

# Living in a Network-Centric World

## Chapter Introduction

We now stand at a critical turning point in the use of technology to extend and empower our human *network*. The globalization of the *Internet* has succeeded faster than anyone could have imagined. The manner in which social, commercial, political and personal interactions occur is rapidly changing to keep up with the evolution of this global network. In the next stage of our development, innovators will use the Internet as a starting point for their efforts - creating new products and services specifically designed to take advantage of the network capabilities. As developers push the limits of what is possible, the capabilities of the interconnected networks that form the Internet will play an increasing role in the success of these projects.

This chapter introduces the platform of *data networks* upon which our social and business relationships increasingly depend. The material lays the groundwork for exploring the services, technologies, and issues encountered by network professionals as they design, build, and maintain the modern network.

In this chapter, you will learn to:

- Describe how networks impact our daily lives.
- Describe the role of data networking in the human network.
- Identify the key components of any data network.
- Identify the opportunities and challenges posed by converged networks.
- Describe the characteristics of network architectures: fault tolerance, scalability, quality of service and security.
- Install and use IRC clients and a Wiki *server*.

## 1.1 Communicating in a Network-Centric World

### 1.1.1 Networks Supporting the Way We Live

Among all of the essentials for human existence, the need to interact with others ranks just below our need to sustain life. Communication is almost as important to us as our reliance on air, water, food, and shelter.

The methods that we use to share ideas and information are constantly changing and evolving. Whereas the human network was once limited to face-to-face conversations, *media* breakthroughs continue to extend the reach of our communications. From the printing press to television, each new development has improved and enhanced our communication.

As with every advance in communication technology, the creation and interconnection of robust data networks is having a profound effect.

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Early data networks were limited to exchanging character-based information between connected computer systems. Current networks have evolved to carry voice, video streams, text, and graphics between many different types of devices. Previously separate and distinct communication forms have converged onto a common platform. This platform provides access to a wide range of alternative and new communication methods that enable people to interact directly with each other almost instantaneously.

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The immediate nature of communications over the Internet encourages the formation of global communities. These communities foster social interaction that is independent of location or time zone.

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### The Global Community

Technology is perhaps the most significant change agent in the world today, as it helps to create a world in which national borders, geographic distances, and physical limitations become less relevant, and present ever-diminishing obstacles. The creation of online communities for the exchange of ideas and information has the potential to increase productivity opportunities across the globe. As the Internet connects people and promotes unfettered communication, it presents the platform on which to run businesses, to address emergencies, to inform individuals, and to support education, science, and government.

**Click PLAY to watch how the Internet, and its underlying technology, brings opportunities to people wherever they live or work.**

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It is incredible how quickly the Internet became an integral part of our daily routines. The complex interconnection of electronic devices and media that comprise the network is transparent to the millions of users who make it a valued and personal part of their lives.

Data networks that were once the transport of information from business to business have been repurposed to improve the quality of life for people everywhere. In the course of a day, resources available through the Internet can help you:

- Decide what to wear using online current weather conditions.
- Find the least congested route to your destination, displaying weather and traffic video from webcams.
- Check your bank balance and pay bills electronically.
- Receive and send *e-mail*, or make an Internet phone call, at an Internet cafe over lunch.
- Obtain health information and nutritional advice from experts all over the world, and post to a forum to share related health or treatment information.
- Download new recipes and cooking techniques to create a spectacular dinner.
- Post and share your photographs, home videos, and experiences with friends or with the world.

Many uses of the Internet would have been hard to imagine just a few years ago. Take for example, one person's experience publishing a home music video:

*"My goal is to make my own movies. One day, my friend Adi and I made a video as a surprise for her boyfriend's birthday. We recorded ourselves lip-synching to a song and dancing around. Then we decided, why not post it. Well, the reaction has been huge. It's had over 9 million views so far, and the movie director Kevin Smith even did a short spoof of it. I don't know what draws people to the video. Maybe it's the simplicity of it, or the song. Maybe it's because it's spontaneous and fun, and it makes people feel good. I don't know. But I do know that I can do what I love and share it*

*online with millions of people around the world. All I need is my computer, digital camcorder, and some **software**. And that's an amazing thing."*

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Lab Activity  
for this chapter

### Lab Activity

Use satellite imagery available through the Internet to explore your world.

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## 1.1.2 Examples of Today's Popular Communication Tools

The existence and broad adoption of the Internet has ushered in new forms of communication that empower individuals to create information that can be accessed by a global audience.

### Instant Messaging

Instant messaging (IM) is a form of **real-time** communication between two or more people based on typed text. The text is conveyed via computers connected over either a private internal network or over a public network, such as the Internet. Developed from earlier Internet Relay Chat (IRC) services, IM also incorporates features such as file transfer, voice, and video communication. Like e-mail, IM sends a written record of the communication. However, whereas transmission of e-mail messages is sometimes delayed, IM messages are received immediately. The form of communication that IM uses is called real-time communication.

### Weblogs (blogs)

Weblogs are web pages that are easy to update and edit. Unlike commercial websites, which are created by professional communications experts, blogs give anyone a means to communicate their thoughts to a global audience without technical knowledge of web design. There are blogs on nearly every topic one can think of, and communities of people often form around popular blog authors.

### Wikis

Wikis are web pages that groups of people can edit and view together. Whereas a blog is more of an individual, personal journal, a **wiki** is a group creation. As such, it may be subject to more extensive review and editing. Like blogs, wikis can be created in stages, and by anyone, without the sponsorship of a major commercial enterprise. There is a public wiki, called Wikipedia, that is becoming a comprehensive resource - an online encyclopedia - of publicly-contributed topics. Private organizations and individuals can also build their own wikis to capture collected knowledge on a particular subject. Many businesses use wikis as their internal **collaboration tool**. With the global Internet, people of all walks of life can participate in wikis and add their own perspectives and knowledge to a shared resource.

### Podcasting

Podcasting is an audio-based **medium** that originally enabled people to record audio and convert it for use with iPods - a small, portable device for audio playback manufactured by Apple. The ability to record audio and save it to a computer file is not new. However, **podcasting** allows people to deliver their recordings to a wide audience. The audio file is placed on a website (or blog or wiki) where others can **download** it and play the recording on their computers, laptops, and iPods.

### Collaboration Tools

Collaboration tools give people the opportunity to work together on shared documents. Without the constraints of location or time zone, individuals connected to a shared system can speak to each other, share text and graphics, and edit documents together. With collaboration tools always

available, organizations can move quickly to share information and pursue goals. The broad distribution of data networks means that people in remote locations can contribute on an equal basis with people at the heart of large population centers.

### 1.1.3 Networks Supporting the Way We Learn

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Communication, collaboration, and engagement are fundamental building blocks of education. Institutions are continually striving to enhance these processes to maximize the dissemination of knowledge. Robust and reliable networks support and enrich student learning experiences. These networks deliver learning material in a wide range of formats. The learning materials include interactive activities, assessments, and feedback.

Courses delivered using network or Internet resources are often called online learning experiences, or e-learning.

The availability of e-learning courseware has multiplied the resources available to students many times over. Traditional learning methods provide primarily two sources of expertise from which the student can obtain information: the textbook and the instructor. These two sources are limited, both in the format and the timing of the presentation. In contrast, online courses can contain voice, data, and video, and are available to the students at any time from any place. Students can follow links to different references and to subject experts in order to enhance their learning experience. Online discussion groups and message boards enable a student to collaborate with the instructor, with other students in the class, or even with students across the world. Blended courses can combine instructor-led classes with online courseware to provide the best of both delivery methods.

Access to high quality instruction is no longer restricted to students living in proximity to where that instruction is being delivered. Online distance learning has removed geographic barriers and improved student opportunity.

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The Cisco Networking Academy Program, which offers this course, is an example of a global online learning experience. The instructor provides a syllabus and establishes a preliminary schedule for completing the course content. The Academy program supplements the expertise of the instructor with an interactive curriculum that provides many forms of learning experiences. The program provides text, graphics, animations, and a simulated networking environment tool called Packet Tracer. Packet Tracer provides a way to build virtual representations of networks and emulate many of the functions of networking devices.

Students may communicate with the instructor and fellow students using online tools, like e-mail, bulletin/discussion boards, chat rooms, and *instant messaging*. Links provide access to learning resources outside of the courseware. Blended e-learning provides the benefits of computer-based training while retaining advantages of instructor-led curriculum. Students have the opportunity to work online at their own pace and skill level while still having access to an instructor and other live resources.

In addition to the benefits for the student, networks have improved the management and administration of courses as well. Some of these online functions include enrollment, assessment delivery and grade books.

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In the business world, the use of networks to provide efficient and cost-effective employee training is increasing in acceptance. Online learning opportunities can decrease time-consuming and costly travel yet still ensure that all employees are adequately trained to perform their jobs in a safe and productive manner.

Online courseware and delivery offer many benefits to businesses. Among the benefits are:

- ***Current and accurate training materials.*** Collaboration between vendors, equipment manufacturers and training providers ensures that the courseware is up-to-date with the latest processes and procedures. When errors in materials are found and corrected, the new courseware is immediately available to all employees.
- ***Availability of training to a wide audience.*** Online training is not dependent on travel schedules, instructor availability or physical class size. Employees can be given deadlines by which training is to be completed and the employees can access the courseware when it is convenient.
- ***Consistent quality of instruction.*** The quality of the instruction does not vary as it would if different instructors were delivering an in-person course. The online curriculum provides a consistent core of instruction to which instructors can add additional expertise.
- ***Cost reduction.*** In addition to reducing the cost of travel and the lost time associated with travel, there are other cost reducing factors for business related to online training. It is usually less expensive to revise and update online courseware than it is to update paper-based material. Facilities to support in-person training can also be reduced or eliminated.

Many businesses also provide customer training online. This courseware enables the customers to use the products and services provided by the business in the best manner, reducing calls to the help lines or customer service centers.

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### 1.1.4 Networks Supporting the Way We Work

Initially, data networks were used by businesses to internally record and manage financial information, customer information, and employee payroll systems. These business networks evolved to enable the transmission of many different types of information services, including e-mail, video, messaging, and telephony.

Intranets, private networks in use by just one company, enable businesses to communicate and perform transactions among global employee and branch locations. Companies develop *extranets*, or extended internetworks, to provide suppliers, vendors, and customers limited access to corporate data to check order status, inventory, and parts lists.

Today, networks provide a greater integration between related functions and organizations than was possible in the past.

Consider these business scenarios.

- A wheat farmer in Australia uses a laptop enabled with a Global Positioning System (GPS) to plant a crop with precision and efficiency. At harvest time, the farmer can co-ordinate harvesting with the availability of grain transporters and storage facilities. Using mobile *wireless technology*, the grain transporter can monitor the vehicle in-route in order to maintain the best fuel efficiency and safe operation. Changes in status can be relayed to the driver of the vehicle instantly.
- Remote workers, called teleworkers or telecommuters, use secure remote access services from home or while traveling. The data network enables them to work as if they were on-site, with access to all the network-based tools normally available for their jobs. Virtual meetings and conferences can be convened which include people in remote locations. The network provides audio and video capability so all participants can both see and hear each other. The

information from the meetings can be recorded to a wiki or blog. The latest versions of the agenda and minutes can be shared as soon as they are created.

There are many success stories illustrating innovative ways networks are being used to make us more successful in the workplace. Some of these scenarios are available through the Cisco web site at <http://www.cisco.com>

### 1.1.5 Networks Supporting the Way We Play

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The widespread adoption of the Internet by the entertainment and travel industries enhances the ability to enjoy and share many forms of recreation, regardless of location. It is possible to explore places interactively that previously we could only dream of visiting, as well as preview the actual destinations before making a trip. The details and photographs from these adventures may be posted online for others to view.

The Internet is used for traditional forms of entertainment, as well. We listen to recording artists, preview or view motion pictures, read entire books and download material for future offline access. Live sporting events and concerts can be experienced as they are happening, or recorded and viewed on demand.

Networks enable the creation of new forms of entertainment, such as online games. Players participate in any kind of online competition that game designers can imagine. We compete with friends and foes around the world in the same manner if they were in the same room.

Even offline activities are enhanced using network collaboration services. Global communities of interest have grown rapidly. We share common experiences and hobbies well beyond our local neighborhood, city, or region. Sports fans share opinions and facts about their favorite teams. Collectors display prized collections and get expert feedback about them.

Online markets and auction sites provide the opportunity to buy, sell and trade all types of merchandise.

Whatever form of recreation we enjoy in the human network, networks are improving our experience.

## 1.2 Communication - An Essential Part of Our Lives

### 1.2.1 What is Communication?

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Communication in our daily lives takes many forms and occurs in many environments. We have different expectations depending on whether we are chatting via the Internet or participating in a job interview. Each situation has its corresponding expected behaviors and styles.

#### Establishing the Rules

Before beginning to communicate with each other, we establish rules or agreements to govern the conversation. These rules, or protocols, must be followed in order for the message to be successfully delivered and understood. Among the protocols that govern successful human communication are:

- An identified sender and receiver
- Agreed upon method of communicating (face-to-face, telephone, letter, photograph)
- Common language and grammar
- Speed and timing of delivery

- Confirmation or acknowledgement requirements

Communication rules may vary according to the context. If a message conveys an important fact or concept, a confirmation that the message has been received and understood is necessary. Less important messages may not require an acknowledgement from the recipient.

The techniques that are used in network communications share these fundamentals with human conversations. Because many of our human communication protocols are implicit or are ingrained in our cultures, some rules can be assumed. In establishing data networks, it is necessary to be much more explicit about how communication takes place and how it is judged successful.

## 1.2.2 Quality of Communications

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Communication between individuals is determined to be successful when the meaning of the message understood by the recipient matches the meaning intended by the sender.

For data networks, we use the same basic criteria to judge success. However, as a message moves through the network, many factors can prevent the message from reaching the recipient or distort its intended meaning. These factors can be either external or internal.

### External Factors

The external factors affecting communication are related to the complexity of the network and the number of devices a message must pass through on its route to its final destination.

External factors affecting the success of communication include:

- The quality of the pathway between the sender and the recipient
- The number of times the message has to change form
- The number of times the message has to be redirected or readdressed
- The number of other messages being transmitted simultaneously on the communication network
- The amount of time allotted for successful communication

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### Internal Factors

Internal factors that interfere with network communication are related to the nature of the message itself.

Different types of messages may vary in complexity and importance. Clear and concise messages are usually easier to understand than complex messages. Important communications require more care to ensure that they are delivered and understood by the recipient.

Internal factors affecting the successful communication across the network include:

- The size of the message
- The complexity of the message
- The importance of the message

Large messages may be interrupted or delayed at different points within the network. A message with a low importance or priority could be dropped if the network becomes overloaded.

Both the internal and external factors that affect the receipt of a message must be anticipated and controlled for network communications to be successful. New innovations in network *hardware* and software are being implemented to ensure the quality and reliability of network communications.



## 1.3 The Network as a Platform

### 1.3.1 Communicating over Networks

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Being able to reliably communicate to anyone, anywhere, is becoming increasingly important to our personal and business lives. In order to support the immediate delivery of the millions of messages being exchanged between people all over the world, we rely on a web of interconnected networks. These data or information networks vary in size and capabilities, but all networks have four basic elements in common:

- Rules or agreements to govern how the messages are sent, directed, received and interpreted
- The messages or units of information that travel from one device to another
- A means of interconnecting these devices - a medium that can transport the messages from one device to another
- Devices on the network that exchange messages with each other

The standardization of the various elements of the network enables equipment and devices created by different companies to work together. Experts in various technologies can contribute their best ideas on how to develop an efficient network, without regard to the brand or manufacturer of the equipment.

### 1.3.2 The Elements of a Network

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The diagram shows elements of a typical network, including devices, media, and services, tied together by rules, that work together to send messages. We use the word *messages* as a term that encompasses web pages, e-mail, instant messages, telephone calls, and other forms of communication enabled by the Internet. In this course, we will learn about a variety of messages, devices, media, and services that allow the communication of those messages. We will also learn about the rules, or protocols, that tie these network elements together.

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In this course, many networking devices will be discussed. Networking is a very graphically oriented subject, and icons are commonly used to represent networking devices. On the left side of the diagram are shown some common devices which often originate messages that comprise our communication. These include various types of computers (a PC and laptop icon are shown), servers, and IP phones. On local area networks these devices are typically connected by LAN media (wired or wireless).

The right side of the figure shows some of the most common intermediate devices, used to direct and manage messages across the network, as well as other common networking symbols. Generic symbols are shown for:

- Switch - the most common device for interconnecting local area networks
- Firewall - provides security to networks
- Router - helps direct messages as they travel across a network
- Wireless Router - a specific type of *router* often found in home networks
- Cloud - used to summarize a group of networking devices, the details of which may be unimportant to the discussion at hand
- Serial Link - one form of WAN interconnection, represented by the lightning bolt-shaped line

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For a network to function, the devices must be interconnected. Network connections can be wired or wireless. In wired connections, the medium is either copper, which carries electrical signals, or



optical fiber, which carries light signals. In wireless connections, the medium is the Earth's atmosphere, or space, and the signals are microwaves. Copper medium includes cables, such as twisted pair telephone wire, *coaxial* cable, or most commonly, what is known as Category 5 Unshielded Twisted Pair (*UTP*) cable. Optical fibers, thin strands of glass or plastic that carry light signals, are another form of networking media. Wireless media may include the home wireless connection between a wireless router and a computer with a wireless network card, the terrestrial wireless connection between two ground stations, or the communication between devices on earth and satellites. In a typical journey across the Internet, a message may travel across a variety of media.

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Human beings often seek to send and receive a variety of messages using computer applications; these applications require services to be provided by the network. Some of these services include the World Wide Web, e-mail, instant messaging, and IP Telephony. Devices interconnected by medium to provide services must be governed by rules, or protocols. In the chart, some common services and a protocol most directly associated with that service are listed.

Protocols are the rules that the networked devices use to communicate with each other. The industry *standard* in networking today is a set of protocols called *TCP/IP* (Transmission Control Protocol/Internet Protocol). TCP/IP is used in home and business networks, as well as being the primary protocol of the Internet. It is TCP/IP protocols that specify the formatting, addressing and *routing* mechanisms that ensure our messages are delivered to the correct recipient.

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We close this section with an example to tie together how the elements of networks - devices, media, and services - are connected by rules to deliver a message. People often only picture networks in the abstract sense. We create and send a text message and it almost immediately shows up on the destination device. Although we know that between our sending device and the receiving device there is a network over which our message travels, we rarely think about all the parts and pieces that make up that infrastructure.

### The Messages

In the first step of its journey from the computer to its destination, our instant message gets converted into a format that can be transmitted on the network. All types of messages must be converted to *bits*, *binary* coded digital signals, before being sent to their destinations. This is true no matter what the original message format was: text, video, voice, or computer data. Once our instant message is converted to bits, it is ready to be sent onto the network for delivery.

### The Devices

To begin to understand the robustness and complexity of the interconnected networks that make up the Internet, it is necessary to start with the basics. Take the example of sending the text message using an instant messaging program on a computer. When we think of using network services, we usually think of using a computer to access them. But, a computer is only one type of device that can send and receive messages over a network. Many other types of devices can also be connected to the network to participate in network services. Among these devices are telephones, cameras, music systems, printers and game consoles.

In addition to the computer, there are numerous other components that make it possible for our instant message to be directed across the miles of wires, underground cables, airwaves and satellite stations that might exist between the *source* and destination devices. One of the critical components in any size network is the router. A router joins two or more networks, like a home network and the Internet, and passes information from one network to another. Routers in a network work to ensure that the message gets to its destination in the most efficient and quickest manner.

### The Medium

To send our instant message to its destination, the computer must be connected to a wired or wireless local network. Local networks can be installed in homes or businesses, where they enable

computers and other devices to share information with each other and to use a common connection to the Internet.

Wireless networks allow the use of networked devices anywhere in an office or home, even outdoors. Outside the office or home, wireless networking is available in public hotspots, such as coffee shops, businesses, hotel rooms, and airports.

Many installed networks use wires to provide connectivity. Ethernet is the most common wired networking technology found today. The wires, called cables, connect the computers and other devices that make up the networks. Wired networks are best for moving large amounts of data at high speeds, such as are required to support professional-quality multimedia.

### The Services

Network services are computer programs that support the human network. Distributed on devices throughout the network, these services facilitate online communication tools such as e-mail, bulletin/discussion boards, chat rooms, and instant messaging. In the case of instant messaging, for example, an instant messaging service, provided by devices in the *cloud*, must be accessible to both the sender and recipient.

### The Rules

Important aspects of networks that are neither devices nor media are rules, or protocols. These rules are the standards and protocols that specify how the messages are sent, how they are directed through the network, and how they are interpreted at the destination devices. For example, in the case of Jabber instant messaging, the XMPP, TCP, and IP protocols are all important sets of rules that enable our communication to occur.

## 1.3.3 Converged Networks

### Multiple services-multiple networks

Traditional telephone, radio, television, and computer data networks each have their own individual versions of the four basic network elements. In the past, every one of these services required a different technology to carry its particular communication signal. Additionally, each service had its own set of rules and standards to ensure successful communication of its signal across a specific medium.

### Converged networks

Technology advances are enabling us to consolidate these disparate networks onto one platform - a platform defined as a *converged network*. The *flow* of voice, video, and data traveling over the same network eliminates the need to create and maintain separate networks. On a converged network there are still many points of contact and many specialized devices - for example, personal computers, phones, TVs, personal assistants, and retail point-of-sale registers - but only one common network infrastructure.

### Intelligent Information Networks

The role of the network is evolving. The intelligent communications platform of tomorrow will offer so much more than basic connectivity and access to *applications*. The convergence of the different types of communications networks onto one platform represents the first phase in building the intelligent information network. We are currently in this phase of network evolution. The next phase will be to consolidate not only the different types of messages onto a single network, but to also consolidate the applications that generate, transmit, and secure the messages onto integrated network devices. Not only will voice and video be transmitted over the same network, the devices that perform the telephone switching and video broadcasting will be the same devices that route

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the messages through the network. The resulting communications platform will provide high quality application functionality at a reduced cost.

### Planning for the Future

The pace at which the development of exciting new converged network applications is occurring can be attributed to the rapid expansion of the Internet. This expansion has created a wider audience and a larger consumer base for whatever message, product or service can be delivered. The underlying mechanics and processes that drive this explosive growth have resulted in a network architecture that is both resilient and scalable. As the supporting technology platform for living, learning, working, and playing in the human network, the network architecture of the Internet must adapt to constantly changing requirements for a high quality of service and security.

## 1.4 The Architecture of the Internet

### 1.4.1 The Network Architecture

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Networks must support a wide range of applications and services, as well as operate over many different types of physical infrastructures. The term network architecture, in this context, refers to both the technologies that support the infrastructure and the programmed services and protocols that move the messages across that infrastructure. As the Internet, and networks in general, evolve, we are discovering that there are four basic characteristics that the underlying architectures need to address in order to meet user expectations: fault tolerance, scalability, quality of service, and security.

#### Fault Tolerance

The expectation that the Internet is always available to the millions of users who rely on it requires a network architecture that is designed and built to be fault tolerant. A fault tolerant network is one that limits the impact of a hardware or software failure and can recover quickly when such a failure occurs. These networks depend on redundant links, or paths, between the source and destination of a message. If one link or path fails, processes ensure that messages can be instantly routed over a different link transparent to the users on either end. Both the physical infrastructures and the logical processes that direct the messages through the network are designed to accommodate this redundancy. This is a basic premise of the architecture of current networks.

#### Scalability

A scalable network can expand quickly to support new users and applications without impacting the performance of the service being delivered to existing users. Thousands of new users and service providers connect to the Internet each week. The ability of the network to support these new interconnections depends on a hierarchical layered design for the underlying physical infrastructure and logical architecture. The operation at each layer enables users or service providers to be inserted without causing disruption to the entire network. Technology developments are constantly increasing the message carrying capabilities and performance of the physical infrastructure components at every layer. These developments, along with new methods to identify and locate individual users within an *internetwork*, are enabling the Internet to keep pace with user demand.

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#### Quality of Service (QoS)

The Internet is currently providing an acceptable level of fault tolerance and scalability for its users. But new applications available to users over internetworks create higher expectations for the quality of the delivered services. Voice and live video transmissions require a level of consistent quality and uninterrupted delivery that was not necessary for traditional computer applications. Quality of these services is measured against the quality of experiencing the same audio or video presentation in person. Traditional voice and video networks are designed to support a single type

of transmission, and are therefore able to produce an acceptable level of quality. New requirements to support this quality of service over a converged network are changing the way network architectures are designed and implemented.

### Security

The Internet has evolved from a tightly controlled internetwork of educational and government organizations to a widely accessible means for transmission of business and personal communications. As a result, the security requirements of the network have changed. The security and privacy expectations that result from the use of internetworks to exchange confidential and business critical information exceed what the current architecture can deliver. Rapid expansion in communication areas that were not served by traditional data networks is increasing the need to embed security into the network architecture. As a result, much effort is being devoted to this area of research and development. In the meantime, many tools and procedures are being implemented to combat inherent security flaws in the network architecture.

## 1.4.2 A Fault Tolerant Network Architecture

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The Internet, in its early inception, was the result of research funded by the United States Department of Defense (DoD). Its primary goal was to have a communications medium that could withstand the destruction of numerous sites and transmission facilities without disruption of service. It only follows that fault tolerance was the focus of the effort of the initial internetwork design work. Early network researchers looked at the existing communication networks, which were primarily for the transmission of voice traffic, to determine what could be done to improve the fault tolerance level.

### Circuit Switched Connection-oriented Networks

To understand the challenge that the DoD researchers were faced with, it is necessary to look at how early telephone systems work. When a person makes a call using a traditional telephone set, the call first goes through a setup *process*, where all of the telephone switching locations between the person and the phone set that they are calling are identified. A temporary path, or circuit, is created through the various switching locations to use for the duration of the telephone call. If any link or device participating in the circuit fails, the call is dropped. To reconnect, a new call must be made, and a new circuit created between the source telephone set and the destination. This type of connection-oriented network is called a circuit-switched network. Early circuit switched networks did not dynamically recreate dropped circuits. In order to recover from failure, new calls had to be initiated and new circuits built *end-to-end*.

Many circuit switched networks give priority to maintaining existing circuit connections, at the expense of new circuit requests. In this type of connection-oriented network, once a circuit is established, even if no communication is occurring between the persons on either end of the call, the circuit remains connected and resources reserved until one of the parties disconnects the call. Since there is a finite capacity to create new circuits, it is possible to occasionally get a message that all circuits are busy and a call cannot be placed. The cost to create many alternate paths with enough capacity to support a large number of simultaneous circuits, and the technologies necessary to dynamically recreate dropped circuits in the event of a failure, led the DoD to consider other types of networks.

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### Packet Switched Connectionless Networks

In the search for a network that could withstand the loss of a significant amount of its transmission and switching facilities, the early Internet designers reevaluated early research regarding *packet* switched networks. The premise for this type of networks is that a single message can be broken

into multiple message blocks. Individual blocks containing addressing information indicate both their origination point and their final destination. Using this embedded information, these message blocks, called packets, can be sent through the network along various paths, and can be reassembled into the original message upon reaching their destination.

### Utilizing Packets

The devices within the network itself are unaware of the content of the individual packets, only visible is the address of the final destination and the next device in the path to that destination. No reserved circuit is built between sender and receiver. Each packet is sent independently from one switching location to another. At each location, a routing decision is made as to which path to use to forward the packet towards its final destination. If a previously used path is no longer available, the routing function can dynamically choose the next best available path. Because the messages are sent in pieces, rather than as a single complete message, the few packets that may be lost in the advent of a failure can be retransmitted to the destination along a different path. In many cases, the destination device is unaware that any failure or rerouting has occurred.

### Packet-switched Connectionless Networks

The DoD researchers realized that a packet switched connectionless network had the features necessary to support a resilient, fault tolerant network architecture. The need for a single, reserved circuit from end-to-end does not exist in a packet switched network. Any piece of a message can be sent through the network using any available path. Packets containing pieces of messages from different sources can travel the network at the same time. The problem of underutilized or idle circuits is eliminated — all available resources can be used at any time to deliver packets to their final destination. By providing a method to dynamically use redundant paths, without intervention by the user, the Internet has become a fault tolerant, scalable method of communications.

### Connection-oriented Networks

Although packet-switched connectionless networks met the needs of the DoD, and continue to be the primary infrastructure for today's Internet, there are some benefits to a connection-oriented system like the circuit-switched telephone system. Because resources at the various switching locations are dedicated to providing a finite number of circuits, the quality and consistency of messages transmitted across a connection-oriented network can be guaranteed. Another benefit is that the provider of the service can charge the users of the network for the period of time that the connection is active. The ability to charge users for active connections through the network is a fundamental premise of the telecommunication service industry.

## 1.4.3 A Scalable Network Architecture

Refer to  
Figure  
in online course

The fact that the Internet is able to expand at the rate that it is, without seriously impacting the performance experienced by individual users, is a function of the design of the protocols and underlying technologies on which it is built. The Internet, which is actually a collection of interconnected private and public networks, has a hierarchical layered structure for addressing, for naming and for connectivity services. At each level or layer of the hierarchy, individual network operators maintain peering relationships with other operators at the same level. As a result, network traffic that is destined for local or regional services does not need to traverse to a central point for distribution. Common services can be duplicated in different regions, thereby keeping traffic off the higher level backbone networks.

Although there is no single organization that regulates the Internet, the operators of the many individual networks that provide Internet connectivity cooperate to follow accepted standards and protocols.

The adherence to standards enables the manufacturers of hardware and software to concentrate on product improvements in the areas of performance and capacity, knowing that the new products can integrate with and enhance the existing infrastructure.

The current Internet architecture, while highly scalable, may not always be able to keep up with the pace of user demand. New protocols and addressing structures are under development to meet the increasing rate at which Internet applications and services are being added.

### 1.4.4 Providing Quality of Service

Refer to  
**Figure**  
in online course

Networks must provide secure, predictable, measurable, and, at times, guaranteed services. The packet-switched network architecture does not guarantee that all packets that comprise a particular message will arrive on time, in their correct order, or even that they will arrive at all.

Networks also need mechanisms to manage congested network traffic. Congestion is caused when the demand on the network resources exceeds the available capacity.

If all networks had infinite resources, there would not be a need to use QoS mechanisms to ensure quality of service. Unfortunately, that is not the case. There are some constraints on network resources that cannot be avoided. Constraints include technology limitations, costs, and the local availability of high-bandwidth service. Network bandwidth is the measure of the data carrying capacity of the network. When simultaneous communications are attempted across the network, the demand for network bandwidth can exceed its availability. The obvious fix for this situation is to increase the amount of available bandwidth. But, because of the previously stated constraints, this is not always possible.

In most cases, when the volume of packets is greater than what can be transported across the network, devices queue the packets in memory until resources become available to transmit them. Queuing packets causes delay. If the number of packets to be queued continues to increase, the memory queues fill up and packets are dropped.

Refer to  
**Figure**  
in online course

Achieving the required Quality of Service (QoS) by managing the delay and packet loss parameters on a network becomes the secret to a successful end-to-end application quality solution. Thus, ensuring QoS requires a set of techniques to manage the utilization of network resources. In order to maintain a high quality of service for applications that require it, it is necessary to prioritize which types of data packets must be delivered at the expense of other types of packets that can be delayed or dropped.

#### Classification

Ideally, we would like to assign a precise priority for each type of communication. Currently, this is neither practical nor possible. Therefore, we classify applications in categories based on specific quality of service requirements.

To create QoS classifications of data, we use a combination of communication characteristics and the relative importance assigned to the application. We then treat all data within the same classification according to the same rules. For example, communication that is time-sensitive or important would be classified differently from communication that can wait or is of lesser importance.

#### Assigning priorities

The characteristics of the information being communicated also affect its management. For example, the delivery of a movie uses a relatively large amount of network resources when it is delivered continuously without interruption. Other types of service - e-mail, for example - are not nearly as demanding on the network. In one company, an administrator might decide to allocate



the greatest share of the network resources to the movie, believing that this is the priority for his customers. This administrator may decide that the impact will be minimal if e-mail users have to wait a few additional seconds for their e-mail to arrive. In another company, the quality of a video *stream* is not as important as critical process control information that operates the manufacturing machinery.

Refer to  
Figure  
in online course

QoS mechanisms enable the establishment of queue management strategies that enforce priorities for different classifications of application data. Without properly designed and implemented QoS mechanisms, data packets will be dropped without consideration of the application characteristics or priority. Examples of priority decisions for an organization might include:

- Time-sensitive communication - increase priority for services like telephony or video distribution.
- Non time-sensitive communication - decrease priority for web page retrieval or e-mail.
- High importance to organization - increase priority for production control or business transaction data.
- Undesirable communication - decrease priority or block unwanted activity, like peer-to-peer file sharing or live entertainment.

The Quality of Service a network can offer is a vital issue, and in some situations, it is crucial. Imagine the consequences of a dropped distress call to an emergency response center, or of a lost control signal to an automated piece of heavy machinery. A key responsibility for the network managers in an organization is to establish a Quality of Service policy and ensure that the mechanisms are in place to meet that goal.

### 1.4.5 Providing Network Security

Refer to  
Figure  
in online course

The network infrastructure, services, and the data contained on network attached computers are crucial personal and business assets. Compromising the integrity of these assets could have serious business and financial repercussions.

Consequences of a network security breach could include:

- Network outage that prevents communications and transactions occurring, with consequent loss of business
- Misdirection and loss of personal or business funds
- Company intellectual property (research ideas, patents or designs) that is stolen and used by a competitor
- Customer contract details that become known to competitors or made public, resulting in a loss of market confidence in the business

A lack of public trust in the business's privacy, confidentiality, and integrity levels may lead to loss of sales and eventual company failure. There are two types of network security concerns that must be addressed to prevent serious consequences: network infrastructure security and content security.

Securing a network infrastructure includes the physical securing of devices that provide network connectivity and preventing unauthorized access to the management software that resides on them.

Content security refers to protecting the information contained within the packets being transmitted over the network and the information stored on network attached devices. When transmitting



information over the Internet or other network, the content of the individual packets is not readily known to the devices and facilities through which the packets travel. Tools to provide security for the content of individual messages must be implemented on top of the underlying protocols which govern how packets are formatted, addressed and delivered. Because the reassembly and interpretation of the content is delegated to programs running on the individual source and destination systems, many of the security tools and protocols must be implemented on those systems as well.

Refer to  
**Figure**  
in online course

Security measures taken in a network should:

- Prevent unauthorized disclosure or theft of information
- Prevent unauthorized modification of information
- Prevent Denial of Service

Means to achieve these goals include:

- Ensuring confidentiality
- Maintaining communication integrity
- Ensuring availability

### Ensuring Confidentiality

Data privacy is maintained by allowing only the intended and authorized recipients - individuals, processes, or devices - to read the data.

Having a strong system for user *authentication*, enforcing passwords that are difficult to guess, and requiring users to change them frequently helps restrict access to communications and to data stored on network attached devices. Where appropriate, encrypting content ensures confidentiality and minimizes unauthorized disclosure or theft of information.

### Maintaining Communication Integrity

Data integrity means having the assurance that the information has not been altered in transmission, from origin to destination. Data integrity can be compromised when information has been corrupted - willfully or accidentally - before the intended recipient receives it.

Source integrity is the assurance that the identity of the sender has been validated. Source integrity is compromised when a user or device fakes its identity and supplies incorrect information to a recipient.

The use of *digital signatures*, *hashing algorithms* and *checksum* mechanisms are ways to provide source and data integrity across a network to prevent unauthorized modification of information.

### Ensuring Availability

Ensuring confidentiality and integrity are irrelevant if network resources become over burdened, or not available at all. Availability means having the assurance of timely and reliable access to data services for authorized users. Resources can be unavailable during a Denial of Service (DoS) attack or due to the spread of a *computer virus*. Network *firewall* devices, along with desktop and server anti-virus software can ensure system reliability and the robustness to detect, repel, and cope with such attacks. Building fully redundant network infrastructures, with few single *points of failure*, can reduce the impact of these threats.

The result of the implementation of measures to improve both the quality of service and the security of network communications is an increase in the complexity of the underlying network platform. As the Internet continues to expand to offer more and more new services, its future depends

Refer to  
**Lab Activity**  
for this chapter

on new, more robust network architectures being developed that include all four characteristics: fault tolerance, scalability, quality of service, and security.

Upon completion of this activity, you will be able to:

Use the SANS site to quickly identify Internet security threats and explain how threats are organized.

## 1.5 Trends in Networking

### 1.5.1 Where Is It All Going?

Refer to  
**Figure**  
in online course

The convergence of the many different communication media onto a single network platform is fueling exponential growth in network capabilities. There are three major trends that are contributing to the future shape of complex information networks:

- Increasing number of mobile users
- Proliferation of network capable devices
- Expanding range of services

#### Mobile Users

With the increase in the numbers of mobile workers and the increased use of hand-held devices, we are necessarily demanding more mobile connectivity to data networks. This demand has created a market for wireless services that have greater flexibility, coverage, and security.

#### New and More Capable Devices

The computer is only one of many devices on today's information networks. We have a proliferation of exciting new technologies that can take advantage of available network services.

The functions performed by cell phones, Personal Digital Assistants (PDAs), organizers, and pagers are converging into single hand-held devices with continuous connectivity to providers of services and content. These devices, once thought of as "toys" or luxury items, are now an integral part of how people communicate. In addition to mobile devices, we also have Voice over IP (VoIP) devices, gaming systems, and a large assortment of household and business gadgets that can connect and use network services.

#### Increased Availability of Services

The widespread acceptance of technology and the fast pace of innovation in network delivered services create a spiraling dependence. To meet user demands, new services are introduced and older services are enhanced. As the users come to trust these expanded services, they want even more capabilities. The network then grows to support the increasing demand. People depend on the services provided over the network, and therefore depend on the availability and reliability of the underlying network infrastructure.

The challenge of keeping pace with an ever expanding network of users and services is the responsibility of trained network and IT professionals.

### 1.5.2 Networking Career Opportunities

Refer to  
**Figure**  
in online course

Information Technology and networking careers are growing and evolving as fast as the underlying technologies and services. As networks increase in sophistication, the demand for people with networking skills will continue to grow.

Traditional IT positions like programmers, software engineers, data base administrators and network technicians are now joined by new titles, such as network architect, e-Commerce site designer, information security officer, and home integration specialist. Opportunities for forward thinking entrepreneurs are unlimited.

Even non-IT jobs, like manufacturing management or medical equipment design, now require a significant amount of knowledge about network operation in order to be successful.

Chief Technology Officers in many large organizations list the lack of qualified personnel as the primary factor delaying the implementation of innovative new services.

As students of networking technology, we examine the components of data networks and the roles they play in enabling communication. This course, as well as others in the Network Academy series, is designed to empower you with the networking knowledge to build and manage these evolving networks.

## 1.6 Chapter Labs

### 1.6.1 Using Collaboration Tools - IRC and IM

Refer to  
**Lab Activity**  
for this chapter

In this lab, you will define Internet Relay Chat (IRC) and Instant Messaging (IM). You will also list several misuses and data security issues involving IM.

### 1.6.2 Using Collaboration Tools - Wikis and Web Logs

Refer to  
**Lab Activity**  
for this chapter

In this lab, you will define the terms wiki and blog. You will also explain the purpose of a wiki and blog and how these technologies are used for collaboration.

## Summary and Review

Refer to  
**Figure**  
in online course

This chapter explained the importance of data networks as the platform for supporting business communication and the tasks of everyday life.

Data networks play a vital role in facilitating communication within the global human network.

Data networks support the way we live, learn, work, and play. They provide the platform for the services that enable us to connect - both locally and globally - with our families, friends, work, and interests. This platform supports using text, graphics, video, and speech.

Data networks and human networks use similar procedures to ensure that their communication gets to the destination accurately and on time. Agreements on language, content, form, and medium that humans often implicitly use are mirrored in the data network.

The factors that ensure the delivery of our messages and information across a data network are the networking media that connect the networking devices and the agreements and standards that govern its operation. As the demand grows for more people and devices to communicate in a mobile world, data network technologies will have to adapt and develop.

Converged networks, which carry all communications types (data, voice, and video) on one infrastructure, provide an opportunity to reduce costs and offer users feature-rich services and content. However, the design and management of converged networks requires extensive networking knowledge and skills if all services are to be delivered as expected to users.

Different types of communications flowing across our data networks need to be prioritized so that the time-sensitive and important data have the first use of limited network resources.

Integrating security into data networks is essential if our private, personal, and business communications are not going to be intercepted, stolen, or damaged.

Refer to  
**Figure**  
in online course

Refer to **Packet  
Tracer Activity**  
for this chapter

Packet Tracer 4.1 ("PT 4.1") is a standalone simulation and visualization program. PT 4.1 activities are integrated throughout this course. While formal activities using Packet Tracer begin in the next chapter, if time allows please launch the program now, and explore the Help resources, which include "My First PT Lab" and a variety of tutorials to teach you various aspects of the software. Also, please ask your instructor how obtain a copy of PT 4.1 for your personal use. Every chapter will have a Packet Tracer Skills Integration Challenge: an activity that allows you to practice most skills learned to that point in the course in a cumulative fashion. PT Skills Integration Challenges will allow you to build your practical skills for such things as hands-on performance exams and Certification exams.

Packet Tracer Skills Integration Instructions (PDF)

Refer to  
**Figure**  
in online course

To learn more about a milestone in the history of communications, read about Claude Shannon and his famous paper, "A Mathematical Theory of Communication."

Go to  
the online course  
to take the quiz.

## Chapter Quiz

Take the chapter quiz to test your knowledge.

## Your Chapter Notes