COMPUTER HARDWARE AND NETWORKING BASIC CONCEPTS

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Computer Hardware And Networking Basic Concepts

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Computers and Networking

Contents

2.1 Introduction

The core infrastructure of any modern Radiology department is made up of computers/computer workstations and the connectivity or networking capabil-ity between these devices. All transactions between modalities, PACS, schedul-ing, billing, dictation, and reporting systems are made possible through specialized computer programs or applications that are executed by computers. Computer systems are quite diverse and are often designed to augment a specific task, whether it is to support image reconstruction for a modality such as computed tomography (CT) or digital radiography (DR) or rapid image display as in PACS. Fundamentally, all computers are built around a similar base design with enhancements in specific areas to address certain needs such as rapid storage access and data transfer for fileservers and improved video characteristics for PACS client display stations. The purpose of this chapter is to familiarize the reader with the fundamentals of computer architecture, networking, and computer applications.

2.2 Computers 101 – Hardware

2.2.1 Hardware Elements of Computers

There are five core hardware components of the modern digital computer system: the central processing unit or CPU, memory, input devices, output devices, and a bus. While some components are given greater emphasis for a particular computer design (e.g., a faster CPU for computationally intensive tasks), virtually all

types of computers have these

five key components represented.	Key Concept 2.1:	
Most of the hardware compo-	Core Computer Hardware	
nents in the modern digital com-	Components	
puter are contained within small		
modular semiconductor packages		CPU
(integrated circuits [ICs] or chip)		Memory
that, in turn, contain millions of		Input devices
discrete components. Numerous		Output devices
ICs are interconnected on a large		Bus

circuit board, frequently referred

to as the motherboard. The

motherboard is interfaced with other outside components (e.g., disk drives, power supply, keyboard, network, etc.) using specialized couplers that provide necessary power and connectivity to peripheral devices such as disk drives (storage), video displays, and keyboards.

The central processing unit (CPU) or microprocessor is typically the largest integrated circuit on the motherboard and its role is to execute specific commands or instructions/machine code dictated by a computer program and orchestrate the movement of data and instructions through the entire computer system. Although the CPU is frequently personified as the ‘‘brain’’ of the computer, it has no innate ‘‘intelligence’’ or inherent ability to make decisions. The CPU’s strength is in its ability to process instruc-tions and manipulate data at amazing speeds. In this regard, it is the perfect

soldier; it follows all commands presented to it with blazing efficiency.

The number of instructions that a CPU can perform per second is expressed as its clock speed. Typical personal computer CPUs can per-form over 3 billion instructions per second or 3 gigahertz (3 GHz). Modern CPUs actually contain two to eight CPUs in one IC or chip (multi-core CPU). This provides unparalleled computational speed as each core shares the processing tasks formerly assigned to one CPU. While the strength of the CPU is in its ability to process instructions, it has limited capability to store data before or after execution. The CPU relies on physical memory to store this information and provides it to the CPU on demand.

Memory is principally used to temporarily store data (and results) and applications or programs. In contrast to the CPU, a memory module has no capability to process instructions; instead memory is designed to reliably store large chunks of data and then release these data on command (often at the behest of the CPU). Physical memory can exist in solid-state form as an IC or as physical media (spinning disk, compact disk [CD], or digital versatile disk [DVD]). A solid-state memory module that can be erased and rewritten for unlimited number of times is generically referred to as random access memory or RAM.

Memory that can only retain data with power applied is referred to a volatile memory – most of the motherboard memory modules are of this type. These are rated by their storage capacity (given in megabytes or gigabytes), access speed (in nanoseconds), data rate (DDR2), and configuration (single or dual inline memory SIMM or DIMM).

Non-volatile memory will retain data written to it until it is erased or over-written. Examples include USB memory sticks and disk drives. Since the inherent speed of non-volatile memory is substantially slower than that of volatile memory, volatile RAM is typically employed on the motherboard to augment data processing.

Some forms of memory are designed for specific tasks. Video memory (VRAM) is employed on video graphics cards to store graphical information to improve video display performance. A specialized form of high-performance memory is found on most CPUs to help efficiently buffer data that move in and out of the microprocessor core (L2 cache memory).

There are additional forms of computer memory that are classified simply as storage, principally because they are characterized by slower speed compared to solid-state memory and non-volatile characteristics (data persist indefi-nitely until erased/overwritten). These are made up of spinning media (disk

drives, CDs, and DVDs) and linear media (tape).

On-line storage refers to high-performance, non-removable media that requires no human or mechani-

cal intervention to retrieve. Data on spinning hard disk arrays are an example of on-line storage. Near-line storage consists of removable media (e.g., tapes, CDs, or DVDs) that are made available through

Key Concept 2.2:

Types of Data Storage

On-line Near-line Off-line

mechanical means such as a robotic tape or optical disk jukebox. The efficiency of data retrieval with a near-line system is dependant upon the mechanical speed of the robotic system and the queuing mechan-ism of the media. Off-line storage is removable media that requires human intervention to load and retrieve data. As a result, performance

The motherboard, the CPU, and memory retain no previous information about how the computer is configured. Every time the computer turns on, it pulls itself up by its bootstraps (‘‘booting up’’).

Key Concept 2.3: Booting Up

is the lowest for off-line storage. While off-line storage is the least expensive storage strategy, it is otherwise quite inefficient and is therefore reserved for data that have a low probability for future use.

Input/output devices are hardware extensions that allow humans (or other devices) to interact with a computer. Examples of input devices include the keyboard, touch screen, mouse, microphone, and camera. Typical output devices include the video display, printer, plotter, and

speaker.

Because the typical microprocessor can execute several billions of commands per second, it is highly dependant upon an efficient mechanism for delivering instructions and data to it. This requires that there is a well-orchestrated method for moving data between the motherboard components and the CPU. The data bus is the physical data chain built into the motherboard that allows for this efficient data transfer. This is supported by several ICs, known as the chipset, which coordinates uninterrupted data transfers through the bus. Mul-tiple different designs have been developed; the most common in use today is peripheral component interconnect (PCI) and PCI-Express. The data bus is defined by a data-width (typically 32 or 64 bits), which specifies how much data are

delivered across the bus per

cycle and a clock speed (given in megahertz).

Another key component to the typical computer motherboard is the basic input/output system (BIOS). The BIOS is comprised of a non-erasable read only mem-ory (ROM) chip that contains the minimal amount of software necessary to instruct the computer how to access the keyboard,

mouse, display, disk drives, and communications ports.

When the power is first applied to the computer, the motherboard relies on the BIOS to tell what additional components are available to the motherboard for input and output (e.g., disk drives, memory, keyboard, etc.). The motherboard ‘‘becomes aware’’ of what is avail-able and how to access it, each and every time the computer is

restarted.

The BIOS also provides information to the motherboard on where to find the first piece of software to load during the startup process. The startup process is also known as the boot process. The first piece of software to load is usually a portion of the operating system that will coordinate the other software programs.

2.3 Computers 101 – Software

The fundamental distinction between software and hardware is that hardware exists as the tan-gible physical components and connections inside a computer.

Hardware can be seen and handled. Software, on the other hand, is a virtual concept. While we can handle the media that software is written on, we cannot actually ‘‘see’’ the software.

The term ‘‘software’’ applies both	Key Concept 2.4:
to application programs and data.	Software Versus Hardware
Software at its lowest level (the level	

at which it interacts with the CPU) consists of a long series of bits (ones and zeros). All data written to phy-sical media, whether it is magnetic disk, USB stick, CD, DVD, or RAM memory is stored as an

orderly series of bits. Eight-bit clusters of data form a byte of data.

Software is divided into system software (or operating system) and applica-tion software – programs that help users to perform specific tasks and programming software (or development software) – programs that aid in the writing (i.e., coding) of other software.

All software consists of individual procedures that command the computer to follow a precisely orchestrated series of instructions. The number of individual instruc-tions specified in any one program varies depending upon the type and complexity of the software – from 10 to 100 million lines of

Further Reading 2.5:

Core Computer Components

White R, Downs TE. How Computers Work. 9th ed. Indianapolis, IN: Que Publish-ing; 2008.

code. (The Windows XP operating system, for example, contains approxi-mately 40 million lines of code.)

All computer software must be moved into storage (i.e., disk drive) or physical memory (RAM) before it can be executed by the microprocessor. The instructions are passed through a series of software layers where they ultimately reach the microprocessor. Each instruction causes the computer to perform one or more operations.

2.3.1 Computer Operating System

The operating system (OS) is the underlying software that integrates the hardware with software applications. It is distinguished from the essential hardware components in that it consists entirely of software – millions of lines of machine commands that are understood and obeyed by the micro-processor. The OS actually consists of hundreds or thousands of individual programs that bundled together. Many of these individual programs are designed to work cooperatively with each other. The OS is automatically executed each time the computer is started and it is the most important software component running on any computer. A modern computer cannot operate without an OS.

Although the CPU is frequently personified as the ‘‘brain’’ of the computer, it is really the OS software and the CPU acting together that provides the underlying ‘‘intelligence’’ of system. The OS and the CPU are inexorably linked; therefore, the distinction between the software and the hardware is sometimes blurred.

The OS is designed to automatically manage nearly every task (or process) including maintenance of the files on the disk, tracking input from peripheral devices like keyboards or network cards, displaying output on printers and video displays and control of memory allocation. Memory allocation is crucial for maintaining stability of the system because if two programs try to use the same area of memory, both programs will usually fail. Two of the most critical jobs of the OS are ensuring that programs do not unintentionally interfere with each other and maintaining security.

A function paramount to the modern OS is the support of the graphical user interface (GUI). A GUI replaces typed computer commands with a graphical representation of the task (e.g., moving a file). This is accomplished by creating a visual representation of the computer file system (the desktop), icons, and windows and linking them to the movements of a pointing device such as a mouse or trackball.

The OS also provides a foundation or software platform for all other software (application programs). Therefore, the choice of OS, to a large extent, determines which application software can be used on a particular system.

There are a number of operating systems in use today. The most popular is the Windows OS (Microsoft, Redmond Washington) that runs on the majority of computers worldwide. Other choices include UNIX, Linux, DOS, and the Mac OS (Macintosh).

A multiprocessing OS supports use of more than one CPU. A multitasking OS allows more than one program to run simultaneously. A multithreading OS allows different parts of a program to run concurrently and a multi-user OS supports two or more indivi-duals to run programs concur-rently on the same computer system.

An OS may consist of hundreds (or even thousands) of small programs called drivers. Drivers enable soft-ware to interact with the ubiqui-tous hardware devices attached to the motherboard and between

Key Concept 2.6: Drivers

Drivers are small programs that enable the operating system and application programs to interact with each other and with periph-eral hardware devices. They require periodic upgrades, espe-cially when the OS changes.

components on the motherboard itself. In other instances, drivers allow one software component to safely interact with another piece of software.

From the user perspective, the OS provides the framework that application software runs inside of. All application software runs on top of the OS that, in turn, is directly integrated to the hardware. In general, application software cannot interact directly with the hardware; it must work through the OS. The modern OS is intentionally designed to sustain itself automatically with minimal user interaction. The software that is designed to perform real work for users is the application software.

2.3.2 Application Software

OS software is designed to run autonomously with little interaction from the individual user. The OS monitors all internal functions of the computer, maintains stability of the hardware components, and regulates the processing of data in the microprocessor. Application software is a program designed to do real work for a user. Application software does not supplant the base OS software. Instead, application software runs on top of the OS such that an application is written (or coded) to work with a specific OS. Examples of application software include a word processor or spreadsheet.

2.3.3 Low-Level Programming Language

Low-level programming language is the software language that is directly understood by a microprocessor, and is termed machine code or machine language. Every CPU model has its own native machine code or instruction set. The instruction set consists of a limited number of relatively primitive tasks such as adding or subtracting data in specialized memory placeholders called registers, or moving data from one register to the next.

Despite their enormous processing speed, the intrinsic mathematical capabilities of a microprocessor are quite limited; a CPU cannot perform simple multiplication or division on its own – it has to be taught how to do it. By stringing a series of machine codes together, more complex processing (e.g., multiplication) is possible.

Both machine code and its symbolic representation (assembly language) are considered as low-level languages because they are the closest command analog to the actual functional details of the microprocessor. Low-level does not imply diminished quality or efficiency; in fact, programs written directly in machine code or assembly language are very efficient.

2.3.4 High-Level Programming Language

Although low-level programming instructions produce efficient programs, programming in machine code or assembler is difficult, tedious, and very time consuming.

High-level programming language is really an abstraction of machine code programming because it uses natural language elements instead of arcane numbers and abbreviations. This makes the process of programming simpler, intuitive, and more understandable to the human programmer.

High-level programming is the foundation of most software development projects. There are many high-level languages in common use today. Some of the languages currently include C, C#, C++, BASIC, Pascal, Java, FORTRAN, COBOL, and others.

Using high-level programming languages, programmers (or ‘‘coders’’) type out individual lines of the source code for an application, using a develop-ment software program. The lines of the source code need to be translated into machine code before the program can be understood and tested on the microprocessor. This conversion process is known as compiling a program and the software that converts the source code to machine code is known as a compiler.

Most development software platforms include one or more compilers. The compiler turns the source code into an executable program that is customized for the specific OS/microprocessor combination that the program was devel-oped for.

The compiler saves the program-mer a substantial amount of time and effort by constructing the sequence of machine codes that accurately represents each source

code command.

Programmers must follow a tedious sequence of compiling, testing, identifying errors, correct-ing errors, re-coding, and re-com-

Key Concept 2.7: Low-Level Versus High-Level Programming Languages

A single print statement in high-level source code programming language might produce a thou-sand individual machine code commands once it is compiled.

piling a program in a process known as debugging the program. The majority of time devoted to programming is spent on debugging the code.

Scripting languages differ from compiled languages in that the source code is interpreted and converted into machine code at the time of execution – obviating the compiling process. The development process with scripted languages is typically more rapid than with compiled code; however, because scripting languages are interpreted at the time of execution, they are typically slower to execute. Therefore, scripted language is often reserved for smaller programs that are not computationally intensive.

Scripting languages include Apple Script, Visual Basic (or VB) script, shell script, and JavaScript.

2.4 Computer Networking

A computer network is a group of two or more interconnected computers that are capable of sharing data and resources. Networking allows multiple inde-pendent users to share the same resources (i.e., applications and data) and work with these data simultaneously. Fast, reliable networks form the backbone of digital Radiology department and allow large quantities of imaging data to be

efficiently transported between modalities, archives, and viewing stations.

Computer networks can be classified on the basis of scale (i.e., size, complex-ity), scope, topology, architecture, and connection method. The most com-mon network is the local area network (LAN). A LAN is characterized by

serving computers in a small geographic area such as a home or an office. A network that is comprised of two or more LANs is termed a wide area

network (WAN). Although the term is somewhat ambiguous, it is more commonly used to describe networks with a broad geographic coverage – metropolitan, regional, or national. The largest WAN is the public Internet,

which is a global system of interconnected computer networks.

A typical Radiology department network would consist of at least one LAN that may be interconnected to a larger WAN (e.g., hospital network).

Connection of two or more networks (i.e., Internetworking) changes the scope of network resources to any computer on the network. An intranet is one or more networks that are under control of a single administrative authority. Access to any external or unregulated networks is either not provided or is limited to authorized users.

An extranet is an internally managed network (intranet) that maintains limited connectivity to networks that are neither managed, owned, nor controlled by the same entity. An extranet is typically isolated from the public Internet with security measures such as firewalls that regulate connectivity to outside or unmanaged networks. Most hospitals and business organizations configure their internal network in this way.

Many home networks (wireless or wired) are extranets that consist of a LAN with access provided to the public Internet (WAN) via an Inter-net service provider (ISP) (e.g., Comcast, AT&T, Verizon, etc.).

2.4.1 Physical (Hardware) Networking Components

Further Reading 2.8:

Networking

Kurose JF, Ross KW. Computer Networking: A Top-Down Approach. 4th ed. Reading, MA: Addison-Wesley Publishing Co.; 2007.

Basic physical components of a

computer network include the network card, cabling, and a point of connection (e.g., hub, repeater, bridge, router, or network switch).

The network interface card (NIC) is the piece of computer hardware that provides the capability for a computer to communicate over a network. Every NIC possesses a unique number, its media access control (MAC) address. This number can be used to help route data to and from other computers.

The physical connection of the computer to the network is usually accomplished through specialized cabling that contains four pairs of simple copper wires (twisted pair) in a configuration known as cate-gory 5 or Cat5, or its enhanced version Cat5e. Cat5 cabling fre-quently terminates in special rec-tangle plastic connectors that resemble oversized telephone

handset connectors.

Other forms of physical connec-tion used less often include fiber optic cables (optical fiber) and wire-less (802.11x). Fiber optic provides greater transmission capacity (bandwidth) than Cat5 and wireless

Definition 2.9: Bandwidth

The maximum amount of data that can be transmitted over a medium, usually measured in bits per second.

Key Concept 2.10:

Network Devices

There is a one-to-one relationship between computers and network devices. That is, there is only one computer attached to each net-work cable.

affords greater access where physical connections are not readily available.

The term Ethernet describes the wiring and signaling schema for the NIC and the cabling between devices on the network.

2.4.2 Network Switches

The cornerstones of the computer network are switches, the devices that connect other devices together on the network. Switches vary in the degree of functionality by which they manage the data traffic that passes through them. The

Key Concept 2.11:

Types of Network Switches

Hub Bridge Router

term switch is an imprecise term that refers to many types of network devices.

The simplest and most inexpensive of network switches is the network hub. The hub provides a simple and passive method for all computers connected to it to transmit and receive data to each other. Each computer network cable has an individual connection (port) to the hub. The hub creates a shared medium where only one computer can successfully transmit at a time and each computer (host) is responsible for the entire communication process.

The hub is a passive device. The hub merely replicates all messages to all hosts connected to it and does not have any capability to route messages to a specific destination. A network hub is the most basic and inefficient means of connectivity. For this reason, simple hubs are rarely used today.

The network bridge improves upon the design of the basic network hub by providing a level of active management of the communication between attached hosts. The bridge is capable of learning the MAC addresses of the connected host computers and will only send data destined for a specific host through the port associated with a unique MAC address. By routing the data stream to the intended recipient, switching creates a more efficient method for network transmission.

Since the bridge needs to examine all data sent through it, it creates some processing overhead that slows the data transmission rate. Bridges typically support data transmission rates of 10, 100, and 1000 megabits per second (Mb/s).

The network router offers yet another level of technical sophistication over the network bridge. Like the network bridge, a router is capable of examin-ing the contents of the data passing through it and is able to discern the identity of the sender and the recipient. However, instead of relying on the value of the hardware NIC MAC address (which is fixed and not configur-able), the router is capable of discerning data based upon a software configurable identifier known as the Internet protocol address (IP address).

The IP address is a configurable 32-bit numeric value (e.g., 192.123.456.789) that is used to uniquely identify devices and the networks to which they belong. Using this schema, a host that is accessible globally must have a unique IP address; however, a host that is hidden within a private network need not have a globally unique address (it only needs to be unique on the local network). This scheme allows for conservation of

unique IP addresses.

The typical broadband network router used in home networking has additional features such as dynamic host control protocol (DHCP), network address translation (NAT), and a network firewall. These additional features provide a secure connection between the home LAN and the ISP WAN. The router using NAT serves as a proxy that allows multiple computers to share a single public Internet IP address. The broadband network router assigns each computer in the home network its own IP address that is only unique within the home network.

2.4.3 Network Protocols

In order for them to communicate effectively, each device must adhere to a specific set of rules for communication called network protocols. Networks are usually comprised of a heterogeneous group of devices of different make, model, vintage, and performance. The most ubiquitous network protocol over Ethernet is the Internet protocol suite (IPS) or transmission control protocol/Internet protocol (TCP/IP).

TCP/IP is a software abstraction of protocols and services necessary for the establishment of communication between two computers on a network. This network abstraction was set down by the International Organization for Standardization (OSI) and is referred to as the OSI network model. The model describes five to seven information layers that link computer software application to the hardware that must perform the actual transmission and

receipt of data.

The layers in the network OSI model rely upon protocols to regulate how information is passed up through and down the OSI stack.

The Internet protocol suite defines a number of rules for establishment of communication between computers. In most instances, the connection is a one-to-one relationship. Two computers go through a negotiation process prior to making a connection. The negotiations include request and acceptance of an initial connection, the type of connection, the rate of transmission, data packet size, data acknowledgement as well as when and how to transmit missing data.

2.4.4 Data Packets

Data transmitted over a network is broken up into multiple small discrete chunks or packets before being sent over the network by the NIC. Packet size is variable and is part of the ‘‘negotiations’’ when establishing a network connection with another computer.

Since a network segment can only be used by a single computer at any one instant and the physical parts of the network (i.e., cabling and switches) are shared by many computers, splitting data streams up into smaller parcels in a shared network model improves network efficiency

dramatically.

Switching and assigning resources on a shared network is a complex process – one which needs to occur in the order of microseconds to maintain efficient communication between thousands of devices that are potentially competing for these resources. Despite the refined sophistication of the system, there are instances where two or more computers attempt to send data along the same segment simultaneously. This phenomenon is termed a collision. Optimum network design mandates minimizing collisions and maximizing collision detection to maintain fidelity of data

transmission.

Additional metadata is automatically married to each data packet based upon protocols specified in by IPS and contains information such as the data type, packet number, total number of packets as well as the IP address of the sender and receiver. This is analo-gous to placing a letter (packet) in an envelope with delivery informa-tion (sender and return address). Data packets with this additional data wrapper are referred to as data

frames.

Since each frame of transmitted data contains information about where it originated and where it is

Key Concept 2.12: Data Packets

Since each packet is self-contained and auto-routable, different pack-ets from a single message can tra-vel over completely different routes to arrive at the same destination.

supposed to go, routers can then examine each packet and forward it through the relevant port that corresponds to the recipient. Moreover, since each packet is self-contained and auto-routable, packets from a single message can travel over completely different routes to arrive at the same destination. Routers instanta-

neously analyze and balance net-	
work traffic and will route	Checklist 2.13:
packets	Theoretical Bandwidths

over segments that	
are currently under a lighter	Ethernet 10 Mbits/s
load.	
	Ethernet 100 Mbits/s
At the receiving end, the OSI	ATM 155 Mbits/s (OC3)
model also details how to re-	
assemble the individual packets	ATM 622 Mbits/s (OC12)
back into the original file. Each	Ethernet 1000 Mbits/s
packet bears both an identifier	ATM 2488 Mbits/s (OC48)

and sequential number that spe-

cify what part of the original file

each packet contains. The destination computer uses this information to re-create the original file. If packets are lost during the transmission process, TCP/IP also has methods for requesting re-transmission of missing or corrupt packets.

Network bandwidth is defined as the rate at which information can be transmitted per second (bits/s). This can vary tremen-dously depending upon the type of physical connection, switches, and medium (i.e., cabling versus fiber versus wire-less). Theoretical bandwidth of

Key Concept 2.14:

Theoretical Bandwidth

In general, actual bandwidth is approximately one-half of theore-tical values.

Ethernet, for example, varies from 10 to 1000 Mb/s. Another technol-ogy, known as asynchronous transfer mode (ATM) can support band-widths ranging from 155 Mb/s(OC3), 622 Mb/s (OC12) to 2488 Mb/s (OC48).

It is important to recognize that there can be a substantial difference between the values of a theoretical bandwidth and actual bandwidth. While packets of data move at the speed of light, other factors such as quality of cabling and efficiency of network switches contribute to network overhead that can impede actual performance.

2.5 Client–Server Architecture

The client–server computing model is one of interdependency between two or more computers where one computer provides

data or services to the other.

Early networks were used pri-marily to backup data to a cen-tral location during off-hours. As technology has continued to

Definition 2.15: Server–Client

A server is a computer that pro-vides application services or data. A client is a computer or software application that receives those ser-vices and data.

evolve, there has been a growing convergence of desktop computing and network computing. In the past, maximizing computing efficiency required application software and data to reside on the client computer. A fat client (thick or rich client) is a host application that performs the bulk of data processing operations for the user with minimal to no reliance on network resources.

By leveraging the power of faster network services, real-time transfer of data and application resources to the client desktop computer is afforded. The client makes requests from a dedicated, powerful networked host computer (a server) that stands ready to provide application services or data to the

client over the network.

While any computer can be configured to act as a server, most servers have additional hardware capacity to support the increased demands of multiple simultaneous users (i.e., faster multi-core CPUs, large memory stores, and large hard drives).

This close interrelationship of multiple clients and a server is known as client–server architecture. Almost the entire structure of the Internet is based upon the client–ser-ver model. This infrastructure sup-ports delivery of web pages over the World Wide Web and e-mail. The most basic client application is the web browser, which interacts directly with the server to render

Key Concept 2.16:

Client–Server Architecture

In its purest form, client–server architecture concentrates on max-imizing virtually all of the compu-tational power on the server while minimizing the computational requirements of the client stations. This affords great economies of scale without loss of functionality.

data, images, or advanced visualizations. Any application that is accessed via a web browser over a network that is coded in a browser-supported language (i.e., JavaScript, Active Server Pages – ASP, Java, HTML, etc.) are called web applications or webapps.

A thin client (lean or slim client) is an application that relies primarily on the server for processing and focuses principally on conveying input and output between the user

and the server.

The term thin-client application is often misused by industry to refer to any function or application that runs within a web browser – how-

Definition 2.17:

Thin Client

A software application that does not depend upon any additional software components and does not perform any processing on the local host.

ever, this is an incomplete definition. Even if the application is used inside of a web browser, if additional software or browser plug-ins are required or local data processing occurs, the term hybrid-client is more appropriate. Most PACS client viewing software that runs within a web browser is classified as hybrid-client.

Modern PACS systems are designed to leverage this configuration where the majority of the image management is controlled by a powerful central server that responds to multiple simultaneous requests for image data from relatively inexpensive, less-powerful client viewing stations.

Software applications that are designed to operate principally over a network in a client–server configuration are grouped collectively into something known as web services. There are established profiles and specifications that define how these services are supposed to interoperate with service providers and service requesters. Web services differ from web applications in that web services need not run inside a browser or be constructed with web elements.

2.6 Database Applications

Many useful web services and web applications provide direct access to databases.

There are a number of database models; however, the relational model is used most often. In the relational model, data are abstracted into tables with rows and columns. Each row is an indi-vidual record and each column is a separate attribute or field for each record. One or more tables are linked logically by a common

Definition 2.18:

Database

A structured collection of data. Data that are housed in a database are more amenable to analysis and orga-nization. Databases are ubiquitous and are the essential component of nearly every computer application that manages information.

attribute (e.g., an order number, serial number, accession number, etc.).

Databases also support an indexing mechanism that confers greater speed to the system when accessing or updating data. Indexing comes at some cost

since it adds some processing overhead to the system.

The most common programmatic operations on a relational database include reading or selecting records for analysis, adding records, updating

records, or deleting records.

Structured query language (SQL) is a database-specific computer language designed to retrieve and manage data in relational database management systems (RDMS). SQL provides a programmatic interface to databases from

virtually any development platform.

Databases are integral to the infrastructure of most business systems includ-ing information systems in Radiology. Virtually, every aspect of Radiology services is tied to relational database functions from patient scheduling to transcription.

Pearls 2.19

Although the microprocessor is frequently personified as the ‘‘brain’’ of the computer, it has no innate ‘‘intelligence’’ or inherent ability to make decisions. The microprocessor’s strength is in its ability to process instruc-

tions and manipulate data at amazing speeds.

All application software runs on top of the OS that, in turn, is directly integrated to the hardware. In general, application software cannot inter-

act directly with the hardware; all interactions are brokered by the OS. A computer that is accessible globally must have a unique IP address;

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Self-Assessment Questions

1. The core hardware components of a digital computer include everything except

    a. Microprocessor

    b. Memory

    c. Bus

    d. Keyboard

    e. Operating system

2. Volatile memory is distinguished from non-volatile memory by

   a. Poorer performance of volatile memory

   b. Flammability of volatile memory

   c. Inability of volatile memory to retain data with power loss

   d. Greater expense of volatile memory

   e. None of the above

3. Which is not true about storage?

   a. On-line storage is readily available

   b. Near-line storage requires human intervention

   c. Off-line storage is not accessible by robotic devices

   d. Data are stored on media such as tape, compact disk or DVD

   e. None of the above

4. Which is the best statement regarding the motherboard data bus?

   a. It connects to the keyboard

   b. It connects to the power supply

   c. It interconnects the components on the motherboard

   d. It connects to the disk drive

e. None of the above

5. What is the fundamental distinction between software and hardware?

a. Price

b. Hardware is a physical entity

c. Packaging

d. Complexity

e. None of the above

6. The purpose of the operating system (OS) is

a. To manage memory allocations

b. To copy files to disk

c. To manage the user interface

d. To manage computer resources

e. All of the above

7. Computer drivers are

a. Names for a specific type of golf club

b. Large programs that take control of the OS

c. Small programs that provide a bridge or interface between hardware and software

d. Similar to computer viruses

e. None of the above

3. Low-level programming languages are (best answer possible)

a. Fairly simple to learn and use

b. Are primarily used by human computer programmers to create applications

c. Are not as costly as high-level programming languages

d. Are used primarily by the CPU

e. All of the above

9. The most complex network switch is the

a. Network hub

b. Network router

c. Network bridge

d. They are all similar in complexity

e. Not listed

10. Which is true of thin-client applications?

a. They require a web browser to run

b. They do not need additional software

c. They require a networked server

d. They require an internal database

e. All of the above

apte

Basic
Network Concepts

In this chapter, you will learn how to:

- **Identify human and computer networks**
- **Describe the benefits of networks**
- **Distinguish between the different types of networks**

Networks are everywhere—or so it seems. You can hardly do anything with data that does not involve a network. Like the human networks that we are all part of, computer networks let us share information and resources. In business, the reliance on networks is even more pervasive than in homes or schools. Networks help individuals and businesses alike save money, but they also help create income. Without a doubt, networking within the home will catch on over the next few years as it has in business. Soon, nearly all individuals in even moderately developed nations will have networked components throughout their homes. Those that don't will be *netologically* disadvantaged because they will not be able to learn or to function at the same level as those who are networked.

In this chapter, you'll begin by relating networks to situations and concepts you already know. Once you have a basic understanding of what networks are and what they can do, it helps if you can actually begin working with them. In fact, it is so helpful to learn the ropes of networking through hands-on guided practice that that's what is planned for you here. You will play the role of an employee in a fictional company, and you'll have to learn on the job. The more you *become* the person, the more you will learn about the need for and operation of computer networks.

Understanding Networks

Although you are probably taking this class to learn about computer networks, and some of you probably already know how important networks are to businesses that want to survive, we will begin this discussion as though you are an employee in a netologically disadvantaged (my term for those who have minimal network awareness) company. You might actually be an employee working for such a company and trying to help it out of that predicament, or you may know of people or companies that are in this sort of struggle.

Lauren has recently been hired as the computer manager for SinkRSwim Pools. Lauren is a certified networking administrator, but her new company unfortunately has only outdated computers. The owner recognized that the company's lack of growth was directly tied to the employees' lack of computer skills, so in her first meeting after being hired, Lauren was given the authority to purchase the additional computers and create the network she had proposed to the owner in her initial job interview. The owner gave her a six-month timeline in which to implement networking at SinkRSwim Pools in such a way that the workers will understand its use and welcome the new knowledge it requires. She was also informed that the thought of learning new computer skills frightened some long-term SinkRSwim Pools employees. The owner expects Lauren to help them become more at ease with the computers so they will be more likely to learn the necessary skills.

Lauren's first goal is to ease the workers' fears by teaching them about computers and showing them how a need for networks develops naturally. Lauren knows that if her fellow employees understand the concept of networking, the computer network will more likely be successful in the company. Lauren has decided to review basic network concepts with her coworkers as she works with them on their new computers.

Human Networks

In its broadest sense, a **networ k** consists of two or more entities, or objects, sharing resources and information. Although this book is about computer networks, there are networks that don’t involve computers, and those networks are everywhere. You have grown accustomed to working with them, possibly without even knowing it.

It may not matter to you that, in a basic sense, sharing (giving or getting) is a fundamental aspect of networking. You just know that you do it.

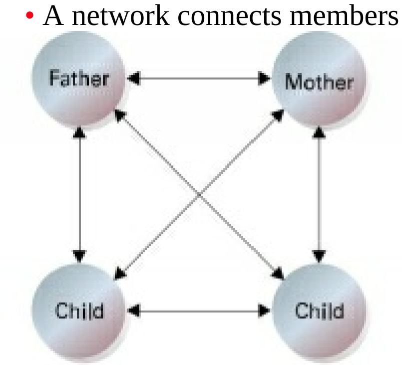
Family Network

Most people belong to a family network in which related people share their resources and information. This sharing is bi-directional because even the youngest family members share information of some sort. As the family grows, so does the network.

Peer Network

Outside the family, there is a community that offers a wider array of re-sources than the typical family can provide. Naturally, it makes sense to

• A network connects members of a family together.



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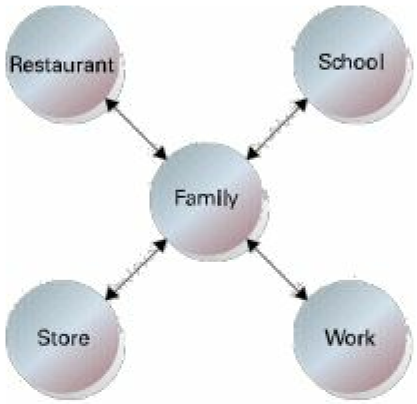


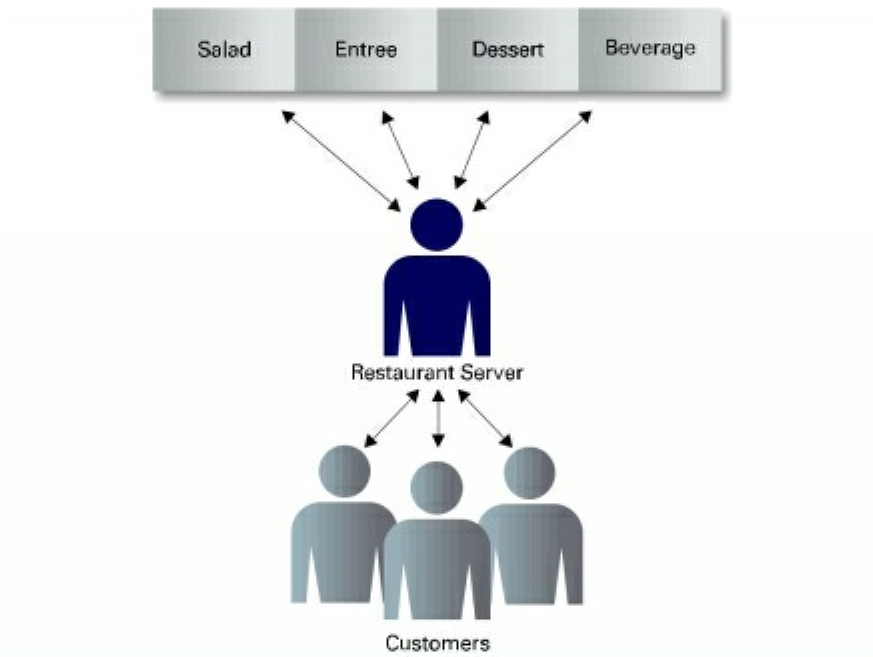
• The family network connects with the greater community.

In sidebars and the end-of-chapter exercises throughout this coursebook, you will be working with a real-world com-pany called Technology Educa-tion and Acquisition Center of Houston (TEACH) that is cur-rently undergoing a sudden expansion. In fact, it has just posted an announcement in the local newspaper, listing several available management positions within the company. It seems there is an opportunity to acquire another highly successful facility in another part of the state, and all the current employees are moving. Later in the chapter, you will find yourself role-playing as one of the replace-ment candidates vying for one of the company's high-paying positions.

connect the family to this community to take advantage of the wealth of re-sources available around town. This type of information/resource sharing can be as simple as loaning a hammer to a neighbor, car-pooling with work associates, or helping a friend with his or her homework. All of these activi-ties involve sharing, or trading, resources. This kind of network is repre-sented by a two-way relationship, a give and take among equals or peers.

Restaurant Network: The Client and the Server

So, in any type of human network, there's a lot of giving and taking. You're already more accustomed to the client/server perspective in networking than you realize. For instance, when you go to dinner at a restaurant, you be-come a customer, or **clien t** , enjoying the food and drink prepared and served to yo by the restaurant. On the other hand, the waiter works as a **serve r** , controllin and providing his customers with access to resources in the form of placing orders for and delivering food items. The server knows that re-quests will be made of him (access is sought when an order is placed) and that he will service those making the requests (access is granted when the order is delivered).


Salad
Entree
Dessert
Beverage
Restaurant Server
Customers

• In a dining situation, it is easy to know whether you are supposed to be serving or being served.

Contact Network

Anyone who has looked for a job knows that one of the best ways to find a job is to network. That is, create a list of friends and associates who will help you find the perfect job. The more people you meet and get to know, the better your chances of obtaining work. As you develop and nurture your career, this contact network will serve you best because your role in it will chances of finding that perfect job.

- The more people in your network, the better your

change as you gain more experience. Soon, you may be able to help the people who helped you. And as your personal and professional networks grow, so do your opportunities.

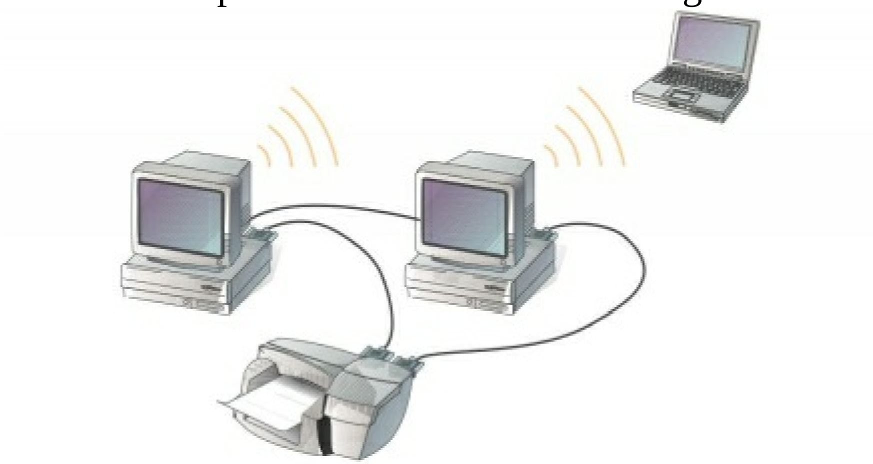
These examples of human networks should help you under-stand that networking is common between people and is not just an activity restricted to computers. However, this book will focus on computer networks—connecting computers and having them communicate with each other.

Computer Networks

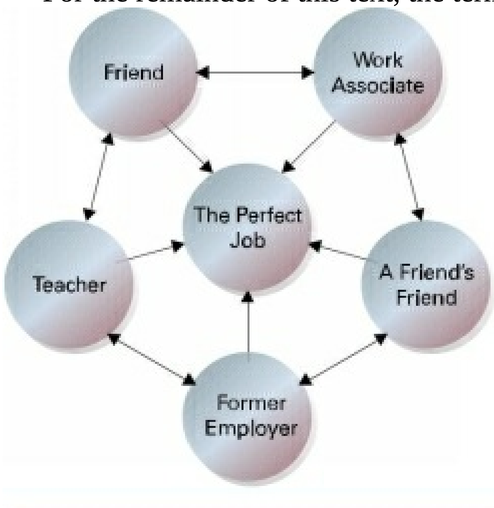
A **computer networ k** consists of two or more computing devices that are connected in order to share the components of your network (its resources) and the information you store there, as shown in Figure 1.1. The most basic computer network (which consists of just two connected computers) can expand and become more usable when additional computers join and add their resources to those being shared.

The first computer, yours, is commonly referred to as your **local com-pute r** . It is more likely to be used as a location where you do work, a **work statio n** , than as a storage or controlling location, a server. As more and mor e computers are connected to a network and share their resources, the network becomes a more powerful tool, because employees using a network with more information and more capability are able to accomplish more through those added computers or additional resources.

The real power of networking computers becomes apparent if you envision your own network growing and then connecting it with other distinct networks, enabling communication and resource sharing across both networks. That is, one network can be connected to another network and become a more powerful tool because of the greater resources. For example,



For the remainder of this text, the term *network* will be used to mean *computer network* .



- Figure 1.1 A computer network can be as simple as two or more computers communicating.

Identify Your Networks

Cross Check

You have already seen that you have been involved in networks for a long time and that computer networks are important tools for businesses. Use what you have learned as you answer the following questions:

1. Which basic human network best represents the interaction between you and your classmates in a discussion about your homework assignments?

2. If your lab had only stand-alone computers, what would be needed to convert it to a networked classroom?

you could connect the network you and your classmates develop for this course to similarly con-structed networks from other intro-ductory networking classes if you wanted them to share your infor-mation and networked resources. Those classes could be within your own school, or they could be anywhere in the world. Wherever that newly joined network is, the communication and resource shar-ing activities in that new network could then be shared with anyone connected to your network. All you have to do is join that new network's

	community or allow its members to join yours.
	In addition, a company’s cost of doing business can be reduced as a

result of sharing **dat a** (defined as a piece or pieces of information) and re-sources. Instead of having individual copies of the data at several locations around the company, and needing to keep all of them similarly updated, a company using a network can have just one shared copy of that data and share it, needing to keep only that one set of data updated. Furthermore, sharing networked resources (like printers) means that more people can use a particular resource and a wider variety of resources (like different printers) can be used by each network user. Any time a company can do more with less, or buy fewer items to do the same job, its total costs are reduced, and it is able to make more money per dollar spent.

Network Plan

Networking computers first and tracking the connections later can quickly become confusing and unmanageable as you try to find which computer communicates with and shares resources with which other computers. In your human network, do you share everything with your friends? In your family network, would you want your parents or guardians to know your every thought? You have your information-sharing plan in your head, and it is important to keep track of it so you don’t make a mistake and share something where it was not intended.

Similar concerns must be considered while designing a computer network. Before you even connect your first computers together, you should have a plan. A **network pla n** , therefore, is a formally created product that shows all the network's components and the planned connections between them. Such a plan is also used to manage the various types of information. Your plan should show what types of information are stored where, and who is allowed to use each type.

Information Management

Your network plan should help you manage the information gathered, stored, and shared between your users. If you were given an empty three-drawer filing cabinet and told to use it to organize your company's in-formation, you would have an excellent (although manual) example of a fil-ing system that needs a plan. Having an overall guide that tells you who will

The hierarchy of information—The more specific the information becomes, the more restricted it should be. What kind of data would you be willing to give to a stranger?

• Figure 1.2

be allowed access to the three drawers will help determine what you store in each one. Once you have that part of the plan, you could put the least-used information in the bottom drawer, the more-used in the middle drawer, and the most-used in the top drawer so that it is easier for your users to access their information. Knowing who needs to know what, and its corollary— who does not need to know what—lets you determine whether to lock a par-ticular drawer, too.

Even when we discuss implementing a three-drawer manual filing sys-tem, the importance of having a network plan ahead of time becomes evi-dent. If you put the limited-access material in a drawer open to all employees, how do you keep it secure? Additional security measures (like adding a lock to a drawer, or moving the secure information somewhere else) may be required later.

A networking plan could tell you that as specific types of sensitive data (like medical, personal, or payroll information) are gathered or grouped, they should be stored higher in the hierarchical structure (ranked from most sensitive to least sensitive), and this can save you time in the end. That plan should specify that the access requirements are stricter for sensitive data and reduce the number of people able to use specific types of information.

The distribution side of the networking plan, as opposed to the accumu-lation side of the plan discussed above, should spell out that the more an in-dividual has access to the data in storage, the less they should be able to share groups of information entrusted to them. For example, you may not mind sharing your first name, but you would probably object to an instruc-tor openly distributing all information in your school records to anyone re-questing it.

Information's Importance

If you think about the manual filing system we discussed using a filing cabi-net, an important computing concept is easy to recognize. Some informa-tion is more important or more sensitive than the rest. It is usually obvious in real filing cabinet systems, because the top drawer is usu-ally where the most sensitive information is stored, and it is locked.

Few people in an organization have access to that information. For example, credit card or Social Security numbers are information that should be given the highest level of security—access to that information is given only to a limited number of people in a company. On the other hand, some information, such as Web pages, newsletters, and product information, is created for everyone to see, even outside a company. Figure 1.2 shows how this kind of information is organized into a **hierarchy of informatio n** , where the most detailed infor-

mation is found at the top and the more general, less secure information is located at the bottom. How much information would you be willing to pro-vide about yourself to a perfect stranger? Coun-try of birth? Sure. State of residence? Why not?

But you might have second thoughts about advertising your street address or phone number to a stranger.

The **format** —or the strict re-quirements placed on the order and structure of how you enter data—is very important. The number 123456789, for instance, could be either a zip code or a Social Security number. If it is formatted as 123-45-6789, you know that it is a Social Security number. What would you do if you were told that your life de-pended on your making a pay-ment to the bank on the date 010203? When would that pay-ment be made? Would the pay-ment date change if that date were in the year-month-day format? Of course it would, and the payment would be long overdue. Format, then, is important!

1961
Leonard Kleinrock at MIT publishes the first paper on packet switching theory discussing communications using packets rather than circuits.

Thinking About a Network Plan

Cross Check

You have just learned about the need to describe information management and data hierarchies in your network plan. It can be equally important when you receive data to know that such a plan is in place. Use what you have learned about creating a network plan as you answer the following questions:

The collection and proper manipulation of many seemingly unimportant pieces of information, and the effective tracking of them, makes information management on networks so important, just as when you are maintaining a manual filing system. A single piece of

1. If you knew that your school's (or your employer's) plan stipulated that sharing sensitive information was to be strictly controlled, and you agreed with those controls, how would that knowledge affect the degree of data sensitivity that you would be willing to share over that network's resources?

2. Although you might choose to share some (or all) of your personal information with selected classmates, would you feel comfortable if you thought your instructor planned on sharing your whole file freely with everyone in your class without your permission?

3. Even if it were not yet true, would the thought of your instructor sharing your information freely affect the amount of information you shared when someone else in authority on the network requested sensitive data?

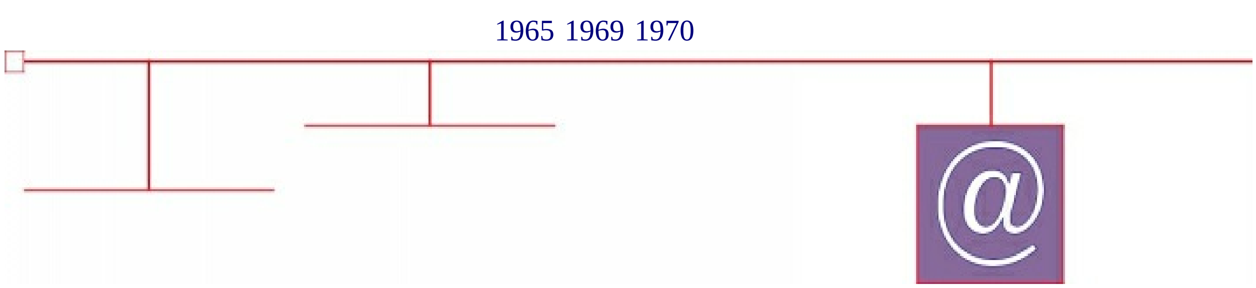
information in a data field, such as your first name, can seem unimportant. However, by combining your first name with other pieces of related information, like your last name, address, age, gender, and phone number (stored in other data fields), the pieces can be put together to create a data record, which can accurately describe something (or someone) that is important—like you. Finally, combining similar records (such as records describing all your classmates) creates a file that, because it contains sensitive information from more than one source, is more sensitive than a single

		record.
	Information sharing, therefore, has serious security issues to be considered,	
	and network access to data must be evaluated carefully so that only those who	
	need it can access it.	

Identifying the Benefits of Networks

Ricky finds himself pondering the question, “What are networks used for?”

He is the second person brought aboard SinkRSwim Pools to enhance its



■	First wide area network (WAN)		
	is created by MIT researchers		
	Lawrence G. Roberts and	A small group at Bell Labs	
	Thomas Merrill.		
	■	begins to work on what	
		eventually becomes UNIX.	
		■	
		ARPANET is created, the first	
		step in the building of the	
		Internet.	
		■	
		The network originally consists	
		of four hosts.	

Ray Tomlinson of BBN creates and sends the first person-to-person e-mail over a network. He also designates the @ sign to separate the user name and the host in an e-mail address.

■

The Network Control Protocol (NCP) was created. NCP was the first standardized network protocol used by ARPANET.

network use. Remember, that's where Lauren is creating a network to re-place the company's outdated computers. Ricky volunteered to help Lauren explain the benefits of networking to the company's workers as part of his computer class project at school. The workers already have the new comput-ers Lauren ordered and are happily doing more with them, but Ricky is helping Lauren network them and is encouraging the workers to use the network.

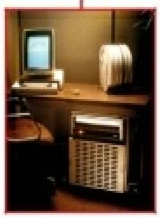
Ricky remembers Mike's words at the opening of this chapter: "In the beginning there were no networks. Life was bad." This may have meant one thing to Mike when he said it, but the beginning for these workers is right now. They haven't had networks, and they don't see why they should need them. Ricky decides to discuss the historical development of computers and show how they helped other businesses.

In the early days of the personal computer (PC), during the late '70s and early '80s, often a PC was used as a **stand-alone compute r** and operated inde-pendently from other computers, as shown in Figure 1.3. When, over the span of just those few years, their use proliferated and more PCs were found relatively close to each other, users began sharing information. The informa-tion was either printed out or copied from one computer to another using backup or storage devices, such as tapes, disks, or other digital storage media.

The printout or the storage device was then physically carried to another computer where the information was reentered or copied from the portable media into the next computer. This process was referred to as a **sneakerne t** because users actually had to walk from computer to computer. It was

- Figure 1.3 Stand-alone computers are operated independently.

1973 1974 1975 1976



PARC creates the Altos, the first PC with a GUI, laser printer, and a connection to the first Ethernet network.

Vint Cerf and Bob Kahn design TCP/IP, today's most widely used network protocol.

BBN creates TELENET, the first

packet-switched network.

Intel releases the

8088 processor.

MITS Altair 8800 is introduced

in *Popular Electronics.*

Bell Labs releases UNIX version 6.

Bill Gates and Paul Allen write a

programming language called
BASIC.

Apple Computer founded by

Steve Jobs and Steve Wozniak.

The Apple I computer is

released.

• One sneakernet alternative was the floppy disk, which was used to transfer data between computers that were not networked.

Computers Assist

Communication

Without computers, TEACH per-sonnel would have a difficult time keeping up with all that is going on in the company. Even though they are in close proximity to each other, the executive section and the training section con-stantly communicate over the network. All employees send elec-tronic mail, have Internet access, and keep current with company policies because they use their network's capabilities fully.

probably the cheapest type of network—unless the computers were large distances apart or the information needed to be shared among many com-puters. Other drawbacks to sneakernets were that printouts were often bulky, and the storage devices could hold a relatively small amount of data compared to the large amount of output users produced.

Once computers were connected by networks, information sharing in-creased dramatically. People found that more data helped them make better decisions, and companies started saving money. Many original networks were designed to facilitate communication, but they were quickly expanded as businesses noticed increased productivity and reduced costs.

Sharing Information

Computers increase your ability to communicate. Once you begin working with a computer, you are likely to become more productive.

However, what do you do with that increased productivity if you are not connected to any-one? Communication requires not only someone with information to share but also someone on the other end with whom to share it. Companies don’t benefit by creating sheer volumes of output—they benefit when the in-creased output helps them make better decisions or increases the likelihood of increased income. Having your computers networked allows you to do both with your newfound increases.

The initial reason for developing most computer networks was to assist users with sharing their increased output, especially between computers in the same general vicinity, as shown in Figure 1.4. However, users wanted not only to share information with others, they wanted to communicate about that information after someone else had it, too. In addition to trans-mitting the user’s original information, computer networks enabled those users to discuss what was being transmitted, and this resulted in even more communication. Additional network communications techniques thus came into being, such as e-mail and video conferencing. Furthermore, with the increases in the sizes of networks, sharing no longer had to be concerned with proximity. The use of networks has effectively erased distance and

1977	1978	1979	1981
Apple II introduced at the West		Novell Data Systems starts	
Coast Computer Faire.		manufacturing computers and	
		creating disk	

		operating systems.	
Commodore PET is introduced.	Apple Computer introduces		
	a 5.25-inch disk drive for the	Jim Ellis and Tom Truscott	
	Apple II.	develop the idea for Usenet, the	
		first peer-to-peer networking	
	Berkeley Software Distribution	program designed to exchange	Adam Osborne introduces the
	(BSD) UNIX is developed at	files between two computers.	Osborne 1.
	UC Berkeley.		
		There are over 100 hosts on the	IBM PC introduced—uses MS
	Bell Labs releases UNIX	Internet.	BASIC in ROM and PC DOS 1.0.
	version 7.		
			First time *Internet* is used to
	TCP is split into two protocols:		describe the ARPANET.
Microsoft is founded by Bill	TCP and IP.		
Gates (bottom left) and Paul			
Allen (bottom right).			

Figure 1.4 Computer communication—Two computers in the same general vicinity should be able to communicate.

time constraints. You can communicate almost instantly to anywhere in the world that is connected to your network.

Networks are an effective way to communicate. Using networks, companies can send the same information to large numbers of employees or customers quickly and efficiently. Examples include company newsletters and announcements for employees, as well as advertisements and purchase information for customers. Also, individual employees are more likely to communicate with larger numbers of individuals both inside and outside the company using **e-mai l** , an electronic means of communicating that is simila to mail but done on computers, usually over the Internet, over net-works. E-mail is the most commonly used feature of the Internet, and its use is growing dramatically. In fact, e-mail is fast becoming the primary choice for much of our daily communication.

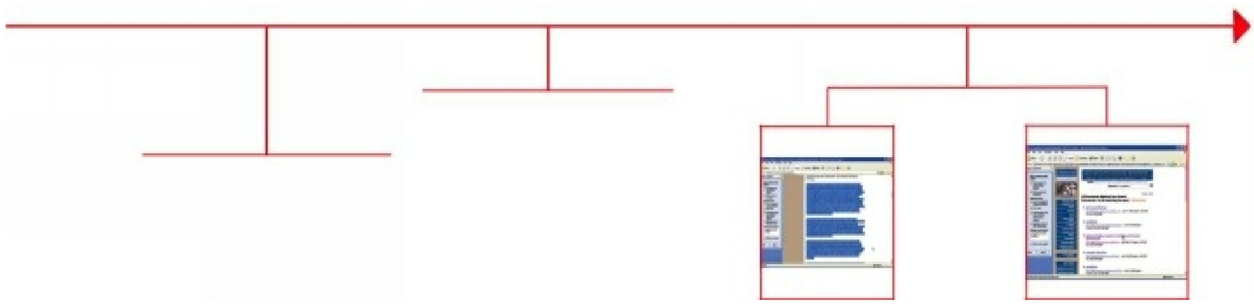
Sharing Resources

In the sneakernet era, users spent huge amounts of time attempting to share their resources. They had to physically distribute files that others needed. Expenditures for printers and other attached computer components rose

The ability of networks to be joined together to form larger networks has resulted in what is called the *Internet* —a worldwide collection of connected comput-ers able to communicate with each other.

You should be aware that there is next to no privacy when sending e-mail. Your electronic message can not only be inter-cepted and read anywhere along its route to your ultimate recipi-ent, but it can later be forwarded, without your permission, to any number of additional recipients. You should, therefore, use care in what you say as well as how you say it.

1982 1983 1984



Mitch Kapor announces Lotus

1-2-3 spreadsheet software.

■

Apple introduces the Lisa, the first commercial computer with a purely graphical operating system and a mouse.

■

TCP/IP is established as the

standard for the Internet.

Novell's NetWare, the first client-server software, is demonstrated at the National Computer Conference.

■

The PING code is created by Mike Muuss at U.S. Army Ballistics Research Lab.

■

The Domain Name System

(DNS) is created and the .com,
.net, .gov, .org, .mil, and .int extensions are designated.

■

Cisco Systems, a manufacturer of internetworking systems, is founded.

Apple releases the Macintosh

with Mac OS System 1.

■

Apple releases a Mac with 512K of memory, called the Fat Mac.

IBM PC AT introduced with 80286 processor and 20MB hard drive.

■

3.5 floppy drives introduced.

■

SRI introduces the WordPerfect

word processor.

rapidly while the individual components themselves were not being used to their full capacity. On top of that, the hard disk storage on each local computer began filling up, partly because everyone had a copy of every document. One copy of that data, and even the applications that produced it, could more efficiently be stored in a single location and shared over a network.

The ability to share resources was another reason networks were created, and it is still one of the main purposes for using networks. The inevitable technology creep (the continuing need for additional investment in technology that is required to stay current) extends the computer user's involvement in technology because companies expect employees to learn new systems as they are installed. Companies also look for ways to make the best use of their investments by sharing the purchased resources among multiple de-partments. Let's look at some of the resources that are commonly shared over computer networks.

Peripherals

Many companies start with multiple stand-alone computers. Not too long after the initial computer purchase, however, additional components that attach to a computer, called **peripheral s** , like printers, scanners, and speak-ers, are purchased and are connected to that computer to expand its use (see Figure 1.5). When there are multiple users and computers, it soon becomes ap-parent that the peripheral devices are seldom fully utilized. Money can be saved if some of these peripherals are shared, instead of having to purchase a separate set for each computer. Networking enables the sharing of peripherals.

The ability to share printers was very often enough of a cost savings for companies to invest in implementing and supporting a simple network. The company could then also realize additional cost savings as it shared additional

• Figure 1.5 Common network peripherals

1985	1986	1987
Microsoft ships the first version		

of Microsoft Windows.		
■		
Bell Labs releases UNIX	Microsoft ships	Microsoft and IBM announce
version 8 to universities.	Windows/286 1.03.	OS/2, a character-mode OS.
■	■	■
Intel releases the 80386	IBM delivers the PC Convertible	Novell introduces the NetWare
processor (also called the 386).	computer, the first Intel-based	network operating system.
■	computer with a 3.5-inch	■
Hewlett-Packard introduces the	floppy disk drive.	There are over 2,300 hosts on
Laser Jet laser printer.		the Internet.
■		
IBM Token Ring networking		
system is developed.		

peripheral devices, such as faxes, modems, scanners, plotters, and virtually any other device that connects to computers. Sharing peripherals often ends up producing significant cost savings and more than justifies the expense of adding a network.

Storage

Data was being loaded on the computers of every fledgling network user as they expanded their network use. Users quickly ran out of space on their own local computers, so the people in charge of the networks began devis-ing ways to store data centrally so that it was accessible to any user who needed it. Large amounts of storage capacity, usually in fast, very powerful computers, were set up to act as storage locations for this data where access to it could be controlled by the person storing the data.

Applications

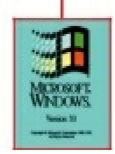
Cost and space savings are achieved when computer users can centrally store their software **application s** —the computer **program s** (organized sets of computer instructions) that make a user's computer do what needs to be done. Applications, such as those used for preparing taxes, creating text documents, or playing computer games, have grown in complexity and size and often take up considerable local storage. Installing an application once on a network and then sharing it cuts down on the storage space required when multiple users need the same application.

Unfortunately, there are still several problems with this type of arrange-ment. Some applications work fine with different setups for each user (dif-ferent choices for screen settings and other custom features), but normally all such settings must be the same for all users. Sometimes, applications still function better when installed on a user's local computer.

Assisting Collaboration

Once you have digital information and the ability to share it instantly with oth-ers over networks, you can have multiple people working on the same process collectively. Much of the initial communication about computer-produced products that occurred during and immediately after the sneakernet era dealt

1989 1990 1991 1992



	Microsoft releases Windows 3.0.	
	■	
	Motorola announces its 32-bit	
Intel releases the 80486 chip	microprocessor, the 68040.	Microsoft releases MS-DOS 5.0.

(also called the 486).		■	■
■		The Internet Toaster is	Linus Benedict Torvalds creates
Tim Berners-Lee develops		connected to the Internet—the	a free version of UNIX for the
HTML, the foundation for the		first machine remotely operated	Intel platform.
World Wide Web.		by computer.	■
		■	Apple Computer launches the
		World.std.com is the first	PowerBook series of portable
		commercial provider of dial-up	computers.
		Internet access.	■
			Macintosh System 7.0 released.
			■
			Internet opened to commercial
			application.

Microsoft releases Windows 3.1, the first widely accepted version of Windows.

■

Microsoft Windows for

Workgroups 3.1 released.

■

IBM releases OS/2 2.0, the first

32-bit OS for PCs.

■

IBM introduces its ThinkPad

laptop computer.

Networks Help

Trainers

TEACH trainers are a creative bunch when it comes to develop-ing training materials. They also like to share their work so they can get everyone else's opinions about it before they go into production with their courses. Before networks, that discussion was handled using the sneakernet procedure and was greatly inhibited. It was just too much trouble to get that information out to everybody, wait for their input, and then incorporate it back into the documents before using them. It was not practical if there was any kind of time constraint, and there always was.

1993

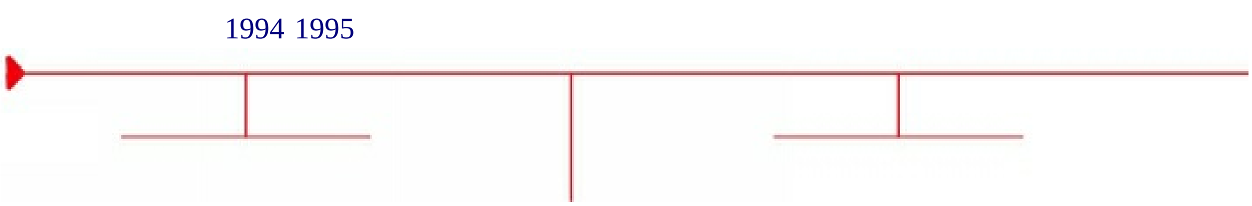
with coworker **collaboratio n** , with coworkers discussing each other's work or possibly even exchanging opinions about what other users had created. Those early computer users found that once they created something and sent it out for review, the comments returned often led to important adjust-ments that would improve the original product. Such collaboration assisted the widespread use of computers because it provided a tangible benefit that businesses could associate with the increased costs of installing computers in the first place.

Many software makers took this early form of collaboration into consideration and added that feature to the capabilities of their software. The newest versions of the applications included in Microsoft's Office suite (such as Word, Access, Excel, and PowerPoint) allow multiple users to access and make changes to the same document at the same time. That way, all users can work together on the original document, and changes made by any collaborating member are immediately posted within the document. A more powerful implementation of this concept can be found in an application designed to facilitate collaboration, such as Microsoft's Terminal Server (see http://www.microsoft.com/windows2000/technologies / terminal/default.asp for more information).

Facilitating Centralized Management

Just connecting computers to a network meant that some sort of similarity existed among them (or else the computers would not be able to communicate), and a maintenance capability may have been available in the early networks. However, it wasn't until much later (in the mid '90s) that maintenance per-sonnel started using networks to assist with the management tasks associated with the network's operation and maintenance.

It came about as a direct result of standardization and interoperability, which meant computers worked the same way and could work with each other. This was a drastic change to the original networks, where all the dif-ferent networked components had different computer programs, or **soft-ware** (a set of instructions that control the operation of a computer) runnin g them. Having more similarities meant lower support costs. These savings were usually due to **economies of scal e** brought about by buying more simi-lar computers and obtaining a lower per-unit cost. Companies soon began



Microsoft releases the first		Microsoft ships Windows 95.
version of Windows NT (3.1).		■
■		Intel releases the Pentium Pro
Microsoft releases MS-DOS 6.0.	Microsoft releases	microprocessor.
■	MS-DOS 6.22.	■

Mosaic, the first web browser,	■	Motorola releases the
developed by National Center	IBM releases OS/2 Warp	PowerPC 604 chip.
for Supercomputing	(OS/2 version 3).	■
Applications (NCSA).	■	Sun Microsystems creates the
■	Netscape Communications	Java development language.
Intel releases the Pentium	releases Netscape Navigator.	■
processor.	■	*Toy Story* , the first fully
■	CompuServe, America Online,	computer animated film,
Novell releases NetWare 4.0.	and Prodigy add Internet access.	released.
	■	
	Yahoo! born in trailer on	
	Stanford University campus.	

directing technicians to purchase similar equipment to obtain the benefit of those savings. Once that happened, the network could be used to help maintain those similar components, and this further increased efficiency and reduced the total amount companies would spend on a particular component over that equipment's usable lifetime, called **total cost of ownership (TCO)**

Managing Software

Using the network helped reduce software costs. Savings occurred when all users on a network used the same software and when software was bought in bulk quantities for a discount. Centralizing the installation of that soft-ware also reduced operation costs because the installations could be accom-plished remotely—over the network. The computer programs that were needed to perform the installations were stored on servers and made accessible over the network. The maintenance personnel would then simply log on to the network from a client computer and install the needed applications us-ing the installation software stored on the server.

Within the past few years, even more savings have been achieved by having the centralized server initiate the software installations or updates on the client computers without the need for maintenance personnel to actually visit any of the clients.

Maintaining the Network

Purchasing similar equipment for use on the network meant that network maintenance costs were reduced because there were fewer dissimilar components. Maintenance workers no longer had to attend numerous training sessions on many different components, which meant they could spend more time maintaining the actual components.

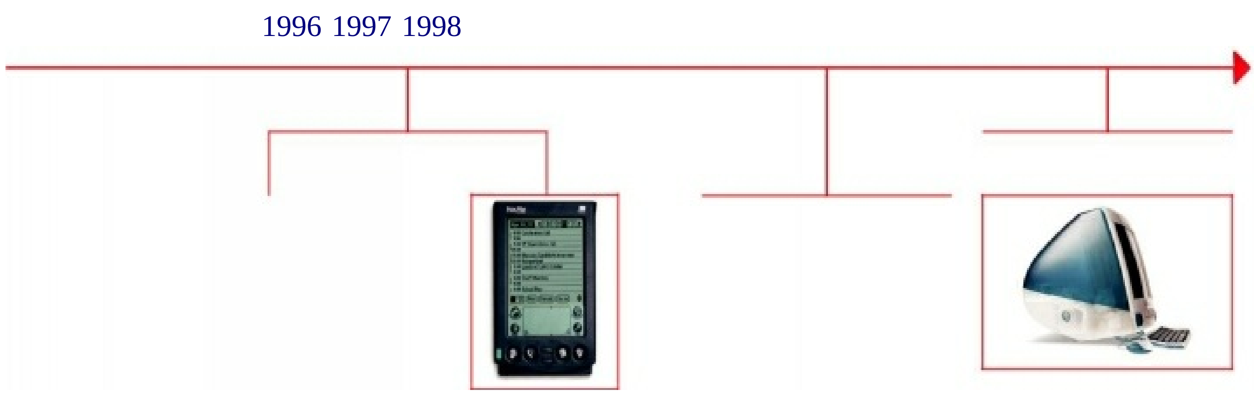
Maintenance

Enhanced over Network

Even when everyone was located in a single facility, and more so later when they expanded, the TEACH maintenance personnel were spending far too much time and money keeping equipment operating properly. Without a network, they had to visit each computer every time anything had to be done. Additionally, there was no incentive for em-ployees to use even vaguely simi-lar software to perform their work. Despite the fact that they were a training facility, the time spent keeping the maintenance technicians trained on all those different pieces of software and the numerous individual computer components was just getting out of hand.

Backing Up Data

Along those same lines, a network minimizes the time spent backing up (saving extra copies, called **backup s**) of necessary files. In the event of a hardware or software failure that causes information or applications to be lost, vital information and necessary applications can be restored if sufficient backups exist. The backup process is normally a regular activity in a company,



Microsoft releases Windows NT

Workstation 4.0.

■

Apple computer buys NeXt.

■

IBM releases OS/2 Warp Server,

an OS for network servers.

■

IBM releases OS/2 Warp 4,

which can simultaneously connect to almost any network server.

■ Distinguishing Between Network Classifications

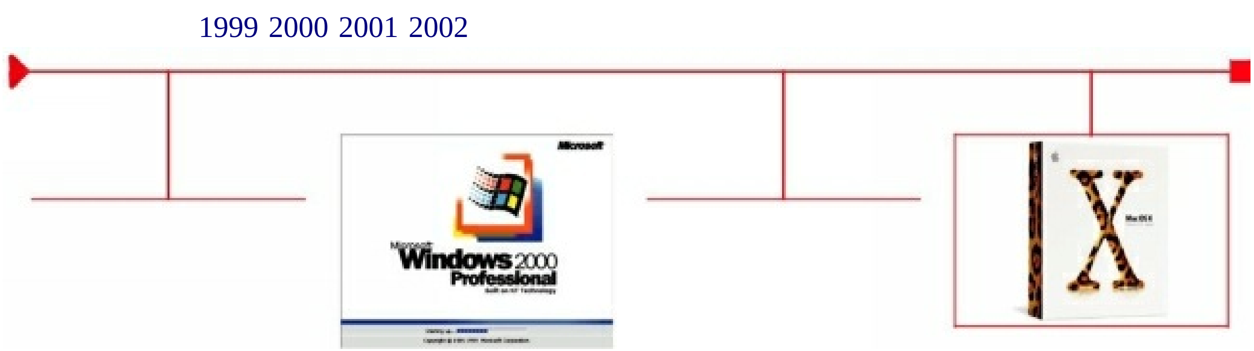
Lauren may have been hired into her networking administration position at SinkRSwim Pools by a forward-thinking company owner, but she has to re-member that it was that forward-thinking manager who kept his workers away from the increases in technology and did not furnish them with comput-ers until now. She knows that even though she was given a budget, she will still have to get her network approved by her new boss. Therefore, Lauren will only get the network she has designed by increasing her new boss's knowledge about the different types of networks and convincing him that the network is necessary as designed. She decides to explain the different ways networks can be classified so she can elicit his input and support to come up with the choice she has already decided upon for the company's network.

There is much current debate about the usefulness of any of the three geographical classifications (LAN, MAN, or WAN) now that the Internet can effectively join all computers.

Classifying Networks by Their Geography

Networks are frequently classified according to the geographical boundaries the network spans. Two basic geographical designations for networks—local area network (LAN) and wide area network (WAN)—are the most common. A third designation, metropolitan area network (MAN), is also used, although its use has become clouded (because it might not be a clear-cut classification anymore) as networks continue connecting to the Internet.

These three classifications, unlike the other methods used to describe networks, are based upon the specific levels of technology they use when going from one level to the other. The three geographical classifications are discussed next because the geographical concepts and the increased emphasis they place on technology as you go from one level to the next still apply.



Intel unveils the Pentium III			Microsoft releases Windows XP.
processor.			■
■			Macintosh OS X released.
Advanced Micro Devices (AMD)			
releases Anthlon CPU, which			
surpasses Intel Pentium III's			
clock speed.			
■	Microsoft introduces		

Napster, a peer-to-peer file-	Windows 2000 and Windows Me.
sharing program, is created. It is	■
an instant hit, allowing millions	First large-scale denial of
of people to share music files,	service attacks shut down
but it raises copyright concerns	major Web sites, including
among music publishers.	Yahoo!, eBay, and Buy.com.

Mac OS X Jaguar released.

■

Microsoft releases Visual

Studio.NET.

■

Intel releases new Pentium 4 HT processor, which offers core speeds beyond 3 GHz.

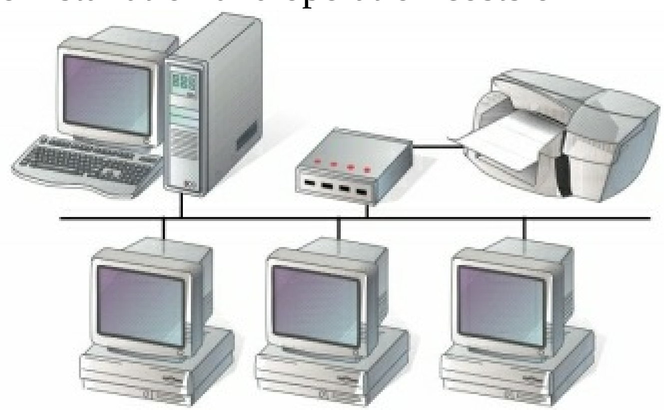
Local Area Network (LAN)

If the network is contained within a relatively small area, such as a class-room, school, or single building, as shown in Figure 1.6, it is commonly re-ferred to as a **local area network (LAN)** . This type of network has the lowest cost and least overall capability of the three geographic classifications. Be-cause the pieces of equipment in a LAN are in relatively close proximity, LANs are inexpensive to install. Despite their decreased capability, how-ever, their closeness and resultant low costs typically result in the use of the fastest technology on a LAN. Thus, this network classification usually has the highest speed components and fastest communications equipment be-fore the other network classifications see such equipment using the same speeds. This is because it takes less overall investment to get the smaller net-work running the faster equipment. LANs, therefore, are commonly consid-ered the building blocks for creating larger networks.

Metropolitan Area Network (MAN)

As the computers get further apart, a LAN becomes more difficult to install, and additional measures such as additional communications equipment may need to be employed. When the network spans the distance of a typical met-ropolitan city, as shown in Figure 1.7, it can be referred to as a **metropolita n area network (MAN**

) . Although this term is beginning to lose its popular use , the concept of the network outgrowing its local confines and requiring additional resources still applies. Much of the same technology, such as the fast networking components and communications equipment used in LANs, can be used in MANs, but more are required, so this classification is not quite as technologically advanced as are LANs. Although the speeds achieved in a MAN are typically as high as in a LAN, it requires high-speed connections, such as fiber optics. Increasing the distance and the technology levels increases the relative installation and operation costs of MANs.



- Figure 1.6 A LAN covers a relatively small distance.

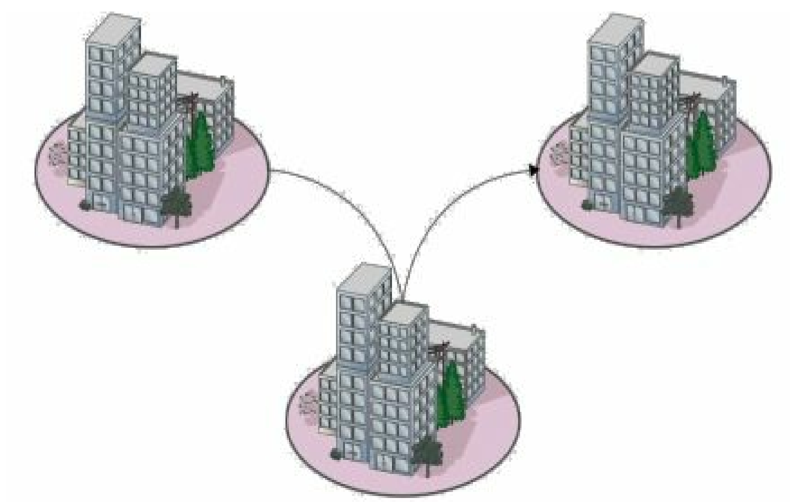


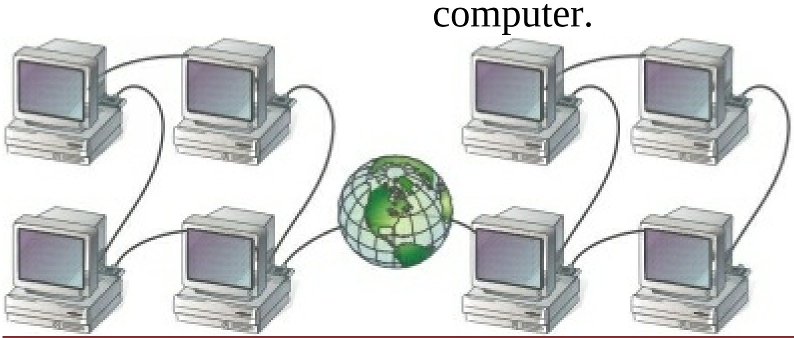
Figure 1.7 The MAN covers a somewhat wider area than a LAN.

Wide Area Network (WAN)

The MAN outgrows its usefulness when the network must expand beyond the confines of the typical metropolitan area. When the network spans a larger area, as shown in Figure 1.8, it is classified as a **wide area networ k (WAN)** . Because of the extensive distances over which WANs communicate , they use long-distance telecommunications networks for their connections, which increases the costs of the network. The Internet is just a giant WAN.

Classifying Networks by Component Roles

Another method used to classify networks focuses on the roles the networked computers play in the network's operation, and more specifically on which computer controls that operation. There are two basic types of role classifica-tions for networks—peer-to-peer networks and server-based networks. The difference between the two revolves around which computer is in charge of the network. A third classification, client-based networks, has come into existence because of the increased capabilities of the typical client computer.



• Figure 1.8 The WAN covers an extremely wide area and involves numerous transmission technologies.

Peer-to-Peer Networks

A peer is considered an equal. All computers on a **peer-to-peer net-work** can be considered equals, a s shown in Figure 1.9. That is to say, no one computer is in charge of the network's operation. Each computer controls its own infor-mation and is capable of function-ing as either a client or a server depending on which is needed at the time.

Peer-to-peer networks are popular as home networks and for use in small companies because they are inexpensive and easy to install. Most **operating system s** (the software that runs the basic computer functionality) come with peer-to-peer networking ca-pability built in. The only other cost involved with setting up a peer-to-peer network comes into

Try This!

Determine Organizational Needs

It’s time to determine the computer and networking needs of your company. Try this:

1. Refer to the TEACH organizational chart (see Lab Project 1.3, at the end of this chapter) and analyze it to determine how many computers the organization should have for its executive, supervisory, and support personnel.

2. Use the organizational chart itself, or a copy of the chart, to mark the location of each management workstation with the letter *W* enclosed in a green circle. For now, disregard the possible use of portable computers in your assessment.

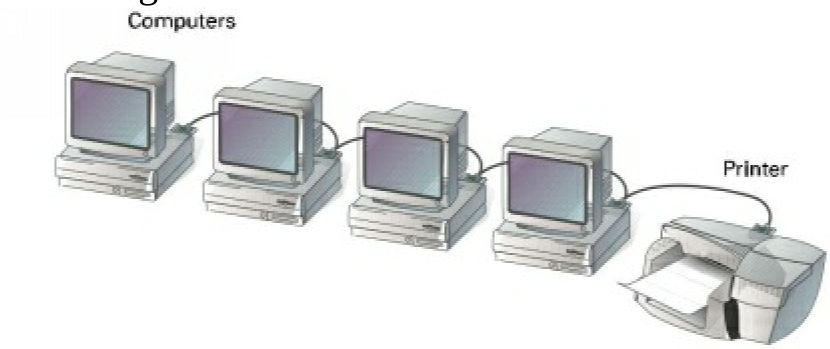
3. Using the geographical classification possibilities, determine the TEACH network’s classification and mark the location of where you would put servers. Mark the server locations with the letter *S* enclosed in a red triangle.

4. At the bottom of the TEACH organizational chart, write the total number of servers and workstations you determined were necessary based upon your analysis.

play if a computer does not have a network interface card, or NIC (the de-vice that physically connects your computer to your network’s cabling), al-ready installed.

Typical initial peer-to-peer networking involves no security measures. Rather, each peer simply shares its resources and allows others open access to them. In fact, a peer-to-peer network becomes difficult to manage when more and more security is added to the resources. This is because users con-trol their own security by adding password protection to each share they create.

Share s are any resources users control on their computers, such as document folders, printers, and other peripherals. Each shared resource can actually have its own password. Someone wanting access to numerous shared resources has to remember many passwords. Security on a peer-to-peer network can quickly become complex and confusing.



- Figure 1.9 A peer-to-peer network. Peer-to-peer networks have no centralized control.

Most servers can actually op-erate as clients but rarely ever do, because such use may inter-fere with their server capability, and they are usually not in an ac-cessible location. Typically, once a server is set up, it is secured in a location where users cannot ac-cess it. Only the network admin-istrator should have access to a server. Therefore, users do not operate it as a workstation, and the client functionality of servers is rarely employed.

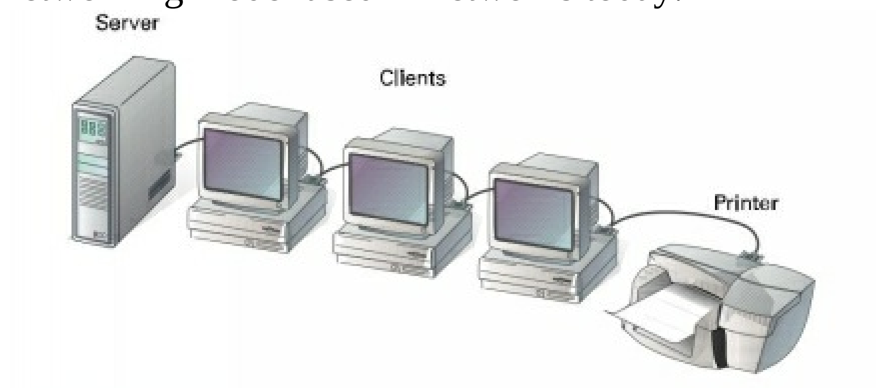
While peer-to-peer networks are inexpensive to set up, they are ex-tremely limited in scope. The accepted maximum number of peers that can operate on a peer-to-peer network is ten. They are, therefore, not appropriate for larger, more secure networks.

Server-Based Networks

Unlike peer-to-peer networks that operate without central control and are difficult to secure, a **server-based networ k** offers centralized control and is designed for secured operations, as shown in Figure 1.10. While there are still both clients and servers on a server-based network, a dedicated server controls the network. A **dedicated serve r** is one that, for all practical pur-poses, operates solely as a server.

A dedicated server on a server-based network services its network clients by storing data, applications, and other resources, and then providing access to those resources when called for by a client. When a client requests a resource such as a document, the server sends the whole resource (the document) over the network to the client, where it is processed and later returned to the server for continued storage.

Dedicated servers can also control the entire network's security from one central location or share that control with other specially configured servers. This central network control also contributes to the economies of scale discussed under the "Facilitating Centralized Management" section earlier in this chapter (using similar equipment results in cheaper equipment prices and fewer training costs) and makes the server-based network the dominant networking model used in networks today.

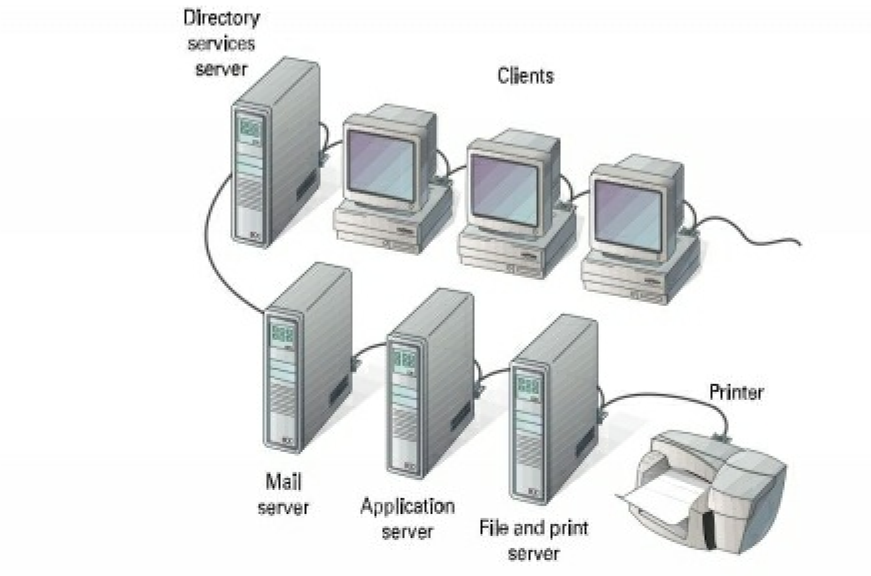


- Figure 1.10 A server-based network. Server-based networks involve centralized control.

Client-Based Networks

Client-based networks are a further refinement to the concept of a server-based network that relieves the heavy burden on the network's capacity re-sulting from frequent server-performed transactions. A client-based net-work takes better advantage of the server's powerful processors and of the increasingly powerful computers used in typical workstations. A client-based network utilizes a client workstation's power in processing some functions locally while requesting additional processing from a server whenever it is needed for increased speed.

Client-based network servers process requests from clients and return just the results, rather than sending the original resource to the client to be processed and returned after computations are complete. Client-based net-works, therefore, take advantage of the powerful processing capabilities of both the client and the server, as shown in Figure 1.11. This type of arrange-ment may include application servers (where entire computer programs are shared from the server) and communications servers (where e-mail and other communications media are operated).


Directory
services
server
Clients
Printer
Mail
server
Application
server
File and print
server

- Figure 1.11 A client-based network. A client-based network takes advantage of the power of both the server and the client alike.

19

Book Summary

After reading this chapter and completing the Try This! exercises, you should understand the following facts about networking:

Identify Human and Computer Networks

- A network consists of two or more entities sharing resources and information.
- Examples of basic networks include your human network, school lunchrooms, restaurant dining, and business contact development.
- The capability to share is enhanced when information is stored on computers.
- Computer networks consist of two or more computers that are connected and able to communicate.
- Networked computers share resources and information.
- Powerful networks result when additional computers are added to the communication possibilities.
- As more and more data becomes available over a network, some kind of a control system must be established.
- The hierarchy of data should be used in network planning.
- Access to data stored higher up in this chain is more strictly controlled, which means fewer people can view that data.
- *Data* is defined as a piece or pieces of information.
- The collection, proper manipulation, and effective tracking of data

makes information management on networks so important.

Describe the Benefits of Networks

- Computers operated independently from others are known as stand-alone computers.
- *Sneakernet* was the term used for running data from one computer to another on disk.
- Most computer networks develop to facilitate communication, initially to share output and later to communicate through e-mail.
- The ability to share resources is another main purpose for initiating networks.
- Peripherals are additional components that attach to computers to expand their use.
- Sharing peripherals, such as printers, often offered enough of a cost savings for companies to invest in networks.
- Large computers can be set up as storage locations where data is offloaded and access to it is controlled by the person storing the data.
- Installing an application on a network and then sharing its use cuts down on the storage space required when multiple users need the same application.
- Coworkers discussing each other's work, or collaboration, assisted the widespread use of computers.
- Networks help centralize the management of software and maintenance of computers, such as installing upgrades and backing up data.

Distinguish Between the Different Types of Networks

- Networks are frequently classified according to the geographical boundaries spanned.

- A network contained within a relatively small area, such as a classroom, school, or single building, is commonly referred to as a local area network.

- A network that spans the distance of a typical metropolitan area is sometimes referred to as a metropolitan area network.

- A network covering a larger area than a single city is classified as a wide area network.

- Another method used to classify networks focuses on which computer controls the network's operation.

- All computers on a peer-to-peer network can be considered equal.

- Peer-to-peer networks are popular as home networks and for use in small companies because they are inexpensive and easy to install.

- Server-based networks offer central control and are designed for secured operations.

A dedicated server operates solely as a server by storing data, applications, and other resources, and providing access to those resources when called for by a client.

- Client-based network servers process requests from clients and return just the results.

- Client-based networks take advantage of their own powerful processors as well as the increasingly powerful computers used as typical workstations.