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Abstract

This project presents the design and implementation of a scalable enterprise Voice over IP (VoIP) network infrastructure for Turtle Consultancy Limited. Due to organizational expansion and increasing communication demands, the company required a modern, integrated communication system capable of handling both voice and data traffic efficiently.

The proposed solution replaces traditional telephony systems with an IP-based communication model that integrates voice services into the existing data network. The network connects four departments—Finance, Human Resources, Sales, and ICT—while maintaining traffic segmentation, high performance, and scalability.

The implementation includes VLAN segmentation, structured IP addressing and subnetting, router-on-a-stick inter-VLAN routing, OSPF dynamic routing protocol, centralized server services, Call Manager Express (CME) for IP telephony, and dial-peering configuration for inter-department VoIP communication.

This project demonstrates practical enterprise-level networking concepts and provides a cost-effective, flexible, and future-ready communication solution.

Introduction

Communication systems are critical components of modern organizations. Traditional Public Switched Telephone Network (PSTN) systems rely on circuit-switched architecture and require separate physical infrastructure for voice transmission. These systems are costly, less scalable, and inefficient for growing enterprises.

Voice over IP (VoIP) technology enables voice communication to be transmitted as digital data packets over IP networks. This approach eliminates the need for separate voice infrastructure and allows organizations to integrate voice, data, and other services into a unified network.

The purpose of this project is to design and implement a fully functional enterprise VoIP network that supports multiple departments while ensuring:

- Scalability
- Reliability
- Performance optimization
- Logical traffic separation
- Centralized service management

The implementation was carried out using Cisco Packet Tracer to simulate real-world enterprise networking practices.

Problem Statement

Turtle Consultancy Limited is expanding and requires a complete network infrastructure for a newly acquired branch office. The organization must support:

- 4 Departments
- 40 IP Phones
- 40 Desktop PCs
- 4 Printers
- 4 Servers

The IT Manager requires:

- Integration of voice and data on a single infrastructure
- Separation of voice and data traffic
- Efficient IP addressing and subnetting
- Inter-department communication
- Secure remote management
- Scalable and dynamic routing

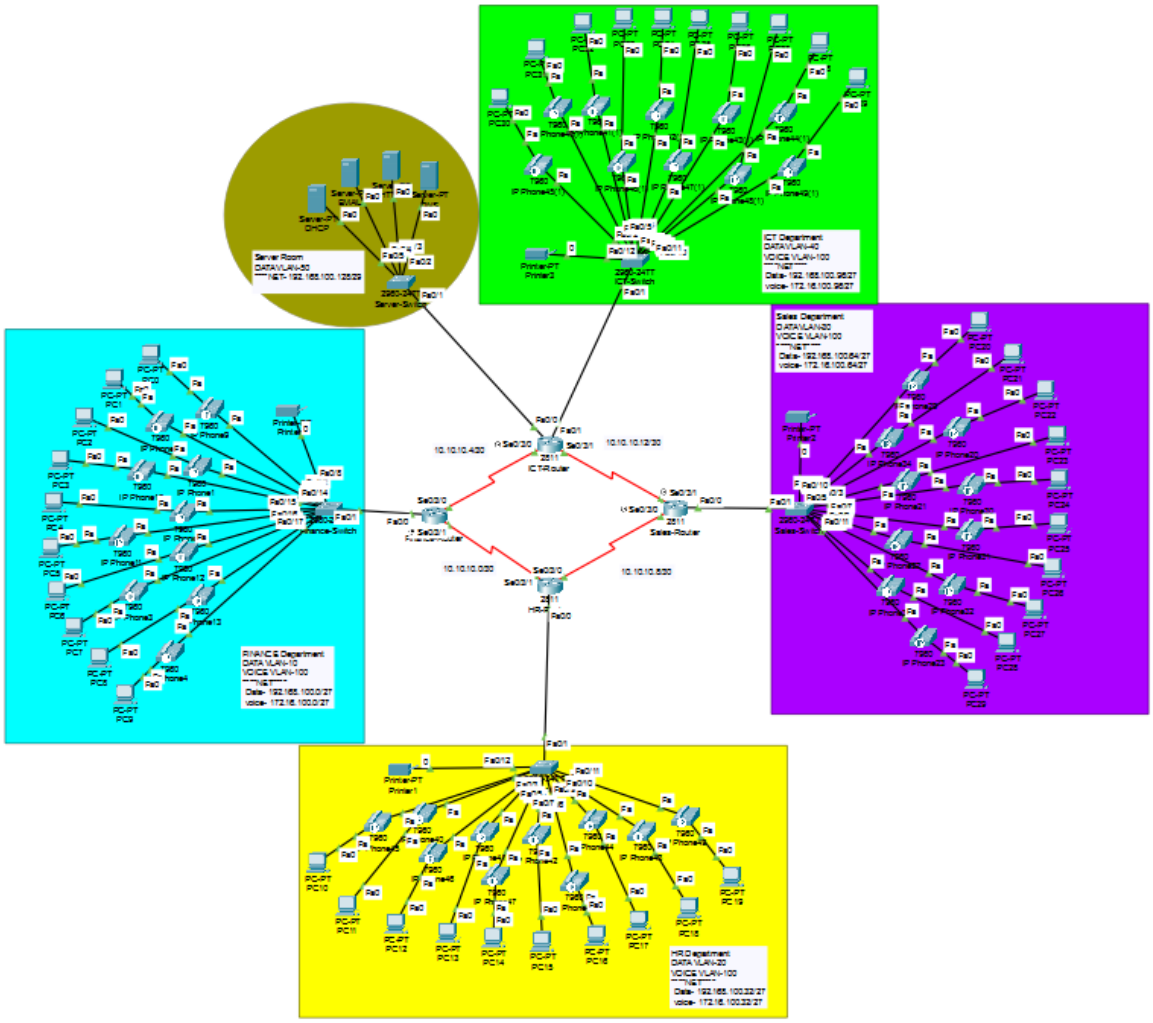
Traditional telephony solutions are expensive and inefficient. Therefore, a VoIP-based enterprise solution is required.

Project Objectives

The main objectives of this project are:

1. To design a scalable enterprise network architecture.
2. To implement VoIP services using Call Manager Express.
3. To separate voice and data traffic using VLAN technology.
4. To configure structured subnetting for efficient IP utilization.
5. To implement router-on-a-stick inter-VLAN routing.
6. To configure OSPF dynamic routing protocol.
7. To enable inter-department voice communication using dial-peering.
8. To deploy centralized server services (DHCP, DNS, Email, HTTP).
9. To implement secure remote access using SSH.
10. To test and verify full network functionality.

“Enterprise Network Topology Architecture”



The above figure illustrates the complete enterprise network topology including departmental segmentation, VLAN implementation, WAN connectivity, and centralized server deployment.

Network Requirements

Departments

- Finance Department
- Human Resources Department
- Sales Department
- ICT Department

Each department includes:

- 10 IP Phones
- 10 PCs
- 1 Printer

Additionally:

- 4 Servers located in the ICT/server site
- Serial connections between routers
- Straight-through cables for LAN connections

Network Design Overview

The network follows a hierarchical enterprise model:

- Access Layer → Cisco 2960 Switches
- Routing & VoIP Layer → Cisco 2811 Routers
- Server Layer → Centralized Services

Each department contains:

- One access switch
- One VoIP-enabled router
- End devices (PCs + IP phones + printers)

Routers are interconnected using point-to-point serial WAN links.

IP Addressing & Subnetting Design

1. Data Network

Base Network: 192.168.100.0/24
Subnet Mask Used: /27

Each department was allocated a /27 subnet providing 30 usable IP addresses.

Example:

Finance: 192.168.100.0/27
HR: 192.168.100.32/27
Sales: 192.168.100.64/27
ICT: 192.168.100.96/27

Reason for /27:

- 21 required devices per department
- Reduced broadcast domain
- Future expansion support

2. Server Network

Subnet: 192.168.100.128/29

Reason for /29:

- Only 4 servers required
- Efficient IP utilization
- Static addressing

3. Voice Network

Base Network: 172.16.100.0/24
Subnet Mask: /27 per department

Voice traffic is logically separated from data traffic to improve:

- Call quality
- Network performance
- Security

4. WAN Network

Base Network: 10.10.10.0
Subnet Mask: /30

Used for point-to-point router connections.
Reason: Only two hosts are required per link, minimizing IP wastage.

VLAN Design

Each department uses:

- One Data VLAN
- VLAN 100 (Voice VLAN)

Purpose of VLANs:

- Logical network segmentation
- Reduced broadcast traffic
- Improved security
- Better VoIP performance

All IP phones were assigned to VLAN 100 across the network.

Inter-VLAN Routing

Router-on-a-stick architecture was implemented.

Each router interface was divided into subinterfaces using 802.1Q encapsulation.

Purpose:

- Enables communication between VLANs
- Allows PCs to access servers
- Allows phones to communicate

Reason for choosing router-on-a-stick:

- Cost-effective
- Suitable for medium-sized enterprise
- Easy to implement

DHCP Implementation

Data DHCP

- Provided by centralized DHCP server
- Routers use IP helper-address to forward requests

Purpose:

- Centralized management
- Simplified IP allocation

Voice DHCP

- Provided by departmental routers
- Includes DHCP Option 150

Purpose:

- IP phones automatically locate Call Manager
- Ensures automatic registration

VoIP Implementation (Call Manager Express)

Each router was configured with Call Manager Express (CME).

Functions:

- Registers IP phones
- Assigns extensions
- Controls call setup
- Manages dial plan

Extension Scheme:

Finance → 101–199
HR → 201–299
Sales → 301–399
ICT → 401–499

Dial-Peering Configuration

Dial-peering was implemented to enable inter-department communication.

Purpose:

- Routes calls between routers
- Matches dial patterns
- Forwards calls to correct destination

Without dial-peering:

- Calls would only work locally

Routing Protocol (OSPF)

OSPF was configured on all routers.

Reasons for choosing OSPF:

- Fast convergence
- Scalable
- Industry standard
- Efficient route calculation

OSPF advertises:

- Data networks
- Voice networks
- WAN networks

Security Implementation

Basic security configurations included:

- Hostnames
- Encrypted passwords
- Banner messages
- Disable IP domain lookup
- SSH configuration

Reason for SSH:

- Secure encrypted remote access
- Prevents password sniffing

Testing & Verification

The following tests were performed:

- PCs obtained IP addresses
- Phones registered with CME
- Inter-VLAN communication successful
- Inter-department calls successful
- Servers reachable from all departments
- OSPF neighbors established

All network functionalities operated as expected.

Challenges Faced

- VLAN trunk configuration issues
- Dial-peer misconfiguration
- OSPF adjacency troubleshooting
- DHCP option 150 configuration errors

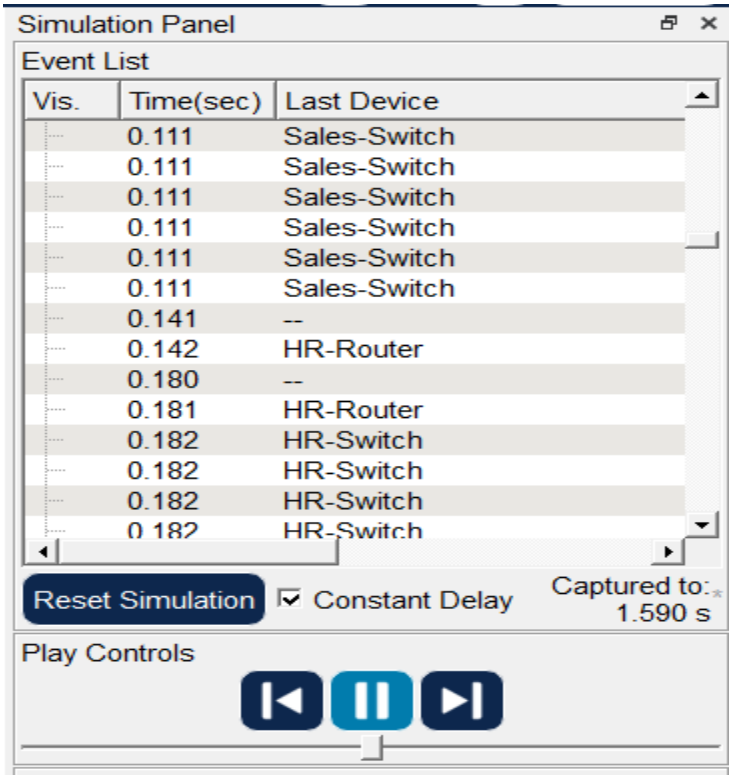
These were resolved through verification commands and systematic debugging.

RESULTS: **(Ringing From 207 to 110)**

(Received At 110 From 207)

(After Pick Receiver Call connected Successfully, Now you can communicate)

(Packets Analysis)



Future Improvements

- Implementation of QoS for traffic prioritization
- Redundant routers for high availability
- Firewall integration
- Wireless VoIP support
- Cloud-based Call Manager

Conclusion

This project successfully demonstrates the design and implementation of a scalable enterprise VoIP infrastructure. By integrating voice and data into a unified IP network, the solution provides cost efficiency, flexibility, and high performance.

The use of VLAN segmentation, structured subnetting, router-on-a-stick inter-VLAN routing, OSPF dynamic routing, Call Manager Express, and dial-peering ensures reliable and seamless communication across departments.

The project reflects real-world enterprise networking practices and highlights the practical application of computer networking concepts.

References

- Cisco Networking Academy Materials
- VoIP Fundamentals Documentation
- OSPF Protocol Documentation
- DHCP & VLAN Configuration Guides

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