CIDR (Classless Inter-Domain Routing) and VLSM (Variable Length Subnet Mask). RIP ver.1 is defined in RFC 1058. It is using hop count as a metric. Routes with a hop count more than 15 are unreachable. RIP ver.1 updates are broadcasted every 30 seconds. RIP ver.1 uses split horizon method with poison reverse. RIP ver.1 message format is shown below in the figure. In the figure, three fields are specified in the four byte header shown in grey. The command field specifies the message type, the value of command field 1 is used for a request and 2 is for a reply. Version field shows the protocol version, 1 for RIP ver.1 and 2 for RIP ver.2. The third field is labelled “Must be Zero” This field provide space for future expansion of the protocol. Next field is “Family Address Identifier”, the value of this field set to 2 for IP unless a router is requesting a full routing table, in which case the field is set to zero. IP Address field carry the address of the destination route, which maybe a network, subnet, or host address. Metric field is used to hop count between 1 and 16. Sending router increases the metric before sending out message. /1/

Data Link Frame Header	IP Packet Header	UDP Segment Header	Rip Message (512bytes, Up to 25 routes)
Expanding Rip Message further			
0	7 8	15 16	23 24 31
Command= 1or 2	Version=1	Must be zero	
Address family identifier (2=IP)		Must be zero	
IP Address (Network Address)			
Must be zero			
Must be zero			
Metric(hops)			
Multiple route entries, up to a maximum 25			

Figure 1. RIP V1 message format /1/

3.1.4 Routing Information Protocol (RIP) Ver.2

Routing information protocol (RIP) was originally used by ARPANET and was designed to work with small-sized network /1/. RIP ver.2 is defined in RFC 1723. RIP ver.2 has the same message format as RIP ver.1 but two significant extensions are added:

The first extension in RIP ver.2 message format is the support of VLSM that allows 32 bit mask to be included in the RIP route entry. The receiving router no longer depends upon the subnet mask of the inbound interface or the classful mask when determine the subnet mask of the route. /3/

The second extension in RIP ver.2 message format is the addition of the next hop address. The purpose of this extension is to find the better next hop address if exists /3/. RIP Ver.2 message format is below in the figure:

Data Link Frame Header	IP Packet Header	UDP Segment Header	RIP Message (512bytes; Up to 25 routes)
Expanding RIP Message further			
0	7 8	15 16	23 24 31
Command= 1or 2	Version=2	Must be zero	
Address family identifier (2=IP)		Route Tag	
IP Address (Network Address)			
Subnet Mask			
Next Hop			
Metric(hops)			
Multiple route entries, up to a maximum 25			

Figure 2. RIP V2. Message format /3/

In RIP V2, three fields (Route Tag, Subnet Mask, Next Hop) are added into RIP message. Route tag field provides a tag for distinguishing between internal routes and external routes, Subnet field contains the subnet information of the destination because of adding this field RIP V2 supports VLSM and Next Hop field indicates the IP address of the next hop where packets are sending to reach the destination.

3.2 Virtual LANs

Logically divided physical network into different IP sub network called Virtual LAN. In Virtual LAN, we can group user logically instead of physical locations. Using VLANs, it can control high bandwidth usage in our network to group high bandwidth users to switch on low-traffic segments. It can also organize users from different Virtual LAN segments according to their need for common resources. Virtual LANS provides many benefits as follows: /6/

- Security (groups that have sensitive data can be separated from the network)
- Increased Performance (Creates layer 2 logical networks reduced broadcast traffic and boost the performance.)
- Cost Reduction (More efficient use of network bandwidth, uplinks and less need for expensive hardware upgrades)

- Broadcast Storm Mitigation (Virtual LANS reduces the number of devices that can participate in the broadcast storm)
- Improve Traffic Control (We can improve traffic control at the edge of our network by separating different protocol traffic)
- Improved IT Staff Efficiency(All the policies and permissions are configured for a particular VLAN, All the policies are applied when provision a new switch and assign the VLAN)

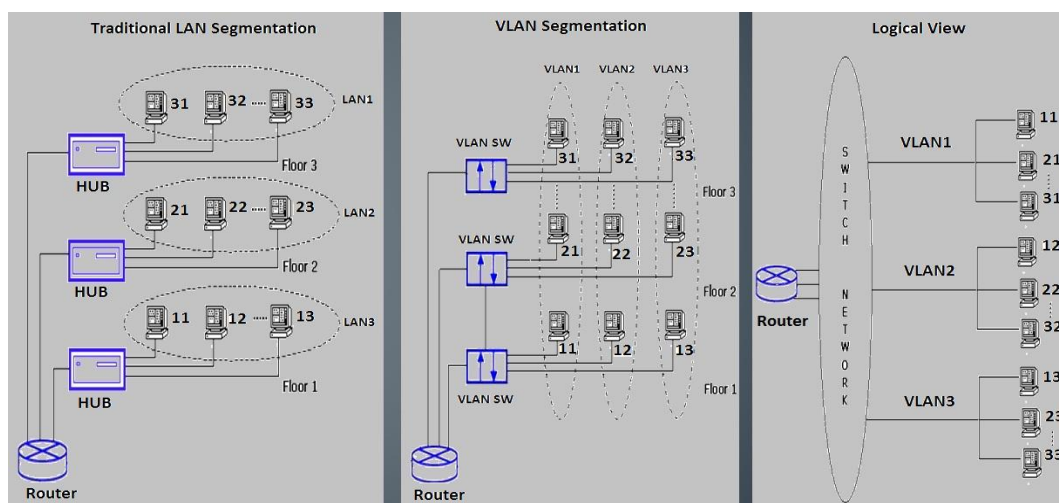


Figure 3. VLAN segmentation

In figure 3, LAN and VLAN segmentation is shown. In traditional LAN segmentation all the segments are in the same broadcast domain and it reduces the efficiency of the network. In VLAN segmentation, broadcast domains are divided into the number of VLANs, as shown in the figure, three broadcast domains are exists, physically the members of VLAN domains are in the different locations but logically they are in the same broadcast domain.

In this HP Procurve 2910al switch we have three types of VLANs,

- Static VLANs
- Dynamic VLANs
- Tagged VLANs (Trunk VLAN)

3.2.1 Static VLANs

In static VLAN, ports are manually assigned to a VLAN. Data packets are bridged from source to destination port in same VLAN and cross domain broadcast packets are eliminated to save bandwidth in the switch. Static VLANs can be configured with CLI interface or Procurve menu interface. Static VLANs are configured with a VLAN ID, VLAN name and port members. Further static VLANs divided into many types as follows: /7, 2-5/

- Port-Based VLANs
- Protocol-Based VLANs
- Designated VLANs

Tagged: A port that complies with the 802.1Q standard, including priority settings and allows a port to join multiple VLANs.

Untagged: The switch allows no more than one untagged VLAN assignment per port. If a port is configured only untagged, it does not use or forward 802.1Q VLAN tagging.

Port-Based VLANs

Port-Based VLAN creates a layer-2 broadcast domain. This layer-2 broadcast domain comprised of member ports that bridge IPv4 traffic among themselves. In Procurve 2910al, a port can be a member of one untagged Port-based VLAN and all other Port-Based VLAN assignments for that port must be tagged. Port-based VLANs can be configured without IP address or with unique IP address. We can use multiple IP address to create multiple subnets in the same port-based VLAN as well. Procurve 2910al switch can route traffic between port-based VLANs, Port-based and Protocol-based (IPV4) if the IP routing is enabled on the switched. /7, 2-7/

Protocol-Based VLANs

Protocol-based VLANs are creating a layer-3 broadcast domain for a specific protocol. In Procurve 2910al, a port's untagged protocol-based VLAN membership can include up to four different protocol types. It means that a port can be an untagged member of one of the following:

- Four single-protocol VLANs
- Two protocol-based VLANs where one includes a single protocol and other includes up to three protocols
- One protocol-based VLAN where VLAN includes four protocols

A protocol-based VLAN port can be tagged member of any protocol-based VLAN. If IP routing is enabled on switch, switch can internally route the traffic between multiple protocol-based (IPV4) VLANs and port-based VLANs. We need to have an external router to route traffic between other protocol-based VLANs. Please see the table below for more routing information on Procurve 2910al switch. /7, 2-8/

	Port-Based	IPX	IPv4	IPv6	ARP	Apple-Talk	SNA ²	Netbeui ²
Port-Based	Yes	—	Yes	—	—	—	—	—
Protocol								
IPX	—	Yes ¹	—	—	—	—	—	—
IPv4	Yes	—	Yes	—	—	—	—	—
IPv6	—	—	—	Yes ¹	—	—	—	—
ARP	—	—	—	—	Yes ¹	—	—	—
AppleTalk	—	—	—	—	—	Yes ¹	—	—

Figure 4. Protocol based VLAN support. /7, 2-10/

Designated VLANs

These designated VLANs are also Port-based VLANs but these VLANs used for special management purposes. These VLANs separate management traffic from

network traffic and provide improved security and availability for management traffic. In Procurve 2910al, these are designated VLANs: /7, 2-5/

- The Default VLAN
- The Primary VLAN
- The Secure Management VLAN
- Voice VLANs

3.2.2 Dynamic VLANs

Dynamic VLAN is not used in this thesis work so it will be explained briefly. However, it is useful to know what a dynamic VLAN is. In dynamic VLAN, we can assign switch ports to VLAN dynamically. Dynamic VLAN assignment is based on the source MAC address of the device connected to the port. Dynamic VLAN is configured with a special server that has a database of all devices MAC addresses to assign VLANs dynamically. If a host moved from one switch port to another switch port in the network, the switch dynamically assign the proper VLAN to the host. /7, 3-3/

3.2.3 Tagged VLANs

Tagged VLAN is point-to-point link between two network devices that carries more than one VLAN in the network. We can extend the VLANs in the entire network with tagged. HP Procurve 2910al supports IEEE 802.1Q for coordinating tagged ports on gigabit Ethernet interfaces. Tagged ports are useful in network backbone, where many VLANs traffic is handled. In Cisco terms we called tagged VLAN as trunk VLAN. /7, 2-41/

3.3 Dynamic Host Configuration Protocol (DHCP)

Dynamic Host Configuration Protocol (DHCP) is an Internet protocol that enables a server to dynamically allocate and distribute IP addresses and additional TCP/IP configuration. RFCs 2131 and 2132 define DHCP as an Internet Engineering Task

Force (IETF) standard based on Bootstrap Protocol (BOOTP). DHCP uses a client/server procedure (see Figure below), where DHCP server receives a DHCPDiscover message for an IP address from a client when it first attempts to the network. After receiving the DHCPDiscover message, DHCP server broadcast DHCPOffer message if server has an IP address configuration to offer to the client. DHCPOffer message contains an unleased IP address, subnet mask, default gateway and other TCP/IP configuration. After DHCP client selects the DHCPOffer, it broadcast the DHCPRequest message. The message contains the IP address from the DHCPOffer that it selected. If the client is renewing to a previous lease, this packet might be unicast to the server. Finally DHCP server acknowledged to DHCPRequest message by broadcast DHCPACK message. After receiving an IP request, the DHCP server assigns it an IP address and updates its database table, noting that which client has the address and expiration time of the address. When the time expires, the DHCP client needs to renew the amount of time or negotiate a new amount of time for a new IP address. /8/

Before the advent of DHCP, most of TCP/IP configurations were maintained statically. Each individual host or workstation needs to be configured manually IP address, subnet mask, default gateway as well as other TCP/IP parameters. Configuring and maintaining static TCP/IP parameters for multiple work stations and network devices might be a difficult task, especially in a large network. DHCP has solved this problem; Using DHCP an administrator can make changes in the Client's IP configuration without visiting each and every client. The user at the workstation only needs to release and renew their DHCP lease.

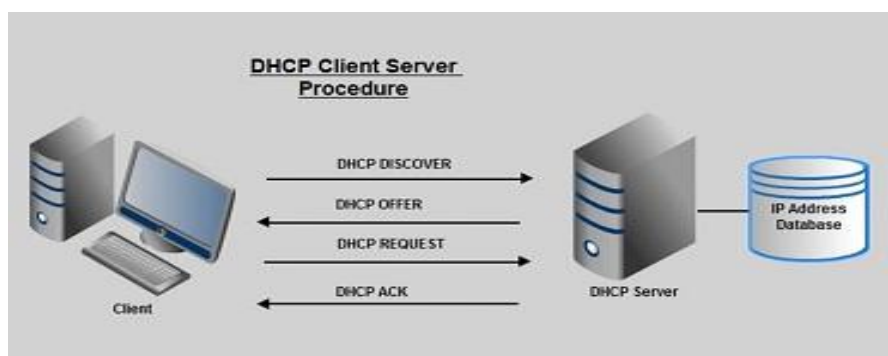


Figure 5. DHCP client server procedure/9/

4 IMPLEMENTATION OF THE PROJECT

4.1 Overview of the Network

VAMK network has basically been divided into two parts, VAMK Staff network and VAMK classroom network. VAMK staff is entirely separate network for staff, office and other management tasks. VAMK classroom network is for students. All the security policies, restrictions, access rights and personal storage quota are applied on this network. The users of this network have limited access to the network resources as configured by the network administrator.

This thesis focuses on the classroom network. Before the implementation of this thesis, VAMK had Layer-2 switching network. All the routing had to be done on the central routing switch. Classrooms were not configured as own VLANs/subnets, but at least two or three classrooms share the same subnet. All the trunk/tagged traffic was sent to the trunk port to reach its destination that increased the network traffic and more bandwidth usage, because the access layer switch could not be able to route the traffic to its destination. See the figure below for more information. In the figure, a Layer-2 network is shown. In this network, 802.1Q VLANs are used to segment network users and broadcast domains. Because of Layer-2 switch limitation no communication is allowed directly between VLANs. All the Inter VLAN communication is done by the routing switch. Routing switch is handling all the Layer-3 traffic for the whole network such as forward DHCP queries to DHCP server.

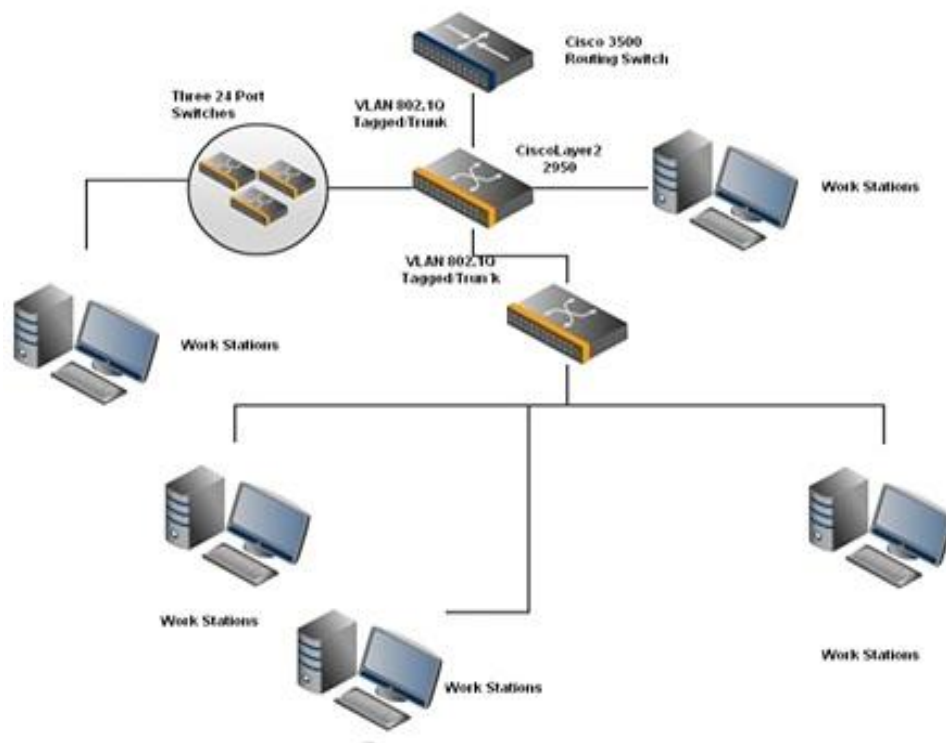


Figure 6. VAMK network design before implementation

4.2 Overview of the Design

The design was started by getting the current running configuration of the Cisco access layers, distribution layer and core layer switches/routers, because it helps to understand, how the network is configured and working.

The whole network was working and students were using it. It was not allowed to interrupt any classroom network because of the configuration. So discussion with network administrator was arranged. I was suggested that firstly, same configure on new HP switches should be made, because it keeps the network running. Later, the desired configuration changing according to the demands can be made.

VAMK has already Dynamic Host Configuration Protocol (DHCP) Server to allocate IP address to the clients/subnet. There was no need to configure new DHCP server, same DHCP server was used to allocate IP addresses to new VLAN subnets. Currently installed Cisco access layer switches do not support routing. The

network routing was not configured on the new HP switches yet, because it does not affect the network now.

4.3 Implementation of the Project

The project implementation is subdivided into five parts:

- Cloning switch configuration
- Replacing the access layer switch
- Configuring DHCP
- Configuring VLANs
- Configuring routing

4.4 Cloning switch configuration

This thesis consists of a real time working network. It was not affordable to lose the network connectivity. After discussion with network administrator, a decision has been made that first HP Procurve switches should configure with the same configuration as Cisco Layer-2 switches, which will keep network running without interruption. Furthermore, configuration could be changed later according to the demands.

For the cloning of the switches configuration, we have started to read the configuration from old Cisco Catalyst switches (Layer 2) and configured new HP Procurve switches with the same configuration (Layer 2). After implementing the (Layer 2) configuration, still all the routing has been done on main routing switch, the routing feature of HP Procurve switch was not used yet. Because of two different hardware manufacturers, the command syntax and configuration interface was different. For more understanding, please see the configuration syntax in the figure below:


```

vlan 401
  name "VLAN401"
  untagged 1-46
  ip helper-address 192.168.1.1
  ip helper-address 192.168.1.2
  ip address 192.168.84.126 255.255.255.128
  tagged 48
  exit
include-credentials
password operator sha1 "$4$10e14/0d4e16355e0e36e409247a1e4a3770f"
password manager sha1 "$4$4310e140d4e16355e0e36e409247a1e4a3770f"
timesync sntp
sntp unicast
sntp server priority 1 192.168.1.1 3
sntp server priority 2 192.168.1.2 3
ip authorized-managers 192.168.1.0/24 255.255.255.255 access manager
ip authorized-managers 192.168.1.0/24 255.255.255.255 access manager
ip authorized-managers 192.168.4.0 255.255.255.0 access manager
ip ssh filetransfer
ip route 0.0.0.0 0.0.0.0 192.168.4.1
router rip
  no auto-summary
  exit
snmp-server community "public" unrestricted
snmp-server host 103.145.140.100 community "public"
snmp-server host 140.145.140.100 community "public"
snmpv3 engineid "00:00:00:0b:00:00:00:23:47:50:3e:80"
vlan 316
  ip rip 192.168.4.51
  exit
no tftp client
no tftp server
loop-protect 1-47
loop-protect trap loop-detected
loop-protect disable-timer 300
no autorun
hp2910-wb210-1#

```

Figure 7. HP Procurve Switch Configuration

4.5 Replacing Access Layer Switches

Once the cloning of the switches configuration has been done, It was time to replace the switches but to make sure that the correct configuration has been made on the switches; a test has been done before replaced the switches in the network. In some places, I could not fix the new HP Procurve switches but this problem was solved with the help of our professional technician. Please see the figure below to have a look of switches:



Figure 8. HP Procurve & Cisco Switch

4.6 Configuring DHCP

In the previous chapter, Dynamic Host Configuration Protocol (DHCP) is explained in detail. In this topic, the configuration of DHCP is described. Well, VAMK have had running DHCP server in the network; there was no need to build a new DHCP server. After replacing the switches, we had not used any feature of new hardware yet; network was running with the same network configuration like earlier. New DHCP subnet scopes have been created for each class room. It was required to separate each class room network. This DHCP server was already configured and running in the VAMK network, new IP scopes were created to fulfil our requirements. In the figure below, DHCP scope configuration is shown:

```

monitor.cc.puv.fi - PuTTY
subnet 192.168.80.0 netmask 255.255.255.128 {
    option routers          192.168.80.126;
    pool {
        failover peer "puv";
        deny dynamic bootp clients;
        range 192.168.80.1 192.168.80.125;
    }
}
Subnet 1

subnet 192.168.80.128 netmask 255.255.255.128 {
    option routers          192.168.80.254;
    pool {
        failover peer "puv";
        deny dynamic bootp clients;
        range 192.168.80.150 192.168.80.253;
    }
}
Subnet 2

subnet 192.168.81.0 netmask 255.255.255.128 {
    option routers          192.168.81.126;
    pool {
        failover peer "puv";
        deny dynamic bootp clients;
        range 192.168.81.1 192.168.81.125;
    }
}
Subnet 3

```

Figure 9. DHCP subnet scopes

4.7 Configuring VLANs

The definition, types and purposes of VLANs are explained in previous chapter. In this topic, implementation and configuration of port-based VLANs and tagged VLANs are explained because this thesis focuses only on these VLANs. In this HP Procurve 2910al switch, we have two ways to configure VLANs:

- Menu Interface
- CLI Interface

4.7.1 Menu Interface

Port-based VLANs can configure with menu interface. Menu interface is simple and easy to use for beginners. In the factory default state, all ports are assigned to default VLAN. Also in the factory default, switch is enabled to support 256

VLANs but it is possible to reconfigure the switch to support up to 2048 VLANs. The figures below shows, how to configure the switch for supporting more VLANs, Adding/Editing VLAN names and creating new VLANs.

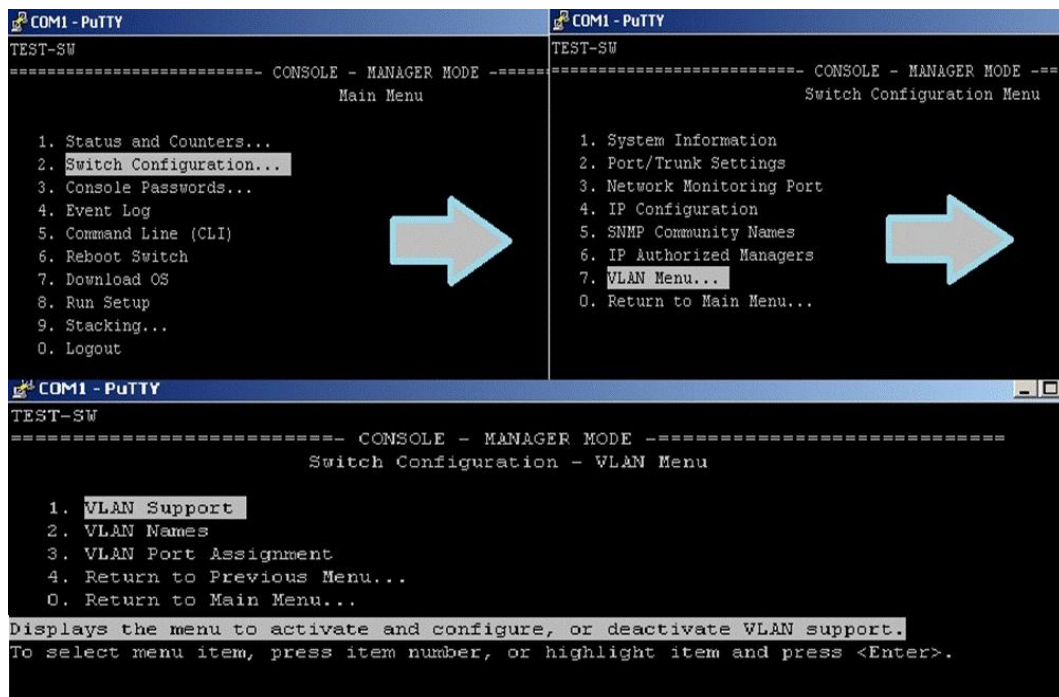


Figure 10. HP Procurve VLAN Menu

After get into the VLAN configuration menu, there are three more submenu options for different VLAN configurations.

- VLAN Support menu is for activate and configure or deactivate VLAN support. Screen shot is below for more details.

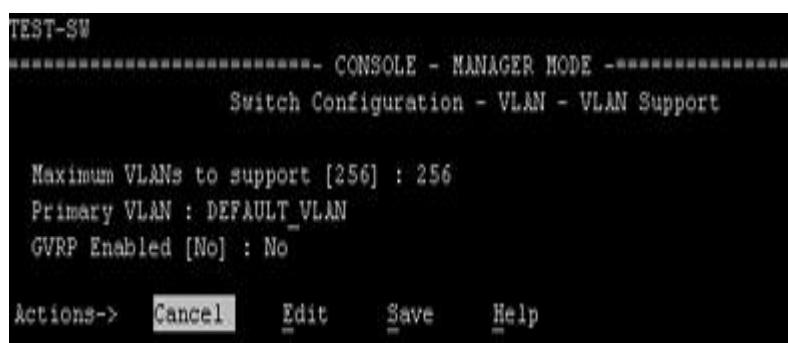


Figure 11. HP Procurve VLAN support menu

- VLAN Name menu is for configures names for VLANs for grouping switch ports. VLAN menu can add, edit and delete VLANs as well in this menu. Screen shots are below for better understanding.

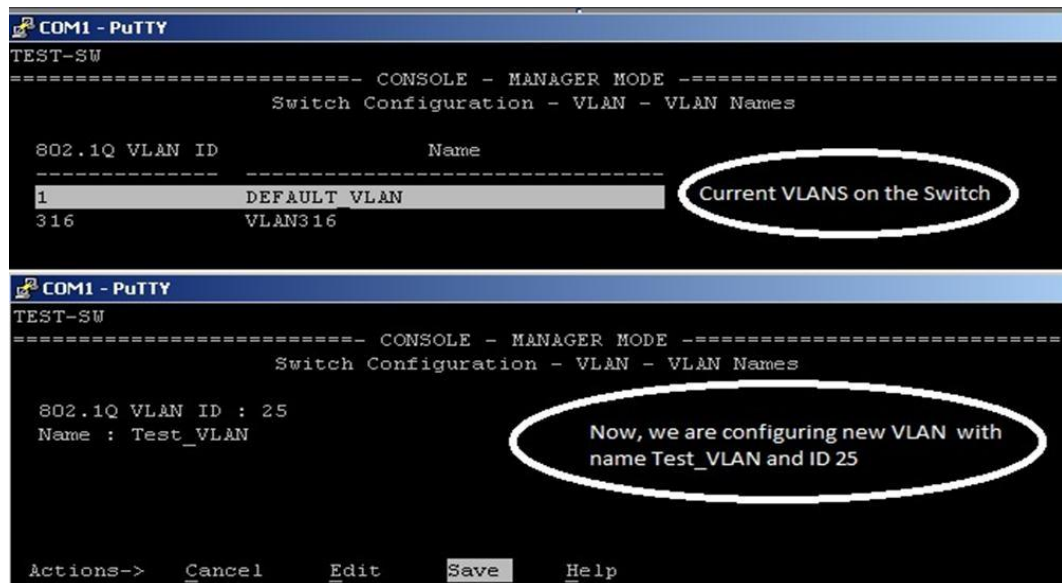


Figure 12. VLAN creation menu

Remember to save the configuration before exiting the submenu. After having saved the configuration, we will see the new VLAN name and ID in the VLAN names menu. See the screen shot below:

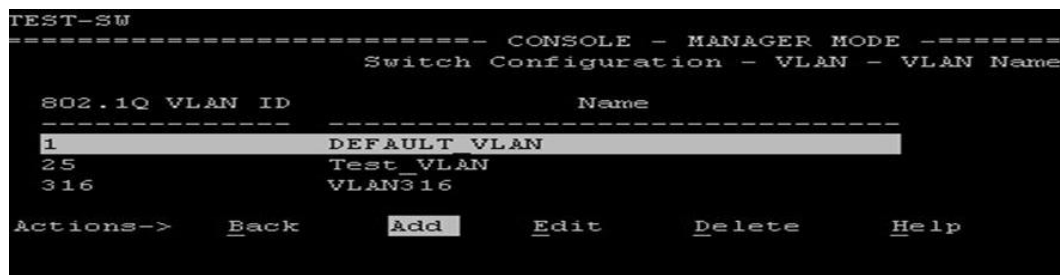


Figure 13. VLAN name menu

- VLAN port assignment menu is used to assigned switch ports to VLANs. Switch allows no more than one untagged VLAN assignment per port. By default, all ports are untagged members of default VLAN. A switch port can be a tagged member of multiple VLANs.

```

shell.puv.fi - PuTTY
TEST-SW
===== - CONSOLE - MANAGER MODE - =====
Switch Configuration - VLAN Menu

1. VLAN Support
2. VLAN Names
3. VLAN Port Assignment
4. Return to Previous Menu...
0. Return to Main Menu...

shell.puv.fi - PuTTY
TEST-SW
===== - TELNET - MANAGER MODE - =====
Switch Configuration - VLAN - VLAN Port Assignment

Port   DEFAULT_VLAN  Test_VLAN  VLAN316
----+-----
1      | Untagged     No         No
2      | Untagged     No         No
3      | Untagged     No         No
4      | No           No         Untagged
5      | No           No         Untagged
6      | No           No         Untagged
7      | Untagged     No         No
8      | Untagged     Tagged     Tagged
9      | Untagged     No         No
10     | Untagged     No         No
11     | Untagged     No         No
12     | Untagged     No         No

Actions->  Cancel  Edit  Save  Help

```

Figure 14. VLAN port assignment

4.7.2 CLI Interface

CLI stands for Command Line Interface. CLI interface is powerful tool and gives more control to manage the switch. Actually, it is the real interface to configure the switch. The configuration of both port-based and protocol-based VLANs can be done with CLI. Each switch port should be at least an untagged member of a VLAN. By default, all ports are untagged members of default VLAN. There are many features of this switch that can only be configured with CLI. The figure below shows the configuration with CLI commands:


```

shell.puv.fi - PuTTY
TEST-SW(config)# show vlans

Status and Counters - VLAN Information

Maximum VLANs to support : 256
Primary VLAN : DEFAULT_VLAN
Management VLAN :

VLAN ID Name | Status Voice Jumbo
-----+-----+-----+-----
1 DEFAULT_VLAN | Port-based No No
316 VLAN316 | Port-based No No

List of VLANs exists on the switch

shell.puv.fi - PuTTY
TEST-SW# config
TEST-SW(config)# vlan 25
TEST-SW(vlan-25)# name Test_VLAN
TEST-SW(vlan-25)# untagged 2,4-6
TEST-SW(vlan-25)# tagged 7
TEST-SW(vlan-25)# wr mem
TEST-SW(vlan-25)#
TEST-SW(vlan-25)# ex
TEST-SW(config)# show vlans

Status and Counters - VLAN Information

Maximum VLANs to support : 256
Primary VLAN : DEFAULT_VLAN
Management VLAN :

VLAN ID Name | Status Voice Jumbo
-----+-----+-----+-----
1 DEFAULT_VLAN | Port-based No No
25 Test_VLAN | Port-based No No
316 VLAN316 | Port-based No No

A new VLAN is created here with name
Test_VLAN and ID 25

New VLAN can be seen in VLAN list

TEST-SW(config)# show vlan 25

Status and Counters - VLAN Information - VLAN 25

VLAN ID : 25
Name : Test_VLAN
Status : Port-based
Voice : No
Jumbo : No

New VLAN details with port information

Port Information Mode Unknown VLAN Status
-----+-----+-----+-----
2 Untagged Learn Down
4 Untagged Learn Down
5 Untagged Learn Down
6 Untagged Learn Down
7 Tagged Learn Down

```

Figure 15. HP Procurve CLI interface

In the following figure, data VLAN and management VLAN are shown, data VLAN is configured to carry only user-generated traffic. Management VLAN is configured to access the management capabilities of the switch. A switch can be managed via Telnet, SSH or SNMP.

```

vlan 1
  name "DEFAULT_VLAN"
  no ip address
  no untagged 1-50
  exit
vlan 381
  name "wb005"
  untagged 1-49
  ip address 192.168.80.254 255.255.255.128
  ip helper-address 192.168.1.1
  ip helper-address 192.168.1.2
  tagged 50
  exit
vlan 316
  name "kytkimet-rt"
  ip address 192.168.4.2 255.255.255.0
  tagged 50
  ip igmp
  exit

```

Figure 16. Management & data VLAN

4.8 Configuring IP routing

IP routing is the process of moving IP packets from source to destination. The routing decision is made by a router which provides the physical connection between the networks. Such router must be configured with routing protocols to establish communication beyond the local network.

Basic IP routing configuration consists of enabling IP routing, configure IP addresses, static routes and dynamic routing protocols. Such as Routing Information Protocol (RIP). HP Procurve 2910al offers the following IP routing features:

- IP Static Route
- Routing Information Protocol (RIP)

- ICMP Router Discovery Protocol (IRDP)
- DHCP Relay

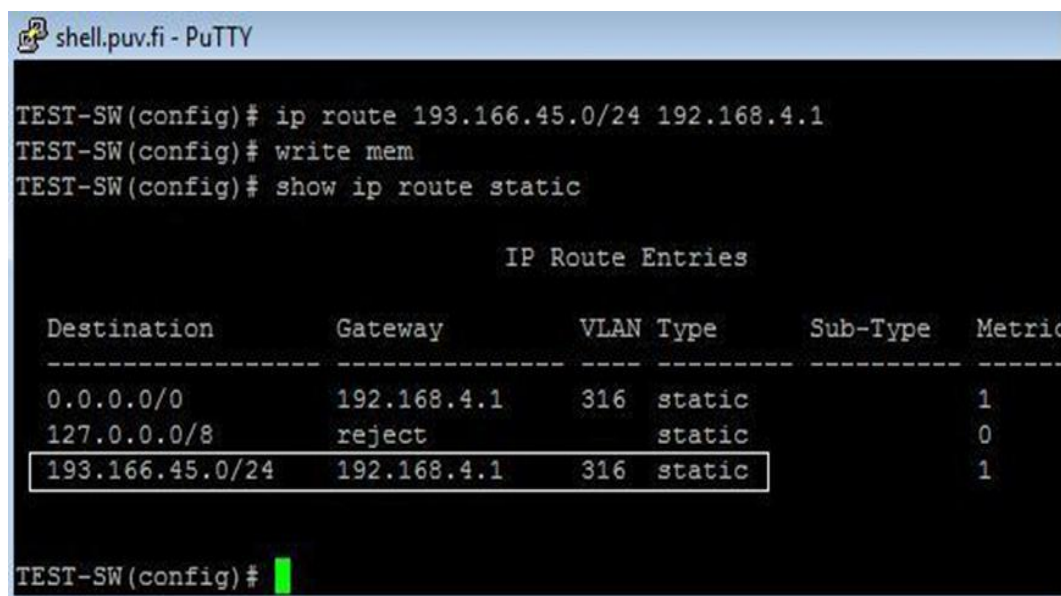
This document will describe the configuration of first two IP routing features because only these features are used in this project:

4.8.1 Configuring IP Static Routes

HP Procurve 2910al supports up to 256 static routes. Static routes can be added directly to the routing table. Static IP routes remain in the routing table as long as the IP interface of next hop router is up. These specific parameter needs to configure a static route:

- IP address and destination mask for route's destination network/host.
- The route path which can be the following: IP address of a next hop router or a null interface to drop the traffic. If the route path is a null interface, all the traffic forward to this interface will be dropped by the router.

The figure below shows the command to create a static route entry in the routing table.



```

shell.puv.fi - PuTTY
TEST-SW(config)# ip route 193.166.45.0/24 192.168.4.1
TEST-SW(config)# write mem
TEST-SW(config)# show ip route static

                                IP Route Entries

Destination      Gateway           VLAN Type      Sub-Type      Metric
-----
0.0.0.0/0        192.168.4.1      316  static      1
127.0.0.0/8     reject           static      0
193.166.45.0/24 192.168.4.1      316  static      1

TEST-SW(config)#

```

Figure 17. Static route configuration

Default route is another static useful route. All the traffic that has destination unreachable through any other IP routing table, sends to this default route interface. Please see the figure below for more information:

```

shell.puv.fi - PuTTY
TEST-SW(config)#
TEST-SW(config)#
TEST-SW(config)# ip route 0.0.0.0/0 192.168.4.1
TEST-SW(config)# show ip route def
Invalid input: def
TEST-SW(config)# show ip route static

                IP Route Entries

Destination      Gateway          VLAN  Type      Sub-Type  Metric
-----
0.0.0.0/0        192.168.4.1     316   static    static     1
127.0.0.0/8      reject           static  static     0
193.166.45.0/24  192.168.4.1     316   static    static     1

```

Figure 18. Default route configuration

4.8.2 Configuring Routing Information Protocol (RIP)

Routing Information Protocol (RIP) is the oldest of the distance vector routing protocols. Detailed explanation is in the last chapter, now the configuration of RIP will be described in this topic. HP Procurve 2910al supports the following RIP types:

- Version 1
- Version 2 (Default)
- V1 compatible with V2

Before the configuration of RIP, I like to explain the RIP global parameters and RIP interface parameters for better understanding.

In HP Procurve 2910al switch, there are four RIP global parameters: RIP State, auto summary, metric and redistribution. RIP state parameter is used to configure the RIP version. By default, “RIP V2 only” is disabled and switch is supporting RIP V1 & V2 in global configuration, Advertisement of auto summarized routes

is enabled, default metric for imported routes is 1 and redistribute of static & connected routes is disabled but RIP redistributes connected routes by default, when RIP is enabled.

RIP interface parameters are more useful. It can be configured differently according to network demands. There are six RIP interface parameters: RIP version, metric, IP address, loop prevention, receive and send. RIP version parameter is used to configure the RIP version on the interface level. By default, this parameter value is V2 only. Metric parameter is used to add the cost of an imported route learned on the interface. IP address parameter is used to control the routes which are learned or advertised. Loop prevention parameter is an important parameter because it protects the network from routing loops. Receive parameter is used to define the RIP version for incoming packets and send parameter is used to define the RIP version for outgoing packets. The following figure shows the default values of RIP global and RIP interface parameters:

RIP GLOBAL PARAMETERS		
Parameter	Description	Default Value
RIP state	RIP V2 Only	Disable
auto-summary	Advertisement of summarized routes	Enable
metric	Default metric for imported routes	1
redistribution	Redistribute static and connected routes	Disable
RIP INTERFACE PARAMETERS		
Parameter	Description	Default Value
RIP version	Supported version of the protocol on interface	V2 only
metric	A numeric cost switch adds to RIP routes learned on the interface	1
IP address	The routes that a routing switch learns or advertises can be controlled	Learn and advertises all rip routes on all rip interfaces
loop prevention	The method that routing switch uses to prevent routing loops (split horizon/poison reverse)	Poison Reverse
receive	Define the RIP version of incoming packets	V2 only
send	Define the RIP version of outgoing packets	V2 only

Figure 19. RIP Parameters

The following configuration shows how to enable RIP routing on a switch. IP routing should be enabled prior to enabling RIP.

```
TEST-SW(config)# ip routing
TEST-SW(config)# router rip
TEST-SW(rip)# exit
TEST-SW(config)# wr mem
TEST-SW(config)#
```

Figure 20. Enabling RIP Routing

To disable RIP, the following command is used:

```
TEST-SW(config)#  
TEST-SW(config)# no router rip  
TEST-SW(config)#
```

Figure 21. Disabling RIP Routing

The most useful RIP parameters are explained below with command syntax and figures:

➤ **RIP on VLAN interface**

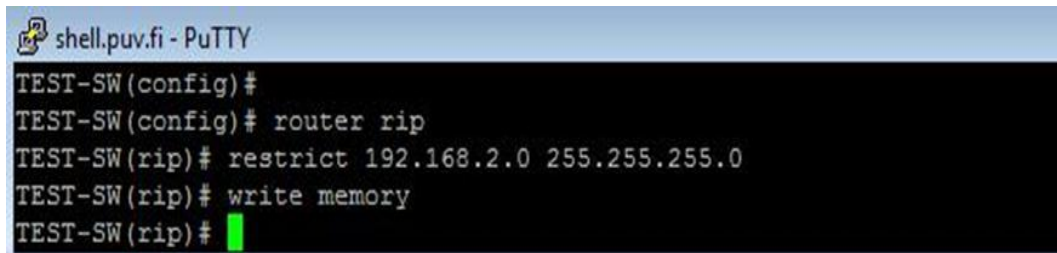
Configuration of RIP protocol on a VLAN interface is an important and useful task. RIP can be configured on a specific or all VLAN IP addresses. By default, RIP V2 is used but we can always change it to individual VLAN interface basis. To enable RIP on VLAN context, see the figure below for configuration commands:

```
shell.puv.fi - PuTTY  
TEST-SW(config)# vlan 316  
TEST-SW(vlan-316)# ip rip 192.168.4.84  
TEST-SW(vlan-316)# exit  
TEST-SW(config)# write memory  
TEST-SW(config)#
```

Figure 22. RIP configuration on VLAN interface

➤ **RIP Redistribution**

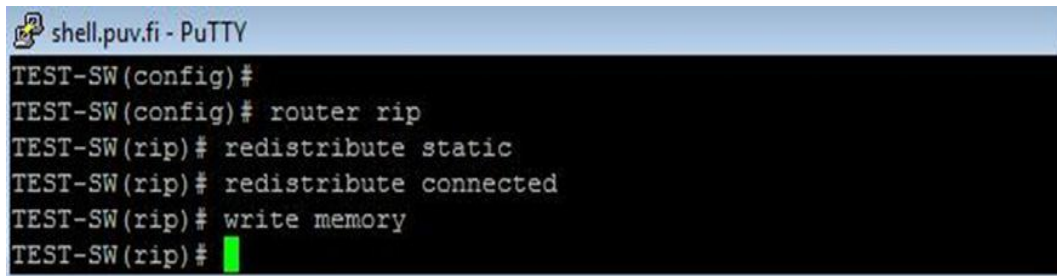
HP Procurve 2910al only supports static and connected route redistribution. Redistribution of any other routing protocol is not supported. Switch is using RIP to advertise redistributed routes to its RIP neighbours. Redistribution filters can be used to get more control on redistribution of routes. These filters permit or deny redistribution for a route based on interface or destination network address. Figure below shows the configuration that how to filter out the static/connected routes on network 192.168.2.0:



```
shell.puv.fi - PuTTY
TEST-SW(config)#
TEST-SW(config)# router rip
TEST-SW(rip)# restrict 192.168.2.0 255.255.255.0
TEST-SW(rip)# write memory
TEST-SW(rip)#
```

Figure 23. RIP redistribution

For enabling the redistribution of static/connected routes into RIP, the command is shown in figure below:

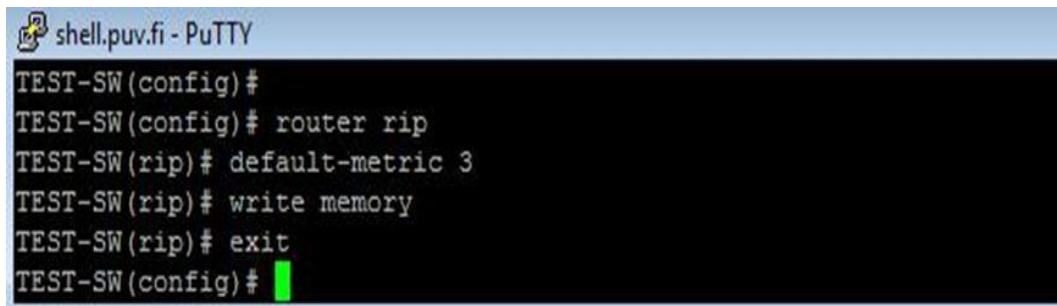


```
shell.puv.fi - PuTTY
TEST-SW(config)#
TEST-SW(config)# router rip
TEST-SW(rip)# redistribute static
TEST-SW(rip)# redistribute connected
TEST-SW(rip)# write memory
TEST-SW(rip)#
```

Figure 24. Redistribute static and connected routes

➤ Cost of routes on VLAN

By default, the switch increases the cost by adding one to the route metric which is learned by RIP interfaces. In RIP, a route that has metric 16 considered unreachable. We can configure a specific interface to increase RIP routes metric. Figure below shows the configuration command to increase the cost of the route by increasing metric:

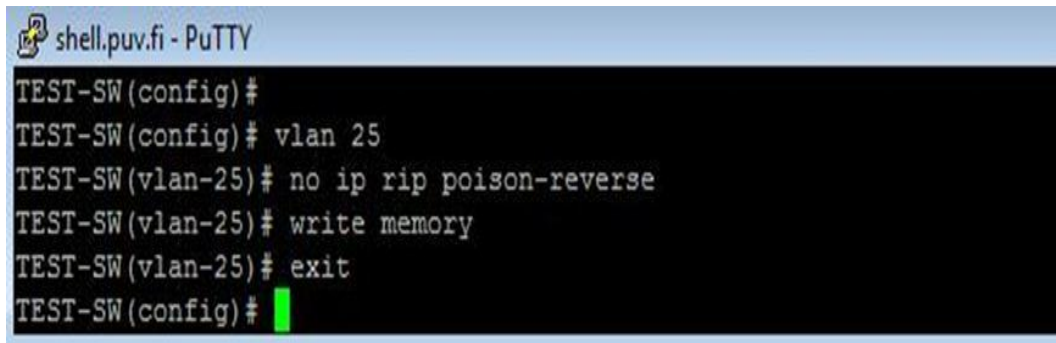


```
shell.puv.fi - PuTTY
TEST-SW(config)#
TEST-SW(config)# router rip
TEST-SW(rip)# default-metric 3
TEST-SW(rip)# write memory
TEST-SW(rip)# exit
TEST-SW(config)#
```

Figure 25. Changing the cost of a route

➤ Root Loop Prevention Method

HP Procurve 2910al switch, RIP uses two methods to prevent routing loops. By default, poison reverse is the default loop prevent method. It basically assigns route cost of 16 before to advertise it to the same interface from the routing switch has been learned the route. Second method is called split horizon. The basic rule of this method is that the routing switch does not advertise a route to the interface from the routing switch learned the route. Routing loop prevention methods can be configured on individual VLAN interfaces. To disable a loop prevention method automatically enables the other one. Figure below shows the configuration command:



```
shell.puv.fi - PuTTY
TEST-SW(config)#
TEST-SW(config)# vlan 25
TEST-SW(vlan-25)# no ip rip poison-reverse
TEST-SW(vlan-25)# write memory
TEST-SW(vlan-25)# exit
TEST-SW(config)#
```

Figure 26. Loop Prevention Method

5 TEST, RESULTS AND ANALYSIS

After the implementation, I could say that a Layer 3 network is build and working properly. Static and dynamic (RIP) routing is enabled on each HP 2910 switch that makes the network to a Layer 3 network and many benefits are realized. These benefits include IP subnetting, greater network security, availability through high speed data connectivity, Layer-3 protocol filtering and intercommunication between Layer-2 VLANs. Now each edge switch is capable of doing IP routing and by limiting to send all the data packets towards the main router to route them, it increased bandwidth conservation. Dynamic routing is configured and working properly that makes the IP routing more efficient. The following figure shows the network structure after the implementation of the project.

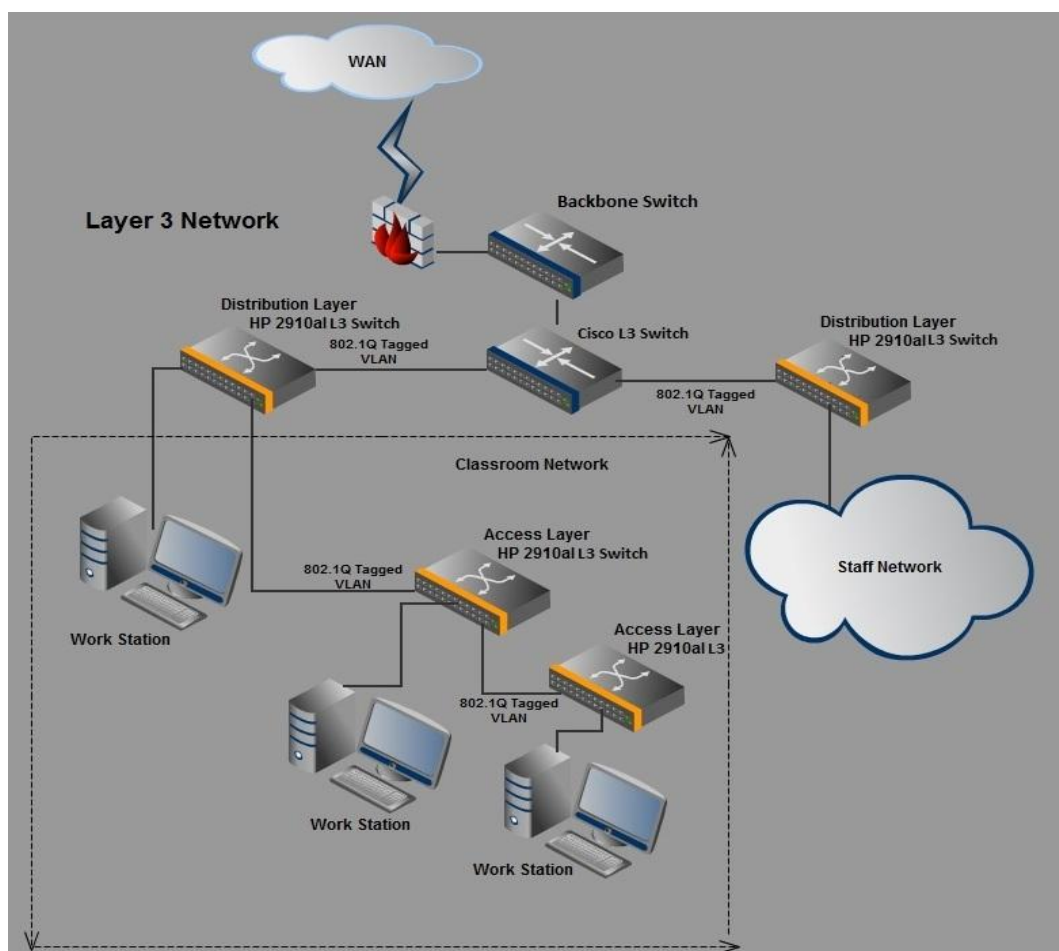


Figure 27. Network structure after the implementation

After the completion of implementation tasks, now a test should be done to make sure that network is working properly. A methodically test has been done to easily find any problem if it exists. The test is divided into three parts:

- Test of the VLAN
- Test of static routing
- Test of dynamic routing

5.1 Test of the VLAN

First VLAN test has been done to make sure that the basic configuration is working properly. In VLAN testing we will make sure that each subnet is getting proper IP addresses and other configuration parameters.

This test has been done in a classroom network. I mentioned earlier that each classroom has its own sub network. All the workstation in the classroom are connected with HP Procurve access switch and configured to be a member of same VLAN. For VLAN test, classroom workstation is used that is connected to the switch with network cable. After successfully login to the workstation, IP configuration of the workstation has been checked to verify that it is getting the proper IP configuration from DHCP server. The figure below shows the test made on the switch:

```

hp2910-wc022-1# show mac-address vlan 405
hp2910-wc022-1# show vlan 405
Status and Counters - VLAN Information - VLAN 405
VLAN ID : 405
Name : wc022
Status : Port-based
Voice : No
Jumbo : No

Status and Counters - Address Table - VLAN 405
MAC Address      Port
-----
0019b9-35a804 28
0019b9-35a84f 27
0019b9-35b497 30
0019b9-35b559 22
0019b9-35bcd4 9
0019b9-35bd2f 20
0019b9-35bf25 7
0019b9-35c336 10
0019b9-35c435 26
0019b9-35c520 18
0019b9-35c542 4
0019b9-35c588 1
0019b9-35c69e 17
0019b9-35c6b5 5
0019b9-35c73d 3
0019b9-35ca08 15

Port Information Mode      Unknown VLAN Status
-----
1          Untagged Learn      Up
2          Untagged Learn      Up
3          Untagged Learn      Up
4          Untagged Learn      Up
5          Untagged Learn      Up
6          Untagged Learn      Up
7          Untagged Learn      Up
8          Untagged Learn      Up
9          Untagged Learn      Up
10 Switch port status  Untagged Learn      Up
11         Untagged Learn      Up

```

MAC address of the client computer in switch VLAN MAC table

10 Switch port status

Figure 28. Testing VLAN

In figure 28, the switch displays the ports status and MAC addresses of the workstations that are connected on the VLAN. The workstation is connected to the switch port 10 which we are using to test the VLAN. As you can see in the figure, the port status is up and the MAC address is registered in the VLAN with port number. Now IP configuration of the workstation has been checked to verify if the VLAN is working properly. The figure below shows the workstation IP configuration:

```

C:\Windows\system32\cmd.exe
WINS Proxy Enabled. . . . . : No
DNS Suffix Search List. . . . . : ad.puv.fi

Ethernet adapter Local Area Connection:

    Connection-specific DNS Suffix . . : ad.puv.fi
    Description . . . . . : Broadcom NetXtreme 57xx Gigabit Controller
    Physical Address. . . . . : 00-19-B9-35-C3-36 MAC address of NIC
    DHCP Enabled. . . . . : Yes
    Autoconfiguration Enabled . . . . : Yes
    Link-local IPv6 Address . . . . . : fe80::65ed:b972:9e6c:66d0%14(Preferred)
    IPv4 Address. . . . . : 192.168.86.60(Preferred) IP address of NIC
    Subnet Mask . . . . . : 255.255.255.128
    Lease Obtained. . . . . : 6. huhtikuuta 2011 7:00:43
    Lease Expires . . . . . : 6. huhtikuuta 2011 19:00:42
    Default Gateway . . . . . : 192.168.86.126
    DHCP Server . . . . . : 192.168.1.1
    DHCPv6 IAID . . . . . : 301996473
    DHCPv6 Client DUID. . . . . : 00-01-00-01-13-B4-C9-12-00-19-B9-35-C3-36

    DNS Servers . . . . . : 193.166.140.100
    . . . . . : 193.166.140.200
    Primary WINS Server . . . . . : 193.166.140.181
    Secondary WINS Server . . . . . : 193.166.140.180

vlan 405
  name "wc022"
  untagged 1-31
  ip helper-address 192.168.1.1
  ip helper-address 192.168.1.2
  ip address 192.168.86.126 255.255.255.128
  tagged 46
  exit
  
```

Figure 29. IP configuration of workstation

Figure 29, shows the IP assigned to the workstation. This IP address is from the subnet 192.168.86.0/25 because the specific switch port is belongs to VLAN 405 and VLAN 405 is configured to get the IP addresses from the subnet 192.168.86.0/25. This is the proper IP address as we configured to assign for this VLAN. Physical address of this network adapter is the same which we have seen in the switch VLAN MAC-addresses. I tried to access the internet and other network resources such as intranet, local student shares, staff shares and personal disk drive. All the network resources are accessible which means that the VLAN is working.

5.2 Test of the Static Routing

Static routing is the simplest form of network routing. Static routing is usually used in small networks to get better performance and static routing could be used in larger network for some specific routes. Because the simplicity of the static routing, it was easy to configure and test it. For the testing of static routing, a routing enable switch has selected which has static routes as well and tried to trace the route to the destination network. For this purpose, traceroute command is used of the routing switch. The figure below shows the test results:

```

monitor.cc.puv.fi - PuTTY
hp2910-wb206-1#
hp2910-wb206-1# show ip route static

                IP Route Entries

Destination      Gateway          VLAN Type      Sub-Type  Metric  Dist
-----
0.0.0.0/0        192.168.2.3     303 static      1         1
10.0.0.0/8       reject          static      1         1
192.168.63.0/24  192.168.2.3     303 static      1         1
192.168.78.0/23  192.168.4.3     316 static      1         1
192.168.80.128/25 192.168.4.2     316 static      1         1

hp2910-wb206-1# traceroute 192.168.78.44
traceroute to 192.168.78.44 ,
          1 hop min, 30 hops max, 5 sec. timeout, 3 probes
 1 192.168.4.3      2 ms    4 ms    4 ms
 2 192.168.4.3      3 ms    4 ms    4 ms
hp2910-wb206-1#
hp2910-wb206-1# ping 192.168.4.3
192.168.4.3 is alive, time = 4 ms
hp2910-wb206-1#

```

Figure 30. Testing Static routing

Figure 30, shows the static routes in the routing switch and when routing switch tried to trace the routes, it shows the next hop address which is configured in the static route. It means the static routing is configured and working properly.

5.3 Test of dynamic routing

Dynamic routing is using many routing protocols but only RIP V2 is used in this project work. For testing the RIP routing, a routing switch is selected, which is configured for RIP routing. Figure below shows the results:

```

monitor.cc.puv.fi - PuTTY
hp2910-wb206-1#
hp2910-wb206-1# show ip route rip

                        IP Route Entries

Destination            Gateway                VLAN Type      Sub-Type  Metric  Dist
-----
172.16.0.0/16          192.168.4.84           316 rip         2         120
192.168.66.0/24        192.168.4.26           316 rip         2         120
192.168.69.0/24        192.168.4.75           316 rip         2         120
192.168.71.0/24        192.168.4.75           316 rip         2         120
192.168.75.0/24        192.168.4.26           316 rip         2         120
192.168.81.128/25     192.168.4.43           316 rip         2         120
192.168.82.128/25     192.168.4.79           316 rip         2         120
192.168.83.0/25        192.168.4.24           316 rip         2         120
192.168.83.128/25     192.168.4.52           316 rip         2         120
192.168.84.0/25        192.168.4.51           316 rip         2         120
192.168.84.128/25     192.168.4.53           316 rip         2         120

hp2910-wb206-1#
hp2910-wb206-1# traceroute 192.168.69.1
traceroute to 192.168.69.1 ,
          1 hop min, 30 hops max, 5 sec. timeout, 3 probes
 1 192.168.4.75      4 ms      4 ms      4 ms
 2 192.168.69.1     3 ms      4 ms      4 ms
hp2910-wb206-1# traceroute 192.168.83.254
traceroute to 192.168.83.254 ,
          1 hop min, 30 hops max, 5 sec. timeout, 3 probes
 1 192.168.4.52     3 ms      5 ms      4 ms
hp2910-wb206-1#
hp2910-wb206-1#
hp2910-wb206-1# ping 192.168.4.75
192.168.4.75 is alive, time = 4 ms
hp2910-wb206-1# ping 192.168.83.254
192.168.83.254 is alive, time = 5 ms

```

Figure 31. Testing RIP routing

Figure 31, shows the RIP routing table of the routing switch. There are many RIP routes and two routes are chosen from the routing table for testing. RIP routing test has made with traceroute command; routing switch has done the routing as it is configured in the routing table. The figure 31 shows the RIP routing test result and the result clearly shows that the RIP routing is working properly.

6 CONCLUSION

In this project, a Layer 2 (Data Link Layer) switching network has been changed to Layer 3 (Network Layer) routing network. The required objective of this project has been achieved within the time frame. In this project work, static routing, dynamic routing, IP subnetting, DHCP configuration, IP configuration, VLAN configuration and intercommunication between Layer 2 VLANs have been done.

This project provides an opportunity to implement the theoretical knowledge of data transmission and packet switched network. Before this project, I was familiar with Cisco switch configuration but we have used HP Procurve switches in this network project. It was a completely new task for me to configure HP switches because of its different command syntax and features. During this project, I have created 20 new IP subnets to DHCP, Approximately 14 new VLANs are created and configured, some VLANs are reconfigured as well, around 25 static/default routes were configured and approximately 30 RIP interfaces were configured to advertises and learn new RIP routes. I have learned many things which could never be learnt by theory without practice.

After the implementation of this whole project, I conclude that:

Layer 3 network provides scalability via routing support, WAN interfaces, and support of network layer protocol, greater security via IP subnetting and IP filtering, availability through high speed connectivity and increased the bandwidth conservation by limiting the users to traverse multiple inter-switch link into a core router to make routing decision. Network routing enables a small network to be linked together with large networks. For example, each classroom has its own network but whole campus is interconnected and communicating because of network routing. Dynamic routing is best approach to use in large networks because it automatically detects network changes and updates routing table.

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