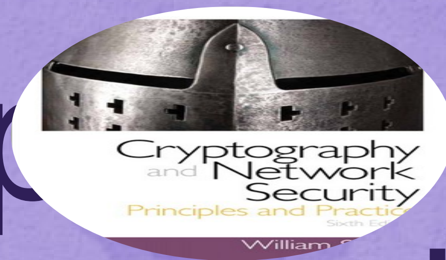
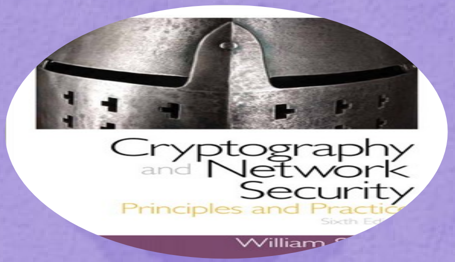
Cryptography and Network Security



Seventh Edition

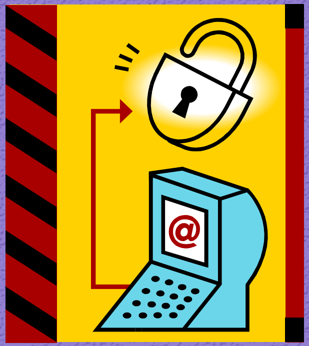
by William Stallings



Chapter 1

Computer and Network Security Concepts

The field of network and Internet security consists of:



measures to deter, prevent, detect, and correct security violations that involve the transmission of information

Computer Security

The NIST *Computer Security Handbook* defines the term computer security as:

"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)

Computer Security Objectives

Confidentiality

- Data confidentiality
  - Assures that private or confidential information is not made available or disclosed to unauthorized individuals
- 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

- 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

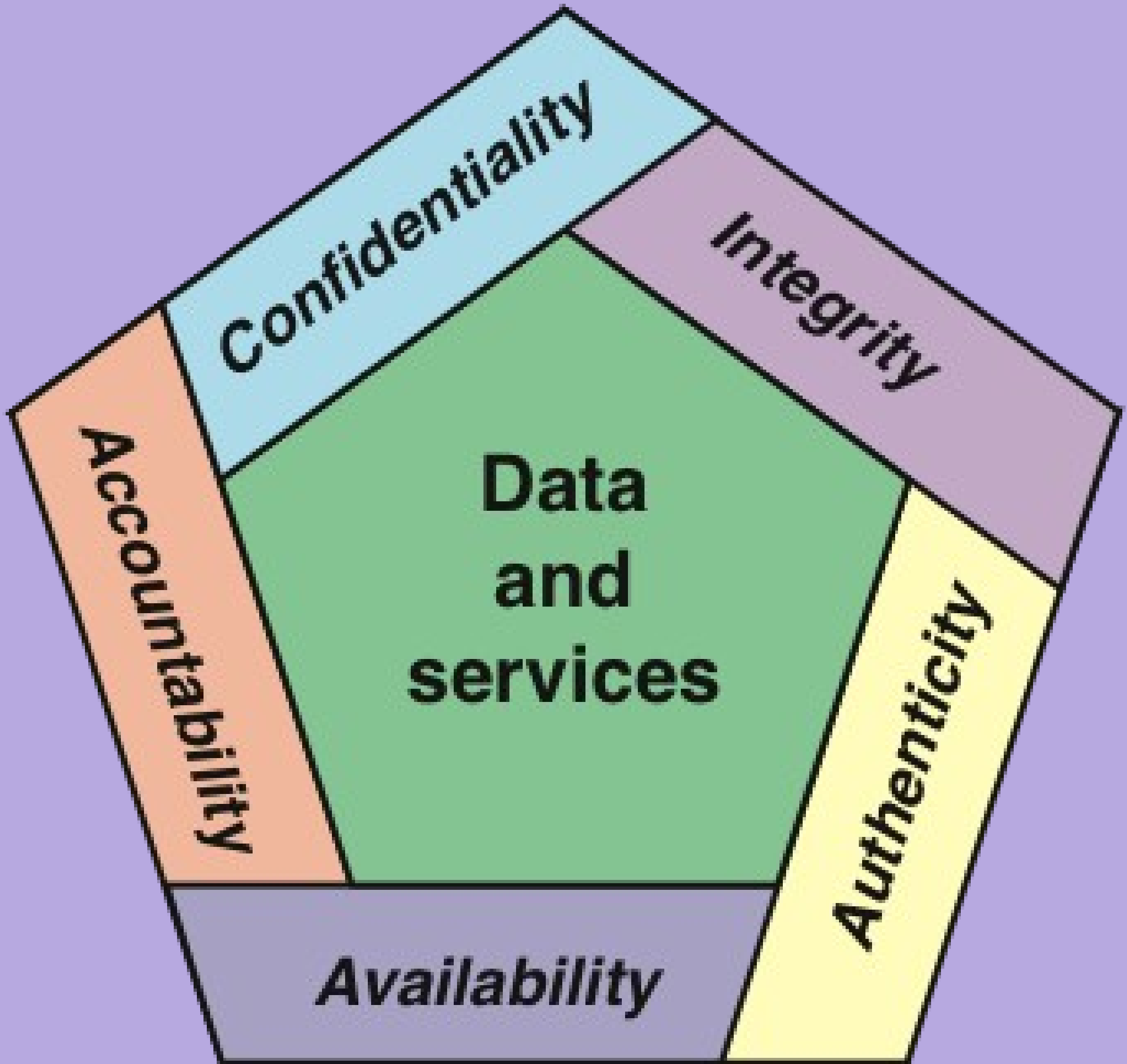


Figure 1.1 Essential Network and Computer Security Requirements

Breach of Security Levels of Impact

High

- The loss could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals

Moderate

- The loss could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals

Low

- The loss could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals

Computer Security Challenges

- Security is not simple
- Potential attacks on the security features need to be considered
- Procedures used to provide particular services are often counter-intuitive
- It is necessary to decide where to use the various security mechanisms
- Requires constant monitoring
- Is too often an afterthought
- Security mechanisms typically involve more than a particular algorithm or protocol
- Security is essentially a battle of wits between a perpetrator and the designer
- Little benefit from security investment is perceived until a security failure occurs
- Strong security is often viewed as an impediment to efficient and user-friendly operation

OSI Security Architecture

- 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
  - Intended to counter security attacks, and they make use of one or more security mechanisms to provide the service

Table 1.1
Threats and Attacks (RFC 4949)

Threat

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.

Attack

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.

Security Attacks

- A means of classifying security attacks, used both in X.800 and RFC 4949, is in terms of *passive attacks* and *active attacks*

- 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

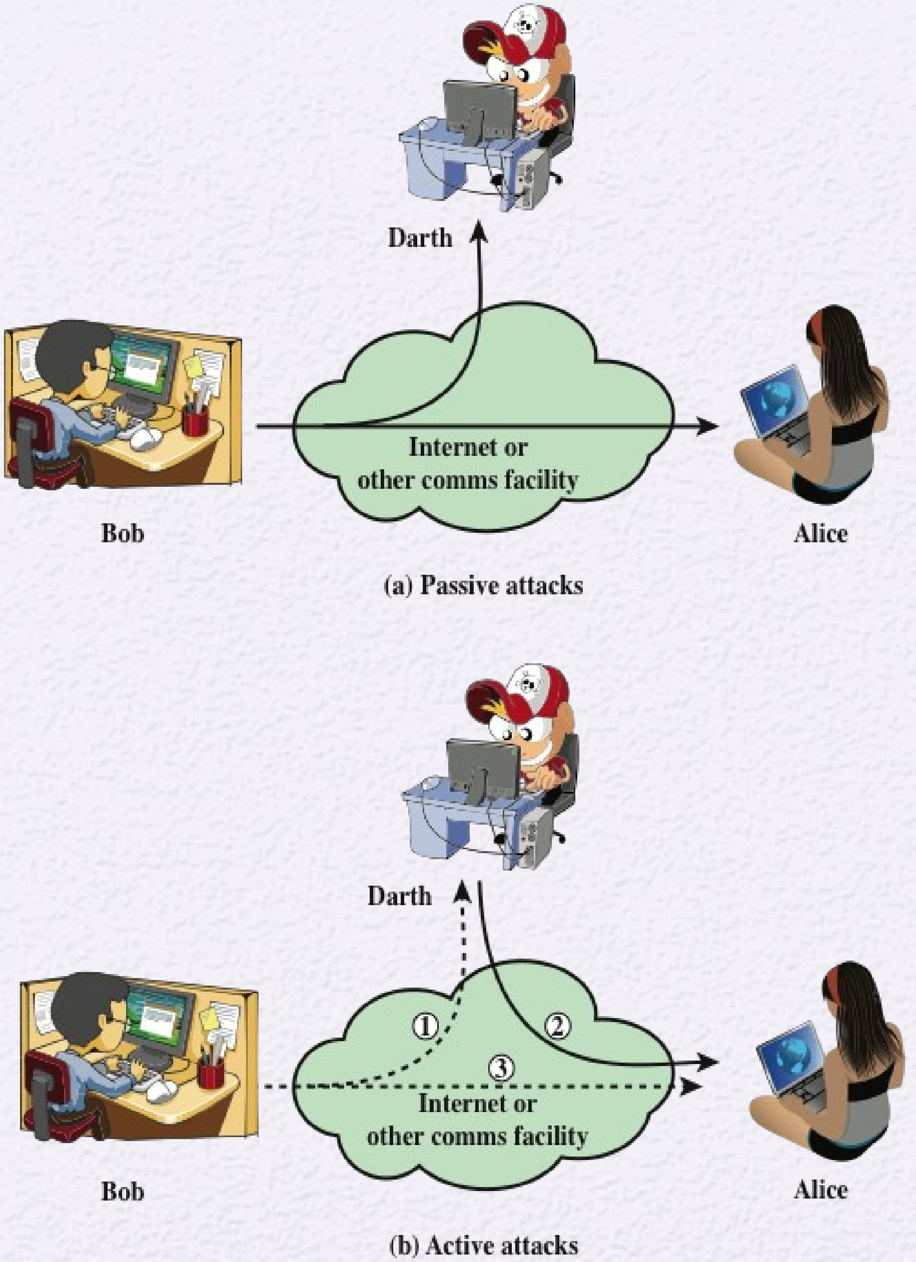


Figure 1.2 Security Attacks

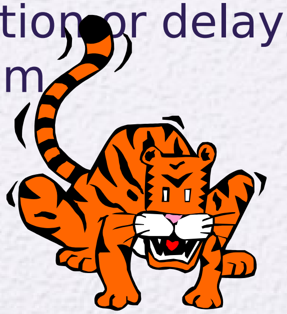
Passive Attacks

- Are in the nature of eavesdropping on, or monitoring of, transmissions
- Goal of the opponent is to obtain information that is being transmitted

- Two types of passive attacks are:
  - The release of message contents
  - Traffic analysis

Active Attacks

- Involve some modification of the data stream or the creation of a false stream
- Difficult to prevent because of the wide variety of potential physical, software, and network vulnerabilities
- Goal is to detect attacks and to recover from any disruption or delays caused by them



Masquerade
- Takes place when one entity pretends to be a different entity
- Usually includes one of the other forms of active attack

Replay
- Involves the passive capture of a data unit and its subsequent retransmission to produce an unauthorized effect

Modification of messages
- Some portion of a legitimate message is altered, or messages are delayed or reordered to produce an unauthorized effect

Denial of service
- Prevents or inhibits the normal use or management of communications facilities

Security Services

- Defined by X.800 as:
  - A service provided by a protocol layer of communicating open systems and that ensures adequate security of the systems or of data transfers

- Defined by RFC 4949 as:
  - A processing or communication service provided by a system to give a specific kind of protection to system resources

Table 1.2

Security Services (X.800)

AUTHENTICATION	DATA INTEGRITY
The assurance that the communicating entity is the one that it claims to be.	The assurance that data received are exactly as sent by an authorized entity (i.e., contain no modification, insertion, deletion, or replay).

AUTHENTICATION

The assurance that the communicating entity is the one that it claims to be.

Peer Entity Authentication
Used in association with a logical connection to provide confidence in the identity of the entities connected.

Data-Origin Authentication
In a connectionless transfer, provides assurance that the source of received data is as claimed.

ACCESS CONTROL

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).

DATA CONFIDENTIALITY

The protection of data from unauthorized disclosure.

Connection Confidentiality
The protection of all user data on a connection.

Connectionless Confidentiality
The protection of all user data in a single data block

Selective-Field Confidentiality
The confidentiality of selected fields within the user data on a connection or in a single data block.

Traffic-Flow Confidentiality
The protection of the information that might be derived from observation of traffic flows.

DATA INTEGRITY

The assurance that data received are exactly as sent by an authorized entity (i.e., contain no modification, insertion, deletion, or replay).

Connection Integrity with Recovery
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.

Connection Integrity without Recovery
As above, but provides only detection without recovery.

Selective-Field Connection Integrity
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.

Connectionless Integrity
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.

Selective-Field Connectionless Integrity
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.

NONREPUDIATION

Provides protection against denial by one of the entities involved in a communication of having participated in all or part of the communication.

Nonrepudiation, Origin
Proof that the message was sent by the specified party.

Nonrepudiation, Destination
Proof that the message was received by the specified party.

Authentication

- Concerned with assuring that a communication is authentic
  - In the case of a single message, assures the recipient that the message is from the source that it claims to be from
  - In the case of ongoing interaction, assures the two entities are authentic and that the connection is not interfered with in such a way that a third party can masquerade as one of the two legitimate parties

Two specific authentication services are defined in X.800:

- Peer entity authentication
- Data origin authentication

Access Control

- 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 indentified, or authenticated, so that access rights can be tailored to the individual

Mandatory Access Controls

- Discretionary & Nondiscretionary AC
- Security perimeter
- Security Levels
  - People, processes and information each have a security label consisting of
    - Security level (unclassified<confidential<secret<top secret
    - Category (eg; comsec, intel, crypto, nuclear)

Covert Channels

- Timing Channel (processor cycles)
- Storage Channel (shared resources)
- Low Bandwidth (introduce noise)
- Example: 64 Mbyte message and a covert channel with a bandwidth of 1 bit/sec. How long will it take to transmit the plaintext of the message. If the message is encrypted with a 56 bit key and transmitted over an insecure channel. How long will it take the covert channel to deliver the key?

Data Confidentiality

- The protection of transmitted data from passive attacks
  - Broadest service protects all user data transmitted between two users over a period of time
  - Narrower forms of service includes the protection of a single message or even specific fields within a message

- 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

- Can apply to a stream of messages, a single message, or selected fields within a message
- 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
- A connectionless integrity service, one that deals with individual messages without regard to any larger context, generally provides protection against message modification only

Nonrepudiation

- Prevents either sender or receiver from denying a transmitted message
- When a message is sent, the receiver can prove that the alleged sender in fact sent the message
- When a message is received, the sender can prove that the alleged receiver in fact received the message

Availability Service

- 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

Security Mechanisms (X.800)

Specific Security Mechanisms

- Encipherment
- Digital signatures
- Access controls
- Data integrity
- Authentication exchange
- Traffic padding
- Routing control
- Notarization

Pervasive Security Mechanisms

- Trusted functionality
- Security labels
- Event detection
- Security audit trails
- Security recovery

Table 1.3

Security Mechanisms (X.800)

SPECIFIC SECURITY MECHANISMS	PERVASIVE SECURITY MECHANISMS
May be incorporated into the appropriate protocol layer in order to provide some of the OSI security services.	Mechanisms that are not specific to any particular OSI security service or protocol layer.
Encipherment 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.	**Trusted Functionality** That which is perceived to be correct with respect to some criteria (e.g., as established by a security policy).
Digital Signature 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).	**Security Label** The marking bound to a resource (which may be a data unit) that names or designates the security attributes of that resource.
Access Control A variety of mechanisms that enforce access rights to resources.	**Event Detection** Detection of security-relevant events.
Data Integrity A variety of mechanisms used to assure the integrity of a data unit or stream of data units.	**Security Audit Trail** Data collected and potentially used to facilitate a security audit, which is an independent review and examination of system records and activities.
Authentication Exchange A mechanism intended to ensure the identity of an entity by means of information exchange.	**Security Recovery** Deals with requests from mechanisms, such as event handling and management functions, and takes recovery actions.
Traffic Padding The insertion of bits into gaps in a data stream to frustrate traffic analysis attempts.	
Routing Control Enables selection of particular physically secure routes for certain data and allows routing changes, especially when a breach of security is suspected.	
Notarization The use of a trusted third party to assure certain properties of a data exchange.	

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

- Schemes based on the use of cryptographic algorithms designed to authenticate the identity of entities

Cryptography (defined)

- Definition: Cryptography is the study of mathematical techniques related to aspects of information security such as confidentiality, data integrity, entity authentication, and data origin authentication.

Handbook of Applied Cryptography, by A. Menezes, P. van Oorschot, and S. Vanstone, CRC Press, 1996

Cryptographic goals

(1) privacy or confidentiality

(2) data integrity

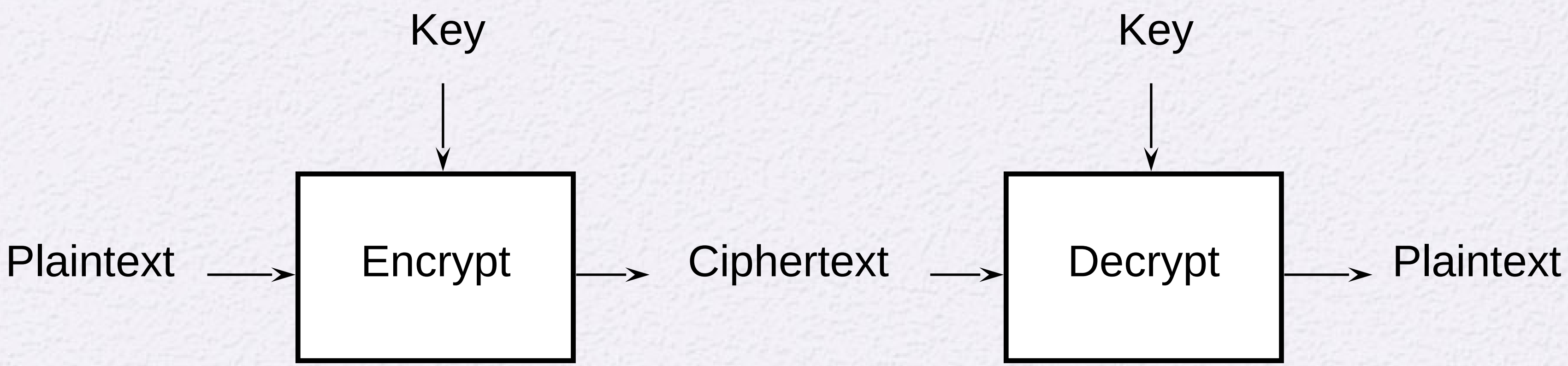
(3) authentication (entity and data origin)

(4) non-repudiation

What is Encryption?

- You and I agree on a secret way to transform data
- Later, we use that transform on data we want to pass over an unsafe communications channel
- Instead of coming up with new transforms, design a common algorithm customized with a “key”

Secret Key Encryption for Privacy



How Secure is Encryption?

- An attacker who knows the algorithm we’re using could try all possible keys
- Security of cryptography depends on the limited computational power of the attacker
- A fairly small key (e.g. 64 bits) represents a formidable challenge to the attacker
- Algorithms can also have weaknesses, independent of key size

Computational Difficulty: How do we know how good an algorithm is?

- A problem of mathematics: it is very hard to prove a problem is hard
- It's never impossible to break a cryptographic algorithm - we want it to be as hard as trying all keys
- Fundamental Tenet of Cryptography: *If lots of smart people have failed to solve a problem then it probably won't be solved* (soon)

To Publish or Not to Publish

- If the good guys break your algorithm, you'll hear about it
- If you publish your algorithm, the good guys provide free consulting by trying to crack it
- The bad guys will learn your algorithm anyway
- Today, most commercial algorithms are published; most military algorithms are not

Uses of Cryptography

- Transmitting secret data over an insecure channel
- Storing secret data on an insecure medium
- Message integrity checksum/authentication code (MIC/MAC)
- Authentication: “challenge” the other party to encrypt or decrypt a random number

Breaking an Encryption Scheme

- Ciphertext only (search through the keyspace)
- Known Plaintext
- Chosen Plaintext
  - The quick brown fox jumps over the lazy dog

Binary & Logic

- Binary Systems
- Boolean Operations
- Bitmaps and gray scale images

Example: A 16 bit plaintext message in hex is AE0F. Create a 16 bit random key by flipping a coin 16 times. Which of the following Boolean operations offer the best encryption capabilities (AND, OR, XOR). Why?

The XOR

Questions?