CHAPTER 6
NETWORK DESIGN

Chapter Summary

This chapter starts the next section of the book, which focuses on how we design networks. We usually design networks in six network architecture components: Local Area Networks (LANs), Building Backbone Networks, Campus Backbones that connect buildings, Wide Area Networks (WANs) that connect campuses, Internet access, and Data Centers. Network design is an interactive process in which the designer examines users' needs, develops an initial set of technology designs, assesses their cost, and then revisits the needs analysis until the final network design emerges.

Learning Objectives

After reading this chapter, students should be able to:

- Understand the seven network architecture components
- Describe the overall process of designing and implementing a network
- Describe techniques for developing a logical network design
- Describe techniques for developing a physical network design
- Understand network design principles

Key Terms

access layer
baseline
bottleneck
building backbone network
building-block process
campus backbone network
capacity planning
circuit loading
common carrier
core layer
cost assessment
data center
desirable requirements
distribution layer
e-commerce edge
enterprise campus
enterprise edge
geographic scope
Internet access
logical network design
mandatory requirements
needs analysis
network architecture component
physical network design
request for proposal (RFP)
simulation
technology design
traditional network design process
turnpike effect
Wide Area Network (WAN) access
wish-list requirements

Chapter Outline

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    d. Categorizing Network Needs
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3. TECHNOLOGY DESIGN
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4. COST ASSESSMENT
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    c. Deliverables
5. IMPLICATIONS FOR MANAGEMENT
6. SUMMARY

Answers to Textbook Exercises

Answers to End-of-Chapter Questions

1. What are the keys to designing a successful data communications network?

A thorough needs analysis, developing one or more physical network designs, designing to operate and maintain with minimal staff intervention.

2. How does the traditional approach to network design differ from the building block approach?

Traditional network designs used a very structured approach for the analysis and design. This by default built in limitations to the growth and need to change network designs as the needs of the organization and technology itself changed.

3. Describe the three major steps in current network design.

Needs analysis, technology design and cost assessment.

4. What is the most important principle in designing networks?

Completing a thorough needs analysis that takes into consideration the needs of the organization over the short and long-term. From this analysis then a logical network design can be developed to ensure that the network can satisfy all needs over time.

5. Why is it important to analyze needs in terms of both application systems and users?

Because you want to make sure that the network can support the bandwidth and other operational characteristics required by the user applications.

6. Describe the key parts of the technology design step.

It examines the available technologies and assesses which options will meet the users' needs. The designer makes some estimates about the network needs of each category of user and circuits in terms of current technology and matches needs to technologies.

7. How can a network design tool help in network design?

Network design tools can perform a number of functions to help in the technology design process.

Other network design tools can discover the existing network; that is, once installed on the network, they will explore the network to draw a network diagram. For example, simulation is used to model the behavior of the communication network.

Network modeling and design tools can perform a number of functions to help in the technology design process. With most tools, the first step is to enter a map or model of the existing network or proposed network design. Some modeling tools require the user to create the network map from scratch. That is, the user must enter all of the network components by hand, placing each server, client computer, and circuit on the map and defining what each. Other tools can "discover" the existing network. In this case, the user provides some starting point; the modeling software explores the network and automatically draws the map itself.
Once the map is complete, the next step is to add information about the expected network traffic and see if the network can support the level of traffic that is expected. Simulation is used to model the behavior of the communication network. Once the simulation is complete, the user can examine the results to see the estimated response times and throughput. It is important to note that these network design tools only provide estimates, which may vary from the actual results. At this point the user can change the network design in an attempt to eliminate bottlenecks and re-run the simulation.
Good modeling tools not only produce simulation results, but also highlight potential trouble spots (e.g., servers, circuits, or devices that experienced long response times). The very best tools offer suggestions on how to overcome the problems that the simulation identified (e.g., network segmentation, increasing from T1 to T3).

8. On what should the design plan be based?

The design plan should be based on the geographic scope of the network, the number of users and applications, the current and future network needs of the various network segments, and the costs of the network and maintaining the network.

9. What is an RFP, and why do companies use them?

While some network components can be purchased "off-the-shelf," most organizations develop a request for proposal (RFP) before making large network purchases. RFPs specify what equipment, software, and services are desired and ask vendors to provide their best prices. Some RFPs are very specific about what items are to be provided in what time frame. In other cases, items are defined as mandatory, important, or desirable, or several scenarios are provided and the vendor is asked to propose the best solution. In a few cases, RFPs specify generally what is required and the vendors are asked to propose their own network designs. Once the vendors have submitted their proposals, the organization evaluates them against specified criteria and selects the winner(s). Depending upon the scope and complexity of the network, it is sometimes necessary to redesign the network based on the information in the vendor's proposals.
The RFP process helps the company to refine and determine what to purchase. It establishes a formal process that becomes well-documented and as a result leaves the company with not only a rationale for what has been purchased but documented proof of how the company arrived at its conclusions as to what vendors would be awarded contract(s) from the company.

10. What are the key parts of an RFP?

The following contains the key parts in an RFP:

Background Information
- Organizational profile
- Overview of current network
- Overview of new network
- Goals of new network

Network Requirements
- Choice sets of possible network designs (hardware, software, circuits)
- Mandatory, desirable, and wish list items
- Security and control requirements
- Response time requirements
- Guidelines for proposing new network designs

Service Requirements
- Implementation time plan
- Training courses and materials
- Support services (e.g., spare parts on site)
- Reliability and performance guarantees

Bidding Process
- Time schedule for the bidding process
- Ground rules
- Bid evaluation criteria
- Availability of additional information

Information required from vendor
- Vendor corporate profile
- Experience with similar networks
- Hardware and software benchmarks
- Reference list

11. What are some major problems that can cause network designs to fail?

Some major problems that can cause network designs to fail can be categorized by the steps of the building block design approach.

Technology design problems
- buying the wrong equipment or services; often the right technology but the wrong products or features
- vendor misrepresentation; the products and/or services did not work as promised

Needs analysis problems
- requirements were incomplete or inaccurate
- a significant change in business requirements as the network was installed.

Overall problems with the design process
- lack of network design skills internally; did not use external consultants or systems integrators external network consultants or systems integrators who bungle the project

12. What is a network baseline, and when is it established?

Most network design projects today are network upgrades, rather than the design of entirely new networks. In this case, there is already a fairly good understanding of the existing traffic in the

network, and most importantly, the rate of growth of network traffic. In this case, it is important to gain an understanding of the current operations (application systems and messages).
The needs analysis step provides a network baseline against which future design requirements can be gauged. It should provide a clear picture of the present sequence of operations, processing times, work volumes, current communication network (if one exists), existing costs, and user/management needs. Whether the network is a new network or a network upgrade, the primary objective of this stage is to define the geographic scope of the network and the users and applications that will use the network.

13. What issues are important to consider in explaining a network design to senior management?

One of the main problems in network design is obtaining the support of senior management. In their mind, the network is simply a cost center, something on which the organization is spending a lot of money with little apparent change. The network keeps on running just as it did the year before.
The key to gaining senior management acceptance of the network design lies in speaking their language (cost, network growth, and reliability), not the language of the technology (ethernet, ATM, and DSL). It is pointless to talk about upgrades from 10 Mbps to 100 Mbps on the backbone, because this terminology is meaningless to them. A more compelling argument is to discuss the growth in network use.
Likewise, a focus on network reliability is an easily understandable issue. For example, if the network supports a mission critical system such as order processing or moving point-of-sale data from retail stores to corporate offices, it is clear from a business perspective that the network must be available and performing properly, or the organization will lose revenue.

14. What is the turnpike effect, and why is it important in network design?

The turnpike effect results when the network is used to a greater extent than was anticipated because it is available, is very efficient, and provides new services. The growth factor for network use may vary from 5 to 50 percent and, in some cases, exceed 100 percent for high growth organizations. It is important in network design not only because usage is higher than anticipated, which slows response time, but also because the types of messages may be different than those for which the network was originally designed.

15. What are the seven network architecture components?

The seven network architecture components are LANs, building backbones, campus backbones, WANs, Internet access, e-commerce edge and data centers.

16. What is the difference between a building backbone and a campus backbone, and what are the implications for the design of each?
A building backbone distributes network traffic to and from the LANs. The building backbone typically uses the same basic technology that we use in the LAN (a network switch) but usually we buy faster switches because the building backbone carries more network traffic than a LAN.

A campus backbone connects all the buildings on one campus. Some vendors call this the Core Layer.
The campus backbone is usually faster than the backbones we use inside buildings because it typically carries more traffic than they do. We use routers or layer 3 switches that do routing when we design the campus.

The cost of each can be significant as they each consist of high-speed fiber optic cable and hardware such as switches and routers. In designing each one though, we can provide an infrastructure that provides for efficient movement of data across the entire network.

17. What are typical speeds for the LAN, building backbone, and campus backbone? Why?

LAN – 1 Gbps
Building backbone – 10 Gbps
Campus backbone – 40 Gbps
In most cases, because network traffic is consolidated onto the broader networks, the building backbone is one speed level above the LAN and the campus backbone speed is one speed level about the building backbone.

18. What is a bottleneck, and why do network managers care about them?

A bottleneck is a place where performance of an entire system is limited by capacity at some point in a network. Bottlenecks can exist on physical circuits or networking devices. Managers care about them because these are points that can be fixed or upgraded and after doing so, the network performance becomes improved.

19. Is it important to have the fastest wireless LAN technology in your apartment? What about in the library of your school? Explain.

It is not necessarily important to have the fastest wireless LAN technology in your apartment because that technology may be faster than your Internet access to your apartment. For example, if you have 10 Mbps Internet access to your apartment, a 54 Mbps access point in your apartment is still limited to 10 Mbps downloads from the Internet. The 54 Mbps access within the apartment is only good for connections between networking devices within the apartment.

The answer is similar as it applies to the library within your school. As long as the traffic stays within the library, a fast wireless network is beneficial.

20. Why do you think some organizations were slow to adopt a building-block approach to network design?

They were slow because this approach requires network managers to speak the language of upper management (cost, network growth, reliability) rather than the language of technology (Ethernet, ATM, and DSL).

21. For what types of networks are network design tools most important? Why?

Large, complex networks require the use of network design tools. The many devices on such systems and the variety of services requested by users requires that network managers organize and manage the process using system management software.

Mini-Cases
I. Computer Dynamics

Computer Dynamics is a microcomputer software development company that has a 300-computer network. The company is located in three adjacent five-story buildings in an office park, with about 100 computers in each building. The LANs in each building are similar, but one building has the data center on the second floor. There are no other office locations. The current network is poorly designed for its current needs and must be completely replaced. Develop a logical design for this enterprise campus that considers the seven network architecture components. There are no other campuses, so you can omit WAN access. You will need to make some assumptions, so be sure to document your assumptions and explain why you have designed the network in this way.

Refer to Figure 6-1 for a good example of a typical configuration for a network of this type.

The LAN would typically be designed as a physical star topology connecting the computers on each floor with UTP cabling to a switch. A wireless network is recommended in each building in addition to the wired network. Based on the size of the buildings, number of users, and the fact that a wired network is already in place, the company could get by with 802.11n access points on odd numbered floors (3 per building). These would probably provide enough wireless access to support the users.

The switch(es) on each floor would connect to the main switch on the first floor of each building, which would then connect to a router in that building. The connections among the switches would be fiber.

It is recommended to use multi-mode fiber optic cable to connect all three buildings to the others. One of the three buildings would be designated as the main building, as it contains the data center on the second floor. Each of the respective building LANs would connect into a device like a data switch that had a fiber uplink port. At the main building, the other two buildings would be terminated via the other end of the fiber into ports on the main campus data switch.

Any needs for connectivity to the outside, for example the Internet, could be supported by connecting the gateway router directly into a port on the main data switch. The router could connect to a CSU which brought into the campus network a high-speed circuit. In this design everyone on campus could have Internet connectivity and also connect to any server or printer physically located at any of the other buildings.

The data center would contain the e-commerce edge. This would consist of at least the web server that allows potential and existing customers to view their website.

II. Drop and Forge

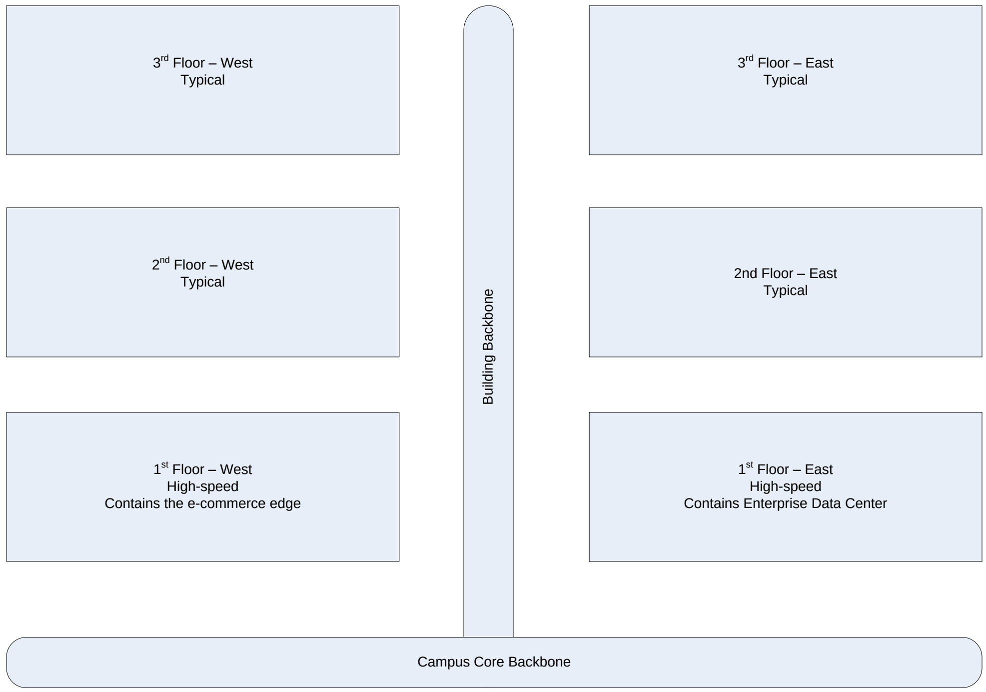
Drop and Forge is a small manufacturing firm with 60 computers on their network. Describe the network you would recommend and how it would be configured. The goal is to build a new network that will support the company's needs for the next three years with few additional investments. Be sure to include the devices and type of network circuits you would use. You will need to make some assumptions, so be sure to document your assumptions and explain why you have designed the network in this way.

For this situation, if we assume that all of the computers, including servers, can support the installation of a 10/100Mbps Ethernet card, the recommended approach for this company's network needs would be to install Switched Ethernet switches and a supportive new cable plant that can run Ethernet. For example a Category 5 cable plant. Each of the computers would need to have installed a 10/100Mbps Ethernet NIC. Each computer would connect via CAT 5 to a port on the nearest switch. Each switch connected to a main switch in each building. The two main switches in the buildings would be connected together.

III. AdviceNet

AdviceNet is a consulting firm with offices in Toronto, New York, Los Angeles, Dallas, and Atlanta. The firm currently uses the Internet to transmit data, but its needs are growing and it is concerned over the security of the Internet. The firm wants to establish its own private WAN. Consultants in all offices are frustrated at the current 1.5Mbps circuits they use for Internet access, so the firm believes that it needs faster data transmission capabilities. The firm has no records of data transmission, but it believes that the New York and Toronto offices send and receive the most data. The New York office is the primary headquarters and has the enterprise data center. Develop a logical design for the New York enterprise campus that considers the seven network architecture components. Describe the assumptions you have made.

A logical design may be as follows. The assumptions will vary depending on the student.



IV. Accurate Accounting

Accurate Accounting is a regional accounting firm that has 15 local offices throughout Georgia, Florida, and the Carolinas. The company is constructing a new office building for use as its main headquarters. The building will have two floors with a total of 40 offices, each with a desktop computer. Develop a logical design for the Atlanta headquarters enterprise campus that considers the seven network architecture components. You will need to make some assumptions, so be sure to document your assumptions and explain why you have designed the network in this way.

Student answers will vary considerably based on their assumptions and preferences. A logical design could look similar to the one in Minicase III or Figure 6-4.

In order to link all of the computers in the main headquarters together, you could install an Ethernet 10/100/1000Base-T 48 port switch. Due to the size of the building, each PC should be able to connect to this switch with a UTP Cat 5e cable. A couple of wireless 802.11n access points could be installed as well to provide wireless access.

The equipment for the WAN connectivity will be based on the preferences of the network manager and the circuit options available.

It should be assumed that traffic management, security, and other software will be purchased as the budget allows.

V. Donald's Distributing

Donald's Distributing is a regional trucking firm that is constructing a new office building (its only office). The network has 80 desktop computers and 2 servers. Develop a logical design for the enterprise campus that considers the seven network architecture components. You will need to make some assumptions, so be sure to document your assumptions and explain why you have designed the network in this way.

Student answers will vary considerably based on their assumptions and preferences. A logical design could look similar to the one in Minicase III or Figure 6-4.

In order to link all of the computers in the main headquarters together, you could install a couple of Ethernet 10/100/1000Base-T 48 port switches in the MDF. Due to the size of the building, each PC should be able to connect to one of these switches with a UTP Cat 5e cable. A couple of wireless 802.11n access points could be installed as well to provide wireless access.

The equipment for the Internet access will be based on the preferences of the network manager and the circuit options available.

The network will also need a router (the specific one, again depending on preferences of the network manager).

It should be assumed that traffic management, security, and other software will be purchased as the budget allows.

Next Day Air Service Case Study

1. Create an RFP for the new network.

Students will of course have varying levels of detail in the RFP, but at a minimum should include the information listed in Figure 6.6. The RFPs should be expected to be 3-6 pages on average.

Additional Content

Teaching Notes
I usually only spend 1-3 hours on this, plus I give the students a project to do.

The most commonly used design process was the "building block" approach described in this chapter. One of the major reasons for this is that network technology has changed dramatically in the last 5 years. For this reason, the Internet related fundamentals have been extrapolated from this chapter and housed into their own dedicated Chapter (Chapter 10) and the complete design process elements have been incorporated into this chapter on design.

The goals in this chapter are to provide a checklist of steps to help students in designing networks and to outline the pros and cons of several commonly used networks. The building block process is a very "clean" and simple approach that I have seen used. The biggest difference between it and the traditional approach is that it assumes that network demand will grow and therefore makes no attempt to accurately understand current network demand.

However, I have added a great deal of information on the design process itself. This includes: Needs Analysis, Technology Design form circuits to servers and Cost Assessment from RFP to Deliverables. Many of the concepts are abstract such as "logical design." You will find that students will need more visual information to comprehend network design.

War Stories
(Objective: illustrate the futility of trying to accurately predict growth)
In the mid-1980s when I was on the faculty of Queen's University in Canada, the mainframe and its network were very slow. Most faculty did not give course assignments because of the problems. The university then upgraded its network. The upgrade cost several million dollars and was predicted to last 5 years before another upgrade would be necessary. Then the turnpike effect kicked in. Faculty began to use the network in their courses and demand grew. The network was saturated in 2 years.

A new upgrade was done and again the networking group predicted it would last for 5 years. This time it was only 18 months before the network was saturated.

I would like to say that this is an isolated incident, but I have seen the same pattern at many organizations. Network designers often badly underestimate the growth in network demand. New applications add to this turnpike effect, as upgrades are saturated due to not only growth in existing usage patterns, but also due to the addition of new and more data intensive applications.

