Computer Networks PBL Report

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Project Title:

TCN MULTI-FLOOR NETWORK DESIGN REPORT

Using Cisco Packet Tracer

1. Introduction: Critical Analysis of Networking Requirements

The organization TCN operates across five floors, each hosting a distinct department with its own communication and performance requirements. The network must support inter-department connectivity, resource sharing, secure segmentation, and internet access, while remaining scalable and easy to troubleshoot. The project requires designing a **Local Area Network (LAN)** that connects over 100 workstations and servers using efficient addressing, logical segmentation, and reliable hardware configuration.

A critical requirement was the implementation of **VLANs** to isolate departmental traffic for security and performance. Additionally, the network must provide **inter-VLAN routing**, centralized management from the ground floor, and full connectivity to internal servers and the external Internet. Another key requirement was addressing scalability challenges, such as departments exceeding 24 PCs, requiring multi-switch cascading and efficient IP allocation using **Variable Length Subnet Masking (VLSM)**.

The design also needed to support future expansion without requiring major redesign. Thus, hierarchical design principles were followed:

- **Core Layer:** Router + SW-GROUND

- **Distribution Layer:** SW-GROUND trunk aggregation

- **Access Layer:** Floor switches for each department

2. Local Area Network (LAN) Design and Description

2.1 Network Topology

A **hierarchical star topology** (extended star) was selected for the LAN. In this topology, a central switch (SW-GROUND) connected directly to floor switches, and each floor switch connected to departmental workstations.

Topology Preview:
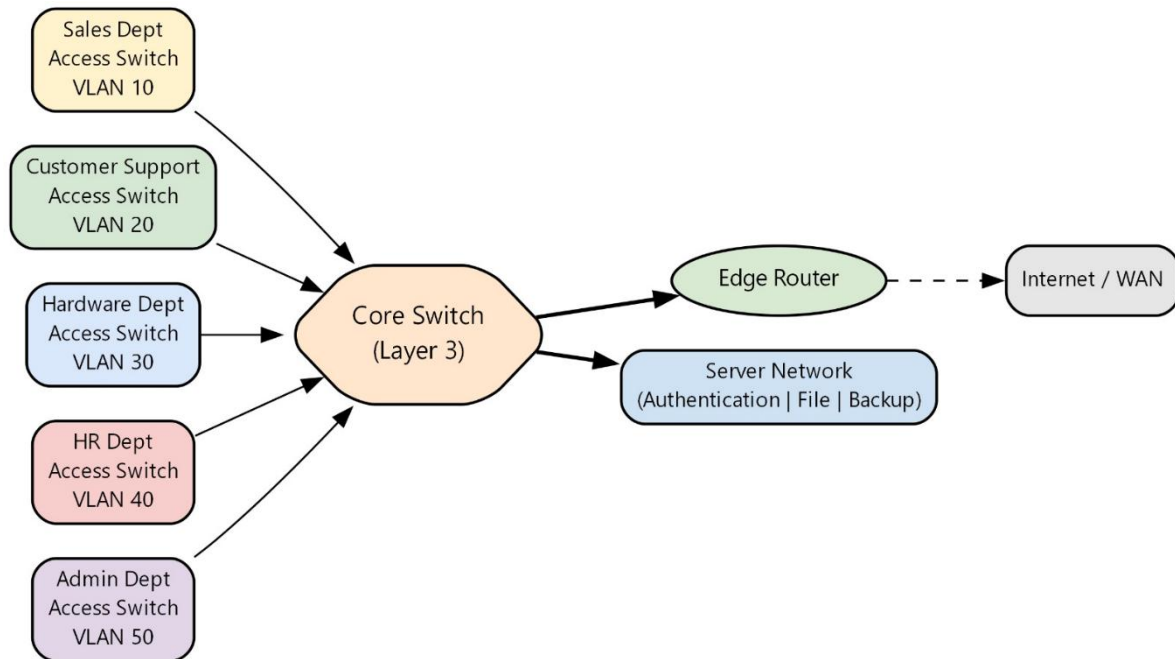
Reasons for Choosing Extended Star:

1. **Scalability:** New floors, switches, or devices can be added without redesigning the whole network.

2. **Centralized Management:** SW-GROUND acts as the aggregation point for all VLANs, simplifying monitoring and troubleshooting.

3. **Fault Isolation:** Failures on one floor do not impact the entire network.

4. **Security Segmentation:** Easier implementation of VLAN-based departmental isolation.

5. **Industry Standard:** Commonly used in enterprise buildings with multiple floors.

Because some floors hosted more than 24 PCs (HR and Sales), switches were cascaded using trunk links, maintaining the extended-star structure.

2.2 LAN Design Description

Every department is assigned a dedicated VLAN. All floor switches connect to **SW-GROUND** using trunk ports that carry all VLANs to the router via **Router-on-a-Stick**.

A Web Server was deployed on the Ground Floor within the Management VLAN (VLAN 99) to host the organization's internal website and provide DNS services for all departments.

An Email Server was also deployed in the Management VLAN (VLAN 99) to provide internal email communication using SMTP and POP3 services.

LAN Components:

- **Ground Floor:** Management, server farm (Web & Email servers), router (R1), and SW-GROUND.

- **1st Floor:** Administration department (VLAN 50).

- **2nd Floor:** Customer Support (VLAN 20).

- **3rd Floor:** Hardware Department (VLAN 30).

- **4th Floor:** HR Department (25 PCs, VLAN 40) using two switches.

- **5th Floor:** Sales Department (27 PCs, VLAN 10) using two switches.

Connections:

- **Each PC** → Its floor switch (access port)

- **Floor switch** → SW-GROUND (trunk)

- **SW-GROUND** → Router (R1 Gi0/0 trunk)

- **SW-GROUND** → Servers (access ports)

- **Router Gi0/1** → Cloud (Internet)

This ensures departmental segmentation, centralized routing, full server access, internet availability.

2.3 IP Addressing Using VLSM (Based on 199.99.99.99/24)

The base network **199.99.99.0/24** was subnetted using VLSM to meet each department's host requirements.

Department	Hosts	Subnet	Usable IP Range	Gateway
Sales (27 PCs)	27	199.99.99.0/27	199.99.99.2–30	199.99.99.1
HR (25 PCs)	25	199.99.99.32/27	199.99.99.34–62	199.99.99.33
Customer Support (16 PCs)	16	199.99.99.96/27	199.99.99.98–126	199.99.99.97

Administration (10 PCs)	10	199.99.99.128/28	199.99.99.130–142	199.99.99.129
Hardware (20 PCs)	20	199.99.99.160/27	199.99.99.162–190	199.99.99.161
Management/Servers	N/A	199.99.99.144/28	Server IPs assigned	199.99.99.145

All PCs used:

- **Subnet Mask:** Based on subnet

- **DNS Server:** 199.99.99.146 (Web Server)

- **Default Gateway:** VLAN sub-interface on R1

This method eliminated address waste and provided future scalability.

(i). Dynamic Address Allocation Using DHCP

To automate IP configuration for all departments, DHCP services were deployed on Router R1 using router-based DHCP pools. Each pool corresponds to a departmental VLAN and defines the subnet, default gateway, and DNS server. R1 also maintains DHCP bindings, ensuring each workstation receives a valid IP address consistent with its VLAN. This centralized DHCP design eliminates manual configuration, reduces addressing errors, and supports organizational scalability.

2.4 Routing Strategy and Protocol Justification

Routing Strategy: Router-on-a-Stick (Inter-VLAN Routing)

Because all departments are separated by VLANs, inter-department communication required routing. Instead of multiple physical router interfaces, **sub-interfaces** were used:

Example:

Gi0/0.10 for VLAN 10 (Sales), Gi0/0.20 for VLAN 20 (Customer Support)

Routing Protocol Choice: Static Routing

Justification:

1. **Simple Architecture:** Only one router (R1) is performing inter-VLAN routing.

2. **No need for dynamic routing protocols**

3. **Better security:** No automatic route learning.

4. **Full administrative control** over routing paths.

To improve scalability and reduce administrative overhead, DHCP (Dynamic Host Configuration Protocol) was implemented on the main router (R1). Since R1 handles all inter-VLAN routing, it has visibility of all department subnets, making it the ideal centralized DHCP server. DHCP pools were configured for each subnet created using VLSM, with gateway and DNS settings assigned automatically. Gateway IPs were explicitly excluded to prevent address conflicts. This automated addressing approach eliminates manual IP assignment, prevents configuration errors, and supports rapid future expansion of the enterprise network.

2.5 Role of MAC Addresses in the LAN

MAC addresses are essential for LAN communication, especially in Ethernet networks.

Importance of MAC Addresses:

- **Layer-2 Identification:** Every network interface card (NIC) uses its MAC address to communicate within a LAN.

- **Switch Learning:** Switches use MAC addresses to populate MAC tables, enabling efficient frame forwarding.

- **Broadcast/ARP Mechanisms:** Devices use ARP to map IP addresses to corresponding MAC addresses.

- **Collision/Loop Avoidance:** Protocols such as STP operate at Layer-2 and rely on MAC addresses.

Without MAC addressing, switches could not determine where to forward Ethernet frames, making LAN communication impossible.

3. Hardware Description and Justification

3.1 Routers Cisco 1941 Router (R1)

- Supports sub-interfaces for VLAN routing.

- Offers high performance for inter-VLAN communication.

- Includes GigabitEthernet ports supporting trunking and cloud connectivity.

3.2 Switches (Cisco 2960 Series)

- 24 FastEthernet ports used for PC connections.

- 2 GigabitEthernet uplink ports used for trunk links.

- VLAN-capable Layer 2 switching, essential for segmentation.

- Used multiple switches on Software and Sales floors due to >24 PCs.

3.3 Servers

- **Web Server:** Configured to host the enterprise website and act as the DNS server, enabling name-based access to internal services such as email and web applications.

- **Email Server:** Configured to support enterprise email communication, allowing users from all VLANs to exchange messages using domain-based addressing.

3.4 Cloud-PT Device

- Simulates external Internet networks.

- Provides Ethernet interface for default gateway connection.

- Essential for testing real-world connectivity.

3.5 Cabling

- **Copper Straight-Through Cables:** For PC-to-switch and switch-to-server connections.

- **Copper Cross-Over Cables:** For switch-to-switch trunk links.

- **Serial or Ethernet (on Cloud):** For Internet simulation.

Hardware Justification

- **Cisco devices** follow universal commands used in real industry.

- **2960 switches** are ideal for academic and enterprise Layer-2 environments.

- **1941 router** is stable and widely supported in inter-VLAN and static routing configurations.

- Router R1 also functions as a centralized **DHCP server**. This eliminates the need for additional physical servers and simplifies addressing administration for all VLANs.

- **Extended star topology compatibility** with chosen hardware ensures scalability and high availability.

4. Conclusion and Recommendations

This project successfully designed and implemented a complete enterprise LAN across five floors, integrating VLAN segmentation, VLSM subnetting, trunk-based interconnection, and router-on-a-stick routing. Each department received its own IP subnet, dedicated VLAN, and secure segmentation, while maintaining full connectivity with the server farm and Internet.

The network demonstrated:

- Efficient and scalable IP address management

- Logical separation of departments

- Centralized routing with full inter-VLAN communication

- Strong hierarchical design

- Accurate troubleshooting and verification

The inclusion of DHCP significantly enhanced network manageability by automating IP addressing for all hosts, further improving scalability and reducing the likelihood of configuration errors.

Issues Resolved During Implementation

- VLANs missing on SW-GROUND caused ping failures → resolved by creating VLANs on the core switch.

- Trunk ports not carrying VLANs → fixed with correct allowed VLAN lists.

- Cloud not reachable → resolved by configuring proper IP on Cloud Ethernet6.

- Switch port limitations → solved by cascading additional switches with trunk links.

- Incorrect subnet assignments → fixed by recalculating VLSM.

- Email client configuration errors due to incorrect domain and user format → resolved by correctly configuring the Email Server domain, user accounts, and DNS records.

Recommendations

- Implement **DHCP servers** to automate future IP assignments.

- Add **redundant uplinks** between floors for high availability.

- Use **Layer-3 switches** for faster inter-VLAN routing in large environments.

- Document future changes using a change-management process.

Overall, the network meets all organizational requirements and provides a professional, scalable, and secure solution suitable for enterprise-level operations.

- Add **redundant uplinks** between floors for high availability.