Top-Down Network Design

Third Edition

A systems analysis approach to enterprise network design

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Chapter 5

Designing a Network Topology

In this chapter, you will learn techniques for developing a network topology. A *topology* is a map of an internetwork that indicates network segments, interconnection points, and user communities. Although geographical sites can appear on the map, the purpose of the map is to show the geometry of the network, not the physical geography or technical implementation. The map is a high-level blueprint of the network, analogous to an architectural drawing that shows the location and size of rooms for a building, but not the construction materials for fabricating the rooms.

Designing a network topology is the first step in the logical design phase of the top-down network design methodology. To meet a customer's goals for scalability and adaptability, it is important to architect a logical topology before selecting physical products or technologies. During the topology design phase, you identify networks and interconnection points, the size and scope of networks, and the types of internetworking devices that will be required, but not the actual devices.

This chapter provides tips for both campus and enterprise WAN network design and focuses on hierarchical network design, which is a technique for designing scalable campus and WAN networks using a layered, modular model. In addition to covering hierarchical network design, the chapter also covers redundant network design topologies and topologies that meet security goals. (Security is covered in more detail in Chapter 8, "Developing Network Security Strategies.") This chapter also discusses the Cisco SAFE security reference architecture.

Upon completion of this chapter, you will know more about designing secure, redundant, hierarchical, and modularized topologies. A topology diagram is a useful tool to help you and your customer begin the process of moving from a logical design to a physical implementation of the customer's network environment.

Hierarchical Network Design

To meet a customer's business and technical goals for a corporate network design, you might need to recommend a network topology consisting of many interrelated components. This task is made easier if you can "divide and conquer" the job and develop the design in layers.

Network design experts have developed the hierarchical network design model to help you develop a topology in discrete layers. Each layer can be focused on specific functions, allowing you to choose the right systems and features for the layer. For example, in Figure 5-1, high-speed WAN routers can carry traffic across the enterprise WAN backbone, medium-speed routers can connect buildings at each campus, and switches can connect user devices and servers within buildings.

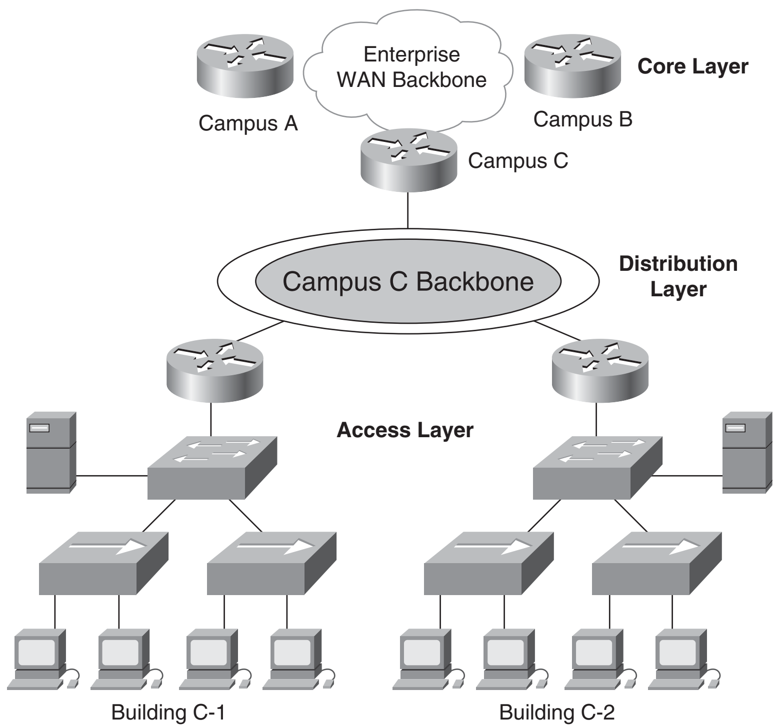

Figure 5-1 *Hierarchical Topology*

A typical hierarchical topology is

- A *core* layer of high-end routers and switches that are optimized for availability and performance.
- A *distribution* layer of routers and switches that implement policies. In small and medium-sized organizations, the core and distribution layers can be combined.
- An *access* layer that connects users via lower-end switches and wireless access points.

Why Use a Hierarchical Network Design Model?

Networks that grow unheeded without any plan in place tend to develop in an unstructured format. Dr. Peter Welcher, the author of network design and technology articles for *Cisco World* and other publications, refers to unplanned networks as *fur-ball networks*.

Welcher explains the disadvantages of a fur-ball topology by pointing out the problems that too many CPU adjacencies cause. When network devices communicate with many other devices, the workload required of the CPUs on the devices can be burdensome. For example, in a large flat (switched) network, broadcast packets are burdensome. A broadcast packet interrupts the CPU on each device within the broadcast domain and demands processing time on every device (including routers, workstations, and servers) for which a protocol understanding for that broadcast is installed.

Another potential problem with nonhierarchical networks, besides broadcast packets, is the CPU workload required for routers to communicate with many other routers and process numerous route advertisements. A hierarchical network design methodology enables you to design a modular topology that limits the number of communicating routers.

Using a hierarchical model can help you minimize costs. You can purchase the appropriate internetworking devices for each layer of the hierarchy, thus avoiding spending money on unnecessary features for a layer. Also, the modular nature of the hierarchical design model enables accurate capacity planning within each layer of the hierarchy, thus reducing wasted bandwidth. Network management responsibility and network management systems can be distributed to the different layers of a modular network architecture to control management costs.

Modularity enables you to keep each design element simple and easy to understand. Simplicity minimizes the need for extensive training for network operations personnel and expedites the implementation of a design. Testing a network design is made easy because there is clear functionality at each layer. Fault isolation is improved because network technicians can easily recognize the transition points in the network to help them isolate possible failure points.

Hierarchical design facilitates changes. As elements in a network require change, the cost of making an upgrade is contained to a small subset of the overall network. In large flat or meshed network architectures, changes tend to impact a large number of systems. Replacing one device can affect numerous networks because of the complex interconnections.

How Can You Tell When You Have a Good Design?

Here are some wise answers from Peter Welcher that are based on the tenets of hierarchical, modular network design:

- When you already know how to add a new building, floor, WAN link, remote site, e-commerce service, and so on

- When new additions cause only local change to the directly connected devices
- When your network can double or triple in size without major design changes
- When troubleshooting is easy because there are no complex protocol interactions to wrap your brain around

When scalability is a major goal, a hierarchical topology is recommended because modularity in a design enables creating design elements that can be replicated as the network grows. Because each instance of a module is consistent, expansion is easy to plan and implement. For example, planning a campus network for a new site might simply be a matter of replicating an existing campus network design.

Today's fast-converging routing protocols were designed for hierarchical topologies. Route summarization, which Chapter 6, "Designing Models for Addressing and Naming," covers in more detail, is facilitated by hierarchical network design. To control routing CPU overhead and bandwidth consumption, modular hierarchical topologies should be used with such protocols as Open Shortest Path First (OSPF), Intermediate System-to-Intermediate System (IS-IS), Border Gateway Protocol (BGP), and Enhanced Interior Gateway Routing Protocol (Enhanced IGRP).

Flat Versus Hierarchical Topologies

A flat network topology is adequate for small networks. With a flat network design, there is no hierarchy. Each network device has essentially the same job, and the network is not divided into layers or modules. A flat network topology is easy to design and implement, and it is easy to maintain, as long as the network stays small. When the network grows, however, a flat network is undesirable. The lack of hierarchy makes troubleshooting difficult. Rather than being able to concentrate troubleshooting efforts in just one area of the network, you might need to inspect the entire network.

Flat WAN Topologies

A WAN for a small company can consist of a few sites connected in a loop. Each site has a WAN router that connects to two other adjacent sites via point-to-point links, as shown at the top of Figure 5-2. As long as the WAN is small (a few sites), routing protocols can converge quickly, and communication with any other site can recover when a link fails. As long as only one link fails, communication recovers. When more than one link fails, some sites are isolated from others.

A flat loop topology is generally not recommended for networks with many sites, however. A loop topology can mean that there are many hops between routers on opposite sides of the loop, resulting in significant delay and a higher probability of failure. If your analysis of traffic flow indicates that routers on opposite sides of a loop topology exchange a lot of traffic, you should recommend a hierarchical topology instead of a loop. To avoid any single point of failure, you can place redundant routers or switches at upper layers of the hierarchy, as shown at the bottom of Figure 5-2.

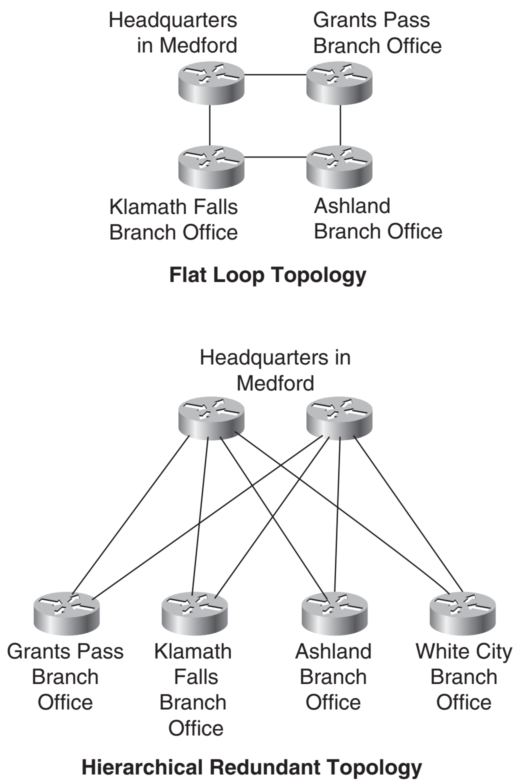

Figure 5-2 *Flat Loop Topology (Top) and Hierarchical Redundant Topology (Bottom)*

The flat loop topology shown at the top of Figure 5-2 meets goals for low cost and reasonably good availability. The hierarchical redundant topology shown at the bottom of Figure 5-2 meets goals for scalability, high availability, and low delay.

Flat LAN Topologies

In the early and mid-1990s, a typical design for a LAN was PCs and servers attached to one or more hubs in a flat topology. The PCs and servers implemented a media-access control process, such as token passing or carrier sense multiple access with collision detection (CSMA/CD) to control access to the shared bandwidth. The devices were all part of the same bandwidth domain and had the capability to negatively affect delay and throughput for other devices.

These days, network designers recommend attaching the PCs and servers to data link layer (Layer 2) switches instead of hubs. In this case, the network is segmented into small