The background of the entire page is a microscopic view of a circuit board, showing intricate patterns of copper traces and various components. The top half is in warm, golden light, while the bottom half is in a cooler, blue light. A white horizontal band is positioned across the middle, containing the main title and subtitle.

Introduction to Networks

Getting Wired



NYSCATE
NEW YORK STATE CURRICULUM
for Advanced Technology Education

*Integrated MIT Design Activities for
High School and Community College Students*

Partners in New York State Curriculum for Advanced Technology Education

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The University of the State of New York
The State Education Department



Introduction to Networks:

Getting Wired

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Online Appendix

Go to www.nyscate.net under NYSCATE products and find the *Introduction to Networks* Appendix. This appendix includes images suitable for projection and computer display.

SOURCES

Cisco's CCNA online curriculum
CCNA Jumpstart: Networking and Internetworking Basics by Patrick Ciccarelli and Christina Faulkner, published by Sybex, 2001.

Introduction and Overview

Abstract

This high school concentration-level module introduces students to computer networks through a variety of experiences, including:

- Applying components of the NYSCATE informed design process and using appropriate tools and materials to design a solution to a given problem. The design and redesign must be based upon understanding and application of scientific and mathematical concepts;
- Completing Knowledge and Skill Builder activities;
- Developing a timeline describing the history of computer networking;
- Installing a network interface card and driver software;
- Determining the OSI model and attributes;
- Generating a computer simulation of network topology; and
- Developing a proposal for a new computer system designed for a small business.

Grade Level

This module is intended for use in grades 11–12.

TIME ALLOCATION IN 45-MINUTE PERIODS

30 periods

EXISTING COURSES ENHANCED BY THE MODULE

For a concentration-level HS module, students are expected to have a measure of computer literacy. Some knowledge of computer system hardware would be helpful as well, but is not required. This module can be delivered through a variety of computer applications courses, or through technology education courses such as Digital Electronics, Computer Electronics, AC and DC Electronics, or Principles of Engineering.

Design Challenge Overview

SETTING THE CONTEXT FOR STUDENTS

Introduction

Computers have come a long way since the time when a single computer filled an entire room. In the early days of computer use, and up through the mid-1970s, remote access was the only viable method of connecting to a computer. People usually worked on a terminal wired to a computer that might have been in the next room or many miles away. Dedicated telephone lines typically served as the common link between the user's terminal and the "mainframe" computer. This situation changed with the development of integrated circuits (microchips) and the microcomputer in the late '70s. For the first time, people were able to work on a stand-alone computer on their desktop, independently of any other system. This independence, however, brought certain disadvantages. Many desktop computers lack the capacity to store and access the large amounts of data associated with typical business applications, and they often require needless duplication of resources that can (and should) be shared.

As a result, the need today is for networks that enable computers to share data, software, devices, and other resources. One might say that computers have come full circle over the past two decades: We are now all getting connected again. As much as we like our independence, we often need the benefits of connectivity.

Design Challenge

Your team will design a system for a business that is modernizing its computer system. You will upgrade a 386 Novell Server-based accounting system that uses 4-mps token rings to network six computers, and replace it with a new state-of-the-art integrated system that will put terminals at every point in this growing warehouse-based business and connect to the Internet. Optionally, a small dot-com might be created, allowing iCommerce with additional routers, switches, and servers. Your team will analyze the operation of the company and then design a system that best matches current and future (projected) needs. Your team will submit a formal proposal describing your recommended system.

Specifications

The recommended system will be based on a needs assessment that your team develops by analyzing the operation of the company. Your solution will include the following items:

- A sales proposal indicating the name, model, quantity, and cost of all devices and materials. Each team's proposal will include prices of hardware, software (e.g., OS and Office Suite), and installation. A one-page spreadsheet summarizing prices and a one-page summary of the reasoning behind this proposal will comprise the first two pages of the proposal.
- A computer simulation describing the topology of the connected hardware. This simulation will confirm that all of the network components work together. Cisco's ConfigMaker will be used for this.
- A wiring diagram (cut sheets) illustrating the layout and connections for all network wiring.

Constraints

Your team must address the needs of the new network in regard to bandwidth, security, reliability, and speed. In addition, prices must be competitive. Presentations are to be professional.

This Design Challenge overview is also provided in Handout 1.

Goals and Learning Outcomes

Standards-Driven Learning Outcomes

This module places major emphasis on the following learning standards.

New York State Learning Standards for Mathematics, Science, and Technology

Standard 2 - Information Systems

Information technology is used to retrieve, process and communicate information and as a tool to enhance learning.

- Prepare multimedia presentations demonstrating a clear sense of audience and purpose.
- Access, select, collate and analyze information obtained from a wide range of sources.
- Model solutions to a range of problems in MST, using computer simulation software.

Standard 5 - Technology

Engineering design is an iterative process involving modeling and optimization, used to develop technological solutions to problems within given constraints.

- Carry out a thorough investigation of an unfamiliar situation and identify needs for technological innovation.
- Generate creative solutions.
- Choose the optimal solution to the problem.
- Construct a model of the solution.
- In a group setting, devise a test of the solution relative to design criteria and perform the test.

Computers as tools for designing, modeling, information processing, communication, and system control have greatly increased human productivity and knowledge.

- Select a computer system that meets needs.

Technological systems are designed to achieve specific results and produce outputs, such as products, structures, services, energy, and other systems.

- Explain why making trade-offs among characteristics such as function and cost is necessary when selecting systems for specific purposes.

Technology can have positive and negative impacts.

- Explain how computers have changed the nature of work.

Standard 6 - Interconnectedness: Common Themes

Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

- Collect information about the behavior of a system and use modeling tools to represent the operation of the system.

Standard 7 - Interdisciplinary Problem Solving

Solving interdisciplinary problems involves a variety of skills and strategies including effective work habits, making connections among common themes, and presenting results.

Participating in an extended, culminating project would require students to:

- work effectively
- gather and process information
- generate and analyze ideas
- observe common themes
- realize ideas
- present results

National Standards for Technological Literacy

Standard 1 - The Scope of Technology

K: The rate of technological development and diffusion is increasing rapidly.

L: Inventions and innovations are the results of specific, goal-directed research.

Standard 2 - The Core Concepts of Technology

W: Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

AA: Requirements involve identification of the criteria and constraints of a product or system and determination of how they affect the final design and development.

BB: Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

Standard 7 - The History of Technology

G: Most technological development has been evolutionary, the result of a series of refinements to a basic invention.

O: The Information Age places emphasis on the processing and exchange of information.

Standard 8 - The Attributes of Design

H: The design process includes defining a problem, generating ideas, identifying criteria and constraints, making a model or prototype, testing and evaluating the design, refining the design, communicating process and results.

I: Design problems are seldom presented in a clearly defined form.

J: The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

K: Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9 - Engineering Design

L: The process of engineering design takes into account a number of factors.

Standard 10 - Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

I: Research and development is a specific problem-solving approach that is used extensively in business and industry to prepare devices and systems for the

marketplace.

J: Technological problems must be researched before they can be solved.

Standard 11 - Applying the Design Process

N: Identify criteria and constraints and determine how these will affect the design process.

O: Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

Standard 12 - Use and Maintain Products and Systems

P: Use computers to access, retrieve and evaluate data and information.

Standard 17 - Information and Communication Technologies

L: Information and communication technologies include inputs, processes, and outputs associated with sending and receiving information.

O: Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval and destination.

Materials and Resources

Materials

- For each design team (3 or 4 students): One PC 486 or higher, with 16 MB of RAM, 1 GB hard disk, CD-ROM and network card, running Windows 95 or higher
- Two PCs (for the entire class) that can be opened to install the NIC cards (NYSCATE recommends that students not open computers normally used for instructional purposes.)
- Hub with 4 or more ports
- Access to the World Wide Web
- Cable tester
- 2 RJ45 patch cables for connecting hub to computers
- ConfigMaker software: Provides a topology of the network to confirm connectivity of components. Available free from Cisco Systems at www.cisco.com and will work with Cisco Systems devices; other information needed by students may be found at this site as well.
- Floor plan diagrams of the small business in which the new network will be installed (in online appendix)
- Various colored pencils and drawing tools for cut sheets/wiring diagrams
- Optional phone line, modem, and ISP account for research

Safety Considerations

This module provides students with an opportunity to perform a variety of troubleshooting tasks on a computer. Since the computers will be open for some of these tasks, precautions must be taken to limit student exposure to line voltage. Power should be removed from any line voltage device before the computer is opened. Although this can be accomplished at either the circuit panel or power strip, the surest method is to unplug the computer directly from the power source.

Power should not be reapplied until the teacher has ascertained that all work is complete and correct, and covers have been returned to their normal, closed position. Students' work areas should be kept dry, and clear of conductive materials (including screws or paper clips).

Resources Access to WWW

Timeline Chart

This module is designed to be completed within 30 class periods, when each class period is 45 minutes long.

Session	FOCUS MODEL COMPONENT (for teachers)	INFORMED DESIGN LOOP COMPONENT (for students)	ACTIVITY
1–2	Focus Discussion on Problem Context Organize for Informed Design	Clarify Design Specifications and Constraints	Begin discussion of Handout 1 (module overview) Organize groups; discuss Handout 2 (informed design loop)
3–17	Coordinate Student Progress	Research and Investigation	Conduct KSB 1: History of Computer Networking Conduct KSB 2: The Open Systems Interconnect (OSI) Model Conduct KSB 3: Installing a Network Interface (NIC) Card Conduct KSB 4: Bandwidth and Frequency of Digital Signals Conduct KSB 5: Using Cisco's ConfigMaker
18–27	Coordinate Student Progress	Generate Alternative Designs Choose and Justify Optimal Design Construct various network topologies having different hardware solutions	Develop solutions with different hardware and networking models. Create preliminary design solutions. Select and defend choice of preferred (optimal) solution. Develop and optimize "network proposal."
28–30	Unite Class Thinking on Accomplishments Sum Up Progress on Learning Goals	Test and Evaluate "Network" Design	Students make presentations by group with class questions and evaluation. Review learning goals; practice constructive assessment.

Procedural Suggestions

Pedagogical Framework Reference

A separate document, the NYSCATE *Pedagogical Framework* (www.nyscate.net), provides an in-depth understanding of the NYSCATE challenge statements, the FOCUS on Informed Design pedagogical model for teachers, student Knowledge and Skill Builders (KSBs), the informed design loop for students, and more.

Suggestions

PERIOD 1

Distribute Handout 1. Introduce the problem context and the Design Challenge. Discuss the student requirements and assessments; set the expectations for each team. Student requirements include: KSBs, a Design Journal or Folio, completion of Design Challenge, and a final report.

PERIOD 2

Conduct a discussion on the reasons for designing a network. Challenge students to think of various products that accomplish the same thing. Explore the question, “Why is it necessary to employ a thoughtfully conceived design process when designing systems?” Introduce the informed design loop, Handout 2.

PERIOD 3: KSB 1

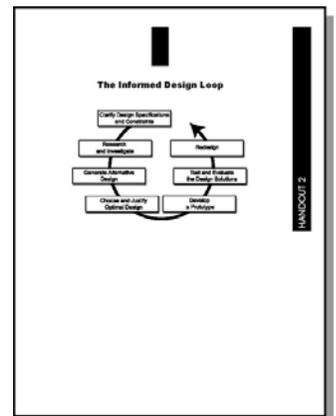
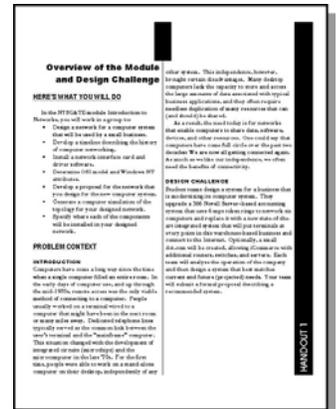
- Assign members to groups.
- Groups select a name for their team and design a logo (optional). They might then divide up team responsibilities into roles such as systems analyst, software engineer, and hardware engineer.
- Present a short history of computers, focusing on the need for connectivity.
- Elicit reasons for connecting computers.
- Explain the way mainframes use terminals, allowing many users to connect at once. Give examples of current use of terminals (accept any use mentioned, even if it seems insignificant).
- Explain how the hub, switch, router, modem, and other connections to the Internet work.
- Define *LAN*, *WAN*, *MAN*, and *Internet*.
- Discuss the use of the Internet/library to research a timeline chronicling the history of computer networking.

PERIOD 4

- Have groups create their timelines, picking out the five most important developments in networking.
- Discuss the results as a class.

PERIODS 5 – 6: KSB 2

- See teacher resource Appendix B: OSI. (Topics explored are: Why a Layered Network Model?; Layer Functions; Data Protocol Units: Bits, Frames, Packets, Segments, Data and Layers; Data Encapsulation &



Layers).

- Explain the format of the chart that each group is responsible for creating (refer students to chart in Handout).
- Discuss with students the need for industry standards and the OSI-layered model itself.
- Describe how each connection typically had to be wired differently for a printer, a terminal, etc., before there were industry standards.
- Relate that if you want to introduce a new type of media, only physical and data link layers have to be considered—all other layers will interact in the same way with them.
- Relate that at the top layer, only application and presentation layers will have to be considered to change to a new e-mail program.
- Have students explore each layer function and determine how data is passed all the way down each time from source device Layer 7 to Layer 1 and then back up from Layer 1 to Layer 7 at destination device.
- Explain Layers 1 through 3 in detail; include the role of each layer.
- Physical layers: Media (wire, optical fiber, wireless), hub, transceiver, encoding to binary
- Data link layers: Access to media, switches, MAC addresses (flat 6 Hex codes)
- Network layers: Addressing and best path, logical addressing, hierarchical IP addressing (dotted decimal and classes), and routers
- Deal briefly with the remaining layers.



PERIOD 7

- Explain data encapsulation.
- Explain this process: data to segments to packets to frames to bits and back up to data at destination.
- Relate that data must be split up (segmented) for the Internet so multiple users can share the same media.
- Explain that since data is segmented, it must have information so it can be reassembled in correct order and as part of the correct message (packet headers have to be added).
- Elicit that data must be set up and framed differently for each kind of media.
- Remind students that all data is changed to binary digits (bits) to travel across the network.

PERIOD 8

- Have student groups complete charts of the OSI model on the basis of layers.

PERIOD 9: KSB 3

- Ask and foster questions about the different types of cards and interfaces (PCI and ISA) on a motherboard.
- Show some examples of NIC cards having different connectors.
- Discuss the Ethernet and CAT-5 standards.
- Discuss TCP/IP, NetBEUI, and Novell IPX protocols.
- Explain why TCP/IP is the Internet standard.
- Demonstrate installation procedures for a NIC and driver.



PERIOD 10

- Describe classes of IP addresses including the loopback address 127.0.0.1.
- Demonstrate, using “ping 127.0.0.1,” how to test a NIC. Encourage discussion.
- Have groups install and test a NIC and driver in the test machines.
- Have students test, using loopback ping.
- Have students connect two machines and check the “network neighborhood” icon for connectivity.
- Have students check IP configure info, using operating system utilities WINIPCFG and IPCONFIG.

PERIOD 11

- Have students connect the two machines using a hub, putting both machines into the same work group and turning on file sharing.
- Encourage students to transfer files from machine to machine.
- Elicit why security is important in a networked environment.
- Explain how passwords are used to restrict user rights.
- Invite students to discuss how to choose and store passwords.
- Relate how to improve security by using passwords properly (changing them, making sure they aren’t individual words).

PERIOD 12: KSB 4

- Describe the history of telecommunications from telegraph to DSL lines and wireless.
- Discuss attenuation, distortion, delay, and noise. Use Nyquist’s formula to establish the capability of different methods of transmission as a function of the bandwidth. (See Additional Support for Teachers.)

PERIOD 13

- Encourage students to bring in research about different methods of connecting to the Internet from modems to ISDN, to cable, to DSL, to T1.
- Featuring Shannon’s formula, relate the effect of noise on different transmission methods. (See Additional Support for Teachers.)
- Have students use worksheets to figure out and comprehend formulas.

PERIOD 14

- Have students work in groups to complete a chart on bandwidth and the KSB questions.

PERIOD 15: KSB 5

- Elicit the difference between MAC addresses and IP addressing. Describe analogies to ZIP codes, Social Security numbers, and addresses.
- Discuss IP addressing and subnetting.
- Have students start the tutorial on ConfigMaker and take notes.

Bandwidth and Frequency of Digital Signals

High-speed networks and lines were originally designed for transmission of voice signals and their limited bandwidth. Today, however, digital networks also transmit data. Transmission is controlled by the characteristics of those networks, which are a design for a time-division program. This has several important implications for the transmission of high-speed digital signals.

The high-speed networks for the transmission of each of the following services include:

- conventional telephone systems
- ISDN (digital subscriber)
- ISDN (integrated services digital network)
- DSL (digital service line)

Great care must be taken in determining the advantages and uses of each of these transmission methods. Use formulas to compare values of signal-to-noise ratio (SNR) and channel capacity (Nyquist's formula) for a variety of digital lines. Determine the relationship between the SNR and BW in this ratio to signal line performance.

DEVELOP YOUR UNDERSTANDING

1. What are the factors that limit the bandwidth of a conventional telephone line?
2. What are the advantages and disadvantages of a conventional line to a program for ISDN?
3. Describe why loading coils are used and how they improve telephone lines. Would these coils now need to be removed?
4. Explain why ISDN is used in a voice system and how it differs from a conventional system.

Using Cisco's ConfigMaker

Cisco's ConfigMaker program is available for use on a network. It includes a tutorial that is easy to understand. The program is used by designers to "hook up" a LAN or WAN and check its operability. ConfigMaker can also be used to define a very simple configuration to represent a LAN.

You can use Cisco's ConfigMaker program to define the topology of a LAN within the boundaries of a network. The program requires that you enter a list of network devices to be used for each of the following:

1. All addressing information.
2. Types of equipment to be used. The list of equipment is available in the program. If you are using the program to create your LAN or WAN, then you must be familiar with the list available and use only the ones listed.
3. Types of equipment that you are going to give these names (e.g., Macintosh, Router, Switch, etc.).
4. How you are going to connect everything (the LAN) to the outside world (the Internet). For example, you might use Frame Relay, or ISDN.

DEVELOP YOUR UNDERSTANDING

1. How can you use the program to take notes?
2. How can the program be used to create a LAN or WAN using only one network, one router, and one line. In the following diagram with the attached IP address and subnet mask.
3. How can the program that defines the boundaries of a network be used to create a LAN or WAN? How can you use the program to create a LAN or WAN using only one network, one router, and one line. In the following diagram with the attached IP address and subnet mask.
4. Advantages and disadvantages of each will be discussed.

Diagram: A central router is connected to two switches. The left switch is connected to a PC with IP 192.168.1.10. The right switch is connected to a PC with IP 192.168.1.20. The router is connected to the Internet.

Note: The student study are written in CIDR notation. "192" after the IP address means that the address and subnet mask are in decimal form. For example, 192.168.1.10/24 means 192.168.1.10/255.255.255.0.

PERIOD 16

- Have students bring in research on different devices such as hubs, switches, bridges, and routers.
- Emphasize the effect on security and bandwidth for each device.
- Allow students to finish the tutorial on ConfigMaker and encourage them to take notes.

PERIOD 17

- Have students create the pictured LAN on ConfigMaker.
- Monitor students as they work in groups to create the chart of devices and record advantages and disadvantages.

PERIOD 18: DESIGN CHALLENGE—DEVELOPMENT OF COMPUTER SYSTEM PROPOSAL

As needed, review the Design Challenge and design loop and their implications for student work—what is expected of each team and the desired end product. Students should be able to cite examples of good design. Emphasize the role of research in reaching an optimal design solution.

Establish the roles of the members of the group, such as:

- **Hardware chief engineer:** Coordinates the selection of hardware devices and determines their location. This job includes the development of cut sheets and all wiring.
- **Software chief engineer:** Develops topology for network system, using ConfigMaker software. Determines software requirements and the training needed (including costs).
- **Systems analyst:** Coordinates the writing of the proposal and the preparation of the class presentation.

PERIODS 19 – 20: DETERMINE HARDWARE NEEDS AND COSTS

- Have groups select hardware, using the Internet and/or catalogs to decide on items such as: servers, routers, computers, printers, hubs, and switches.
- Monitor groups as they use spreadsheet software to work up cost sheets.

PERIODS 21 – 22: CREATE CUT SHEETS AND CALCULATE LABOR

- Have groups create cut sheets. See that they use appropriate symbols and follow industry standards.
- Remind groups to figure out labor costs for installing (see chart in Appendix D).

PERIODS 23 – 24: DETERMINE TOPOLOGY

- Motivate groups to develop the topology of the LAN (local area network) including location of computers, servers, routers, switches, and hubs.
- Have groups demonstrate use of ConfigMaker software to simulate network topology.
- Show appropriate pride and appreciation as groups create the topology on ConfigMaker.

PERIODS 25 – 27: PROPOSAL WRITING

- See that students create a written proposal to accompany costs, topology, and cut sheets, and make sure they develop final prices.
- Make use of the NYSCATE *Pedagogical Framework* (pp. 27–28) to advise students as they develop their oral presentations.

PERIODS 28 – 29: PRESENTATION OF PROPOSALS

- See that photocopies are made of all team proposals, and distribute them to all class members for review prior to the group presentations.

PERIOD 30: FINAL SUMMATION

- Involve students in discussing to what degree the objectives of the *Introduction to Networks* module were attained.
- Include discussion on ways of improving instruction and learning for future classes who use the module.

Additional Support for Teachers

See teacher resource items in the *Introduction to Networks* Appendix and in the NYSCATE *Pedagogical Framework*, both of which can be found at the NYSCATE website: www.nyscate.net.

Attenuation and Distortion

Any signal carried on a transmission medium will be affected by attenuation, limited bandwidth, delay distortion, and noise.

Attenuation

Signal attenuation happens when the signal travels along the transmission medium. Thus, a limit is set to the length of the cable. Amplifiers (repeaters) are needed if a longer run of cable is required.

There are four (4) types of distortion:

- Distortion caused by attenuation
- Distortion caused by limited bandwidth
- Distortion caused by propagation delay
- Distortion caused by noises from the medium

Limited Bandwidth

The human ear has a limited bandwidth. Bandwidth, or channel capacity, means the range of frequencies (bits per second) that are allowed to pass through without distortion. The telephone network is designed to carry voice with range of frequencies of 3000 Hz. This frequency spectrum for voice-graded cable does not allow for high bits per second (bps) to be transmitted. In 1924, while working for AT&T, Henry Nyquist developed an equation that calculates the maximum data rate in a noiseless channel (C in bps) that can be supported using a given bandwidth (W). His formula can be used to find the capacity of the channel (cable) as a function of the bandwidth:

$$C = 2B \log_2 M$$

where

C = maximum capacity in bits per second

B = bandwidth of the cable

M = signaling level (8-bit byte)

Example

Data is to be transmitted over the PSTN using a transmission scheme with eight levels per signaling element (8-bit byte). If the bandwidth of the cable is 2600 Hz, determine the Nyquist maximum data transfer rate.

$$\begin{aligned}C &= 2 \times 2600 \times \log_2 8 \\ &= 2 \times 2600 \times 3 \\ &= 15,600 \text{ pbs}\end{aligned}$$

Nyquist's formula is for noiseless cable; in practice, there are noises on the cable and we should use Shannon's formula.

$$C = B \log_2(1+S/N)$$

where

C = maximum capacity in bps

W = bandwidth

S/N = ratio of signal power (S) to noise power (N) expressed in decibels (dB)

Let us suppose that a phone line has a number of decibels of 20 dB. This means that the noise power is 1/100 of the signal power. Proved in this way:

$$\text{Number of dB} = 10 \log_{10} (S/N)$$

$$20 = 10 \log_{10} (S/N)$$

divide by 10 both sides:

$$20/10 = \log_{10} S/N$$

$$2 = \log_{10} S/N$$

Now, using the log properties:

$$10 \text{ to the power of } 2 = S/N = 100$$

Therefore S/N = 100. If this line has a bandwidth of 2600 Hz, find C.

$$C = 2600 \times \log_2 (1 + 100)$$

$$C = 2600 \times \log_2 (101)$$

$$= 2600 \times \log_{10} 101 / \log_{10} 2$$

$$= 2600 \times 2 / 0.3$$

$$= 2600 \times 6.643$$

$$= 17,270 \text{ bps}$$

Propagation Delay Ratio

$$a = T_p / T_x$$

where

$$T_p = \text{Propagation delay} = D/v$$

where

D = distance

v = velocity of electrical signal (inside the medium)

T_x = Transmission delay = N/r

where

N = number of bits to transfer

r = bit-rate of the transmission

The following, adapted from the QualNet website, discusses some of the problems associated with today's fast modems.

56K: Fact and Fiction

The media hype has been out for well over a year now. TV ads, newspapers, and commercial breaks in online games all tell you to speed up your Internet connection. What is this all about?

How it Works

Let's look at your traditional modem. Basically, it does nothing but pass a string of 1's and 0's over a standard analog phone line to and from the computer to which you are connected. This phone line only has so much bandwidth in which to transmit this data. Back when 33.6K modems (v.34) were introduced, it was thought that this would be the limit at which computers could communicate over the analog phone network because of the signal-to-noise ratio. (This is called Shannon's formula, or Shannon's law.) When you connected to an ISP or a BBS in the past, your data was sent over the analog network to your phone company's central office (CO) and converted to digital. It was then passed to the CO serving the computer you were dialing and converted back to analog and delivered. Each one of these conversions introduced a certain amount of line noise, thus limiting the maximum speed, according to Shannon's law, to approximately 35K.

Today, however, the phone network is becoming more and more digital. A digital connection, while still limited by Shannon's law, has a much lower signal-to-noise ratio and increased bandwidth. By having only one conversion from analog to digital in the route between you and your ISP, the lower signal-to-noise ratio allows for a faster connection from the digital side of the connection. Hence the birth of 56K technology.

56K Hype: Abracadabra

According to Nyquist's formula, it is impossible to achieve speeds over 32K (1/2 of the 64K digitized analog channel). Any speed over 32K is practically a feat of magic, according to the laws of physics.

53K: It's Not Just a Good Idea—It's the Law!

The Federal Communications Commission has limited all data transmissions over the standard phone network to 53K. The most important reason for this is that if ISPs were to push the amount of power over the phone line required to achieve 56K, they would cause interference in other electrical devices in the phone network.

In and Out—and Back in Again

If the connection between you and your ISP leaves the digital network for a few hops, 56K will not work for you. (Refer above to Shannon's law, and remember that line noise is created by converting from analog to digital.) This occurrence is not all that common inside urban areas (where your call most likely passes through only one or two COs to reach its destination), but the farther away you are from the computer you are dialing, the more of a concern it becomes. It is a result of practices like this that Ameritech will only guarantee 14.4K on its phone network in Ohio. If you are getting any speeds above 14.4K, Ameritech will tell you that you are doing better than the rated performance for its lines.

Choices, Choices, Choices

There are basically two different camps in the 56K modem industry: x2 and K56flex. Before the implementation of v.90 by the ITU, both sides were in competition with each other to dominate the 56K industry. With v.90, both sides have agreed on a standard protocol. The problem lies in the fact that not all of the bugs in v.90 have been worked out with all of the parties involved in the big push to be the first to market it. (Common protocol or not, Company A's equipment needs to be forced to "talk" to Company B's equipment, which has an entirely different internal setup.) To further muddy the issue, some modem manufacturers have been known to take an existing ITU protocol and make their own "improvements" to it without properly testing it with all of their competitors' equipment. This has left some 56K modem users stuck again at 33.6 when they connect, or worse yet, unable to connect at all. It is highly recommended that you check the website for your manufacturer often for any potential upgrades as each "bug" is discovered.

I'm Not Going to Be the One Who Tells the Boss

Many multiline businesses use a personal business exchange (PBX) for their phone network. Generally speaking, if you dial 9 to get an outside line, there's a very good chance you're using a PBX. Because of some of the signal conversions that take place in these PBXs, you may not be able to utilize 56K technology without running a separate phone line that connects to the phone network (bypassing the PBX).

But the Box Said

56K competition is so fierce that there are a few subtle truths the manufacturers won't tell you. Due to the amount of noise in the phone system, you probably will never be able to connect at the full 53K allowed by law. In a test run by mindspring.com, 58.2% of their users could connect above 45K; however, 18.7% of their 56K users (almost one in five) were connecting below 40K.

What Did You Say?

The biggest problem with 56K is line noise. With every bit of increased speed, you use up a little more of your 4Khz "window" on the analog portion of your phone line. This leaves less tolerance for imperfections in the line. The amount of noise introduced into your connection is by far the most limiting factor in 56K technology. It is also the most likely cause of why you get disconnected more often running 56K than you did when you were running v.34 speeds.

ISDN

So you've seen all the hype, you've done the research, and you're probably wondering if there isn't a more reliable way to have high-speed Internet connectivity to your home. Say hello to the integrated services digital network (ISDN). ISDN is a fully digital link between your computer and your service provider. It requires you to have your local phone company run a basic rate interface (BRI) line to your house. This line operates on two copper wires (just like your standard phone line) and has two 64K channels ("B" channels) and one 16K channel ("D" channel). The D channel is used to pass logistical information back and forth to the phone company, while the two B channels are used strictly for data transfer, allowing the reliable transfer of 128K without any of the analog modem issues. All of QualNet's dial-up lines are ISDN capable.

There are many tutorials on these issues at the National Instruments website www.ni.com. For those of you who have additional time to devote to *Introduction to Networks*, we suggest using this activity with your students:

Joe Wrench and Plumbers 'R' Us

In order to make the students “speak” to someone who isn’t familiar with information technology (IT), you can use the Joe Wrench and Plumbers 'R' Us competition.

Joe Wrench (played by you) is a competent businessperson running a plumbing supply house that exactly fits the description of the company for which the network is being designed. He even wears a Joe Wrench hat. The students have to ask him questions about the project. Although he knows his business thoroughly, they can’t ask him how many routers or servers he wants. They can’t ask him how much he wants to spend, either. They have to figure that out.

Since Joe knows nothing about IT, everything must be explained to him. The presentations—oral, PowerPoint, and written—must now bear that burden. In addition, the contract will actually be awarded. The prize can be anything: Putting the winning PowerPoint up on a spare computer in a window that can be viewed by passersby, with a sign describing the competition and identifying the winning group, works great.

The rules for this competition are a little tougher than the rubric for grading. If any one thing makes the network not work, the group is eliminated from the competition. For instance, if they forget to include software, they might only lose points on the grading rubric, but they are dropped out of the competition. In addition, if their price is way out of line, they are also eliminated. (In a pilot test of this activity, one group thought they were supposed to have 30% more computers—not just points of access—and their price was about 40% higher than any other group’s. Other groups were eliminated for using hubs that cost more than most switches.)

After groups are eliminated for having models that don’t work, they are judged on the basis of the following chart. The second number is the weight that each item is given. If there are four groups left, each group is assigned a number from 1 to 4. That number is multiplied by the weight, and the group having the lowest number wins.

	Price	Presentation	Notebook and Journal	Bandwidth Access	Software	Computer Hardware	Reliability	Backup	Robustness	Routers	Servers	Wiring	Logical Setup
Weight	8	1	1	3	1	1	3	1	3	3	2	3	1

ASSESSMENT STRATEGIES

Presented below are assessment-scoring ideas, which might be used to assess student performance in the following five categories:

A. Design Challenge Solution: The proposed selection of hardware for the newly

designed system. Computer simulation of the network topology must confirm connectivity. The wiring diagram, or cut sheets, will specify how the system will be installed. Price, quality, and service will all be considered.

B. Oral Presentation to Class: Preparation and presentation of material to the class. Was the design solution justified? Optional: A small PowerPoint presentation—no more than 12 slides at a maximum of 24 words each—might supplement the oral presentation.

C. Student Class Work and Group Work: Participation of each student including individual effort and contribution to the group effort.

D. Design Journal (or Design Folio): Student record keeping; need to document all investigations. Answers are given to summary questions at end of KSBs.

E. Final Report: Does the final design solution reflect work on the KSBs? Has the design process been followed correctly? Does the report demonstrate good use of English?

Assessment Student Scoring

A. Design Challenge Solution

Proposal

1. Proposal contains all of the required components and is organized in a logical manner. (0–12 pts.)
2. Proposal specifies the appropriate number of computers. (0–12 pts.)
3. Proposal specifies the appropriate number of servers. (0–12 pts.)
4. Proposal specifies the appropriate number of printers and other peripheral devices. (0–12 pts.)
5. Names of manufacturers, model numbers, and prices are specified for all proposed devices. (0–12 pts.)

Computer Simulation

6. The computer simulation topology is clear and easy to understand. (0–10 pts.)
7. Components are clearly identified in the topology. (0–12 pts.)
8. The correct number each of hubs, routers, and switches is specified. (0–12 pts.)
9. The computer simulation confirms that the topology is operationally correct. (0–12 pts.)
10. The topology describes a system that is both efficient and easy to maintain. (0–12 pts.)
11. The topology provides for potential future growth. (0–12 pts.)

Cut Sheets/Wiring Diagram

12. Cut sheets are neatly and accurately drawn. (0–12 pts.)
13. Cut sheets accurately represent the computer-simulated topology. (0–12 pts.)
14. Color coding and wire numbering are clear and easy

- to understand. (0–10 pts.)
- 15. Wires are optimally placed with respect to the equipment and the intended use. (0–12 pts.)
- 16. Wires are placed to avoid electrical interference problems. (0–12 pts.)
- 17. All wiring distribution facilities are properly placed. (0–12 pts.)

Total (200 pts.)_____

B. Oral Presentation to Class

- 1. Presentation followed a logical sequence. (0–5 pts.)
- 2. All team members actively participated. (0–5 pts.)
- 3. Presenters were clear and audible. (0–5 pts.)
- 4. Presenters' appearance was appropriate. (0–5 pts.)
- 5. Presentation held the attention of the audience. (0–5 pts.)
- 6. Audience participation was encouraged. (0–5 pts.)
- 7. Questions were answered in a professional manner. (0–5 pts.)
- 8. Presenters were well prepared (all materials were ready). (0–5 pts.)
- 9. Technical terms (when appropriate) were correctly used. (0–5 pts.)
- 10. The design solution was justified to the class. (0–5 pts.)

Total (50 pts.)_____

C. Student Class Work and Group Work

- 1. Assigned tasks were completed in a timely fashion. (0–10 pts.)
- 2. Student demonstrated good time management skills. (0–10 pts.)
- 3. Student worked collaboratively with teammates. (0–10 pts.)
- 4. Student followed teacher's instructions well. (0–10 pts.)
- 5. Student contributed her/his share of the group effort. (0–10 pts.)
- 6. Student conducted herself/himself in a businesslike manner. (0–10 pts.)

Total (60 pts.)_____

D. Design Journal (or Design Folio)

- 1. Journal documents all of the work on both the KSBs and the Design Challenge. (0–6 pts.)
- 2. Journal contains observations and data that were collected during the KSBs and the Design Challenge. (0–8 pts.)
- 3. All entries are legible and complete with correct grammar and punctuation. (0–8 pts.)
- 4. Entries are chronologically correct. (0–6 pts.)
- 5. Entries are made on a daily basis. (0–6 pts.)
- 6. Illustrations are used to enhance the journal entries. (0–6 pts.)

Total (40 pts.)_____

Grand Total: Sections A - D (350 pts.)_____

Handouts

Overview of the Module and Design Challenge

HERE'S WHAT YOU WILL DO

In the NYSCATE module *Introduction to Networks*, you will work in a group to:

- Design a network for a computer system that will be used by a small business.
- Develop a timeline describing the history of computer networking.
- Install a network interface card and driver software.
- Determine OSI model and Windows NT attributes.
- Develop a proposal for the network that you design for the new computer system.
- Generate a computer simulation of the topology for your designed network.
- Specify where each of the components will be installed in your designed network.

PROBLEM CONTEXT

INTRODUCTION

Computers have come a long way since the time when a single computer filled an entire room. In the early days of computer use, and up through the mid-1970s, remote access was the only viable method of connecting to a computer. People usually worked on a terminal wired to a computer that might have been in the next room or many miles away. Dedicated telephone lines typically served as the common link between the user's terminal and the "mainframe" computer. This situation changed with the development of integrated circuits (microchips) and the microcomputer in the late '70s. For the first time, people were able to work on a stand-alone computer on their desktop, independently of any

other system. This independence, however, brought certain disadvantages. Many desktop computers lack the capacity to store and access the large amounts of data associated with typical business applications, and they often require needless duplication of many resources that can (and should) be shared.

As a result, the need today is for networks that enable computers to share data, software, devices, and other resources. One could say that computers have come full circle over the past two decades: We are now all getting connected again. As much as we like our independence, we often need the benefits of connectivity.

DESIGN CHALLENGE

Student teams design a system for a business that is modernizing its computer system. They upgrade a 386 Novell Server-based accounting system that uses 4-mps token rings to network six computers and replace it with a new state-of-the-art integrated system that will put terminals at every point in this warehouse-based business and connect to the Internet. Optionally, a small dot-com will be created, allowing iCommerce with additional routers, switches, and servers. Each team will analyze the operation of the company and then design a system that best matches current and future (projected) needs. Your team will submit a formal proposal describing a recommended system.

SPECIFICATIONS

The recommended system will be based on a needs assessment that your team develops by analyzing the operation of the company. Your solution will include the following items:

- A sales proposal indicating the name, model, quantity, and cost of all devices and materials. Each team's proposal will include prices of hardware, software (OS and Office Suite), and installation. A one-page spreadsheet summarizing prices and a one-page summary of the reasoning behind this proposal will comprise the first two pages of the proposal.
- A computer simulation describing the topology of the connected hardware. This will confirm that all of the network components work together. Cisco's ConfigMaker will be used for this.
- A wiring diagram (cut sheets) illustrating the layout and connections for all network wiring.

CONSTRAINTS

Your proposed system must reflect state-of-the-art technology and performance. Your designed system should provide maximum bandwidth for the proposed price. Your team must address the needs of the new network regarding bandwidth, security, reliability, and speed, and prices must be competitive. Presentations are to be professional.

MATERIALS NEEDED

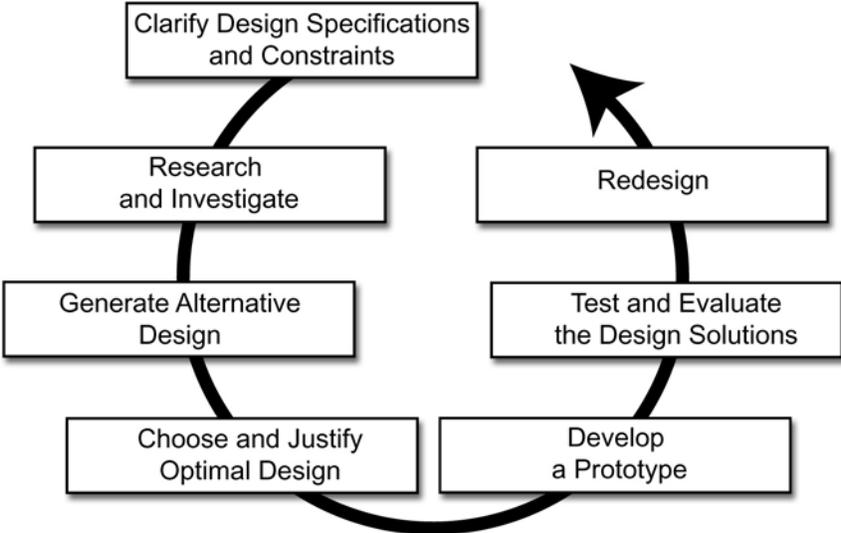
- For each design team (3 or 4 students): One PC 486 or higher, with 16 MB of RAM, 1 GB hard disk, CD-ROM and network card, running Windows 95 or higher
- ConfigMaker software: Provides a topology of the network to confirm connectivity of components. Available from Cisco Systems and will work only with Cisco Systems devices.
- Floor plan diagrams of the building in which the new network will be installed
- Various colored pencils and drawing tools for cut sheets/wiring diagrams

STUDENT REQUIREMENTS

- You will maintain an individual Design Journal (or Design Folio), which will contain all of your observations and collected data. Entries will be made on a daily basis and will document your efforts on the KSBs and the Design Challenge.
- Your team will submit a final report, which will contain information gathered from your Design Journal:
 - literature searches
 - hands-on research (factor investigations)
 - completion of Knowledge and Skill Builders (KSBs)
 - work on the Design Challenge
 - methods used to generate the final design solution
- Your team will make an oral presentation to the members of your class.
 - This presentation should justify your design solution.
 - It should be prepared and delivered in a professional manner.
 - It should demonstrate that the solution meets design criteria.



The Informed Design Loop



History of Computer Networking

This KSB will enable you to understand how computer networking has evolved over the last half century. Many technological changes have occurred during this period of time. The computer has advanced from a device that filled an entire room to one that we can now carry in a briefcase. Computers communicate with each other to enable software deployment and sharing of devices, files (data), and software.

Your team will generate a timeline that documents the progression from the initial development of the computer through the development of multiuser systems, to the microcomputer and the Internet.

You may use the Internet and/or printed sources to research your timeline. Your timeline may be submitted as a graphic, or as a text report written in chronological order. The timeline must identify 30 developments and will specify the five that are the most important.

DEVELOP YOUR UNDERSTANDING

1. Which of the resources that you used for your timeline would you consider the best?
2. Name five major technological breakthroughs that marked advances in the computer revolution.
3. What industry standards have been developed as technological advancements have taken place?
4. What type of computer network would you put in your home?
5. What future innovations can you predict for computers and networks?

The Open Systems Interconnect (OSI) Model

The open systems interconnect (OSI) model is an industry standard for the manufacture of software and hardware. The purpose of this industry standard is to ensure the compatibility of network products. The OSI model is the standard used and it contains seven distinct layers. Some of the layers are hardware based and some are software based; others are a combination of both hardware and software. Each layer in the OSI model provides an important function during the transmission of data (connectivity) in a network system.

The association of the layers and their interaction are important concepts in OSI operation. Investigate the various layers in the OSI model. Then create a chart that describes the different OSI layers. Your chart must differentiate the various hardware and software elements in each layer. Show how data is transformed at each layer in the OSI model, and include this in your chart as well.

DEVELOP YOUR UNDERSTANDING

1. What would happen if we bypass layers from the OSI model?
2. What would happen if we remove layers from the OSI model?
3. On which layer of the OSI model does a router operate? Why?
4. Which layers of the OSI model are both hardware and software related? Back up your claim.
5. Describe how the OSI model packages the data for transmission.
6. Since nothing is perfect, what specific improvements would you recommend for the OSI model?
7. Determine whether all the computer platforms and operating systems use the OSI model. Back up your claim.

Installing a Network Interface (NIC) Card

There are methods (using hardware and using software) that make a computer network ready. Since so many computers now operate on networks, this is important for you to understand. Many computers are shipped network ready, but many still are not. And even those that are network ready may eventually need hardware and software upgrades.

Install a network interface (NIC) card in a PC and install the correct driver software for it. Perform a series of tests to confirm the installation of the NIC card and driver; these include:

- From the DOS/command prompt, do a “loopback ping” to ensure that the NIC card is properly connected.
- Check the “network neighborhood” icon after the computer is connected to the network to verify connectivity.

Use the TCP/IP network configuration because this is the most common configuration and is compatible with the Internet.

DEVELOP YOUR UNDERSTANDING

1. If you were given the choice, would you use the PCI or ISA interface card? Support your choice.
2. Describe the difference between 10baseT and 100baseT.
3. What are the advantages of “plug and play”?
4. What are the limitations of “plug and play”?
5. Describe the purpose of the driver that you installed with the NIC card.
6. Describe procedures used to make home computers Internet ready.
7. Relate the difference between a NIC card and a modem.
8. How do ISPs assign IP addresses? Why is this done?
9. Why can't people expect to remain anonymous while on the Internet?

Bandwidth and Frequency of Digital Signals

Telephone networks and lines were originally designed for transmission of voice signals and their limited bandwidth. Today, however, telephone networks also transmit data. Transmission is controlled by the characteristics of these networks, which were designed for a less complex purpose. This has created numerous difficulties in the transmission of high-speed digital signals.

Through research, determine the characteristics of each of the following access methods:

- conventional telephone system
- xDSLs (digital subscriber)
- ISDN (integrated services digital network) lines
- cable access lines

Create a chart describing the advantages and uses of each of these access methods.

Use formulas to compute values of signal-to-noise ratio (SNR) and channel capacity/bandwidth (BW) for a variety of signal lines. Determine the relationship between the SNR and BW as they relate to signal line performance.

DEVELOP YOUR UNDERSTANDING

1. What are the factors that limit the bandwidth of a conventional telephone line?
2. What modifications are needed for a conventional line to prepare it for DSL?
3. Describe why loading coils are needed on a local-loop telephone line. Would these coils ever need to be removed?
4. Relate why ISDN is still in use today, yet not found in newer installations?
5. Suggest how to deal with the issues of security and shared access when using a cable modem.

Using Cisco's ConfigMaker

Cisco System's ConfigMaker program is available, free of charge, at www.cisco.com. It includes a tutorial that is very informative. The program is used by designers to "mock up" a LAN/WAN system and check its interoperability. ConfigMaker can also be used to deliver a very simple configuration to equipment within the LAN.

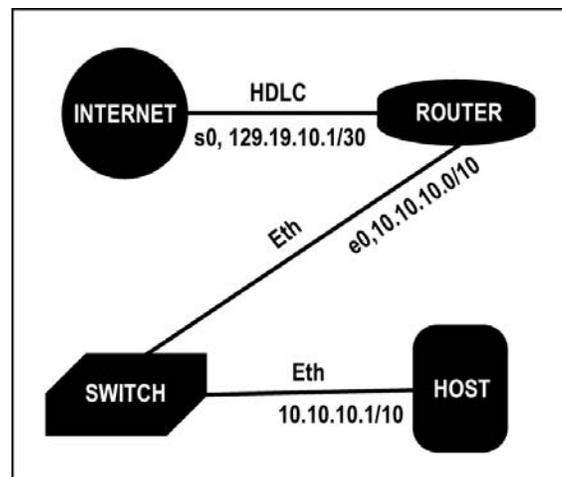
You can use Cisco System's ConfigMaker program to develop the topology of the LAN to address the *Introduction to Networks Design Challenge*.

The program requires that certain pieces of your scenario/design be decided upon beforehand.

1. IP addressing/subnetting scheme.
2. Types of equipment to be used. The list of equipment is somewhat limited; if you are using this program to create your LAN/WAN, then you must become familiar with the list available and use only the items listed.
3. "Names" of the equipment, if you are going to give them names (e.g., MainOffice Router, Lab-A, etc.).
4. How you are going to connect everything (the LAN) to the outside world (the Internet). For example, you might use Frame-Relay, or ISDN.

DEVELOP YOUR UNDERSTANDING

1. First, run the tutorial and take notes.
2. Then use the program to create a sample LAN having only one router, one switch, and one host. Use the following diagram with the attached IP addresses and subnet masks.
3. Now, use the program that addresses the *Introduction to Networks Design Challenge*. First you might want to create a chart about various Internet devices including hubs, modems, routers, bridges, repeaters, switches, hosts, printers, and servers.
4. Advantages and disadvantages of each will be illustrated.



Note: The subnet masks are written in CIDR notation. "/30" after the IP address means that the subnet mask contains 30 binary 1's; therefore, it is 255.255.255.252. "/10" is 255.192.0.0.