

THE DESIGN AND SIMULATION OF UNIVERSITY IP NETWORKS

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ABSTRACT

The design and implementation of IP networks plays an important role in the construction of an IT infrastructure in any organization. The construction of an unified IP network in any large organization should provide IT security within an organization and access to each workstation from the network to the Internet, E-mail or other IT service. This document describes the design and implementation of IP networks based on Cisco technology for the new International University of Sarajevo, which is the capital city of Bosnia and Herzegovina. The aim of the document is to present a study that was conducted after the construction of the International University of Sarajevo, and as a result a proposal should be given to design and implement a new IP network at this University. The conclusion of this paper states financial benefits and time that can be saved by the University as a result of the implementation of these solutions. The scientific contribution of this paper should be a proposal to create a single document that describes the construction of a unified University IP network based on Cisco technology considering that this document could be applied in the construction of any University IP network.

KEYWORDS: *Enhanced Interior Gateway Routing Protocol, Variable Length Subnet Mask, Routing Information Protocol v2, Open Shortest Path First, LAN, VLAN, Virtual Trunking Protocol*

1. INTRODUCTION

The new International University of Sarajevo is planning to start courses at six faculties. These are: The Faculty of Law, Economics, Electrical Engineering, Mechanical Engineering, Civil Engineering and Natural Sciences. The Law School should have four departments: The Department of State and International Law (1012 students), Department of Civil Rights (31 students), Department of Criminal Justice (531 students) and the Department of Legal History and Comparative Law (13 students). The faculty of Economics should have three departments: The Department of Economics (160 students), Department of Management (129 students) and High-class business schools (19 students). Electrical Engineering should have three divisions: The Department of IT (245 students), Department of Telecommunications (120 students) and Department of Power (68 students) [15]. Mechanical Engineering should have two departments: The Department of Mechanical Manufacturing Engineering (78 students) and the Department of Industrial Engineering and Management (26 students). Civil Engineering should have three departments: The Department of Transport (205 students), Department of construction (51 students) and the Department of Geodesy (47 students). The Faculty of Natural Sciences should have only one department, consisting of the Department of mathematics and computers with a total of 311 students [15].

For the design of the network, Cisco technology will be chosen do to its high quality and flexibility of use [3], [14]. As a routing protocol in this paper, Enhanced Interior Gateway Routing Protocol

(EIGRP) will be demonstrated [1], [2], [13]. The reason why this protocol was chosen over other protocols that support Variable Length Subnet Mask (VLSM) such as RIP v2 [2], [4] or OSPF [2], [5] is because of its speed of convergence and the fact that it is a distance-vector routing protocol [17], [18].

Enhanced Interior Gateway Routing Protocol (EIGRP) is Cisco's distance-vector routing protocol [2], which seeks to minimize instability in routing [1], which is caused by the change in topology in a way which increases the permeability and strength of processing of the router. Data gathered by the EIGRP is placed in three tables: neighbour table, topology table and routing table [13].

This paper represents a continuation of the authors research in the field of IP technology. Previously published paper in this field are: [9] in which is decribed the design of information system based on ITIL V3 recommendations, [10] in which is decribed the implementation of ITIL V3 recommendations in IPTV/VoIP system and [11] in which is described the process of changing of central point of IPTV system.

Section 2 describes the design of the University IP network through a detailed scheme of the IP network, which is divided into several router address areas and schemes of the servers where each server provides a certain service in the new University network. Section 3 defines the steps that need to be taken in the implementation of the designed IP network. Section 4 describes results of the implemented IP network. In section 5, which is the conclusion of this paper, are listed the temporal and financial benefits that the University itself will have with the implementation of the proposed IP solution.

2. THE DESIGN OF THE UNIVERSITIES IP NETWORK

When designing the University IP network it should be taken into account that each router is set for a particular college. Each department within a faculty should be in a separate VLAN [6]. The total number of routers used in the design of this network is 7, and the total number of coils is 19. During the configuration of coils a Virtual Trunking Protocol (VTP) will be used [12], so the coils will be divided hierarchically on the server, transparent and client switches. The address space on router R1 refers to the Law School, the address space of router R2 refers to Electrical Engineering, router R3 to the Faculty of Mechanical Engineering, router R4 to Civil Engineering, router R6 to the Faculty of Economics, and the address space of router R7 refers to the Faculty of Science [13], [14]. Address space of router R5 is designed to accommodate servers that the University employees and provide students with certain services such as Internet, E-Mail, Hosting, IPTV and VoIP [9], [10], [11]. All connections between the individual elements of the picture are presented by standard Ethernet cables. Figure 1 shows a schematic of the University IP network with a detailed presentation of all university networks, VLANs, and their interdependence [14].

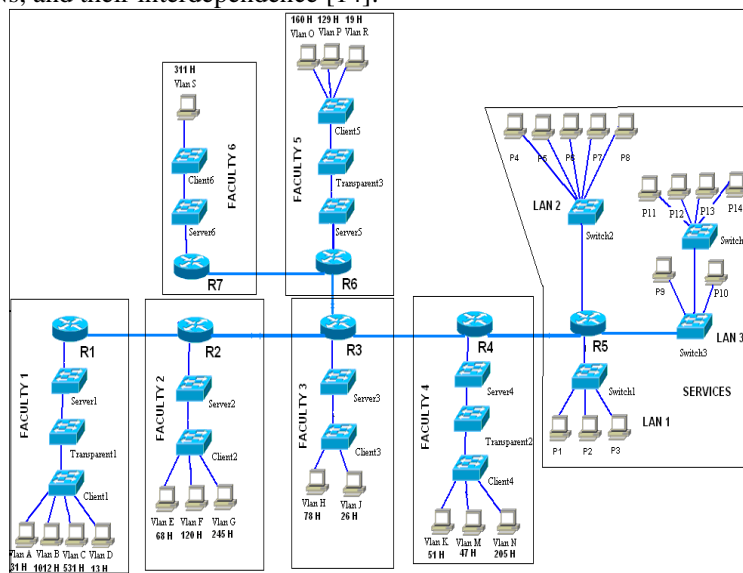


Fig: 1 Scheme of the University network that connects the six faculties

The University IP network will be using the principles of subnet Variable Length Subnet Masks [6] with respect to EIGRP protocol [1]. The principle of using Variable Length Subnet Mask includes sort able subnets starting from those with the largest number of hosts to those with the lowest number of hosts [6]. Table 1 shows the subnet of The University network, where for each subnet the number of hosts are shown, as well as that subnets valid addresses and the appropriate subnet mask [19].

Tab: 1 Subnet of the Universities IP network using the principles of Variable Length Subnet Mask

Number of addresses for one subnet	Name and description of the subnet network	Valid addresses of the subnet network	Subnet mask
1012 H	Virtual LAN B	74.25.0.1 -74.25.3.254	255.255.252.0 (/22)
531 H	Virtual LAN C	74.25.4.1 -74.25.7.254	255.255.252.0 (/22)
311 H	Virtual LAN S	74.25.8.1 - 74.25.9.254	255.255.254.0 (/23)
245 H	Virtual LAN G	74.25.10.1 - 74.25.10.254	255.255.255.0 (/24)
205 H	Virtual LAN N	74.25.11.1 - 74.25.11.254	255.255.255.0 (/24)
160 H	Virtual LAN O	74.25.12.1 - 74.25.12.254	255.255.255.0 (/24)
129 H	Virtual LAN P	74.25.13.1 - 74.25.13.254	255.255.255.0 (/24)
120 H	Virtual LAN F	74.25.14.1 - 74.25.14.126	255.255.255.128 (/25)
78 H	Virtual LAN H	74.25.14.129 - 74.25.14.254	255.255.255.128 (/25)
68 H	Virtual LAN E	74.25.15.1 - 74.25.15.126	255.255.255.128 (/25)
51 H	Virtual LAN K	74.25.15.129 - 74.25.15.190	255.255.255.192 (/26)
47 H	Virtual LAN M	74.25.15.193 - 74.25.15.254	255.255.255.192 (/26)
31 H	Virtual LAN A	74.25.16.1 - 74.25.16.62	255.255.255.192 (/26)
26 H	Virtual LAN J	74.25.16.65 - 74.25.16.94	255.255.255.224 (/27)
19 H	Virtual LAN R	74.25.16.97 - 74.25.16.126	255.255.255.224 (/27)
13 H	Virtual LAN D	74.25.16.129 - 74.25.16.142	255.255.255.240 (/28)
7 H	LAN 3 Router 5	74.25.16.145 - 74.25.16.158	255.255.255.240 (/28)
6 H	LAN 2 Router 5	74.25.16.161 - 74.25.16.166	255.255.255.248 (/29)
4 H	LAN 1 Router 5	74.25.16.169 - 74.25.16.174	255.255.255.248 (/29)
4 H	VLAN1 Ruter1	74.25.16.177 - 74.25.16.182	255.255.255.248 (/29)
4 H	VLAN1 Ruter4	74.25.16.185 - 74.25.16.190	255.255.255.248 (/29)
4 H	VLAN1 Ruter5	74.25.16.193 - 74.25.16.198	255.255.255.248 (/29)
3 H	VLAN1 Ruter2	74.25.16.201 - 74.25.16.206	255.255.255.248 (/29)
3 H	VLAN1 Ruter3	74.25.16.209 - 74.25.16.214	255.255.255.248 (/29)
3 H	VLAN1 Ruter6	74.25.16.217 - 74.25.16.222	255.255.255.248 (/29)
2 H	Connection Ruter1 -Ruter2	74.25.16.225 - 74.25.16.226	255.255.255.252 (/30)
2 H	Connection Ruter2 -Ruter3	74.25.16.229 - 74.25.16.230	255.255.255.252 (/30)
2 H	Connection Ruter3 -Ruter4	74.25.16.233 - 74.25.16.234	255.255.255.252 (/30)
2 H	Connection Ruter4 -Ruter5	74.25.16.237 - 74.25.16.238	255.255.255.252 (/30)
2 H	Connection Ruter3 -Ruter6	74.25.16.241 - 74.25.16.242	255.255.255.252 (/30)

Figure 2 shows the configuration of address space of router R1 [17], which takes into account the existence of the server, client and transparent switch to which VLAN A, VLAN B, VLAN C and VLAN D [12] bound, and a link to a neighbouring router R2 [14].

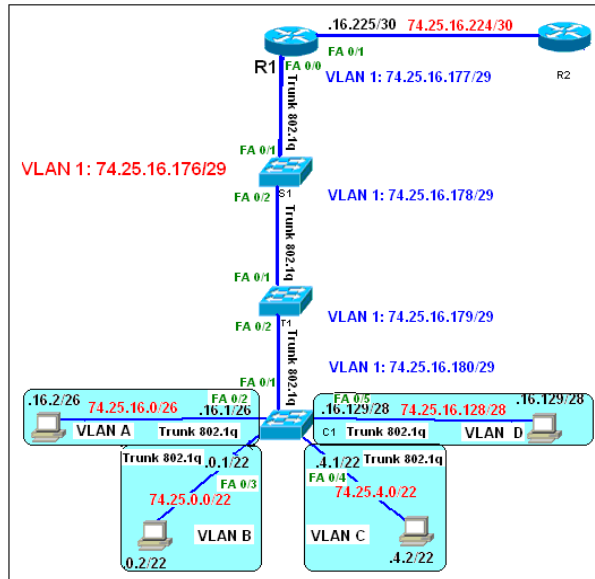


Fig: 2 The configuration of address space of router R1

Figure 3 shows the configuration of address space of router R2 [17] which takes into consideration the existence of a server and client switch which connects VLAN E, VLAN F and VLAN G, and the existence of links to the neighbouring routers R1 and R3.

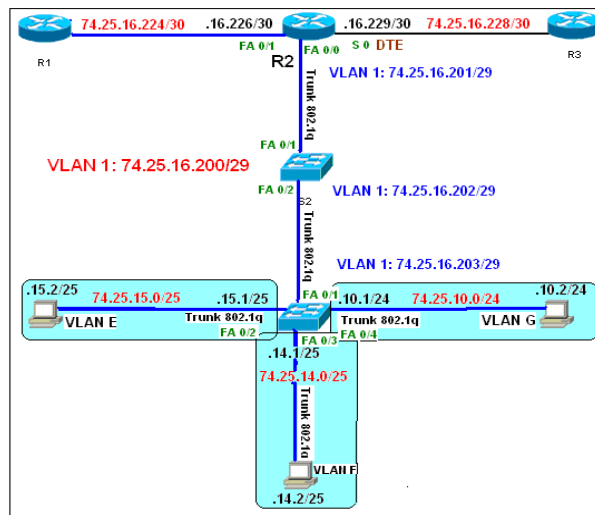


Fig: 3 The configuration of address space of router R2

Figure 4 shows the IP configuration space of router R3 [17], which takes into account the existence of a server and client switch that binds VLAN J and VLAN H, and the existence of links to neighbouring routers R2, R4 and R5 [14].

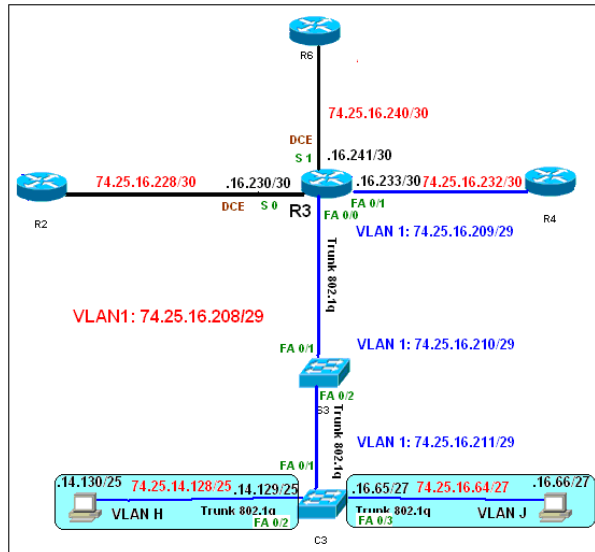


Fig: 4 The configuration of address space of router R3

Figure 5 shows the IP configuration space of router R4 [17], on which go a server, transparent and client switch that binds VLAN K, VLAN M and VLAN N, and the existence of links to neighbouring routers R3 and R5.

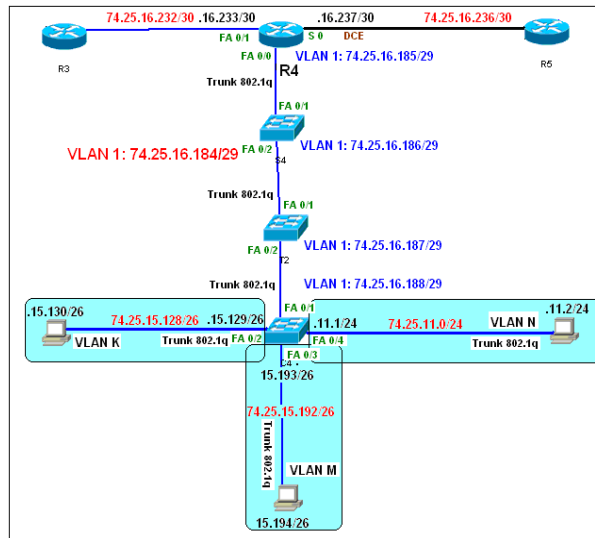


Fig: 5 The configuration of address space of router R4

Figure 6 shows the configuration of IP space on router R5 to which are connected 3 LANs via 3 independent switches and the link between router R5 and R4 [14]. Address space of router R5 is designed for server configuration, which should provide users of the University network with certain services such as Internet, E-mail, VoIP, IPTV [11], Video on Demand and web hosting [7], [8].

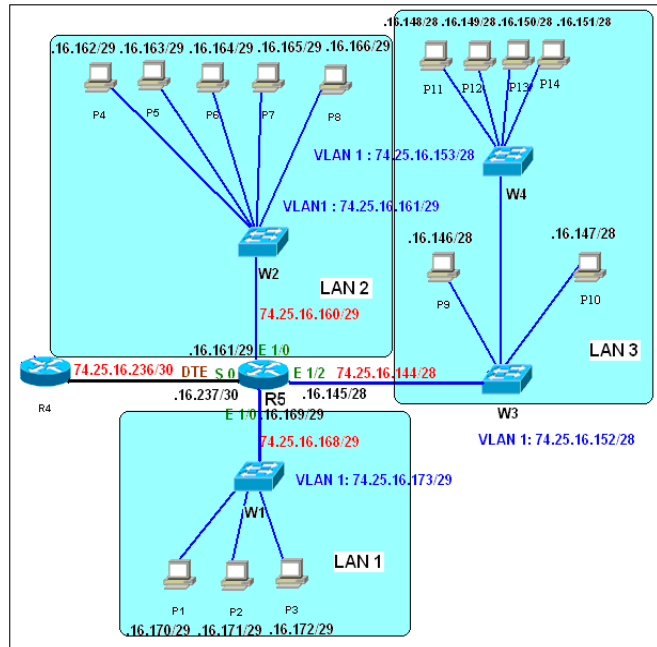


Fig: 6 Configuration of address space of router R5

Table 2 shows the name and use of servers which are located in the address space of the router R5 [17]. Every server, except the Monitoring Server should give one whole IT service or at least a portion of that IT service [6]. The purpose of these IT servers is to provide the users of at International University of Sarajevo all new and modern IT service that are maintained using this IP network [8]. Figure 7 shows the configuration of the IP space router R6 [17] on which server, transparent and client switch are connected on which VLAN O, VLAN P and VLAN R can be found. For the router R6 configuration the connection between the routers R3 and R7 should be taken into consideration [6].

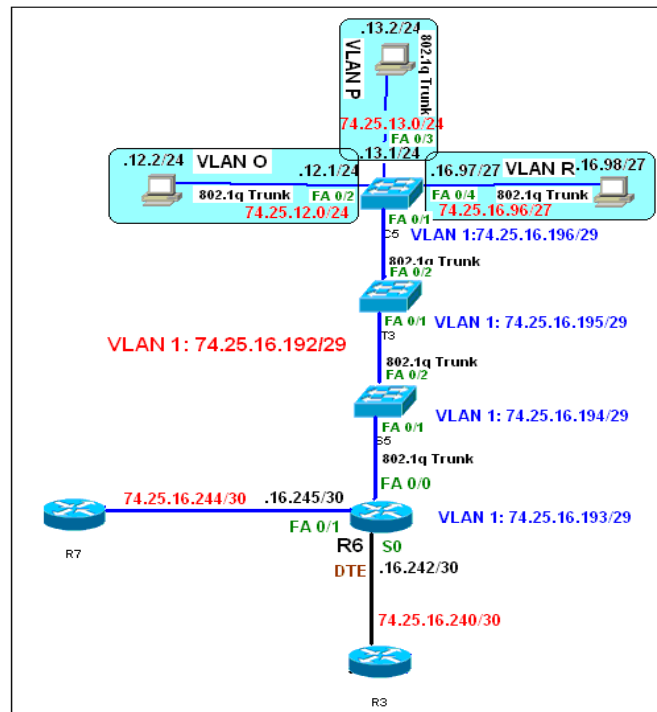


Fig: 7 Configuration of the address space router R6

Tab: 2 The name and usage of servers in address range of Router R5

Name of the working station on figure 6	Name of the server according to the sign of the working station figure 6	Purpose of the server towards offering a service
P1	DNS Server	Domain Name System Server is responsible for the managing above the domain in that all Universities web sites and web applications can be found.
P2	Infocast Server	It is responsible for setting up a software image on which the set top boxes, for delivering IPTV services, connect with the Middleware server.
P3	Network Video Server	Responsible for the surveillance and management of all cameras which monitor the University proctor.
P4	Web Server	Web Server is responsible for a functional and continuous work of the University web site.
P5	E-Mail Server	E-Mail Server should enable access to the University E-Mail to workers as well as to students.
P6	Hosting Server	Hosting Server should enable that every working unit of the University network has a minimum of 200 MB space where it can set their web page.
P7	Radius Server	Radius Server continuously follows the consumption of the Internet from the work stations in the network.
P8	Middleware Server	Middleware (IPTV) Server is responsible for following the work of the Set Top Box at certain workstations as well as for measuring all IPTV consumption for every user..
P9	VoIP Server	VoIP Server follows certain VoIP adapters and servile all included consumption of VoIP for every working station.
P10	RAC Server	RAC Server is responsible for managing the oracle database.
P11	Real Time Encryption Server	Responsible for scripting live TV channels.
P12	Verimatrix Server	Verimatrix Server is responsible for scripting movies on Video Demand Server.
P13	Video On Demand Server	Responsible for managing Video on Demand as a partial favour.
P14	Monitoring Server	Monitoring Server should enable the continuity of following all servers, links and working stations in the network. It should have an implemented mechanism of reporting about alarms in chase a problem in the network.

Figure 8 shows the address space router R7 on that one server and client switch are connected on which VLAN S is attached. In regards during the configuration of the R7 router we should take also the connection with R6 router into consideration [4]. As the Natural-Mathematical university has only one class than only one VLAN will be enough for his configuration. Realization of the address space router R7 it only implies the starting of the server and client switch without transparent switch regarding the existence of only one class which then implies on the existence of only one VLAN service [1].

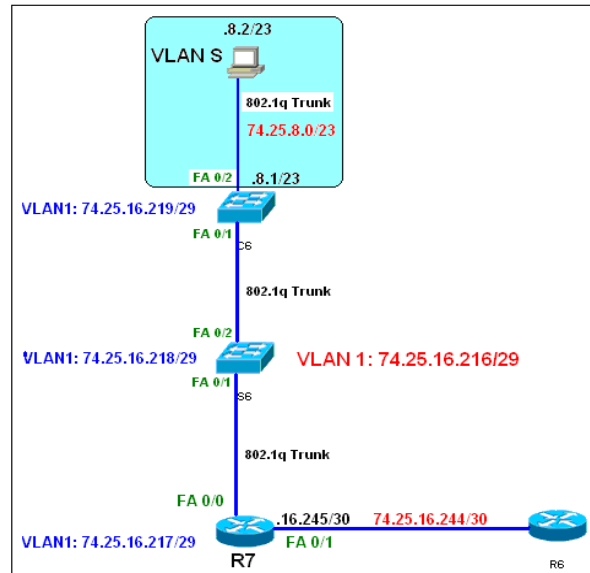


Fig: 8 Configuration of the address space router R7

3. IMPLEMENTATION OF THE UNIVERSITY IP NETWORK

For a complete configuration of the addressed network it is needed to pass 10 basic steps [1], [4]. Because of the importance and wideness of the job, it is desired that every of the nine steps in the configuration for the purpose of one independent IT administrator.

Ten steps through that it is need to fulfil the University network to reach a complete configuration of the University network are [13]:

1. Fulfill the basic configurations of all routers in the network. The basic router configuration means granting names, console passwords and virtual passwords to every router.
2. Perform a basic configuration of all switches in the network. The basic switch configuration means granting names, console passwords and virtual passwords to every switch.
3. Configurations of the interface on routers. Configuration of the interface means giving IP addresses and subnet masks to every interface, defining the type of encapsulation and also defining the eventual connection to the server, transparent or client switch.
4. Configuration of the Enhanced Interior Routing Protocol (EIGRP) on routers [2]. Configuration of this protocol means adding all routes that are directly connected with the specific router.
5. Configuration of the table with hosts on routers towards enabling commands "Telnet". Configuration of the table of hosts eludes defining host connections with other routers.
6. Configuration of the Virtual LAN and Virtual Trunking Protocol with all switches which are directly connected with some virtual LAN. This configuration means defining VTP domain [12], defining VLANs that are connected to the client switch and to the VTP type switch.
7. Configuration the interface with switches. This configuration means mapping certain VLANs onto client switches and defining trunk mode as well as security on every used port.
8. Configuration of the working station in the network. This configuration means allocating IP addresses, subnet masks and default gateways every defined working station.
9. Configuration of every service shown in table 2. This configuration means allocating IP addresses to every server in the network, installing needed software for their work and initially testing the service that has been implemented through the installation of software. After the implementation of all servers in is necessary to test their mutual correlation. In case all tests are positive, then we can go to the next 10th step of this implementation.
10. Testing configured networks using consecutive commands: „Ping“, „Traceroute“and „Telnet“. Ten basic tests which should satisfy the configured network for all three commands are [7], [17]:

- a) The working station in Virtual LAN C needs to access the working station P14 in LAN 3.
- b) The working station in Virtual LAN J needs to access the working station in Virtual LAN O.
- c) The working station in Virtual LAN R needs to access the working station in Virtual LAN K.
- d) Switch Transparent2 needs to access the serial interface Router2.
- e) Router1 needs to access the working station in Virtual LAN R.
- f) Router5 needs to access the working station in Virtual LAN A.
- g) The working station in Virtual LAN P needs to access the working station in Virtual LAN N.
- h) The working station P8 needs to access the working station in Virtual LAN D.
- i) The working station in Virtual LAN J needs to access the Router 7.
- j) Switch Server2 needs to access the serial interface Router5.

Just in case all ten tests have positive results for all three commands, then the network is simulated and it can actually be implemented. In case only one command doesn't pass the given test, then the whole network needs to be redesigned [13].

4. RESULTS OF THE IMPLEMENTED IP NETWORK

Table 3 shows the names of phases and time periods of each phase that is needed for its completion.

Tab 3: Name of the phase and time period of each phase during the project implementation

Ordinal number of phase	Phase name	Time period of phase
Phase I	Installation of the network equipment (setting up equipment and connecting them)	15 days
Phase II	Implementation of the University IP network through 10 steps	40 days
Phase III	Realising the University IP network into production	5 days

When it comes to the implementation of the University IP network through the 10 steps, then the total time of 40 days is achieved through 15 days which are necessary to configure the network equipment, 15 days as needed to install the service and 10 days as needed for their mutual testing. The total time implementation of this project after completing this document should last 60 days (2 months). The time of 60 days is the minimum time it takes to make this extensive project [16].

Table 4 shows the total funds needed to invest in the implementation of this project [3]:

Tab 4: Name of resource and price of resource necessary for the project realization

Name of resources	Cost
Shopping for network and server equipment	14.000 E
Shopping for software necessary for the installation of the service	204.000E
Hiring 10 IT professionals for the implementation of this project for a period of 60 days	80.000 E
Hiring 1 IT professional, for permanent employment at the University, whose task will be to maintain the network and server equipment	36.000 E annually

5. CONCLUSIONS

All prices provided in Table 4 were created as a result of the research cost of IT services in Bosnia and Herzegovina [15]. The total cost of implementation of the entire system amounts to 334 000 E and 36 000 E would be paid yearly for the maintenance [3]. The total amount is the lowest taking into account the cost of IT services as well as the implementation of software and licenses for additional servers, such as Middleware, VoIP, Radius and etc., which affected the formation of the cost E 204 000 to purchase the software. The contract with the IT consulting firm that should install, implement

and maintain a new system needs to be signed by the management of the University [9], [10]. Considering that the International University of Sarajevo should have 3046 students as well as with regard to the price of the cheapest Internet package from the local Service Provider, which includes Internet, E-Mail, Hosting, IPTV and VoIP, amounts to 25 E simple calculation shows that the rental cost of this package annually costs the University 913 800 E [3], [7]. This means that introduction of a new solution the University annually saves 877 800 E, in a period of 10 years saving E 8.778 million which represents a significant sum for the University.

Further research in this area should be provided as a result of a study related to the linking of several universities in Bosnia and Herzegovina [15] into a single network that should enable the entire academic staff in Bosnia and Herzegovina, the use of Internet service, E-Mail, IPTV [11] VoIP and hosting.

Acknowledgments

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Biography

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Fahrudin Orucevic is a lecturer at the Department of Informatics, Faculty of Electrical Engineering, University of Sarajevo, Bosnia and Herzegovina. He became a doctor of science in 1990. During his career, he was a director in several companies, including international companies. His fields of interests are information systems, internet economy, management of information systems and geographical information systems. He published more than 40 papers on international conferences and international journals. He is also the president of IT Service Management Forum of Bosnia and Herzegovina. He finished many university projects, and currently he is doing on projects of development of a new ITIL V3 model which is based on comparative analysis with other ITSM methodologies and standards.

