CHAPTER 4

NETWORK DESIGN AND IMPLEMENTATION

Compiled by: Tsegaye B.

Network Design Overview

- Computer networks are critical to the success of both large and small businesses.
- Computer networks connect people, support applications and services, and provide access to the resources that keep the businesses running.
- To meet the daily requirements of businesses, networks themselves are becoming quite complex.
- There is a direct correlation between the network design project and the company's business success.
- Network design is the ultimate target of todays networking

Network Requirements

- Today, the Internet-based economy often demands around-the-clock customer service. This means that business networks must be available nearly 100 percent of the time.
- They must be smart enough to automatically protect against unexpected security incidents.
- These business networks must also be able to adjust to changing traffic loads to maintain consistent application response times.
- Computer networks need careful planning and design.

Network Requirements

Businesses have requirements for their network:

- The network should stay up all the time, even in the event of failed links, equipment failure, and overloaded conditions.
- The network should deliver applications and provide reasonable response times from any host to any host.
- The network should be easy to modify to adapt to network growth and general business changes.

Network Requirements

- The network should be secure. It should protect the data that is transmitted over it and data stored on the devices that connect to it.
- Because failures occasionally occur, troubleshooting should be easy. Finding and fixing a problem should not be too time-consuming.

Network Design Methodologies

Large network design projects are normally divided into three distinct steps:

Step 1. Identify the network requirements

Step 2. Characterize the existing network

Step 3. Design the network topology and solutions

Network Design Methodologies

Step 1: Identifying Network Requirements

- In this step, the network designer works closely with the customer to document the goals of the project.
- Goals are usually separated into two categories:
  - **Business goals**: Focus on how the network can make the business more successful
  - **Technical requirements**: Focus on how the technology is implemented within the network

Network Design Methodologies

Step 2: Characterizing the Existing Network

- Information about the current network and services is gathered and analyzed.
- It is necessary to compare the functionality of the existing network with the defined goals of the new project.
- The designer determines whether any existing equipment, infrastructure, and protocols can be reused, and what new equipment and protocols are needed to complete the design.

Network Design Methodologies

Step 3: Designing the Network Topology

- A common strategy for network design is to take a ***top-down approach***.
- In this approach, the network applications and service requirements are identified, and then the network is designed to support them.
- When the design is complete, a prototype is performed.
- This approach ensures that the new design functions as expected before it is implemented.

Building a Good Network

- After the network requirements have been identified, the steps to design a good network are followed as the project implementation moves forward.
- Network users generally do not think in terms of the complexity of the underlying network. They think of the network as a way to access the applications they need, when they need them.
- Good networks do not happen by accident.
- They are the result of hardworking by network designers and technicians, who identify network requirements and select the best solutions to meet the needs of a business

Good Network Designs should:

- Deliver services requested by users
- Deliver acceptable throughput and response times
- Be within budget and maximise cost efficiencies
- Be reliable
- Be expandable without major redesign
- Be manageable by maintenance and support staff
- Be well documented

What to be considered?

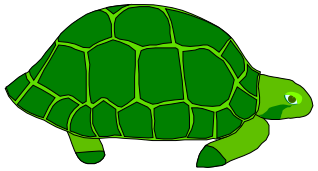
- **Connections**:
  - Provided by Hardware that ties things together.
  - Wires/Wireless, Routers, Switches/Hubs, Computers, Bridges, etc.
- **Communications/Protocols**:
  - Provided by Software
  - A common language for two systems to communicate with each other

    TCP/IP (Internet/Windows), IPX/SPX (Novell Netware 4), AppleTalk, Other NOS
- **Services/Application**:
  - The Heart of Networking .
  - Cooperation between two or more systems to perform some function.
  - Applications such as Telnet, FTP, HTTP, SMTP

What to be considered?

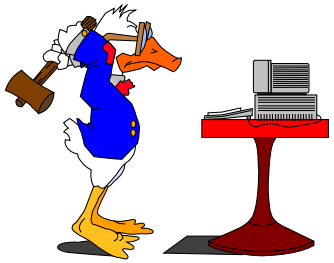
- To build a well-balanced network, a number of factors must be taken into consideration
  - Desired network size (number of machines)
  - Layout/Topology
  - Amount of current traffic
  - Future traffic expectations
  - Security requirements
- Base on these factors, a flexible solution with budget and with sufficient room for expansion can be designed

Network Design: Achievable?



Response Time

Cost



Reliability

Business Growth

Types of Network Design

- New network design
- Re-engineering a network design
- Network expansion design

New Network Design

- Starting from scratch
- Major driver is the budget
- no compatibility issues to worry about
- Getting harder to find these situations

Methodologies

- Planning/Feasibility study
- Study Existing Situation
- Rough proposal of the designed network
- Requirements Analysis
- Design
- Specification of network items and Procurement (Buying items)
- Implementation (Installations and Administration)

Re-engineering a Network Design

- Modifications to an existing network to compensate for original design problems
- Sometimes required when network users change existing applications or functionality
- More of the type of problems seen today

Network Expansion Design

- Network designs that expand network capacity
- Technology upgrades
- Adding more users or networked equipment

Fundamental Design Goals

The four fundamental network design goals are:

- **Scalability**: Scalable network designs can grow to include new user groups and remote sites and can support new applications without impacting the level of service delivered to existing users.
- **Availability**: A network designed for availability is one that delivers consistent, reliable performance, 24 hours a day, 7 days a week. In addition, the failure of a single link or piece of equipment should not significantly impact network performance.

Fundamental Design Goals

- **Security**: Security is a feature that must be designed into the network, not added on after the network is complete. Planning the location of security devices, filters, and firewall features is critical to safeguarding network resources.
- **Manageability**: No matter how good the initial network design is, the available network staff must be able to manage and support the network. A network that is too complex or difficult to maintain cannot function effectively and efficiently.

Network Design Phase

- A topology design is defined as the identification of networks and their interconnection points, the size and the scope of the network, and the type of interconnecting devices used.
- The network designer's task is to develop the physical and logical design of the network project.
- Two phases in Network design
  - Physical Network Design
  - Logical Network Design

Physical Network Design

- The physical design of the network is concerned with the identification of LAN and WAN technologies and network devices that are supposed to realize the performance of the logical design at large.
- During the physical design phase, the network designer is responsible for selecting devices such as cabling, wires, switches, bridges, routers, wireless access point and others.

Logical Network Design

- The logical design phase is a foundation for the physical network design, and it is where the designer develops a hierarchical and modular network.
- The logical design phase includes designing of network layer addressing, selection of switching and routing protocols, security planning and network management design.

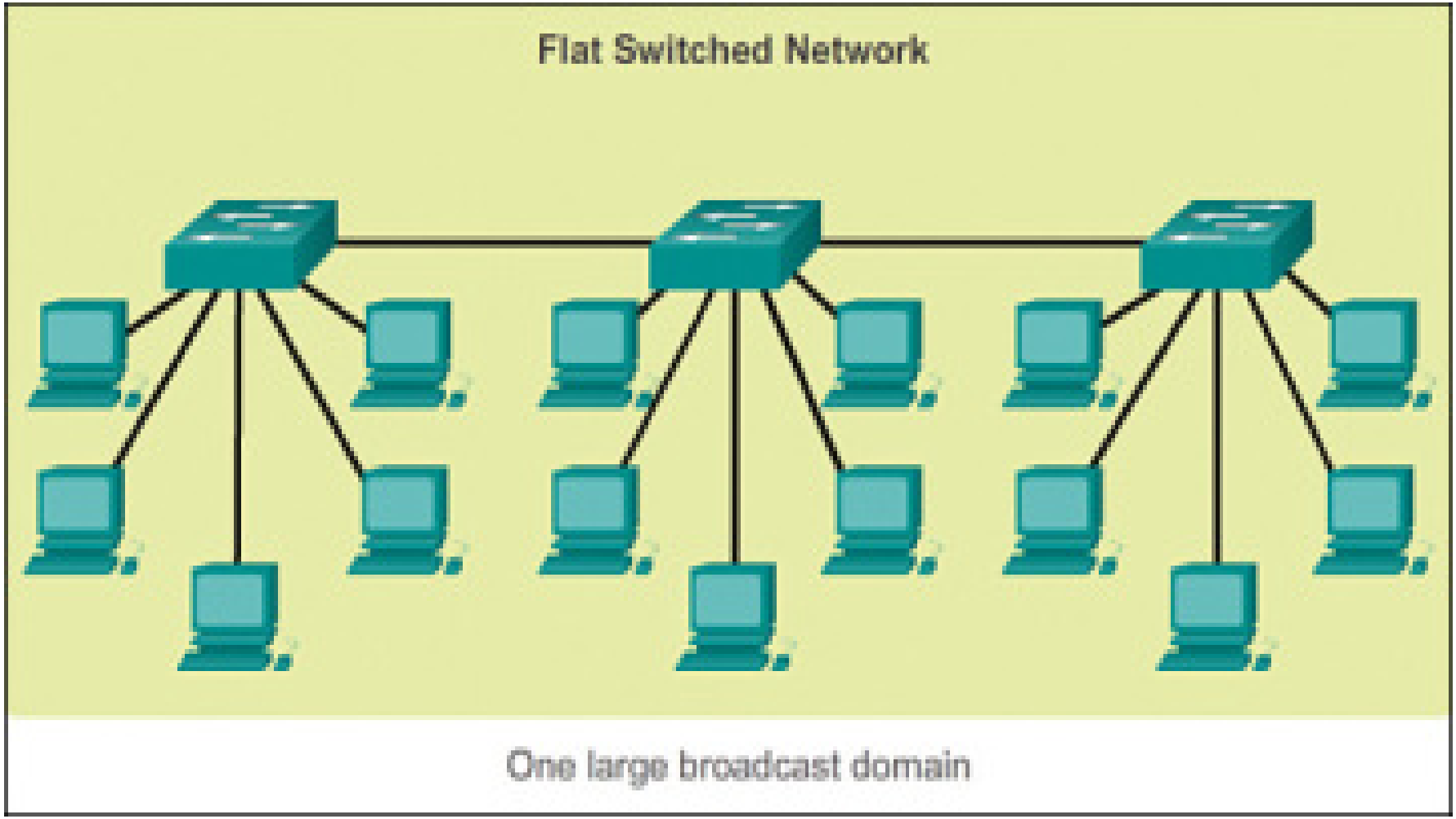
Network Design Topology

- Flat Network Design
- Hierarchical Network Design

Flat Network Design

- A flat network topology is an unstructured type of network designing , which is adequate in designing a small-sized network.
- It is a non-hierarchical designing model where each inter-networking device performs the *same task*.
- This model is easy to plan, design and implement for small-sized networks but it would be difficult to scale up the network when a need for growth arises.
- lack of hierarchy makes network troubleshooting and expansion difficult.

Flat Network Design



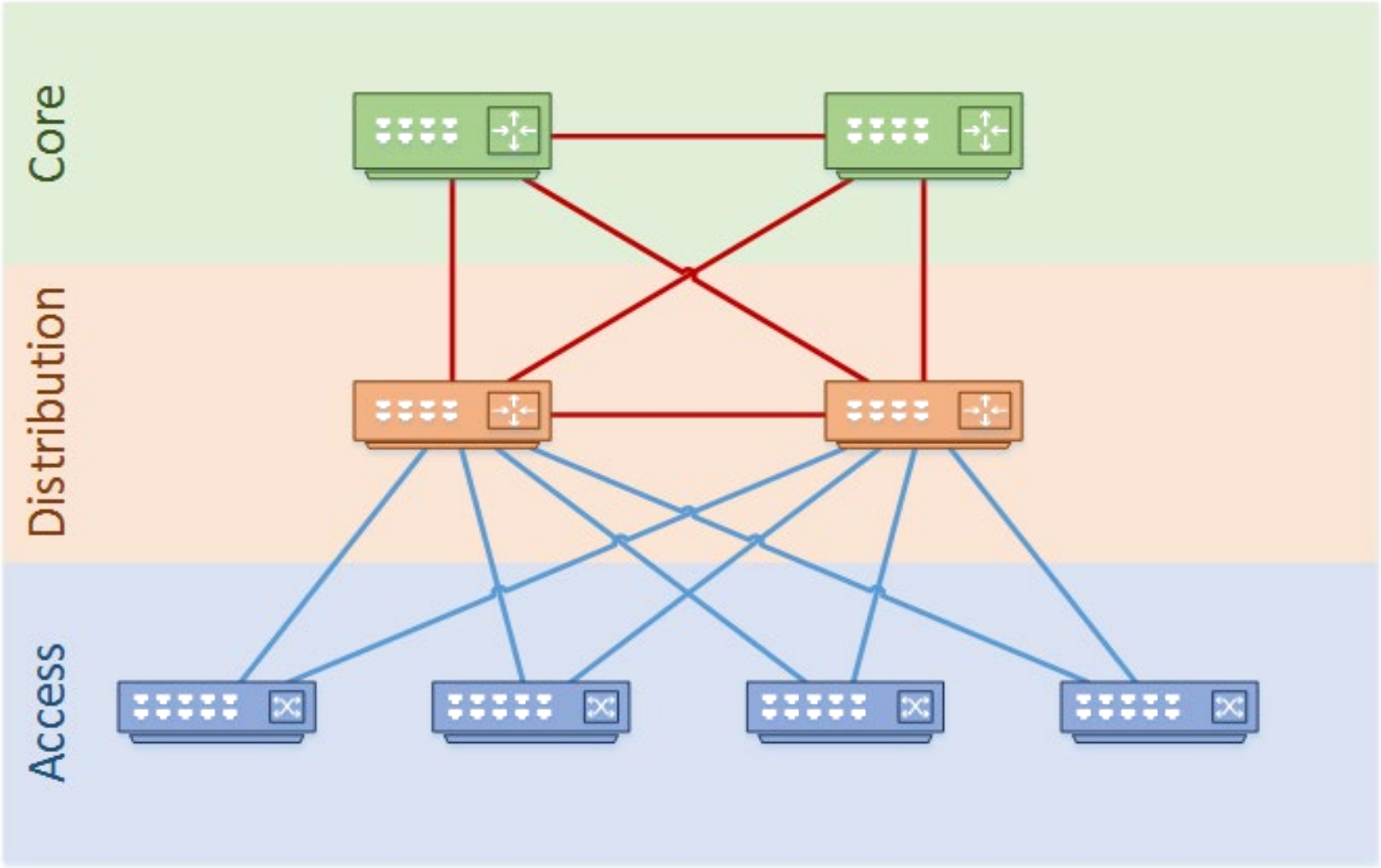
Flat Network Design

- Devices in flat network design belongs to the same broadcast domain and shares the same bandwidth together, and receives a copy of every message sent.
- In the case of link failure, it is difficult to get an alternative path to the destination.

Hierarchical Network Design

- Hierarchical model is a three-layer modular and structural design technique used to design a LAN or WAN network.
- Hierarchical model design has three layers, namely Core, Distribution and Access layers,
- Each layer has its own functions and they are built using network devices like routers or switches or combined in single device.

Hierarchical Network Design



Hierarchical Network Design

Advantages in using a hierarchical model of designing a network are

- bring cost saving
- Scalability
- Flexibility
- Adaptability
- Simplicity
- improved
- fault isolation and
- easer network manageability.

Advantage of Hierarchical Network Model

- **High Performance:** You can design high performance networks, where only certain layers are susceptible to congestion.
- **Efficient management & troubleshooting:** Allows you to efficiently organize network management and isolate causes of network trouble.
- **Policy creation:** You can easily create policies and specify filters and rules.
- **Scalability:** You can grow the network easily by dividing your network into functional areas.
- **Behavior prediction:** When planning or managing a network, the model allows you determine what will happen to the network when new stresses are placed on it.

Hierarchical Network Design Layers

- In networking, a hierarchical design is used to group devices into multiple networks. The networks are organized in a layered approach. The hierarchical design model has three basic layers:

- Access Layer
- Distribution Layer
- Core Layer

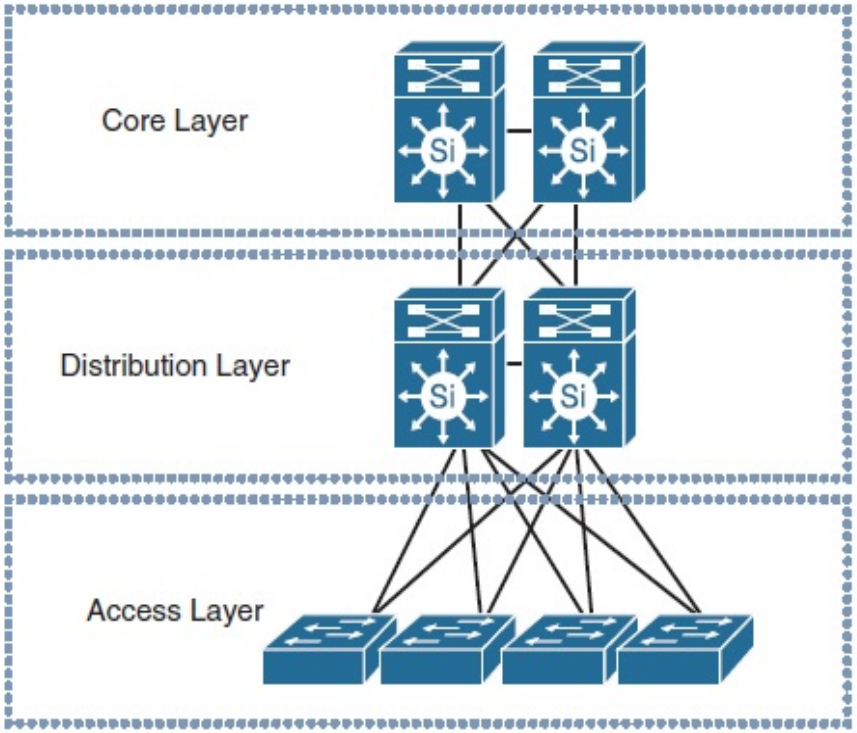
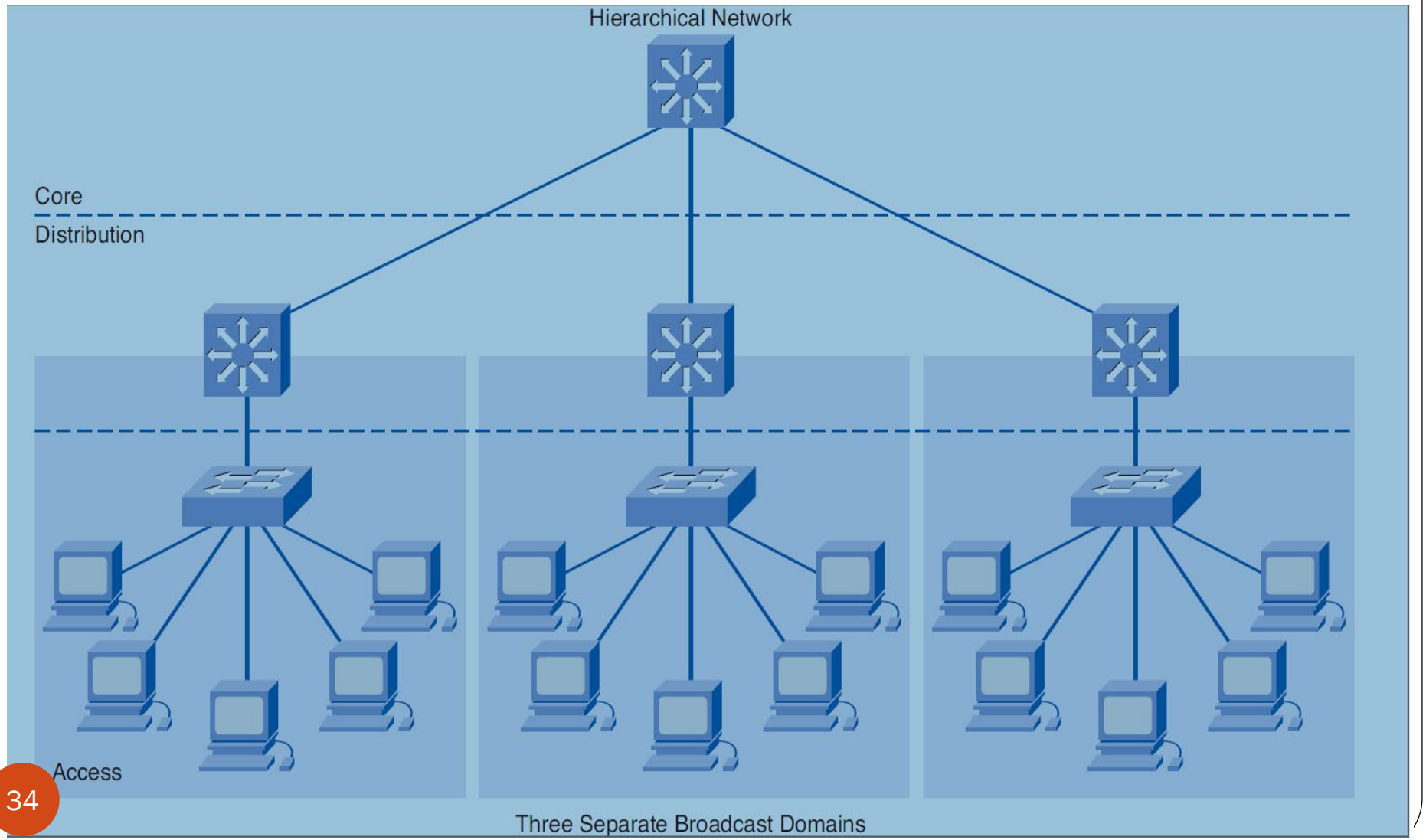


Figure 3-1 *Three-Tier Network Design Model*

Hierarchical Network Design



Core layer

- A core layer is a high-speed switching backbone responsible for interconnecting distribution layer devices.
- This layer aggregates traffic from all distribution layer devices and is responsible for forwarding a large amount of data with a high speed over the network.
- This layer is considered the backbone of the network and includes the high-end Router/switches and high-speed cables such as fiber cables.
- High-end routers and switches that are optimized for availability and speed

Core layer

- no packet manipulation is done by devices in this layer.
- This layer is concerned with speed and ensures reliable delivery of packets.
- The core layer needs to be highly reliable and fault tolerant. This happens by establishing a full mesh redundancy link between the core layer routers and between the distribution layer routers and vice versa.
- It is necessary to have backup power supplies in case of power failures.

Goals of the Core Layer

- The core layer design enables the efficient, high-speed transfer of data between one section of the network and another.
- The primary design goals at the core layer are:
  - Provide 100% uptime.
  - Maximize throughput.
  - Facilitate network growth.

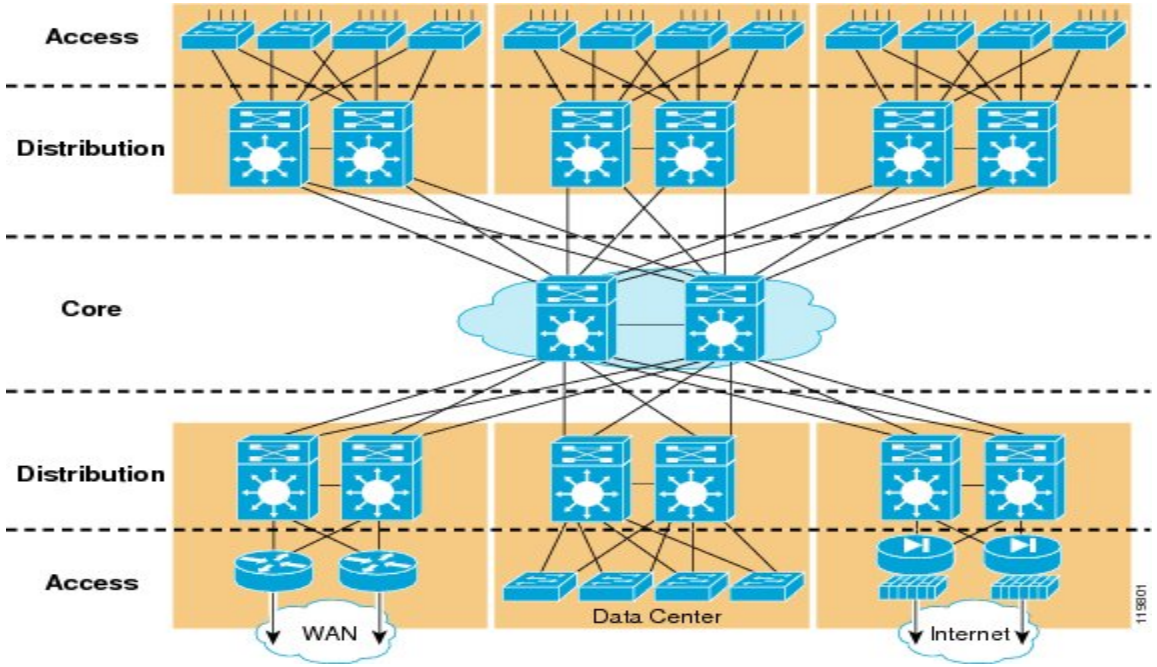
Core Layer Technologies

Technologies used at the core layer include the following:

- ***Routers*** or ***multilayer switches*** that combine routing and switching in the same device
- Redundancy and ***load balancing***
- High-speed and aggregate links
- Routing protocols that scale well and converge quickly, such as ***Enhanced Interior Gateway Routing Protocol (EIGRP)*** and ***Open Shortest Path First (OSPF) Protocol***

Redundant Links

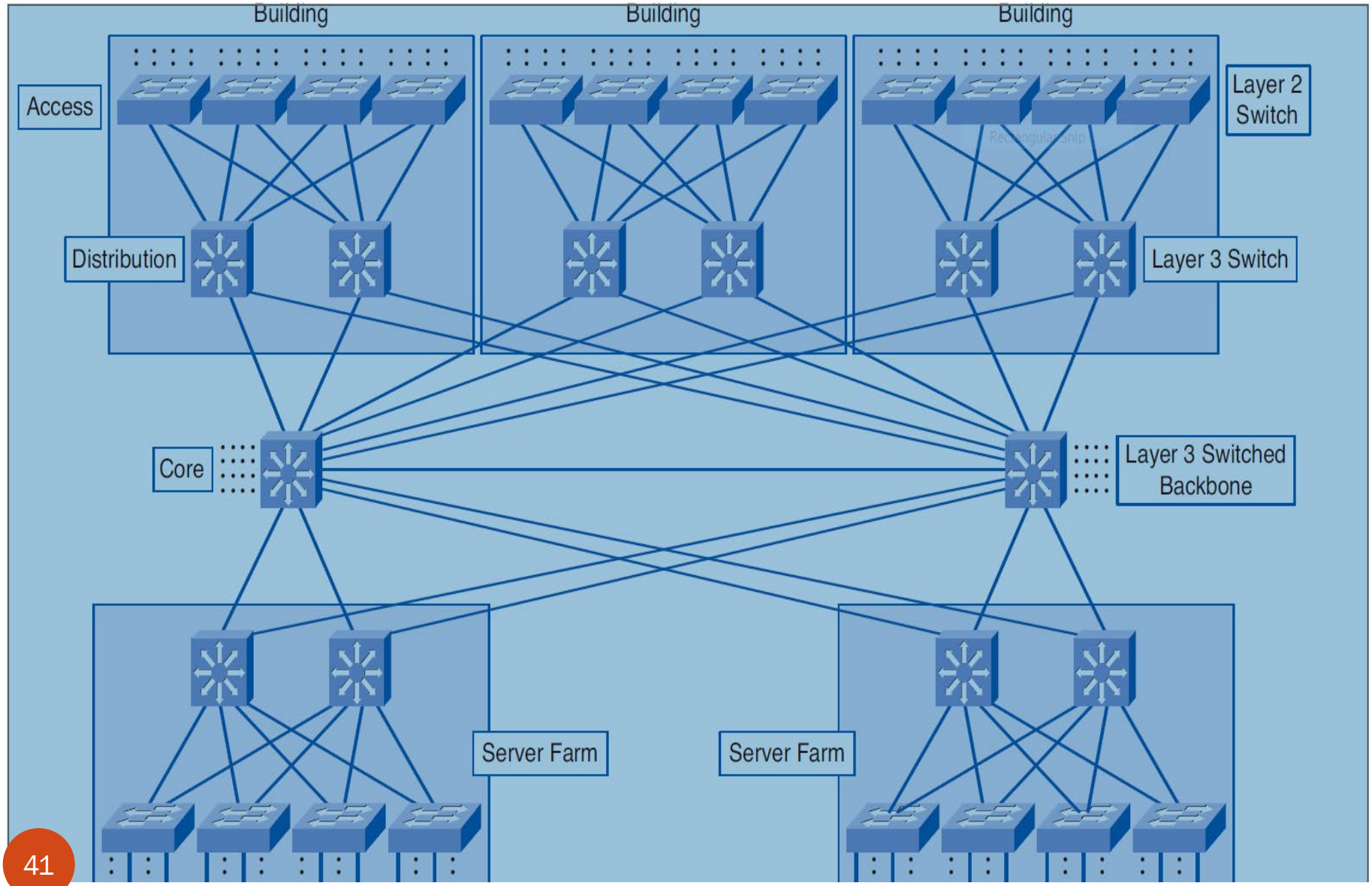
- Implementing redundant links at the core layer ensures that network devices can find alternate paths to send data in the event of a failure. When Layer 3 devices are placed at the core layer, these redundant links can be used for load balancing in addition to providing backup.



Mesh Topology

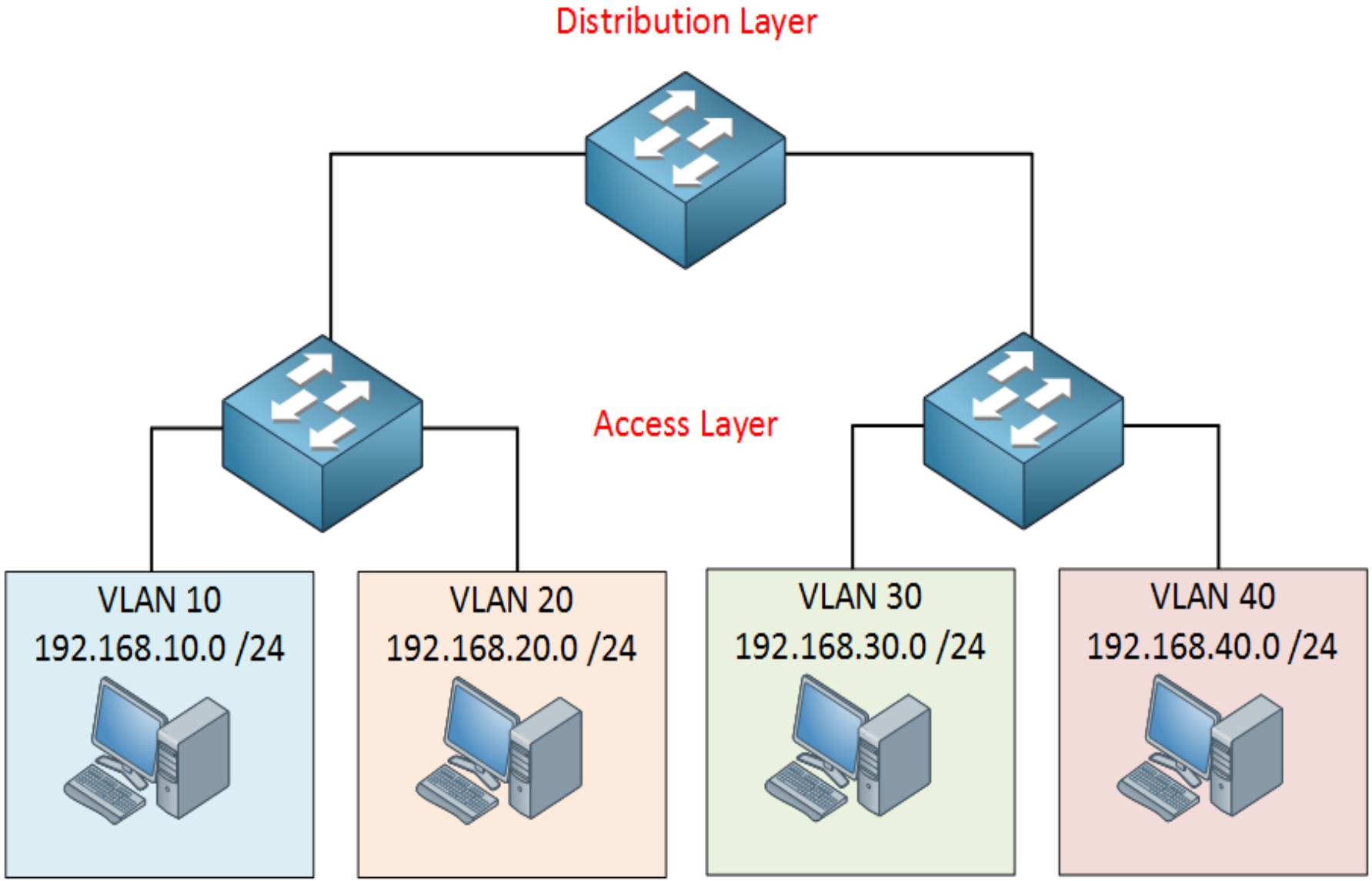
- Most core layers in a network are wired in either a ***full-mesh*** or ***partial-mesh*** topology.
- A full-mesh topology is one in which every device has a connection to every other device. Although full-mesh topologies provide the benefit of a fully redundant network, they can be difficult to wire and manage and are more costly.
- For larger installations, a modified partial-mesh topology is used. In a partial-mesh topology, each device is connected to at least two others, creating sufficient redundancy without the complexity of a full mesh..

Redundancy in a Mesh Topology



Distribution Layer

- The distribution layer is the middle (demarcation point) layer between the access layer and core layer of a network.
- It is at this point where traffic flow control and access control takes place.
- Distribution layer is a preferred place for designing virtual LANs (VLANs) to create one or more broadcast domains and to configure network devices like routers to route IP packets across VLANs.
- This layer ensures that packets are properly routed between subnets and VLANs in your enterprise.
- This layer is also called the Workgroup layer


Distribution Layer
Access Layer
VLAN 10
192.168.10.0 /24
VLAN 20
192.168.20.0 /24
VLAN 30
192.168.30.0 /24
VLAN 40
192.168.40.0 /24

Distribution Layer

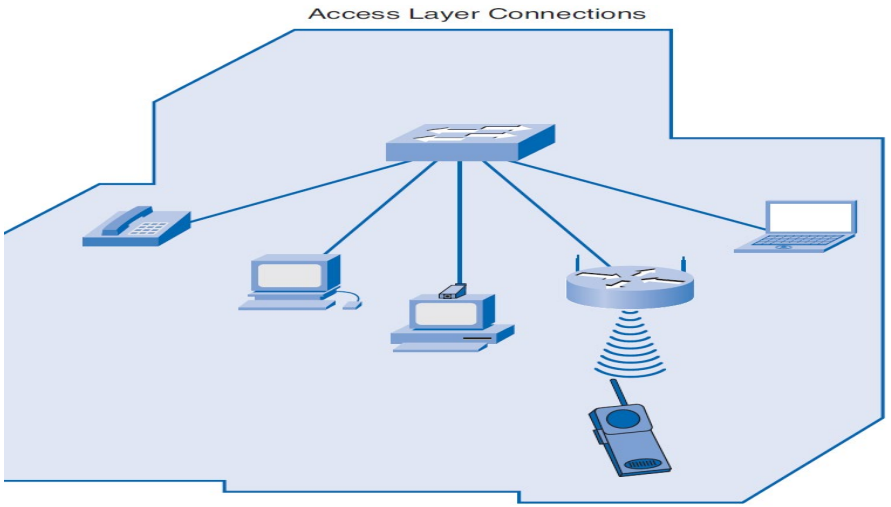
- The distribution layer is commonly built using Layer 2 switching technology.
- Routers or multilayer switches, located at the distribution layer, provide many functions critical for meeting the goals of the network design, including the following:
  - Filtering and managing traffic flows
  - Enforcing access control policies
  - Summarizing routes before advertising the routes to the Core
  - Isolating the core from access layer failures
  - Routing between access layer VLANs

Access Layer

- The main task of the access layer is to connect local users to the network so that they can access network resources and services.
- This layer is designed to deliver local user packets to the targeted end user computer and also to ensure a legitimate access of network resources and services.
- End devices such as personal computers, printers and IP phones are connected to the access layer.
- Besides that, interconnecting devices such as switches, hubs and wireless access points can be part of the access layer.

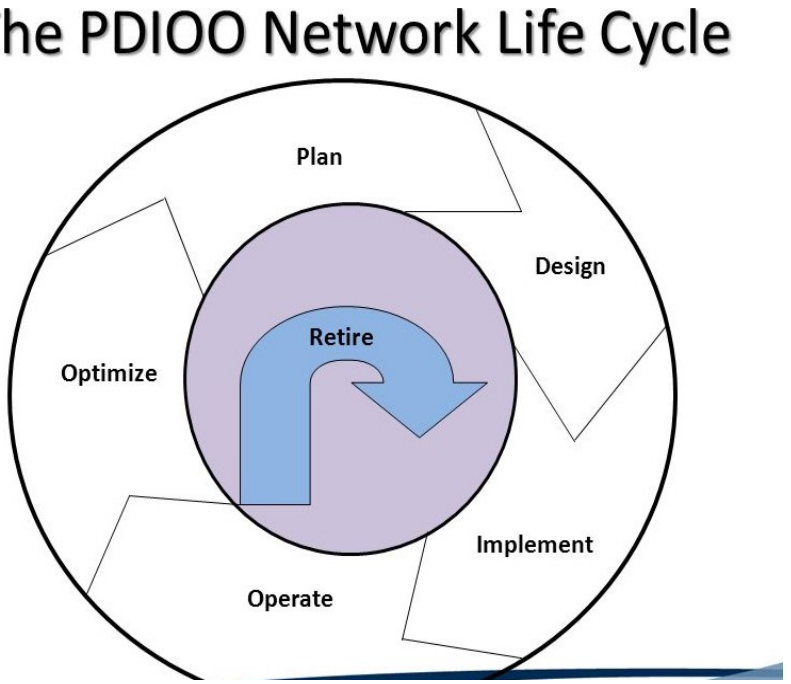
Access Layer

- This layer connects users via hubs, switches, and other devices
- This layer is also called the desktop layer because it focuses on connecting client nodes, such as workstations to the network.
- This layer ensures that packets are delivered to end user computers.



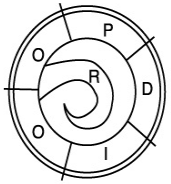
PDIOO Lifecycle Approach to Network Design and Implementation

- PDIOO stands for
  - Plan
  - Design
  - Implement
  - Operate
  - Optimize



- PDIOO is a Cisco methodology phases that defines the continuous life-cycle of services required for a network design and Implementation

Plan Phase:



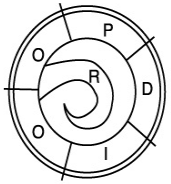
- Network requirements are identified in this phase
  - business and technical requirements
- Analysis of areas where the network will be installed
- Identification of users who will require network services
- If there is an existing network in place, then the project plan is developed (or updated), but only after an audit of the existing infrastructure, sites and operational environment is completed.

PDIOO Network Life Cycle

The typical deliverables from the Plan phase include:

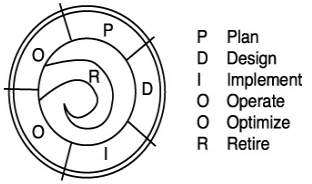
- Site Requirements Specifications
- Solutions Test Plan
- Site Survey Form
- Customer Requirements Document Response

Design Phase:



- Accomplish the logical and physical design, according to requirements gathered during the **Plan** phase
- The company develops (or updates) a comprehensive network design.
- It is important that the information gathered from the first phases is used to ensure that the design meets all of the business and technical requirements that were previously developed.

Design Phase:



- If everything has been completed correctly, the design will provide a network that is able to manage the everyday tasks that are required of it and meet or exceed all expected availability, reliability, security, scalability, and performance metrics.
- There are also a number of different documents that are developed during this phase that guide the deployment, configuration, and commission of network devices and services.
- The typical deliverables from this phase include:
  - Low Level Design (LLD)

Implementation Phase:

- Network is built according to the **Design** specifications
- Implementation also serves to verify the design
- This method allows the implementers the ability to find any potential problems; if found, these problems are resolved inside this test bed before full scale implementation continues.

Implementation Phase

- Once the network has been implemented, a series of tests should be run to ensure that the operation of the new network is as expected and designed.
- If any issues are found, it is best that they are handled as early in the implementation as possible to ensure the issue impacts as few parts of the network as possible.
- The typical deliverables from this phase include:
  - Network Ready For Use
  - Network Ready For Use Test Report
  - Implementation Log

Operate Phase:

- The Operate phase is by far the longest of the PPDIOO phases; this is because in this phase a company is operating without making major changes to the network.
- Operation is the final test of the effectiveness of the design
- The network is monitored during this phase for performance problems and any faults, to provide input into the **Optimize** phase

Operate Phase:

- During this phase, the company spends the majority of their funds managing the network which includes proactive and reactive monitoring, performance management, trouble management, security management, and capacity planning and monitoring, among others.
- The typical deliverables from this phase include:
  - Root Cause Analysis Reports
  - Support Contract Analysis

Optimize Phase:

- Based on proactive network management which identifies and resolves problems before network disruptions arise, the optimize phase may lead to a network redesign if too many problems arise due to design errors, or as network performance degrades over time as actual use and capabilities diverge Redesign may also be required when requirements change significantly

Retire Phase:

- When the network, or a part of the network, is out-of-date, it may be taken out of production
- Although Retire is not incorporated into the name of the life cycle (PDIOO), it is nonetheless an important phase