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**DOKUZ EYLÜL UNIVERSITY**

**ENGINEERING FACULTY**

**DEPARTMENT OF COMPUTER ENGINEERING**

**CME 3204**

**Data Communications and Computer Networks**

**METROPOLITAN AREA NETWORK**

**SIMULATION PROJECT**

**by**

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***Abstract - This project's main goal is to use Cisco Packet Tracer software to simulate and construct a Metropolitan Area Network (MAN). The MAN's purpose is to link two branch offices together in a city, supporting a range of applications and services while guaranteeing optimal performance is achieved. In the network architecture, switches are used for local connectivity within each office and routers are used to connect branch offices. To verify the efficacy of the design, the project includes wiring network devices, modelling network behaviour, and analysing performance. This study provides new perspectives on network design, planning, and modelling, which sets the way for the construction of scalable and durable MAN infrastructures in practical settings.***

**1. Introduction**

**1.1. Project Definition and Problem Formulation**

The design of a Metropolitan Area Network (MAN) that links two office branches inside a city is the subject of this paper. It attempts to address the difficulty of building a solid network infrastructure that satisfies the various requirements of various facilities while preserving peak performance and scalability.

***Problem Statement:*** Network connectivity becomes essential as businesses grow and spread out across different areas. Creating a MAN that effectively links different offices, fosters cooperation, and changes to meet changing digital needs is the difficult part.

**1.2. The purpose and motivation of the project**

***Mission:*** The main goal is to set up a strong network architecture that makes it easier for offices that are spread out geographically to communicate and share data.The project intends to promote employee collaboration across several branches through the establishment of a Metropolitan Area Network (MAN), resulting in increased productivity and innovation.The design prioritizes scalability to support future development and technology breakthroughs, guaranteeing that the network can change to meet evolving business needs.Although performance is the top priority, the project also seeks to balance functionality and cost to make the best use of available resources.

**1.3. Term Definitions**

***Node:*** Any device connected to a network, such as computers, servers, routers, or switches.

***Packet:*** A unit of data transmitted over a network, consisting of a header containing control information and payload containing the actual data.

***Channel:*** The medium through which data is transmitted between nodes in a network, such as wired (Ethernet cable) or wireless (Wi-Fi) communication channels.

***Protocol:*** A set of rules and conventions governing the exchange of data between devices in a network, ensuring standardized communication.

***DNS :*** DNS stands for domain name system. It is an application layer protocol used to provide a human-friendly naming mechanism for internet resources. It is what ties a domain name to an IP address and allows you to access sites by name in your browser.

***IP :*** The IP protocol is one of the fundamental protocols that allow the internet to work. IP addresses are unique on each network and they allow machines to address each other across a network. It is implemented on the internet layer in the IP/TCP model.

***System:*** A collection of interconnected components working together to achieve a common goal, such as a network system comprising hardware, software, and protocols.

***Architecture:*** The overall design and structure of a network system, including its components, connectivity, and organization.

***Network :*** This general term refers to all the components involved in getting computers and other types of hardware to talk to each other.

***Server :*** Also called "file server" and "network server" this term refers to the "nerve center" of your network. It typically needs to be much more high-powered than a regular desktop workstation. The server is home to hardware that is networked (allows more than one person to use it simultaneously). All of your data will typically be stored on this machine.

***Workstation :*** This refers to each person's computer. Your front and back office staff computers and the machines in the examination room will be workstations on the network.

***Wireless :*** This refers to a type of network that broadcasts an access signal to the workstations. This allows for transporting laptops and tablet PCs from room to room while maintaining a network connection continuously. A wireless network also presents some additional security requirements.

***Ethernet :*** This is the backbone of our network. It consists of the cabling and is typically able to transfer data at a rate of 100mb/s.

***Router :*** This is your network's "air traffic controller." It routes all the data on your network to where it is supposed to go. It also assigns unique network addresses to all the computers (IP addresses). Routers can also hide the computer and devices that connect to it from the outside world. To people on the Internet, your entire network looks like one computer (one IP address). This adds another layer of protection to the computers on your network

***Switch:*** Switch is a high-speed device that receives incoming data packets and redirects them to their destination.

**2. Method and Simulation**

**2.1. Simulation and Modelling Concepts**

***Definitions:***

***Discrete-Event Simulation:*** A kind of simulation in which events, usually discrete ones, are the only times the system state changes. Events are important things that happen in the system and cause it to change states.

***Modelling:*** The process of reducing a complex system to a simpler form in order to study its behaviour, forecast results, or test theories. Models are representations of systems that might be conceptual, mathematical, or computational.

***Benefits of modelling:*** By enabling testing of many configurations and situations without requiring physical implementation, modelling and simulation lower the expenses related to experimentation and prototyping. Also compared to real-world implementations, simulation allows for the quick examination of many design possibilities and scenarios, which speeds up decision-making and iteration cycles. Modelling assists in identifying risks and uncertainties early in the design process by simulating possible outcomes and situations. This enables proactive risk management and mitigation techniques.

In the context of the MAN design project, discrete-event modelling and simulation approaches can provide important advantages including fast iteration cycles, economical network configuration discovery, and system performance knowledge. To optimise the efficiency of the modelling and simulation technique, it is necessary to tackle certain issues including guaranteeing model accuracy, controlling complexity, and correctly interpreting simulation results.

**2.2. Simulation Environment/Tool**

***As the simulation environment*** Cisco Packet Tracer was used. Packet Tracer is designed using a client-server architecture, in which the server manages computation and simulation execution, and the client application offers a graphical user interface for modelling and simulation. Network components including switches, routers, PCs, servers, and connections, as well as protocols, configurations, and traffic simulation, are examples of modelling principles in Packet Tracer.

Packet Tracer adopts a ***discrete-event simulation approach***, where system state changes occur at discrete points in time in response to events such as packet arrivals, departures, and routing decisions.

Network topology modelling and simulation, protocol settings, traffic generation, and packet tracing are among the ***capabilities.*** Some network protocols and technologies may be represented more simplistically than in real-world implementations, which is one ***limitation.***

Simulation in Packet Tracer is primarily GUI-based, where users interactively create network topologies, configure devices, and initiate simulations through the graphical interface. Packet Tracer does not typically involve traditional programming; however, users can configure devices using Cisco's proprietary Command Line Interface (CLI) or graphical ***configuration interfaces.***

Routers, switches, wireless routers, ethernet cables, PCs, Laptops, Smartphones, Tablets, VoIP telephones and servers were the ***components of this project***. Besides, some ***modules*** were added to and extracted from some components. ***NM-4A/S module*** is added to the routers to increase the number of necessary ports. ***Linksys-WMP300N*** is added to the PC’s which need connection to wireless routers.

**2.3. Network Design Requirements**

**BRANCH 1:**

***FACILITY 1.1:***

- 3 PC - 3 Laptop (wireless user) - 3 Smartphone - 1 wireless router - 1 switch A

***FACILITY 1.2:***

- 6 PC (2 voIP) - 1 switch B

***FACILITY 1.3: (SERVER FARM)***

- 10 Web servers - 4 FTP servers - 1 DHCP server - 1 Mail server - 1 DNS server - 1 switch C

**BRANCH 2:**

***FACILITY 2.1:***

- 5 PC - 5 wireless user - 5 tablet - 1 wireless router - 1 switch D

***FACILITY 2.2:***

- 5 PC - 2 Smartphone - 1 wireless router - 1 Switch E

***FACILITY 2.3:***

- 5 PC - 2 Mobile devices - 1 wireless router - 1 Switch F

***CONNECTIONS:***

switch A and B are connecting over router 1.1

router 1.1 and switch C are connecting over router 1.2

switch D and E are connecting over router 2.1

router 2.1 and switch F are connecting over router 2.2

router 1.2 and 2.2 are connecting over router 3.0 (the ISP router)

(Total of 9 routers ( 4 of them are wireless routers))

**2.4. Requirement Analysis**

The network design must support various applications and services: Voice over Internet Protocol (VoIP), wireless connection, Web browsing, email services, and file transfer for all users, access to web servers, FTP servers, DHCP, DNS, and mail servers hosted in the server farm. To support VoIP, router 2811 was used as the other routers are not suitable for sending voice. For wireless communication WRT300N Wireless Routers are used. Each device can browse Web contains of 10 web sites supplied by 10 different Web servers and given domain names by 1 DNS server. 4 FTP servers are authorized to support file transfer. There is 1 DHCP server to manage IP addresses, except the IP address’ of servers, they are static.

There are currently 44 ***users of the system*** but this number can increase to 1524 as the IP range supports with the help of connection modules and extra switches if needed.

Several ***constraints*** influence the network design process: The design must strike a balance between the system needs and the cost of network hardware and equipment. The location and configuration of network devices may be affected by restrictions on available physical space and infrastructure. Commitment to industry norms and regulations related to data security and privacy must be guaranteed.

**2.5. Definitions of the System/Model**

***Assumptions:*** It is believed that hardware failures will not frequently occur and that components like switches, routers, and access points will function within predicted reliability standards. It is expected that traffic patterns lack unexpected spikes or abnormalities and instead follow conventional usage scenarios with peak and off-peak hours. It is expected that system is safe and secure. It is expected that the network architecture will be able to develop in the future to handle an increase in the number of users and network services.

***Formulations and Hypotheses on Input Parameters:*** There is 6 different Local Area Networks (LANs) and each must have unique range of IP addresses, also there are 8 ports connecting the 5 routers together. Each port must have its own IP address too. This makes up the need of 6 different Class C IP address range for main routers, 4 different Class C IP address range for wireless routers, 1 Class C IP address range for VoIP and 8 different Class A IP address range for serial connection of routers.

***Network Topologies***: Switches provide local connection and routers link branch offices in hierarchical topologies.

***Network Applications and Services:*** Web browsing, email, file transfers, VoIP phone calls, DHCP, DNS, and FTP services are examples of network applications and services. The day-to-day functioning of branch offices and communication between them depend on these services.

***Network Configuration:***

Branch 1 Facility 1 uses 192.168.32.1/24 as local connection 192.168.32.2/24 as wireless connection.

Branch 1 Facility 2 uses 192.168.31.1/24 as local connection 192.168.33.1/24 for VoIP communications.

Branch 1 Facility 3 is server farm and uses 192.168.1.1/24 static IP range for servers. 192.168.31.2 is DHCP server. 192.168.1.3 is DNS server. 192.168.1.4 to 192.168.1.13 are Web servers. 192.168.1.14 is Mail server. 192.168.1.15 to 192.168.1.18 are FTP servers.

Branch 2 Facility 1 uses 192.168.41.1/24 as local connection 192.168.41.2/24 as wireless connection.

Branch 2 Facility 2 uses 192.168.42.1/24 as local connection 192.168.42.2/24 as wireless connection.

Branch 2 Facility 3 uses 192.168.21.1/24 as local connection 192.168.21.2/24 as wireless connection.

Router 1.1 ‘s serial port 1/0 is 30.0.0.2 and connected to router 1.2’s serial port 3/0 with the IP 30.0.0.1

Router 1.2 ‘s serial port 2/0 is 10.0.0.2 and connected to router 3.0’s serial port 3/0 with the IP 10.0.0.1

Router 3.0 ‘s serial port 2/0 is 20.0.0.1 and connected to router 2.2’s serial port 2/0 with the IP 20.0.0.2

Router 2.2 ‘s serial port 2/0 is 40.0.0.1 and connected to router 2.1’s serial port 2/0 with the IP 40.0.0.2

***Data types*** include IP packets, Ethernet frames, and application-layer data such as HTTP requests and emails. Data sources include network devices (routers, switches, access points), servers, and end-user devices (PCs, laptops, smartphones).

***Device types*** includes;

* ***Hosts***: PCs, laptops, smartphones, tablets, servers.
* ***Managed Devices:*** Routers, switches, wireless routers.

***Service configurations of servers:***

***A screenshot of a computer

Description automatically generated***

***Figure 1. DHCP Server Services***

***A screenshot of a computer

Description automatically generated***

***Figure 2. DNS Server Services***

***A screenshot of a computer

Description automatically generated***

***Figure 3. HTTP/Web Server Services of Google.com***

***A screenshot of a computer

Description automatically generated***

***Figure 4. MAIL Server Services***

***A screenshot of a computer

Description automatically generated***

***Figure 5. FTP Server Services***

**2.6. Simulation Elements**

***System Entities:***

A computer network diagram with many computers connected to each other

Description automatically generated

***Figure 6. BRANCH 1 FACILITY 1***

A computer network diagram with many computers

Description automatically generated with medium confidence

***Figure 7. BRANCH 1 FACILITY 2***

A diagram of a network

Description automatically generated

***Figure 8. BRANCH 1 FACILITY 3 SERVER FARM***

A computer network diagram with many laptops connected to each other

Description automatically generated

***Figure 9. BRANCH 2 FACILITY 1***

A computer network diagram with many circles

Description automatically generated with medium confidence

***Figure 10. BRANCH 2 FACILITY 2***

A diagram of a network

Description automatically generated

***Figure 11. BRANCH 2 FACILITY 3***

A diagram of a network

Description automatically generated

***Figure 12. OVERALL LOGICAL VIEW OF NETWORK***

A map with a couple of squares

Description automatically generated with medium confidence

***Figure 13. OVERALL PYHSICAL VIEW OF NETWORK***

Standard frequency rate of wireless router channels is 1-2.412 GHz.

All network interfaces are currently active.

Clock rate of routers is 2000000.

Baudrate is 9600 bits per second.

A screenshot of a computer

Description automatically generated

***Figure 14. Results of a random general traffic generated by Cisco Packet Simulation***

**3. Traffic Analysis and Simulation Results**

***Scenario 1:*** A wireless user from first facility of second branch wants to read emails and browse Web.

A screenshot of a computer

Description automatically generated

***Figure 15. Reading emails***

A screenshot of a computer

Description automatically generated

***A screenshot of a computer

Description automatically generatedFigure 16***

***Figure 17***

A screenshot of a computer

Description automatically generated***Figure 18. Relevant event list of traffic moving of scenario 1, email sending.***

A screenshot of a computer

Description automatically generated

***Figure 19. Relevant OSI Model of scenario 1***

A screenshot of a computer

Description automatically generated

***Figure 20. Some PDU information of scenario 1,sending mails.***

A screenshot of a computer

Description automatically generated

***Figure 21. Browsing Web.***

A screenshot of a computer

Description automatically generated

***Figure 22***.

A screenshot of a computer

Description automatically generated***Figure 23. Some relevant event traffic of browsing web.***

A screenshot of a computer

Description automatically generated

***Figure 24. Relevant OSI Model on Scenario 1***

A screenshot of a computer

Description automatically generated

***Figure 25. Some PDU information of browsing Web.***

***Scenario 2:*** A computer engineer from second facility of second branch developed a web application and wants to send his/her code files to FTP server in the third facility of first branch.

A computer screen shot of a program

Description automatically generated

***Figure 26. Files of FTP Server, testfile.txt can be seen here at the bottom.***

A screenshot of a computer

Description automatically generated

***Figure 27. Relevant event traffic.***

***A screenshot of a computer

Description automatically generated***

***Figure 28. Relevant OSI Model on Scenario 2***

A screenshot of a computer

Description automatically generated

***Figure 29. Some PDU information on FTP.***

***Scenario 3:*** Two users from second facility of first branch want to talk via VoIP.

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***Figure 30. Talking via VoIP.***

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A screenshot of a computer

Description automatically generated

***Figure 31. Relevant event list of VoIP traffic.***

A screenshot of a computer

Description automatically generated

***Figure 32. Relevant OSI Model on Scenario 3***

A screenshot of a computer

Description automatically generated

***Figure 33. Some PDU information on VoIP communication.***

***Scenario 4:*** A user in the second facility of first branch wants to send an email message to his friend in the second facility of second branch.

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Description automatically generated

***Figure 34. Receiving Email.***

A screenshot of a computer program

Description automatically generated

***Figure 35. Event list of sending e-mail.***

***A screenshot of a computer program

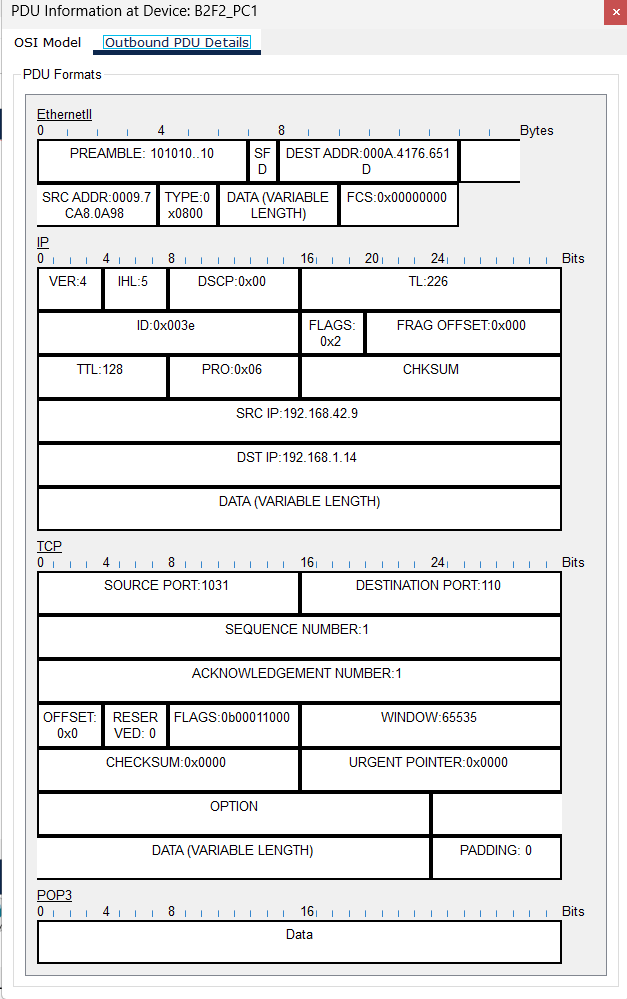
Description automatically generated***

***Figure 36. Event list of receiving e-mail***

***A screenshot of a computer

Description automatically generated***

***Figure 37. Relevant OSI Model on Scenario 4***

***Figure 38. Some PDU information about email, POP3.***

***Scenario 5:*** A user from first facility of second branch pings Web server of third facility of first branch.

***A screenshot of a computer program

Description automatically generated***

***Figure 39. Pinging***

***A screenshot of a computer

Description automatically generated***

***Figure 40.***

***A screenshot of a computer

Description automatically generated***

***Figure 41. Event list of pinging traffic***

***A screenshot of a computer

Description automatically generated***

***Figure 42. Relevant OSI Model on Scenario 5***

***A screenshot of a computer

Description automatically generated***

***Figure 43. Some relevant PDU information on pinging.***

***Scenario 6:*** A laptop user from first facility of first branch office wants to send email to her friend in the first facility of second branch office.

***A screenshot of a computer

Description automatically generated***

***Figure 44. Receiving email.***

***A screenshot of a computer

Description automatically generated***

***Figure 45. Event list of email traffic.***

***A screenshot of a computer

Description automatically generated***

***Figure 46. Relevant OSI Model on Scenario 6***

***A screenshot of a computer

Description automatically generated***

***Figure 47. Some PDU information of Scenario 6.***

***Scenario 7:*** A smartphone user from third facility of second branch office wants to use ssh to connect to a Web server in the third facility of first branch office.

A computer screen with white text

Description automatically generated

***Figure 48. Using SSH Client***

***A screenshot of a computer

Description automatically generated***

***Figure 49. Some events on SSH to Web Server traffic,***

***A screenshot of a computer

Description automatically generated***

***Figure 50. Relevant OSI Model on scenario 7.***

***A screenshot of a computer

Description automatically generated***

***Figure 51. Relevant PDU Details on scenario 7***

***Scenario 8: A tablet user from first facility of second branch wants to browse Web.***

***A screenshot of a computer

Description automatically generated***

***Figure 52. Browsing youtube.com***

***A screenshot of a computer

Description automatically generated***

***Figure 53.***

***A screenshot of a computer

Description automatically generated***

***Figure 54. Event traffic on browsing Web.***

***A screenshot of a computer

Description automatically generated***

***Figure 55. Relevant OSI Model on browsing Web.***

***A screenshot of a logistic

Description automatically generated***

***Figure 56. Some PDU information on browsing Web.***

***Scenario 9:*** A user from first facility of first branch wants to access files in a FTP server in the third facility of first branch.

***A screenshot of a computer program

Description automatically generated***

***Figure 57. Viewing files of a FTP server.***

***A screenshot of a computer

Description automatically generated***

***Figure 58. Event list of scenario 9.***

***A screenshot of a computer

Description automatically generated***

***Figure 59. Relevant OSI Model of FTP Client.***

***A screenshot of a computer

Description automatically generatedFigure 60. Relevant PDU details of FTP Client.***

**4. Conclusion**

In summary, the project's main goal was to apply Cisco Packet Tracer software to build a Metropolitan Area Network (MAN) which connected two branch offices located within a city. The aim of the network architecture was to provide a range of services and applications while satisfying system requirements, cost, and performance standards. Simulation tests and analysis demonstrate that topology and architecture selection are carried out successfully. The necessary speed and safety could be accomplished when you use the metropolitan area network rather than the wide area network. The project helped to gain a better understanding of the network architecture and the challenges that it brings.

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