

# OVERVIEW

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*The combination of space, time, and strength that must be considered as the basic elements of this theory of defense makes this a fairly complicated matter. Consequently, it is not easy to find a fixed point of departure.*

— *On War*, Carl Von Clausewitz

## LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- ◆ Describe the key security requirements of confidentiality, integrity, and availability.
- ◆ Discuss the types of security threats and attacks that must be dealt with and give examples of the types of threats and attacks that apply to different categories of computer and network assets.
- ◆ Summarize the functional requirements for computer security.
- ◆ Describe the X.800 security architecture for OSI.

This book focuses on two broad areas: cryptographic algorithms and protocols, which have a broad range of applications; and network and Internet security, which rely heavily on cryptographic techniques.

**Cryptographic algorithms and protocols** can be grouped into four main areas:

- **Symmetric encryption:** Used to conceal the contents of blocks or streams of data of any size, including messages, files, encryption keys, and passwords.
- **Asymmetric encryption:** Used to conceal small blocks of data, such as encryption keys and hash function values, which are used in digital signatures.
- **Data integrity algorithms:** Used to protect blocks of data, such as messages, from alteration.
- **Authentication protocols:** These are schemes based on the use of cryptographic algorithms designed to authenticate the identity of entities.

The field of **network and Internet security** consists of measures to deter, prevent, detect, and correct security violations that involve the transmission of information. That is a broad statement that covers a host of possibilities. To give you a feel for the areas covered in this book, consider the following examples of security violations:

1. User A transmits a file to user B. The file contains sensitive information (e.g., payroll records) that is to be protected from disclosure. User C, who is not authorized to read the file, is able to monitor the transmission and capture a copy of the file during its transmission.
2. A network manager, D, transmits a message to a computer, E, under its management. The message instructs computer E to update an authorization file to include the identities of a number of new users who are to be given access to

that computer. User F intercepts the message, alters its contents to add or delete entries, and then forwards the message to computer E, which accepts the message as coming from manager D and updates its authorization file accordingly.

3. Rather than intercept a message, user F constructs its own message with the desired entries and transmits that message to computer E as if it had come from manager D. Computer E accepts the message as coming from manager D and updates its authorization file accordingly.
4. An employee is fired without warning. The personnel manager sends a message to a server system to invalidate the employee's account. When the invalidation is accomplished, the server is to post a notice to the employee's file as confirmation of the action. The employee is able to intercept the message and delay it long enough to make a final access to the server to retrieve sensitive information. The message is then forwarded, the action taken, and the confirmation posted. The employee's action may go unnoticed for some considerable time.
5. A message is sent from a customer to a stockbroker with instructions for various transactions. Subsequently, the investments lose value and the customer denies sending the message.

Although this list by no means exhausts the possible types of network security violations, it illustrates the range of concerns of network security.

## 1.1 COMPUTER SECURITY CONCEPTS

### A Definition of Computer Security

The NIST *Computer Security Handbook* [NIST95] defines the term *computer security* as follows:

**Computer Security:** The protection afforded to an automated information system in order to attain the applicable objectives of preserving the integrity, availability, and confidentiality of information system resources (includes hardware, software, firmware, information/data, and telecommunications).

This definition introduces three key objectives that are at the heart of computer security:

- **Confidentiality:** This term covers two related concepts:
  - Data<sup>1</sup> confidentiality:** Assures that private or confidential information is not made available or disclosed to unauthorized individuals.

<sup>1</sup>RFC 4949 defines *information* as “facts and ideas, which can be represented (encoded) as various forms of data,” and *data* as “information in a specific physical representation, usually a sequence of symbols that have meaning; especially a representation of information that can be processed or produced by a computer.” Security literature typically does not make much of a distinction, nor does this book.

**Privacy:** Assures that individuals control or influence what information related to them may be collected and stored and by whom and to whom that information may be disclosed.

- **Integrity:** This term covers two related concepts:

**Data integrity:** Assures that information and programs are changed only in a specified and authorized manner.

**System integrity:** Assures that a system performs its intended function in an unimpaired manner, free from deliberate or inadvertent unauthorized manipulation of the system.

- **Availability:** Assures that systems work promptly and service is not denied to authorized users.

These three concepts form what is often referred to as the **CIA triad**. The three concepts embody the fundamental security objectives for both data and for information and computing services. For example, the NIST standard FIPS 199 (*Standards for Security Categorization of Federal Information and Information Systems*) lists confidentiality, integrity, and availability as the three security objectives for information and for information systems. FIPS 199 provides a useful characterization of these three objectives in terms of requirements and the definition of a loss of security in each category:

- **Confidentiality:** Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information. A loss of confidentiality is the unauthorized disclosure of information.
- **Integrity:** Guarding against improper information modification or destruction, including ensuring information nonrepudiation and authenticity. A loss of integrity is the unauthorized modification or destruction of information.
- **Availability:** Ensuring timely and reliable access to and use of information. A loss of availability is the disruption of access to or use of information or an information system.

Although the use of the CIA triad to define security objectives is well established, some in the security field feel that additional concepts are needed to present a complete picture. Two of the most commonly mentioned are as follows:

- **Authenticity:** The property of being genuine and being able to be verified and trusted; confidence in the validity of a transmission, a message, or message originator. This means verifying that users are who they say they are and that each input arriving at the system came from a trusted source.
- **Accountability:** The security goal that generates the requirement for actions of an entity to be traced uniquely to that entity. This supports nonrepudiation, deterrence, fault isolation, intrusion detection and prevention, and after-action recovery and legal action. Because truly secure systems are not yet an achievable goal, we must be able to trace a security breach to a responsible party. Systems must keep records of their activities to permit later forensic analysis to trace security breaches or to aid in transaction disputes.

## Examples

We now provide some examples of applications that illustrate the requirements just enumerated.<sup>2</sup> For these examples, we use three levels of impact on organizations or individuals should there be a breach of security (i.e., a loss of confidentiality, integrity, or availability). These levels are defined in FIPS PUB 199:

- **Low:** The loss could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals. A limited adverse effect means that, for example, the loss of confidentiality, integrity, or availability might (i) cause a degradation in mission capability to an extent and duration that the organization is able to perform its primary functions, but the effectiveness of the functions is noticeably reduced; (ii) result in minor damage to organizational assets; (iii) result in minor financial loss; or (iv) result in minor harm to individuals.
- **Moderate:** The loss could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals. A serious adverse effect means that, for example, the loss might (i) cause a significant degradation in mission capability to an extent and duration that the organization is able to perform its primary functions, but the effectiveness of the functions is significantly reduced; (ii) result in significant damage to organizational assets; (iii) result in significant financial loss; or (iv) result in significant harm to individuals that does not involve loss of life or serious, life-threatening injuries.
- **High:** The loss could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals. A severe or catastrophic adverse effect means that, for example, the loss might (i) cause a severe degradation in or loss of mission capability to an extent and duration that the organization is not able to perform one or more of its primary functions; (ii) result in major damage to organizational assets; (iii) result in major financial loss; or (iv) result in severe or catastrophic harm to individuals involving loss of life or serious, life-threatening injuries.

**CONFIDENTIALITY** Student grade information is an asset whose confidentiality is considered to be highly important by students. In the United States, the release of such information is regulated by the Family Educational Rights and Privacy Act (FERPA). Grade information should only be available to students, their parents, and employees that require the information to do their job. Student enrollment information may have a moderate confidentiality rating. While still covered by FERPA, this information is seen by more people on a daily basis, is less likely to be targeted than grade information, and results in less damage if disclosed. Directory information, such as lists of students or faculty or departmental lists, may be assigned a low confidentiality rating or indeed no rating. This information is typically freely available to the public and published on a school's Web site.

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<sup>2</sup>These examples are taken from a security policy document published by the Information Technology Security and Privacy Office at Purdue University.

**INTEGRITY** Several aspects of integrity are illustrated by the example of a hospital patient's allergy information stored in a database. The doctor should be able to trust that the information is correct and current. Now suppose that an employee (e.g., a nurse) who is authorized to view and update this information deliberately falsifies the data to cause harm to the hospital. The database needs to be restored to a trusted basis quickly, and it should be possible to trace the error back to the person responsible. Patient allergy information is an example of an asset with a high requirement for integrity. Inaccurate information could result in serious harm or death to a patient and expose the hospital to massive liability.

An example of an asset that may be assigned a moderate level of integrity requirement is a Web site that offers a forum to registered users to discuss some specific topic. Either a registered user or a hacker could falsify some entries or deface the Web site. If the forum exists only for the enjoyment of the users, brings in little or no advertising revenue, and is not used for something important such as research, then potential damage is not severe. The Web master may experience some data, financial, and time loss.

An example of a low integrity requirement is an anonymous online poll. Many Web sites, such as news organizations, offer these polls to their users with very few safeguards. However, the inaccuracy and unscientific nature of such polls is well understood.

**AVAILABILITY** The more critical a component or service, the higher is the level of availability required. Consider a system that provides authentication services for critical systems, applications, and devices. An interruption of service results in the inability for customers to access computing resources and staff to access the resources they need to perform critical tasks. The loss of the service translates into a large financial loss in lost employee productivity and potential customer loss.

An example of an asset that would typically be rated as having a moderate availability requirement is a public Web site for a university; the Web site provides information for current and prospective students and donors. Such a site is not a critical component of the university's information system, but its unavailability will cause some embarrassment.

An online telephone directory lookup application would be classified as a low availability requirement. Although the temporary loss of the application may be an annoyance, there are other ways to access the information, such as a hardcopy directory or the operator.

## The Challenges of Computer Security

Computer and network security is both fascinating and complex. Some of the reasons follow:

1. Security is not as simple as it might first appear to the novice. The requirements seem to be straightforward; indeed, most of the major requirements for security services can be given self-explanatory, one-word labels: confidentiality, authentication, nonrepudiation, or integrity. But the mechanisms used

to meet those requirements can be quite complex, and understanding them may involve rather subtle reasoning.

2. In developing a particular security mechanism or algorithm, one must always consider potential attacks on those security features. In many cases, successful attacks are designed by looking at the problem in a completely different way, therefore exploiting an unexpected weakness in the mechanism.
3. Because of point 2, the procedures used to provide particular services are often counterintuitive. Typically, a security mechanism is complex, and it is not obvious from the statement of a particular requirement that such elaborate measures are needed. It is only when the various aspects of the threat are considered that elaborate security mechanisms make sense.
4. Having designed various security mechanisms, it is necessary to decide where to use them. This is true both in terms of physical placement (e.g., at what points in a network are certain security mechanisms needed) and in a logical sense (e.g., at what layer or layers of an architecture such as TCP/IP [Transmission Control Protocol/Internet Protocol] should mechanisms be placed).
5. Security mechanisms typically involve more than a particular algorithm or protocol. They also require that participants be in possession of some secret information (e.g., an encryption key), which raises questions about the creation, distribution, and protection of that secret information. There also may be a reliance on communications protocols whose behavior may complicate the task of developing the security mechanism. For example, if the proper functioning of the security mechanism requires setting time limits on the transit time of a message from sender to receiver, then any protocol or network that introduces variable, unpredictable delays may render such time limits meaningless.
6. Computer and network security is essentially a battle of wits between a perpetrator who tries to find holes and the designer or administrator who tries to close them. The great advantage that the attacker has is that he or she need only find a single weakness, while the designer must find and eliminate all weaknesses to achieve perfect security.
7. There is a natural tendency on the part of users and system managers to perceive little benefit from security investment until a security failure occurs.
8. Security requires regular, even constant, monitoring, and this is difficult in today's short-term, overloaded environment.
9. Security is still too often an afterthought to be incorporated into a system after the design is complete rather than being an integral part of the design process.
10. Many users and even security administrators view strong security as an impediment to efficient and user-friendly operation of an information system or use of information.

The difficulties just enumerated will be encountered in numerous ways as we examine the various security threats and mechanisms throughout this book.

## 1.2 THE OSI SECURITY ARCHITECTURE

To assess effectively the security needs of an organization and to evaluate and choose various security products and policies, the manager responsible for security needs some systematic way of defining the requirements for security and characterizing the approaches to satisfying those requirements. This is difficult enough in a centralized data processing environment; with the use of local and wide area networks, the problems are compounded.

ITU-T<sup>3</sup> Recommendation X.800, *Security Architecture for OSI*, defines such a systematic approach.<sup>4</sup> The OSI security architecture is useful to managers as a way of organizing the task of providing security. Furthermore, because this architecture was developed as an international standard, computer and communications vendors have developed security features for their products and services that relate to this structured definition of services and mechanisms.

For our purposes, the OSI security architecture provides a useful, if abstract, overview of many of the concepts that this book deals with. The OSI security architecture focuses on security attacks, mechanisms, and services. These can be defined briefly as

- **Security attack:** Any action that compromises the security of information owned by an organization.
- **Security mechanism:** A process (or a device incorporating such a process) that is designed to detect, prevent, or recover from a security attack.
- **Security service:** A processing or communication service that enhances the security of the data processing systems and the information transfers of an organization. The services are intended to counter security attacks, and they make use of one or more security mechanisms to provide the service.

In the literature, the terms *threat* and *attack* are commonly used to mean more or less the same thing. Table 1.1 provides definitions taken from RFC 4949, *Internet Security Glossary*.

**Table 1.1** Threats and Attacks (RFC 4949)

<p><b>Threat</b></p> <p>A potential for violation of security, which exists when there is a circumstance, capability, action, or event that could breach security and cause harm. That is, a threat is a possible danger that might exploit a vulnerability.</p> <p><b>Attack</b></p> <p>An assault on system security that derives from an intelligent threat; that is, an intelligent act that is a deliberate attempt (especially in the sense of a method or technique) to evade security services and violate the security policy of a system.</p>
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<sup>3</sup>The International Telecommunication Union (ITU) Telecommunication Standardization Sector (ITU-T) is a United Nations-sponsored agency that develops standards, called Recommendations, relating to telecommunications and to open systems interconnection (OSI).

<sup>4</sup>The OSI security architecture was developed in the context of the OSI protocol architecture, which is described in Appendix L. However, for our purposes in this chapter, an understanding of the OSI protocol architecture is not required.



## 1.3 SECURITY ATTACKS

A useful means of classifying security attacks, used both in X.800 and RFC 4949, is in terms of *passive attacks* and *active attacks* (Figure 1.1). A passive attack attempts to learn or make use of information from the system but does not affect system resources. An active attack attempts to alter system resources or affect their operation.

### Passive Attacks

Passive attacks (Figure 1.1) are in the nature of eavesdropping on, or monitoring of, transmissions. The goal of the opponent is to obtain information that is being transmitted. Two types of passive attacks are the release of message contents and traffic analysis.

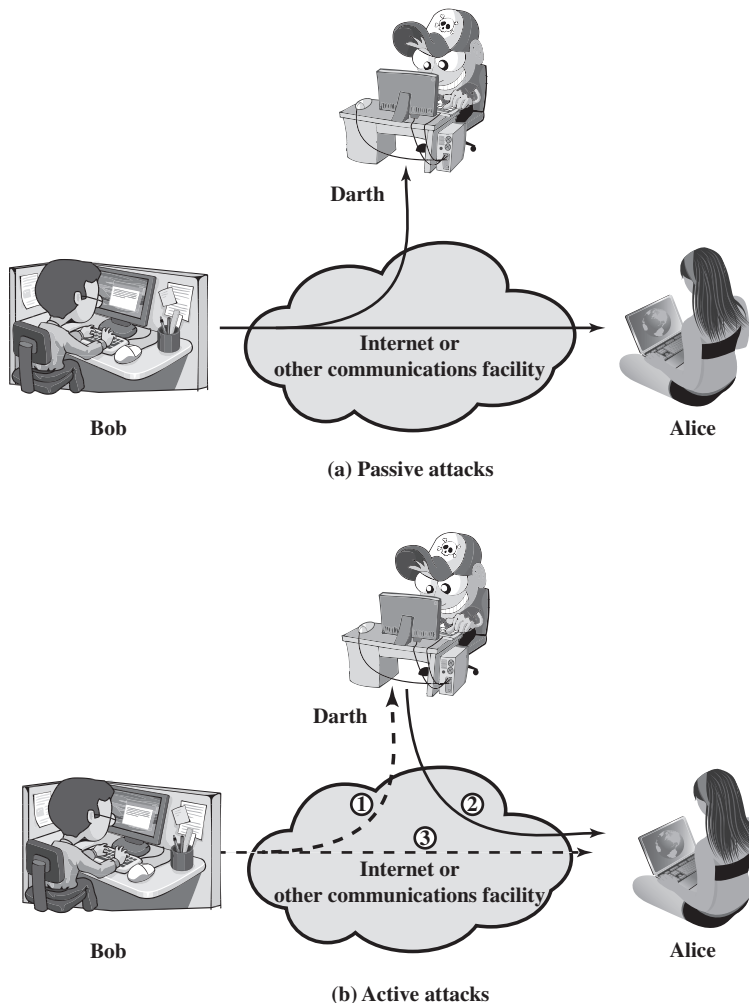


Figure 1.1 Security Attacks

The **release of message contents** is easily understood. A telephone conversation, an electronic mail message, and a transferred file may contain sensitive or confidential information. We would like to prevent an opponent from learning the contents of these transmissions.

A second type of passive attack, **traffic analysis**, is subtler. Suppose that we had a way of masking the contents of messages or other information traffic so that opponents, even if they captured the message, could not extract the information from the message. The common technique for masking contents is encryption. If we had encryption protection in place, an opponent might still be able to observe the pattern of these messages. The opponent could determine the location and identity of communicating hosts and could observe the frequency and length of messages being exchanged. This information might be useful in guessing the nature of the communication that was taking place.

Passive attacks are very difficult to detect, because they do not involve any alteration of the data. Typically, the message traffic is sent and received in an apparently normal fashion, and neither the sender nor receiver is aware that a third party has read the messages or observed the traffic pattern. However, it is feasible to prevent the success of these attacks, usually by means of encryption. Thus, the emphasis in dealing with passive attacks is on prevention rather than detection.

### Active Attacks

Active attacks (Figure 1.1b) involve some modification of the data stream or the creation of a false stream and can be subdivided into four categories: masquerade, replay, modification of messages, and denial of service.

A **masquerade** takes place when one entity pretends to be a different entity (path 2 of Figure 1.1b is active). A masquerade attack usually includes one of the other forms of active attack. For example, authentication sequences can be captured and replayed after a valid authentication sequence has taken place, thus enabling an authorized entity with few privileges to obtain extra privileges by impersonating an entity that has those privileges.

**Replay** involves the passive capture of a data unit and its subsequent retransmission to produce an unauthorized effect (paths 1, 2, and 3 active).

**Modification of messages** simply means that some portion of a legitimate message is altered, or that messages are delayed or reordered, to produce an unauthorized effect (paths 1 and 2 active). For example, a message meaning “Allow John Smith to read confidential file *accounts*” is modified to mean “Allow Fred Brown to read confidential file *accounts*.”

The **denial of service** prevents or inhibits the normal use or management of communications facilities (path 3 active). This attack may have a specific target; for example, an entity may suppress all messages directed to a particular destination (e.g., the security audit service). Another form of service denial is the disruption of an entire network, either by disabling the network or by overloading it with messages so as to degrade performance.

Active attacks present the opposite characteristics of passive attacks. Whereas passive attacks are difficult to detect, measures are available to prevent their success. On the other hand, it is quite difficult to prevent active attacks absolutely

because of the wide variety of potential physical, software, and network vulnerabilities. Instead, the goal is to detect active attacks and to recover from any disruption or delays caused by them. If the detection has a deterrent effect, it may also contribute to prevention.

## 1.4 SECURITY SERVICES

X.800 defines a security service as a service that is provided by a protocol layer of communicating open systems and that ensures adequate security of the systems or of data transfers. Perhaps a clearer definition is found in RFC 4949, which provides the following definition: a processing or communication service that is provided by a system to give a specific kind of protection to system resources; security services implement security policies and are implemented by security mechanisms.

X.800 divides these services into five categories and fourteen specific services (Table 1.2). We look at each category in turn.<sup>5</sup>

### Authentication

The authentication service is concerned with assuring that a communication is authentic. In the case of a single message, such as a warning or alarm signal, the function of the authentication service is to assure the recipient that the message is from the source that it claims to be from. In the case of an ongoing interaction, such as the connection of a terminal to a host, two aspects are involved. First, at the time of connection initiation, the service assures that the two entities are authentic, that is, that each is the entity that it claims to be. Second, the service must assure that the connection is not interfered with in such a way that a third party can masquerade as one of the two legitimate parties for the purposes of unauthorized transmission or reception.

Two specific authentication services are defined in X.800:

- **Peer entity authentication:** Provides for the corroboration of the identity of a peer entity in an association. Two entities are considered peers if they implement to same protocol in different systems; for example two TCP modules in two communicating systems. Peer entity authentication is provided for use at the establishment of, or at times during the data transfer phase of, a connection. It attempts to provide confidence that an entity is not performing either a masquerade or an unauthorized replay of a previous connection.
- **Data origin authentication:** Provides for the corroboration of the source of a data unit. It does not provide protection against the duplication or modification of data units. This type of service supports applications like electronic mail, where there are no prior interactions between the communicating entities.

<sup>5</sup>There is no universal agreement about many of the terms used in the security literature. For example, the term *integrity* is sometimes used to refer to all aspects of information security. The term *authentication* is sometimes used to refer both to verification of identity and to the various functions listed under integrity in this chapter. Our usage here agrees with both X.800 and RFC 4949.

**Table 1.2** Security Services (X.800)

<p style="text-align: center;"><b>AUTHENTICATION</b></p> <p>The assurance that the communicating entity is the one that it claims to be.</p> <p><b>Peer Entity Authentication</b> Used in association with a logical connection to provide confidence in the identity of the entities connected.</p> <p><b>Data-Origin Authentication</b> In a connectionless transfer, provides assurance that the source of received data is as claimed.</p> <p style="text-align: center;"><b>ACCESS CONTROL</b></p> <p>The prevention of unauthorized use of a resource (i.e., this service controls who can have access to a resource, under what conditions access can occur, and what those accessing the resource are allowed to do).</p> <p style="text-align: center;"><b>DATA CONFIDENTIALITY</b></p> <p>The protection of data from unauthorized disclosure.</p> <p><b>Connection Confidentiality</b> The protection of all user data on a connection.</p> <p><b>Connectionless Confidentiality</b> The protection of all user data in a single data block</p> <p><b>Selective-Field Confidentiality</b> The confidentiality of selected fields within the user data on a connection or in a single data block.</p> <p><b>Traffic-Flow Confidentiality</b> The protection of the information that might be derived from observation of traffic flows.</p>	<p style="text-align: center;"><b>DATA INTEGRITY</b></p> <p>The assurance that data received are exactly as sent by an authorized entity (i.e., contain no modification, insertion, deletion, or replay).</p> <p><b>Connection Integrity with Recovery</b> Provides for the integrity of all user data on a connection and detects any modification, insertion, deletion, or replay of any data within an entire data sequence, with recovery attempted.</p> <p><b>Connection Integrity without Recovery</b> As above, but provides only detection without recovery.</p> <p><b>Selective-Field Connection Integrity</b> Provides for the integrity of selected fields within the user data of a data block transferred over a connection and takes the form of determination of whether the selected fields have been modified, inserted, deleted, or replayed.</p> <p><b>Connectionless Integrity</b> Provides for the integrity of a single connectionless data block and may take the form of detection of data modification. Additionally, a limited form of replay detection may be provided.</p> <p><b>Selective-Field Connectionless Integrity</b> Provides for the integrity of selected fields within a single connectionless data block; takes the form of determination of whether the selected fields have been modified.</p> <p style="text-align: center;"><b>NONREPUDIATION</b></p> <p>Provides protection against denial by one of the entities involved in a communication of having participated in all or part of the communication.</p> <p><b>Nonrepudiation, Origin</b> Proof that the message was sent by the specified party.</p> <p><b>Nonrepudiation, Destination</b> Proof that the message was received by the specified party.</p>
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## Access Control

In the context of network security, access control is the ability to limit and control the access to host systems and applications via communications links. To achieve this, each entity trying to gain access must first be identified, or authenticated, so that access rights can be tailored to the individual.

## Data Confidentiality

Confidentiality is the protection of transmitted data from passive attacks. With respect to the content of a data transmission, several levels of protection can be identified. The broadest service protects all user data transmitted between two users over a period of time. For example, when a TCP connection is set up between two systems, this broad protection prevents the release of any user data transmitted over the TCP connection. Narrower forms of this service can also be defined, including the protection of a single message or even specific fields within a message. These refinements are less useful than the broad approach and may even be more complex and expensive to implement.

The other aspect of confidentiality is the protection of traffic flow from analysis. This requires that an attacker not be able to observe the source and destination, frequency, length, or other characteristics of the traffic on a communications facility.

## Data Integrity

As with confidentiality, integrity can apply to a stream of messages, a single message, or selected fields within a message. Again, the most useful and straightforward approach is total stream protection.

A connection-oriented integrity service, one that deals with a stream of messages, assures that messages are received as sent with no duplication, insertion, modification, reordering, or replays. The destruction of data is also covered under this service. Thus, the connection-oriented integrity service addresses both message stream modification and denial of service. On the other hand, a connectionless integrity service, one that deals with individual messages without regard to any larger context, generally provides protection against message modification only.

We can make a distinction between service with and without recovery. Because the integrity service relates to active attacks, we are concerned with detection rather than prevention. If a violation of integrity is detected, then the service may simply report this violation, and some other portion of software or human intervention is required to recover from the violation. Alternatively, there are mechanisms available to recover from the loss of integrity of data, as we will review subsequently. The incorporation of automated recovery mechanisms is, in general, the more attractive alternative.

## Nonrepudiation

Nonrepudiation prevents either sender or receiver from denying a transmitted message. Thus, when a message is sent, the receiver can prove that the alleged sender in fact sent the message. Similarly, when a message is received, the sender can prove that the alleged receiver in fact received the message.

## Availability Service

Both X.800 and RFC 4949 define availability to be the property of a system or a system resource being accessible and usable upon demand by an authorized system entity, according to performance specifications for the system (i.e., a system is available if it provides services according to the system design whenever users request

them). A variety of attacks can result in the loss of or reduction in availability. Some of these attacks are amenable to automated countermeasures, such as authentication and encryption, whereas others require some sort of physical action to prevent or recover from loss of availability of elements of a distributed system.

X.800 treats availability as a property to be associated with various security services. However, it makes sense to call out specifically an availability service. An availability service is one that protects a system to ensure its availability. This service addresses the security concerns raised by denial-of-service attacks. It depends on proper management and control of system resources and thus depends on access control service and other security services.

## 1.5 SECURITY MECHANISMS

Table 1.3 lists the security mechanisms defined in X.800. The mechanisms are divided into those that are implemented in a specific protocol layer, such as TCP or an application-layer protocol, and those that are not specific to any particular protocol layer or security service. These mechanisms will be covered in the appropriate places in the book. So we do not elaborate now, except to comment on the definition of encipherment. X.800 distinguishes between reversible encipherment mechanisms and irreversible encipherment mechanisms. A reversible

**Table 1.3** Security Mechanisms (X.800)

SPECIFIC SECURITY MECHANISMS	PERVASIVE SECURITY MECHANISMS
<p>May be incorporated into the appropriate protocol layer in order to provide some of the OSI security services.</p> <p><b>Encipherment</b> The use of mathematical algorithms to transform data into a form that is not readily intelligible. The transformation and subsequent recovery of the data depend on an algorithm and zero or more encryption keys.</p> <p><b>Digital Signature</b> Data appended to, or a cryptographic transformation of, a data unit that allows a recipient of the data unit to prove the source and integrity of the data unit and protect against forgery (e.g., by the recipient).</p> <p><b>Access Control</b> A variety of mechanisms that enforce access rights to resources.</p> <p><b>Data Integrity</b> A variety of mechanisms used to assure the integrity of a data unit or stream of data units.</p>	<p>Mechanisms that are not specific to any particular OSI security service or protocol layer.</p> <p><b>Trusted Functionality</b> That which is perceived to be correct with respect to some criteria (e.g., as established by a security policy).</p> <p><b>Security Label</b> The marking bound to a resource (which may be a data unit) that names or designates the security attributes of that resource.</p> <p><b>Event Detection</b> Detection of security-relevant events.</p> <p><b>Security Audit Trail</b> Data collected and potentially used to facilitate a security audit, which is an independent review and examination of system records and activities.</p> <p><b>Security Recovery</b> Deals with requests from mechanisms, such as event handling and management functions, and takes recovery actions.</p>

Table 1.3 Continued

SPECIFIC SECURITY MECHANISMS	
<b>Authentication Exchange</b> A mechanism intended to ensure the identity of an entity by means of information exchange.	
<b>Traffic Padding</b> The insertion of bits into gaps in a data stream to frustrate traffic analysis attempts.	
<b>Routing Control</b> Enables selection of particular physically secure routes for certain data and allows routing changes, especially when a breach of security is suspected.	
<b>Notarization</b> The use of a trusted third party to assure certain properties of a data exchange.	

encipherment mechanism is simply an encryption algorithm that allows data to be encrypted and subsequently decrypted. Irreversible encipherment mechanisms include hash algorithms and message authentication codes, which are used in digital signature and message authentication applications.

Table 1.4, based on one in X.800, indicates the relationship between security services and security mechanisms.

Table 1.4 Relationship Between Security Services and Mechanisms

SERVICE	MECHANISM							
	Encipherment	Digital signature	Access control	Data integrity	Authentication exchange	Traffic padding	Routing control	Notarization
Peer entity authentication	Y	Y			Y			
Data origin authentication	Y	Y						
Access control			Y					
Confidentiality	Y					Y		
Traffic flow confidentiality	Y				Y	Y		
Data integrity	Y	Y		Y				
Nonrepudiation		Y		Y				Y
Availability				Y	Y			

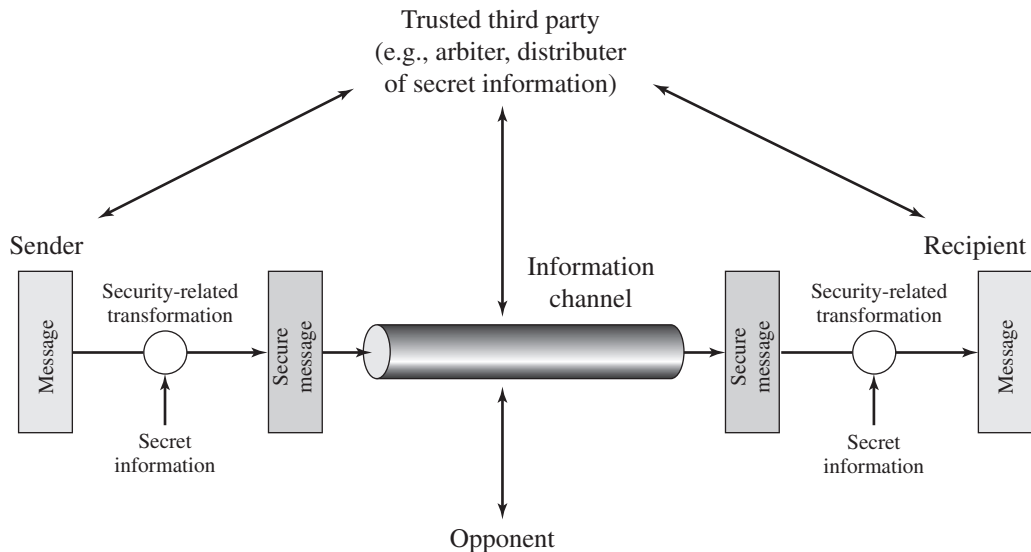
## 1.6 A MODEL FOR NETWORK SECURITY

A model for much of what we will be discussing is captured, in very general terms, in Figure 1.2. A message is to be transferred from one party to another across some sort of Internet service. The two parties, who are the *principals* in this transaction, must cooperate for the exchange to take place. A logical information channel is established by defining a route through the Internet from source to destination and by the cooperative use of communication protocols (e.g., TCP/IP) by the two principals.

Security aspects come into play when it is necessary or desirable to protect the information transmission from an opponent who may present a threat to confidentiality, authenticity, and so on. All the techniques for providing security have two components:

- A security-related transformation on the information to be sent. Examples include the encryption of the message, which scrambles the message so that it is unreadable by the opponent, and the addition of a code based on the contents of the message, which can be used to verify the identity of the sender.
- Some secret information shared by the two principals and, it is hoped, unknown to the opponent. An example is an encryption key used in conjunction with the transformation to scramble the message before transmission and unscramble it on reception.<sup>6</sup>

A trusted third party may be needed to achieve secure transmission. For example, a third party may be responsible for distributing the secret information



**Figure 1.2** Model for Network Security

<sup>6</sup>Part Two discusses a form of encryption, known as a symmetric encryption, in which only one of the two principals needs to have the secret information.



to the two principals while keeping it from any opponent. Or a third party may be needed to arbitrate disputes between the two principals concerning the authenticity of a message transmission.

This general model shows that there are four basic tasks in designing a particular security service:

1. Design an algorithm for performing the security-related transformation. The algorithm should be such that an opponent cannot defeat its purpose.
2. Generate the secret information to be used with the algorithm.
3. Develop methods for the distribution and sharing of the secret information.
4. Specify a protocol to be used by the two principals that makes use of the security algorithm and the secret information to achieve a particular security service.

Parts One through Five of this book concentrate on the types of security mechanisms and services that fit into the model shown in Figure 1.2. However, there are other security-related situations of interest that do not neatly fit this model but are considered in this book. A general model of these other situations is illustrated in Figure 1.3, which reflects a concern for protecting an information system from unwanted access. Most readers are familiar with the concerns caused by the existence of hackers, who attempt to penetrate systems that can be accessed over a network. The hacker can be someone who, with no malign intent, simply gets satisfaction from breaking and entering a computer system. The intruder can be a disgruntled employee who wishes to do damage or a criminal who seeks to exploit computer assets for financial gain (e.g., obtaining credit card numbers or performing illegal money transfers).

Another type of unwanted access is the placement in a computer system of logic that exploits vulnerabilities in the system and that can affect application programs as well as utility programs, such as editors and compilers. Programs can present two kinds of threats:

- **Information access threats:** Intercept or modify data on behalf of users who should not have access to that data.
- **Service threats:** Exploit service flaws in computers to inhibit use by legitimate users.

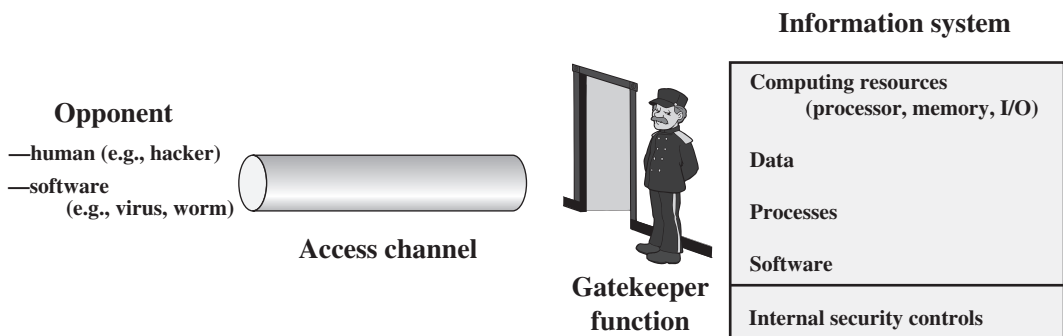


Figure 1.3 Network Access Security Model

Viruses and worms are two examples of software attacks. Such attacks can be introduced into a system by means of a disk that contains the unwanted logic concealed in otherwise useful software. They can also be inserted into a system across a network; this latter mechanism is of more concern in network security.

The security mechanisms needed to cope with unwanted access fall into two broad categories (see Figure 1.3). The first category might be termed a gatekeeper function. It includes password-based login procedures that are designed to deny access to all but authorized users and screening logic that is designed to detect and reject worms, viruses, and other similar attacks. Once either an unwanted user or unwanted software gains access, the second line of defense consists of a variety of internal controls that monitor activity and analyze stored information in an attempt to detect the presence of unwanted intruders. These issues are explored in Part Six.

## 1.7 RECOMMENDED READING

[STAL12] provides a broad introduction to both computer and network security. [SCHN00] is valuable reading for any practitioner in the field of computer or network security: It discusses the limitations of technology, and cryptography in particular, in providing security and the need to consider the hardware, the software implementation, the networks, and the people involved in providing and attacking security.

It is useful to read some of the classic tutorial papers on computer security; these provide a historical perspective from which to appreciate current work and thinking.<sup>7</sup> The papers to read are [WARE79], [BROW72], [SALT75], [SHAN77], and [SUMM84]. Two more recent, short treatments of computer security are [ANDR04] and [LAMP04]. [NIST95] is an exhaustive (290 pages) treatment of the subject. Another good treatment is [NRC91]. Also useful is [FRAS97].

**ANDR04** Andrews, M., and Whittaker, J. “Computer Security.” *IEEE Security and Privacy*, September/October 2004.

**BROW72** Browne, P. “Computer Security—A Survey.” *ACM SIGMIS Database*, Fall 1972.

**FRAS97** Fraser, B. *Site Security Handbook*. RFC 2196, September 1997.

**LAMP04** Lampson, B. “Computer Security in the Real World,” *Computer*, June 2004.

**NIST95** National Institute of Standards and Technology. *An Introduction to Computer Security: The NIST Handbook*. Special Publication 800–12, October 1995.

**NRC91** National Research Council. *Computers at Risk: Safe Computing in the Information Age*. Washington, D.C.: National Academy Press, 1991.

**SALT75** Saltzer, J., and Schroeder, M. “The Protection of Information in Computer Systems.” *Proceedings of the IEEE*, September 1975.

**SCHN00** Schneier, B. *Secrets and Lies: Digital Security in a Networked World*. New York: Wiley, 2000.

<sup>7</sup>These classic papers are available in the Premium Content Web site for this book.