**Learning Outcome 3: Design Efficient Networked Systems – Vocational Project Tutorial**

**Scenario Overview: TechSolutions Ltd. Network Expansion Project**

**Background**

TechSolutions Ltd. is a medium-sized IT consultancy based in Birmingham, providing services in **network infrastructure design**, **cybersecurity**, and **cloud integration**. The company has experienced rapid growth and is expanding into a **new headquarters** with multiple departments and a **remote satellite office** in Manchester.

As part of the expansion, the company’s senior network architect has tasked you — a **junior network engineer** — with designing, configuring, and documenting a complete **secure, scalable network solution** using **Cisco Packet Tracer**.

This project simulates a **real client deployment** where you must:

* Design the network architecture,
* Configure all core services and routing,
* Apply security controls,
* Produce documentation and test reports.

**Current Situation**

The new headquarters is divided into three operational departments and includes an external guest Wi-Fi area.  
A small remote office connects via a router-to-router link, and plans are in progress to enable VPN access for remote workers.

The existing IT setup is limited — most configurations are manual, there is no VLAN segmentation, and DHCP/DNS are not automated.  
The new system must address these shortcomings while supporting **future scalability**.

**Network Environment Overview**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Department** | **Devices** | **Function** | **Typical Applications** | **Sensitivity** |
| Administration | 10 PCs | Finance, HR, internal admin | ERP, email, VoIP | High |
| Technical | 15 PCs | Development, testing, client projects | File servers, remote lab access | Medium |
| Guest | 5 wireless users | Visitors and clients | Web access only | Low |
| Remote Office | 1 router + 3 PCs | Remote branch | File sharing, reports | Medium |
| Remote Workers (Future) | VPN users | Offsite staff | Secure remote access | High |

**Project Requirements**

**Functional Requirements**

Your network design must:

1. Provide full IP connectivity between internal departments and the remote office.
2. Use **subnetting** to efficiently divide the address space 192.168.10.0/24.
3. Implement **DHCP** and **DNS** services for automated IP management.
4. Use **VLANs** to logically separate departments.
5. Enable **inter-VLAN routing** through a router or Layer 3 switch.
6. Implement **Access Control Lists (ACLs)** to restrict guest network access.
7. Ensure the network is **secure, efficient, and scalable** for at least 30% future growth.

**Security Requirements**

* Departmental networks must be isolated using VLANs.
* Guest users must not have access to internal servers or other VLANs.
* Devices should use DHCP for address allocation to prevent static conflicts.
* Administrative access to routers and switches should be password protected (optional advanced extension).

**Documentation Requirements**

You must produce:

* A **network topology diagram** (physical and logical).
* An **IP addressing plan**.
* A **configuration record** (with line-by-line commands).
* A **testing log** showing verification results.
* A **brief evaluation report** explaining how the solution meets requirements.

**🎯 Learning Objectives**

By completing this vocational project, you will be able to:

1. Analyse organisational requirements and design an efficient network structure.
2. Apply subnetting and IP allocation to support scalability.
3. Configure DHCP, DNS, routing, and VLANs using Cisco Packet Tracer.
4. Implement “secure-by-design” principles using ACLs.
5. Test and evaluate a professional network implementation.

**Activity 1 – Requirements Analysis and Bandwidth Planning**

**Descriptive Text**

Before configuring any hardware, engineers must conduct a **network requirements analysis** to determine what the business needs the network to support.  
Bandwidth, scalability, and security are key performance factors.

**Analytical Text**

The number of users, types of applications, and expected traffic patterns determine how much bandwidth the network must provide. Overestimating increases cost; underestimating leads to poor user experience.

**Task 1.1 – Estimate Departmental Bandwidth**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Department** | **Users** | **Avg/User** | **Peak/User** | **Peak Total** | **Tasks** |
| Admin | 10 | 2 Mbps | 3 Mbps | 30 Mbps | ERP, VoIP, email |
| Technical | 15 | 5 Mbps | 8 Mbps | 120 Mbps | File sharing, virtual labs |
| Guest | 5 | 1 Mbps | 2 Mbps | 10 Mbps | Web browsing |

**Total uplink requirement:** 160 Mbps × 1.2 = **192 Mbps**

**Task 1.2 – Define Design Constraints**

* Fibre Internet available at 500 Mbps maximum.
* Budget limits network to **one core router**, **three departmental switches**, and **one central server**.
* All internal IPs must originate from **192.168.10.0/24**.
* Network must support an additional **20% user growth**.

**Activity 2 – Subnetting and IP Addressing Scheme**

**Descriptive Text**

Subnetting divides a single address range into logical segments, allowing departments to operate independently. It improves performance and isolates broadcast domains.

**Analytical Text**

Subnetting for TechSolutions Ltd. must provide at least three subnets now and one for future growth. Using /26 provides 62 hosts per subnet — enough for each department with room to expand.

**Task 2.1 – Subnet Calculation**

**Base Network:** 192.168.10.0/24  
Borrow 2 bits → 4 subnets → **Mask 255.255.255.192 (/26)**

| **Subnet** | **Range** | **Broadcast** | **VLAN** | **Department** |
| --- | --- | --- | --- | --- |
| 192.168.10.0/26 | .0–.63 | .63 | 10 | Admin |
| 192.168.10.64/26 | .64–.127 | .127 | 20 | Technical |
| 192.168.10.128/26 | .128–.191 | .191 | 30 | Guest |
| 192.168.10.192/26 | .192–.255 | .255 | 40 | Future/Remote |

**Activity 3 – DHCP and DNS Services**

**Descriptive Text**

DHCP and DNS simplify administration. DHCP allocates IPs automatically; DNS resolves names to addresses.

**Analytical Text**

Manually assigning IPs across multiple subnets is inefficient. DHCP ensures consistency and rapid configuration, while DNS supports internal name resolution.

**Task 3.1 – Configure DHCP**

**Server Setup**

# Assign static IP to the DHCP/DNS Server

Server> ip 192.168.10.2 255.255.255.192 192.168.10.1

# Enable DHCP service and add a pool

Services > DHCP > ON

Pool Name: AdminLAN

Default Gateway: 192.168.10.1 # Router for Admin VLAN

DNS Server: 192.168.10.2 # Same local server

Start IP: 192.168.10.10

Subnet Mask: 255.255.255.192

Max Users: 50

**Task 3.2 – Configure DNS**

# Enable DNS service on same server

Services > DNS > ON

# Add host records for local devices

router.techsolutions.local → 192.168.10.1

server.techsolutions.local → 192.168.10.2

# Test DNS from an Admin PC

PC> ping server.techsolutions.local

# Should resolve to 192.168.10.2

**Activity 4 – Routing Configuration**

**Descriptive Text**

Routers link networks and direct packets between them.  
**Static routing** offers full control, while **dynamic routing** automates updates in growing networks.

**Analytical Text**

TechSolutions Ltd. will start with static routes but will later test RIPv2 for scalability between the HQ and remote office.

**Task 4.1 – Configure Static Routing**

**Router 1 (Admin Router)**

Router> enable

Router# configure terminal

# Configure local interface

Router(config)# interface fa0/0

Router(config-if)# ip address 192.168.10.1 255.255.255.192

Router(config-if)# no shutdown # Activate interface

# Configure link to Router2 (Tech)

Router(config)# interface s0/0/0

Router(config-if)# ip address 10.0.0.1 255.255.255.252

Router(config-if)# no shutdown

# Add static routes to other subnets

Router(config)# ip route 192.168.10.64 255.255.255.192 10.0.0.2 # Technical

Router(config)# ip route 192.168.10.128 255.255.255.192 10.0.0.6 # Guest

**Task 4.2 – Configure RIPv2 (Dynamic Routing)**

Router(config)# router rip

Router(config-router)# version 2

Router(config-router)# network 192.168.10.0

Router(config-router)# network 10.0.0.0

Router(config-router)# no auto-summary

**Verification:**

Router# show ip route

# Other subnets should appear marked with 'R'

**Activity 5 – VLANs and Inter-VLAN Routing**

**Descriptive Text**

VLANs logically separate devices on the same switch into independent domains.  
A trunk port carries multiple VLANs using **802.1Q encapsulation**.

**Analytical Text**

VLANs mirror real business divisions, allowing security policies to differ by department. Using **Router-on-a-Stick**, one router interface can route between all VLANs.

**Task 5.1 – Configure VLANs on Switch**

Switch> enable

Switch# configure terminal

# Create VLANs

Switch(config)# vlan 10

Switch(config-vlan)# name Admin

Switch(config)# vlan 20

Switch(config-vlan)# name Technical

Switch(config)# vlan 30

Switch(config-vlan)# name Guest

Switch(config)# vlan 40

Switch(config-vlan)# name Remote

**Task 5.2 – Assign Ports**

# Admin VLAN

Switch(config)# interface fa0/1

Switch(config-if)# switchport mode access

Switch(config-if)# switchport access vlan 10

Switch(config-if)# description Admin-PC

# Technical VLAN

Switch(config)# interface fa0/2

Switch(config-if)# switchport mode access

Switch(config-if)# switchport access vlan 20

Switch(config-if)# description Tech-PC

# Guest VLAN

Switch(config)# interface fa0/3

Switch(config-if)# switchport mode access

Switch(config-if)# switchport access vlan 30

Switch(config-if)# description Guest-PC

**Task 5.3 – Configure Trunk and Router-on-a-Stick**

**On Switch**

Switch(config)# interface fa0/24

Switch(config-if)# switchport mode trunk

Switch(config-if)# switchport trunk encapsulation dot1q

Switch(config-if)# switchport trunk allowed vlan 10,20,30,40

Switch(config-if)# description Trunk-to-Router

**On Router**

Router> enable

Router# configure terminal

# Subinterfaces for VLANs

Router(config)# interface g0/0.10

Router(config-subif)# encapsulation dot1Q 10

Router(config-subif)# ip address 192.168.10.1 255.255.255.192

Router(config-subif)# description Admin VLAN Gateway

Router(config)# interface g0/0.20

Router(config-subif)# encapsulation dot1Q 20

Router(config-subif)# ip address 192.168.10.65 255.255.255.192

Router(config-subif)# description Technical VLAN Gateway

Router(config)# interface g0/0.30

Router(config-subif)# encapsulation dot1Q 30

Router(config-subif)# ip address 192.168.10.129 255.255.255.192

Router(config-subif)# description Guest VLAN Gateway

Router(config)# interface g0/0.40

Router(config-subif)# encapsulation dot1Q 40

Router(config-subif)# ip address 192.168.10.193 255.255.255.192

Router(config-subif)# description Remote VLAN Gateway

# Enable interface

Router(config)# interface g0/0

Router(config-if)# no shutdown

**Activity 6 – Security by Design (Access Control Lists)**

**Descriptive Text**

ACLs control which traffic is permitted or denied between networks. They are essential for enforcing company security policy.

**Analytical Text**

The guest network should only access the Internet, not internal systems.  
Applying an ACL inbound on the Guest VLAN prevents unauthorised access.

**Task 6.1 – Configure ACL**

Router> enable

Router# configure terminal

# Deny Guest VLAN access to internal LANs

Router(config)# access-list 100 deny ip 192.168.10.128 0.0.0.63 192.168.10.0 0.0.0.63

Router(config)# access-list 100 deny ip 192.168.10.128 0.0.0.63 192.168.10.64 0.0.0.63

Router(config)# access-list 100 permit ip any any # Allow Internet access

# Apply ACL inbound on Guest interface

Router(config)# interface g0/0.30

Router(config-if)# ip access-group 100 in

**Activity 7 – Testing, Documentation, and Evaluation**

**Descriptive Text**

Network testing validates design decisions and confirms that configurations meet client requirements.  
Documentation provides a record for maintenance and troubleshooting.

**Analytical Text**

Professional network engineers always document addressing, configurations, and test outcomes. This ensures traceability and supports future upgrades.

**Task 7.1 – Validation Checklist**

| **Test** | **Command** | **Expected Result** |
| --- | --- | --- |
| Inter-VLAN Ping | ping between Admin and Tech PCs | Successful |
| Guest Isolation | ping Admin from Guest PC | Blocked |
| DHCP Function | View PC IP Configuration | Correct addresses assigned |
| DNS Resolution | ping server.techsolutions.local | Resolves |
| ACL Check | show access-lists | Displays ACL 100 applied |
| Routing Table | show ip route | All subnets listed |

**Task 7.2 – Documentation Deliverables**

* **Network diagrams:** logical and physical.
* **Addressing plan:** full table for all devices.
* **Configuration log:** all router/switch commands.
* **Testing record:** evidence of pings, routing, ACL checks.
* **Evaluation summary:** written reflection on performance, scalability, and security.

**Final Reflection**

Through this vocational project, you have designed, implemented, secured, and tested a professional business network from concept to deployment.  
This mirrors real workplace practice where planning, accuracy, and documentation are as critical as technical skill.