UNIT I INTRODUCTION

Basic Terminologies in Cryptography- CIA Triad- Security trends - Need for Security at Multiple levels, Security Policies - Model of network security – OSI security architecture -Security attacks, services and mechanisms — Classical encryption techniques: substitution techniques, transposition techniques, Steganography

Definition

Cryptography is the science of using mathematics to encrypt and decrypt data.

Phil Zimmermann

Cryptography is the art and science of keeping messages secure.

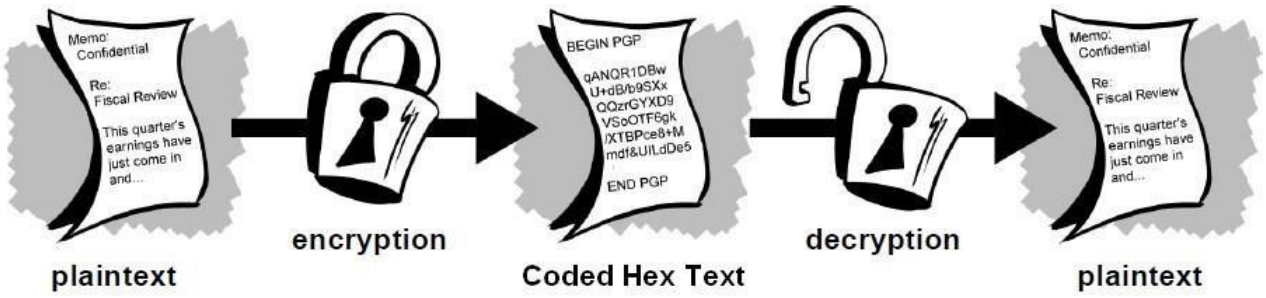
Bruce Schneier

The art and science of concealing the messages to introduce secrecy in information Security is recognized as cryptography.

It is the study and practice of techniques for secure communication in the presence of third parties called adversaries. Data Confidentiality, Data Integrity, Authentication and Non-repudiation are core principles of modern-day cryptography.

Terminologies

A message is **plaintext** (sometimes called clear text). The process of disguising a message in such a way as to hide its substance is **encryption**. An encrypted message is **cipher text**. The process of turning cipher text back into plaintext is **decryption**.



A **cryptosystem** is an implementation of cryptographic techniques and their accompanying infrastructure to provide information security services. A cryptosystem is also referred to as a **cipher system**. The various components of a basic cryptosystem are as follows

- Plaintext
- Encryption Algorithm
- Cipher text
- Decryption Algorithm
- Encryption Key
- Decryption Key

While **cryptography** is the science of securing data, **cryptanalysis** is the science of analyzing and breaking secure communication. Classical cryptanalysis involves an interesting combination of analytical reasoning, application of mathematical tools, pattern finding, patience, determination, and luck. **Cryptanalysts** are also called attackers. **Cryptology** embraces both cryptography and cryptanalysis.

Security Trends

Definition of 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)

Confidentiality

- **Data confidentiality**
  Assures that private or confidential information is not made available or disclosed to unauthorized
- **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 authorize users.

CIA Triad

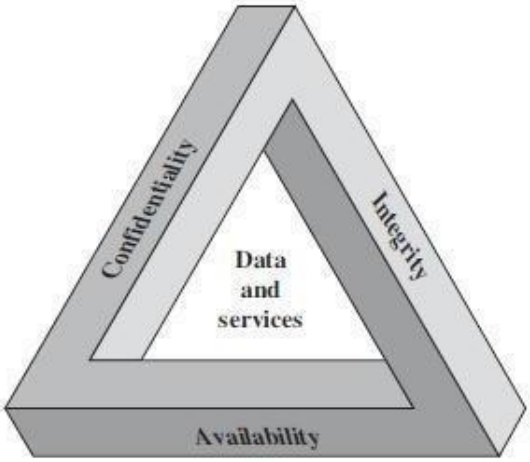


Figure 1.1 The Security Requirements Triad

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.

Authenticity

- The property of being genuine and being able to be verified and trusted

Accountability

- The security goal that generates the requirement for actions of an entity to be traced uniquely to that entity

Legal, Ethical and Professional aspects of security

We must understand the scope of an organization's legal and ethical responsibilities. To minimize liabilities/reduce risks, the security practitioner must:

1. Understand current legal environment.
2. Stay current with laws and regulations.
3. Watch for new issues and emerge.

Information is endangered both by external factors, such as hackers, computer viruses, thefts, and internal ones - the loss of data as a result of improper protection, the lack of backup copies or the loss of a flash drive that contains unprotected data. An improper protection of data may result in the loss of company's reputation, its customers' trust or in financial losses. This issue is of particular importance as regards the court system due to the volume of personal data that are processed and stored in courts and their unique character (sentences, orders, and statements of reasons, convictions, and personal details of victims or land registers). They all constitute information that must be protected against theft, loss or alterations. The loss of data could affect negatively the trial and the judicial independence by possible external pressure in cases where data was lost.

Law and Ethics in Security

- Definition of Laws
- Rules that mandate or prohibit certain behavior
- Drawn from ethics
- Definition of Ethics
- Define socially acceptable behaviors
- Key difference between law and ethics
- Laws carry the authority of a governing body
- Ethics do not carry the authority of a governing body
- Based on cultural mores
- Fixed moral attitudes or customs
- Some ethics standards are universal

Organizational Liability and the Need for Counsel

What if an organization does not behave ethically? Even if there is no breach of criminal law, there can still be liability.

- What is Liability?
- Legal obligation of organization
- Extends beyond criminal or contract law
- Include legal obligation to restitution
- Employee acting with or without the authorization performs and illegal or unethical act that causes some degree of harm
- Employer can be held financially liable

An organization increases its liability if it refuses to take measures known as due care.

- What is Due care?
- Organization makes sure that every employee knows what is acceptable or unacceptable
- Knows the consequences of illegal or unethical actions
- Due diligence
- Requires
- Make a valid effort to protect others
- Maintains the effort
- In legal system, any court can assert its authority over an individual or organization if it canestablish jurisdiction
- What is Jurisdiction?
- Court's right to hear a case if a wrong is committed
- Term – long arm
- Extends across the country or around the world

Policy Versus law

- Policies
- Guidelines that describe acceptable and unacceptable employee behaviors
- Functions as organizational laws
- Has penalties, judicial practices, and sanctions
- Difference between policy and law
- Ignorance of policy is acceptable
- Ignorance of law is unacceptable
- Keys for a policy to be enforceable
- Dissemination (distribution)
- Review (reading)
- Comprehension (understanding)
- Compliance (agreement)
- Uniform enforcement

Types of Law

Civil – govern a nation or state

Criminal – addresses activities and conduct harmful to public

Private – encompasses family, commercial, labor, and regulates the relationship between individuals and organizations

Public – regulates the structure and administration of government agencies and their relationships with citizens, employees, and other governments

International Laws and Legal Bodies

Organizations do business on the Internet – they do business globally

Professionals must be sensitive to the laws and ethical values of many different cultures, societies, and countries

Few international laws relating to privacy and informational security

International laws are limited in their enforceability

Ethics and Security

The Ten Commandments of Computer Ethics[6]

From The Computer Ethics Institute

1. Thou shalt not use a computer to harm other people.
2. Thou shalt not interfere with other people's computer work.
3. Thou shalt not snoop around in other people's computer files.
4. Thou shalt not use a computer to steal.
5. Thou shalt not use a computer to bear false witness.
6. Thou shalt not copy or use proprietary software for which you have not paid.
7. Thou shalt not use other people's computer resources without authorization or proper compensation.
8. Thou shalt not appropriate other people's intellectual output.
9. Thou shalt think about the social consequences of the program you are writing or the system you are designing.
10. Thou shalt always use a computer in ways that ensure consideration and respect for your fellow humans.

Overriding factor in leveling ethical perceptions within a small population is education

- Employees must be trained in expected behaviors of an ethical employee, especially in areas of information security
- Proper ethical training vital to creating informed, well prepared, and low-risk system user

- **Deterrence To Unethical And Illegal Behaviours**
- Deterrence: best method for preventing an illegal or unethical activity; e.g., laws, policies, technical controls
- Laws and policies only deter if three conditions are present:
    - Fear of penalty
    - Probability of being caught
    - Probability of penalty being administered

- **Codes of Ethics And Professional Organizations**

Several professional organizations have established codes of conduct/ethics

Codes of ethics can have positive effect unfortunately, many employers do not encourage joining of these professional organizations

Responsibility of security professionals to act ethically and according to policies of employer, professional organization, and laws of society

Need for Multilevel Security

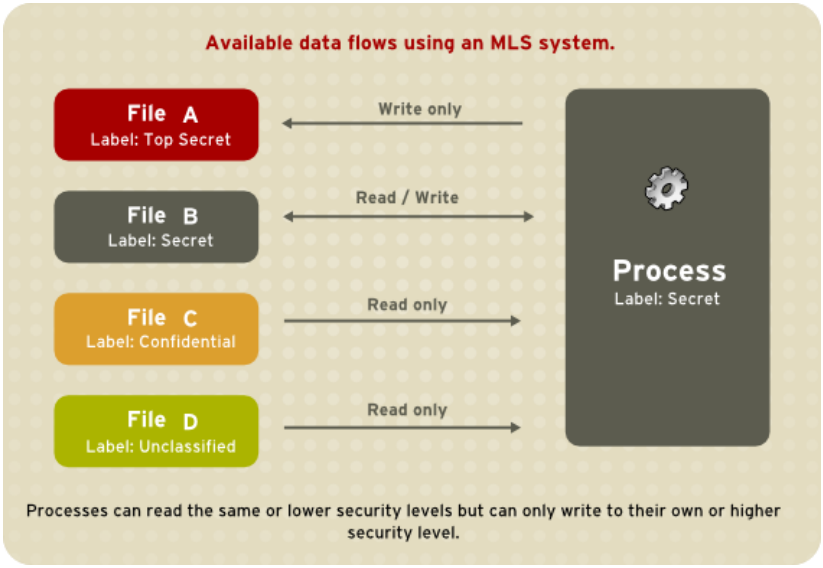
Having information of different security levels on the same computer systems poses a real threat. It is not a straight-forward matter to isolate different information security levels, even though different users log in using different accounts, with different permissions and different access controls.

Some organizations go as far as to purchase dedicated systems for each security level. This is often prohibitively expensive, however. A mechanism is required to enable users at different security levels to access systems simultaneously, without fear of information contamination.

The term multi-level arises from the defense community's security classifications: Confidential, Secret, and Top Secret.

Individuals must be granted appropriate clearances before they can see classified information. Those with Confidential clearance are only authorized to view Confidential documents; they are not trusted to look at Secret or Top Secret information. The rules that apply to data flow operate from lower levels to higher levels, and never the reverse. This is illustrated below.

Information Security Levels



Available data flow using MLS system

Under such a system, users, computers, and networks use labels to indicate security levels. Data can flow between like levels, for example between "Secret" and "Secret", or from a lower level to a higher level. This means that users at level "Secret" can share data with one another, and can also retrieve information from Confidential-level (i.e., lower-level), users. However, data cannot flow from a higher level to a lower level. This prevents processes at the "Secret" level from viewing information classified as "Top Secret". It also prevents processes at

a higher level from accidentally writing information to a lower level. This is referred to as the "no read up, no write down" model.

MLS and System Privilege

MLS access rules are always combined with conventional access permissions (file permissions). For example, if a user with a security level of "Secret" uses Discretionary Access Control (DAC) to block access to a file by other users, this also blocks access by users with a security level of "Top Secret". A higher security clearance does not automatically give permission to arbitrarily browse a file system.

Users with top-level clearances do not automatically acquire administrative rights on multi-level systems. While they may have access to all information on the computer, this is different from having administrative rights.

Security Levels, Objects and Subjects

As discussed above, subjects and objects are labeled with Security Levels (SLs), which are composed of two types of entities:

Sensitivity: — A hierarchical attribute such as "Secret" or "Top Secret".

Categories: — A set of non-hierarchical attributes such as "US Only" or "UFO".

An SL must have one sensitivity, and may have zero or more categories.

Examples of SLs are: { Secret / UFO, Crypto }, { Top Secret / UFO, Crypto, Stargate } and { Unclassified }

Note the hierarchical sensitivity followed by zero or more categories. The reason for having categories as well as sensitivities is so that sensitivities can be further compartmentalized on a need-to-know basis.

Security Polices

Following are some points which help in security policy of an organization.

- Who should have access to the system?
- How it should be configured?
- How to communicate with third parties or systems?

Policies are divided in two categories −

- User policies
- IT policies.

User policies generally define the limit of the users towards the computer resources in a workplace. For example, what are they allowed to install in their computer, if they can use removable storages.

Whereas, IT policies are designed for IT department, to secure the procedures and functions of IT fields.

- **General Policies** − This is the policy which defines the rights of the staff and access level to the systems. Generally, it is included even in the communication protocol as a preventive measure in case there are any disasters.
- **Server Policies** − This defines who should have access to the specific server and with what rights. Which software's should be installed, level of access to internet, how they should be updated.
- **Firewall Access and Configuration Policies** − It defines who should have access to the firewall and what type of access, like monitoring, rules change. Which ports and services should be allowed and if it should be inbound or outbound.
- **Backup Policies** − It defines who is the responsible person for backup, what should be the backup, where it should be backed up, how long it should be kept and the frequency of the backup.
- **VPN Policies** − These policies generally go with the firewall policy, it defines those users who should have a VPN access and with what rights. For site-to-site connections with partners, it defines the access level of the partner to your network, type of encryption to be set.

Structure of a Security Policy

When you compile a security policy you should have in mind a basic structure in order to make something practical. Some of the main points which have to be taken into consideration are −

Description of the Policy and what is the usage for?

- Where this policy should be applied?
- Functions and responsibilities of the employees that are affected by this policy.
- Procedures that are involved in this policy.
- Consequences if the policy is not compatible with company standards.

Types of Policies

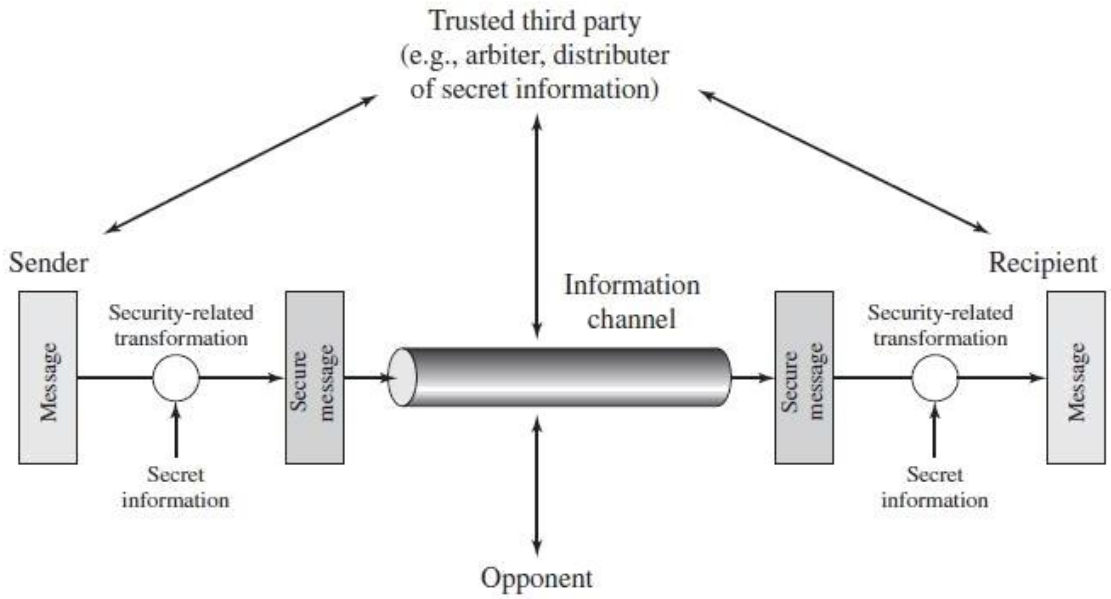
In this section we will see the most important types of policies.

- **Permissive Policy** − It is a medium restriction policy where we as an administrator block just some well-known ports of malware regarding internet access and just some exploits are taken in consideration.

- **Prudent Policy** − This is a high restriction policy where everything is blocked regarding the internet access, just a small list of websites are allowed, and now extra services are allowed in computers to be installed and logs are maintained for every user.
- **Acceptance User Policy** − This policy regulates the behavior of the users towards a system or network or even a webpage, so it is explicitly said what a user can do and cannot in a system. Like are they allowed to share access codes, can they share resources, etc.
- **User Account Policy** − This policy defines what a user should do in order to have or maintain another user in a specific system. For example, accessing an e-commerce webpage. To create this policy, you should answer some questions such as −
    - Should the password be complex or not?
    - What age should the users have?
    - Maximum allowed tries or fails to log in?
    - When the user should be deleted, activated, blocked?
- **Information Protection Policy** − This policy is to regulate access to information, hot to process information, how to store and how it should be transferred.
- **Remote Access Policy −** This policy is mainly for big companies where the user and their branches are outside their headquarters. It tells what should the users access, when they can work and on which software like SSH, VPN, RDP.
- **Firewall Management Policy** − This policy has explicitly to do with its management, which ports should be blocked, what updates should be taken, how to make changes in the firewall, how long should be the logs be kept.
- **Special Access Policy −** This policy is intended to keep people under control and monitor the special privileges in their systems and the purpose as to why they have it. These employees can be team leaders, managers, senior managers, system administrators, and such high designation based people.
- **Network Policy** − This policy is to restrict the access of anyone towards the network resource and make clear who all will access the network. It will also ensure whether that person should be authenticated or not. This policy also includes other aspects like, who will authorize the new devices that will be connected with network? The documentation of network changes. Web filters and the levels of access. Who should have wireless connection and the type of authentication, validity of connection session?
- **Email Usage Policy** − This is one of the most important policies that should be done because many users use the work email for personal purposes as well. As a result information can leak outside. Some of the key points of this policy are the employees should know the importance of this system that they have the privilege to use. They should not open any attachments that look suspicious. Private and confidential data should not be sent via any encrypted email.
- **Software Security Policy −** This policy has to do with the software's installed in the user computer and what they should have. Some of the key points of this policy are Software of the company should not be given to third parties. Only the white list of software's should

be allowed, no other software's should be installed in the computer. Warez and pirated software's should not be allowed

Model for Network Security



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.

All the techniques for providing security have two components:

A security-related transformation on the information to be sent.
Examples: encryption of the message, addition of a code based on the contents

Some secret information shared by the two principals, unknown to the opponent
Example: encryption key used in conjunction with the transformation

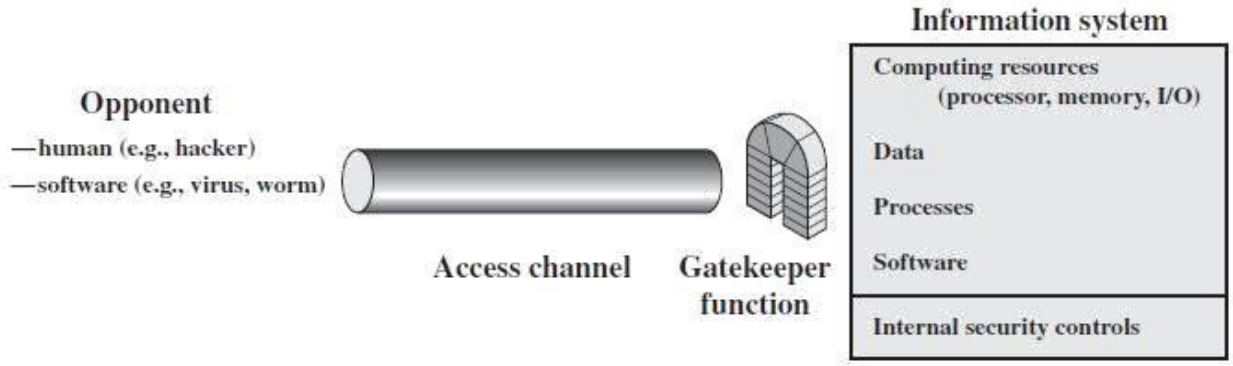
A trusted third party may be needed to achieve secure transmission.

- for distributing the secret information to the two principals
- to arbitrate disputes between the two principals concerning the authenticity of a message transmission

Four basic tasks in designing a particular security service:

1. Design an algorithm for performing the security-related transformation 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

Network Access Security Model



- Protecting an information system from unwanted access from hacker, intruder hacker who, with no malign intent, simply gets satisfaction from breaking and entering a computer system.
- Intruder can be a disgruntled employee who wishes to do damage or a Criminal who seeks to exploit computer assets for financial gain
- 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

Two kinds of threats:

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

  Examples: Viruses and worms, spread using disks & inserted over network

The OSI Security Architecture

- ITU-T Recommendation X.800, Security Architecture for OSI, defines such a systematic approach
- The OSI security architecture focuses on security attacks, mechanisms, and services.

Security attack

- Any action that compromises the security of information owned by an organization.

Security mechanism

- A process (or a device) 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

Security Attacks

- means of classifying security attacks, used both in X.800 and RFC 2828
- A passive attack attempts to learn or make use of information but does not affect system resources.
- An active attack attempts to alter system resources or affect their operation.

Passive Attacks

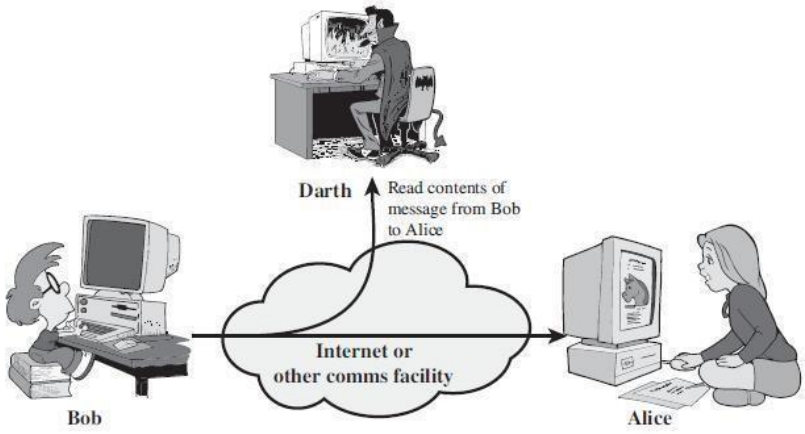
- It is the nature of eavesdropping on, or monitoring of, transmissions.
- The goal is to obtain information that is being transmitted.
- very difficult to detect, because they do not involve any alteration of the data
- feasible to prevent the success of these attacks, usually by means of encryption
- emphasis in dealing with passive attacks is on prevention rather than detection

Two types of passive attacks

- Release of message contents
- Traffic analysis.

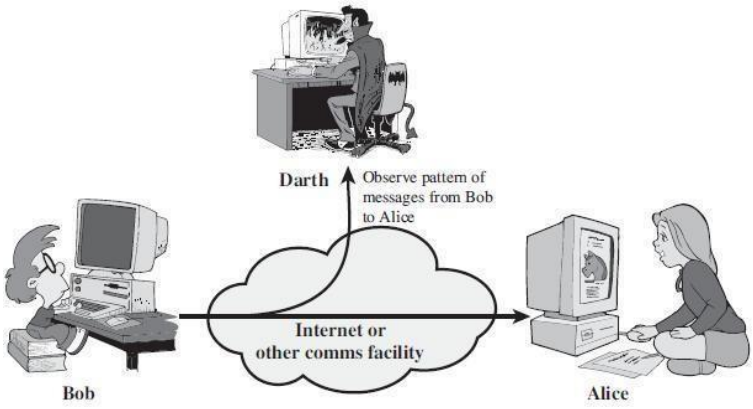
Release of Message Contents

- A telephone conversation, an electronic mail message, and a transferred file may contain sensitive or



confidential information

- prevent an opponent from learning the contents of these transmissions



Traffic Analysis

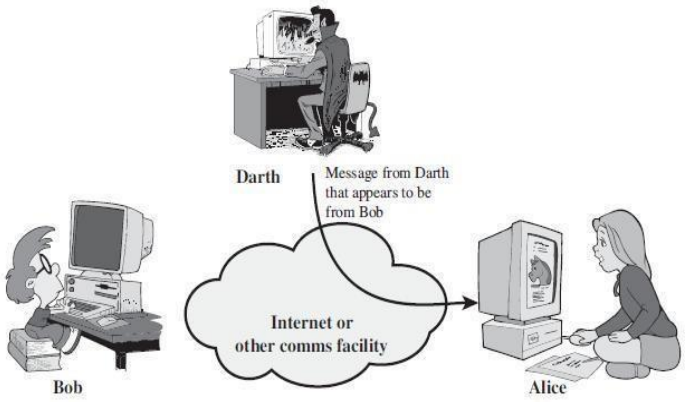
- observe the pattern of these messages
- The opponent could determine the location and identity of communicating hosts and could observe the frequency and length of messages being exchanged.
- This information might be useful in guessing the nature of the communication that was taking place

Active Attacks

- Active attacks involve some modification of the data stream or the creation of a false stream
- detect and to recover from any disruption or delays caused by them
- can be subdivided into four categories:
  - masquerade,
  - replay,
  - modification of messages
  - denial of service

Masquerade

- one entity pretends to be a different entity
- usually includes one of the other forms of active attack

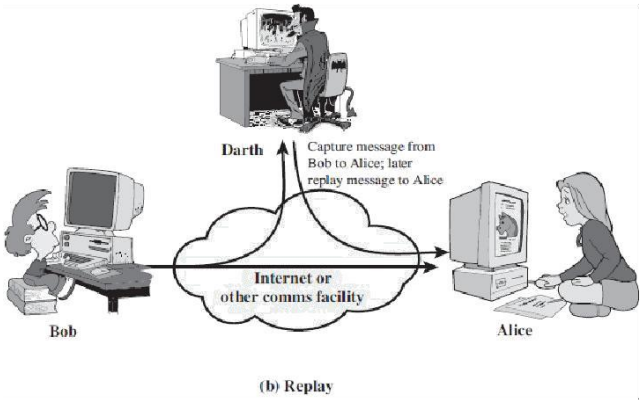


Example

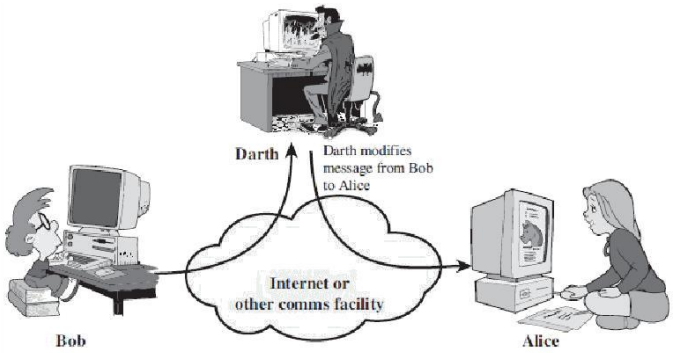
Authentication sequences can be captured and replayed after a valid authentication sequence

Replay

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



(b) Replay



(c) Modification of messages

Modification of Messages

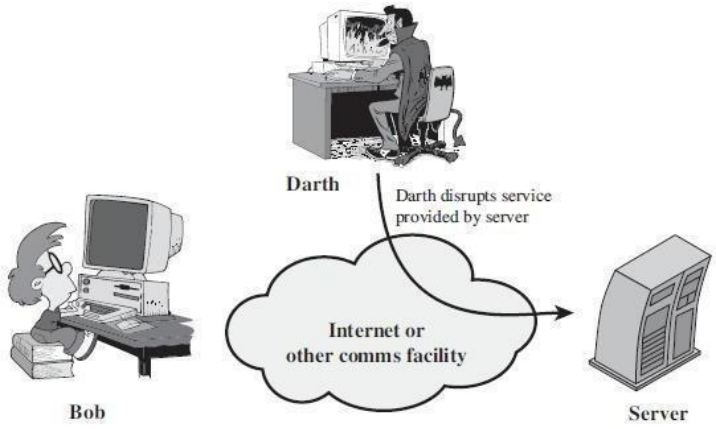
- Some portion of a legitimate message is altered, or that messages are delayed or reordered, to produce an unauthorized effect

Example

- A message meaning "Allow John Smith to read confidential file accounts" is modified to mean "Allow Fred Brown to read confidential file accounts."

Denial of Service

- Prevents or inhibits the normal use or management of communications facilities
- May have a specific target; for example, an entity may suppress all messages directed to a particular destination
- Disruption of an entire network, either by disabling the network or by overloading it with messages so as to degrade performance



(d) Denial of service

Security Services in X.800

- 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.
- RFC 2828, defines as 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

Authentication

- The assurance that the communicating entity is the one that it claims to be
- Two types
  - Peer Entity Authentication
  - Data-Origin Authentication

Access control

- The prevention of unauthorized use of a resource

Data confidentiality

- The protection of data from unauthorized disclosure.
- Four Types
  - Connection Confidentiality
  - Connectionless Confidentiality
  - Selective-Field Confidentiality
  - Traffic-Flow Confidentiality

Data integrity

- The assurance that data received are exactly as sent by an authorized entity (i.e., contain no modification, insertion, deletion, or replay).
- Five types
  - Connection Integrity with Recovery
  - Connection Integrity without Recovery
  - Selective-Field Connection Integrity
  - Connectionless Integrity
  - Selective-Field Connectionless Integrity

Nonrepudiation

- Provides protection against denial by one of the entities involved in a communication of having participated in all or part of the communication
- Two types
  - Nonrepudiation, Origin
  - Nonrepudiation, Destination

Security Mechanisms in X.800.

Specific security mechanisms:

May be incorporated into the appropriate protocol layer in order to provide some of the OSI security services.

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.

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).

Access Control
A variety of mechanisms that enforce access rights to resources.

Data Integrity
A variety of mechanisms used to assure the integrity of a data unit or stream of data units.

Authentication Exchange
A mechanism intended to ensure the identity of an entity by means of information exchange.

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.

Pervasive Security Mechanisms
Mechanisms that are not specific to any particular OSI security service or protocol layer.

Trusted Functionality
That which is perceived to be correct with respect to some criteria (e.g., as established by a security policy).

Security Label
The marking bound to a resource (which may be a data unit) that names or designates the security attributes of that resource.

Event Detection
Detection of security-relevant events.

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.

Security Recovery
Deals with requests from mechanisms, such as event handling and management functions, and takes recovery actions.

Classical Encryption Techniques

- Symmetric encryption is a form of cryptosystem in which encryption and decryption are performed using the same key. It is also known as conventional encryption.
- Symmetric encryption transforms plaintext into ciphertext using a secret key and an encryption algorithm. Using the same key and a decryption algorithm, the plaintext is recovered from the ciphertext.
- Traditional (precomputer) symmetric ciphers use substitution and/or transposition techniques. Substitution techniques map plaintext elements (characters, bits) into ciphertext elements. Transposition techniques systematically transpose the positions of plaintext elements.
- Rotor machines are sophisticated precomputer hardware devices that use substitution techniques.
- Steganography is a technique for hiding a secret message within a larger one in such a way that others cannot discern the presence or contents of the hidden message.

- Symmetric Cipher Model

o Cryptanalysis and Brute-Force Attack

- Substitution Techniques
  - Caesar Cipher

    - Monoalphabetic Ciphers
    - Playfair Cipher
    - Hill Cipher
    - Polyalphabetic Ciphers
    - One-Time Pad
- Transposition Techniques
- Rotor Machines
- Steganography

Introduction

- **Symmetric encryption** is a form of cryptosystem in which encryption and decryption are performed using the **same key**. It is also known as **conventional encryption**.
- Symmetric encryption transforms plaintext into ciphertext using a secret key and an encryption algorithm. Using the same key and a decryption algorithm, the plaintext is recovered from the ciphertext.
- The two types of attack on an encryption algorithm are **cryptanalysis**,based on properties of the encryption algorithm, and **brute-force**, which involves trying all possible keys.
- Traditional (precomputer) symmetric ciphers use substitution and/or transposition techniques. Substitution techniques map plaintext elements (characters, bits) into ciphertext elements. Transposition techniques systematically transpose the positions of plaintext elements.
- Rotor machines are sophisticated precomputer hardware devices that use substitution techniques.
- Steganography is a technique for hiding a secret message within a larger one in such a way that others cannot discern the presence or contents of the hidden message.
- An original message is known as the **plaintext**, while the coded message is called the **ciphertext**.
- The process of converting from plaintext to ciphertext is known as **enciphering or encryption**; restoring the plaintext from the ciphertext is **deciphering or decryption**.
- The many schemes used for encryption constitute the area of study known as **cryptography**. Such a scheme is known as a **cryptographic system or a cipher**.
- Techniques used for deciphering a message without any knowledge of the enciphering details fall into the area of cryptanalysis. **Cryptanalysis** is what the layperson calls

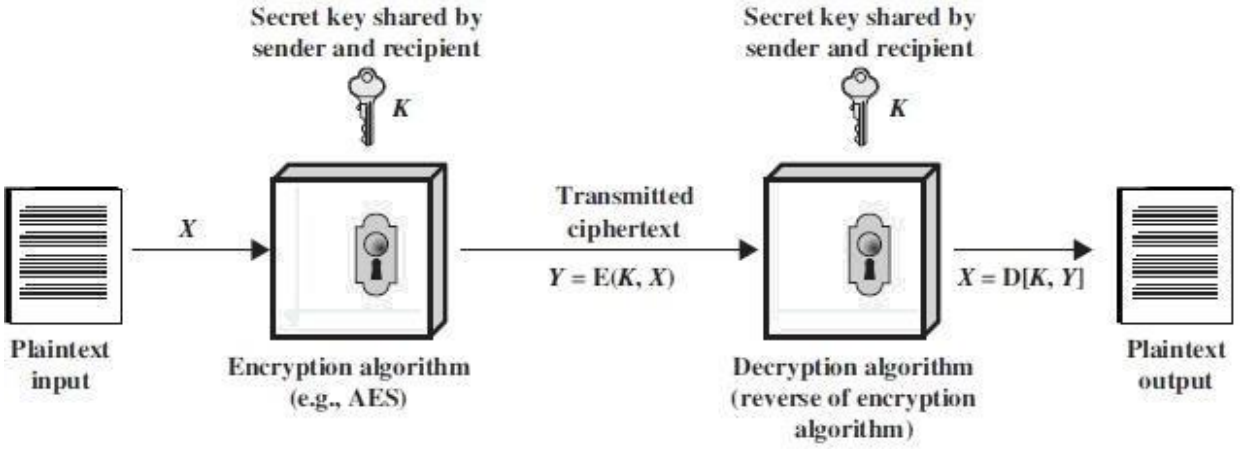
"breaking the code."The areas of cryptography and cryptanalysis together are called **cryptology**

Symmetric Cipher Model

A symmetric encryption scheme has five ingredients

- **Plaintext:** This is the original intelligible message or data that is fed into the algorithm as input.
- **Encryption algorithm:** The encryption algorithm performs various substitutions and transformations on the plaintext.
- **Secret key:** The secret key is also input to the encryption algorithm. The key is a value independent of the plaintext and of the algorithm. The algorithm will produce a different output depending on the specific key being used at the time. The exact substitutions and transformations performed by the algorithm depend on the key.
- **Ciphertext:** This is the scrambled message produced as output. It depends on the plaintext and the secret key. For a given message, two different keys will produce two different cipher texts. The cipher text is an apparently random stream of data and, as it stands, is unintelligible.
- **Decryption algorithm:** This is essentially the encryption algorithm run in reverse. It takes the cipher text and the secret key and produces the original plaintext

Simplified Model of Symmetric Encryption



Two requirements for secure use of conventional / symmetric encryption

- We need a strong encryption algorithm

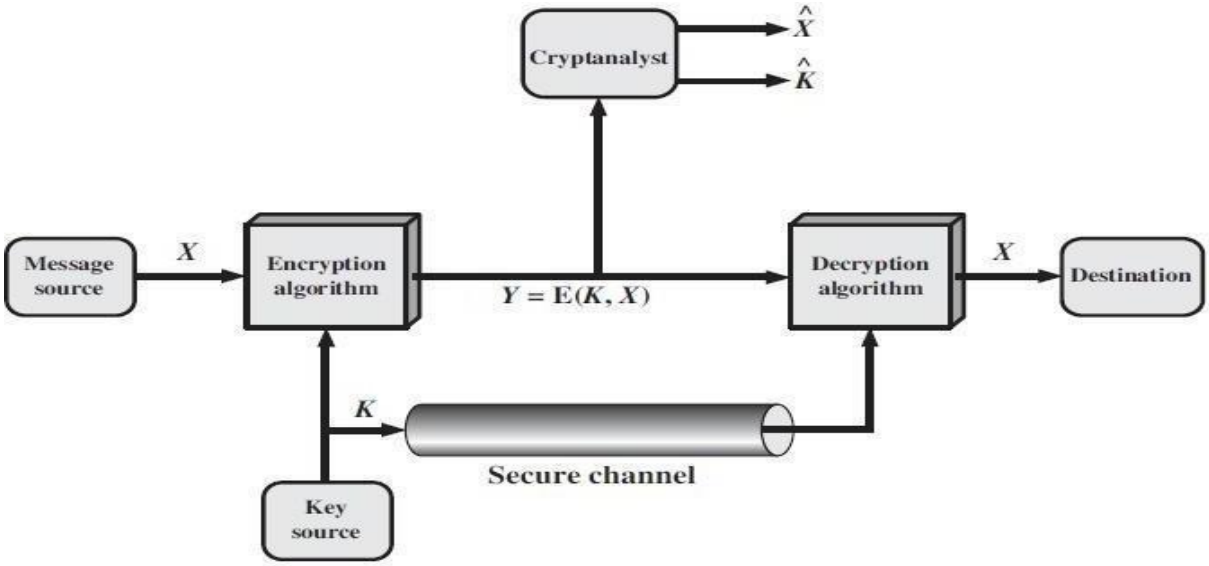
  The opponent should be unable to decrypt ciphertext or discover the key even if he or she is in possession of a number of ciphertexts together with the plaintext that produced each ciphertext

- Sender and receiver must have obtained copies of the secret key in a secure fashion and must keep the key secure. If someone can discover the key and knows the algorithm, all

communication using this key is readable, do not need to keep the algorithm secret; we need to keep only the key secret. The principal security problem is maintaining the secrecy of the key

Model of Conventional Cryptosystem

A source produces a message in plaintext, X = [X1, X2, ..., XM]. The M elements of X are letters in some finite alphabet. Traditionally, the alphabet usually consisted of the 26 capital letters. Nowadays, the binary alphabet {0, 1} is typically used. For encryption, a key of the form K = [K1, K2, ..., KJ] is generated. If the key is generated at the message source, then it must also be provided to the destination by means of some secure channel. Alternatively, a third party could generate the key and securely deliver it to both source and destination.



With the message X and the encryption key K as input, the encryption algorithm forms the ciphertext Y = [Y1, Y2, ..., YN]. We can write this as

Y = E(K, X)

This notation indicates that Y is produced by using encryption algorithm E as a function of the plaintext X, with the specific function determined by the value of the key K.

The intended receiver, in possession of the key, is able to invert the transformation:

X = D(K, Y)

An opponent, observing Y but not having access to K or X, may attempt to recover X or K or both X and K. It is assumed that the opponent knows the encryption (E) and decryption (D)

algorithms. If the opponent is interested in only this particular message, then the focus of the effort is to recover X by generating a plaintext estimate.

Substitution Techniques

- A substitution technique is one in which the letters of plaintext are replaced by other letters or by numbers or symbols
- If the plaintext is viewed as a sequence of bits, then substitution involves replacing plaintext bit patterns with ciphertext bit patterns

1. Caesar Cipher

The earliest known, and the simplest, use of a substitution cipher was by Julius Caesar. The Caesar cipher involves replacing each letter of the alphabet with the letter standing three places further down the alphabet. For example,

plain: meet me after the toga party

cipher: PHHW PH DIWHU WKH WRJD SDUWB

Note that the alphabet is wrapped around, so that the letter following Z is A.

plain: a b c d e f g h i j k l m n o p q r s t u v w x y z

cipher: D E F G H I J K L M N O P Q R S T U V W X Y Z A B C

a	b	c	d	e	f	g	h	i	j	k	l	m
0	1	2	3	4	5	6	7	8	9	10	11	12
n	o	p	q	r	s	t	u	v	w	x	y	z
13	14	15	16	17	18	19	20	21	22	23	24	25

For each plaintext P substitute the ciphertext letter C

$C = E(3, p) = (p + 3) \bmod 26$

A shift may be of any amount, so that the general Caesar algorithm is

$C = E(k, p) = (p + k) \bmod 26$

where takes on a value in the range 1 to 25.The decryption algorithm is simply

$p = D(k, C) = (C - k) \bmod 26$

Cryptanalysis of Caesar Cipher

- only have 26 possible ciphers
- A maps to A,B,..Z
- could simply try each in turn
- a brute force search
- given ciphertext, just try all shifts of letters
- do need to recognize when have plaintext

Exercise:

Plain Text : civil engineering

Key : 7

Cipher Text :

Cipher Text : RTXYFRFENSLUJWXTSGFPMJNX

Key : 5

Plain Text : ?

Monoalphabetic Ciphers

- Rather than just shifting the alphabet shuffle (jumble) the letters arbitrarily
- Each plaintext letter maps to a different random ciphertext letter
- Hence key is 26 letters long
- The “cipher” line can be any permutation of the 26 alphabetic characters, then there are 26! or greater than 4x1026 possible keys.
- This is 10 orders of magnitude greater than the key space for DES and would seem to eliminate brute- force techniques for cryptanalysis
- Monoalphabetic ciphers are easy to break because they reflect the frequency data of the original alphabet
- A countermeasure is to provide multiple substitutes, known as homophones, for a single letter.
- For example, the letter e could be assigned a number of different cipher symbols, such as 16, 74, 35, and 21, with each homophone assigned to a letter in rotation or randomly

Language Redundancy and Cryptanalysis

- human languages are redundant
- eg "th lrd s m shphrd shll nt wnt"
- letters are not equally commonly used
- in English E is by far the most common letter
- followed by T,R,N,I,O,A,S
- other letters like Z,J,K,Q,X are fairly rare
- have tables of single, double & triple letter frequencies for various languages
- two-letter combinations, known as digrams (ex: th)

2. Playfair Cipher

The best-known multiple-letter encryption cipher is the Playfair. The Playfair algorithm is based on the use of a 5×5 matrix of letters constructed using a keyword.

Playfair Key Matrix

- 5 × 5 matrix of letters constructed using a keyword
- filling in the letters of the keyword (minus duplicates) from left to right and from top to bottom,
- filling in the remainder matrix with the remaining letters in alphabetic order.
- The letters I and J count as one letter
- Example matrix using the keyword MONARCHY

M	O	N	A	R
C	H	Y	B	D
E	F	G	I/J	K
L	P	Q	S	T
U	V	W	X	Z

In this case, the keyword is monarchy. The matrix is constructed by filling in the letters of the keyword (minus duplicates) from left to right and from top to bottom, and then filling in the remainder of the matrix with the remaining letters in alphabetic order. The letters I and J count as one letter. Plaintext is encrypted two letters at a time, according to the following rules:

1. Repeating plaintext letters that are in the same pair are separated with a filler letter, such as x, so that balloon would be treated as ba lx lo on.

2. Two plaintext letters that fall in the same row of the matrix are each replaced by the letter to the right, with the first element of the row circularly following the last. For example, ar is encrypted as RM.

3. Two plaintext letters that fall in the same column are each replaced by the letter beneath, with the top element of the column circularly following the last. For example, mu is encrypted as CM.

4. Otherwise, each plaintext letter in a pair is replaced by the letter that lies in its own row and the column occupied by the other plaintext letter. Thus, hs becomes BP and ea becomes IM / JM.

Exercise:

Plain Text : civil engineering

Key : abishek

Cipher Text : ?

Note: The letters M and N count as one letter

Example

Given the key MONARCHY apply Play fair cipher to plain text "FACTIONALISM"

Solution

(p) FA CT IO NA LI SM

(c) IO DL FA AR SE LA

(d) FA CT IO NA LI SM

Security of Playfair Cipher

- security much improved over monoalphabetic since have 26 x 26 = 676 digrams
- would need a 676 entry frequency table to analyse and correspondingly more ciphertext
- was widely used for many years eg. by US & British military in WW1

it can be broken, given a few hundred letters since still has much of plaintext structure

3. Hill Cipher

Another interesting multiletter cipher is the Hill cipher, developed by the mathematician Lester Hill in 1929.

This encryption algorithm takes successive M plaintext letters and substitutes for them M ciphertext letters. The substitution is determined by linear equations in which each character is assigned a numerical value (a=0, b=1, c=2, , z=25). For M=3, the system can be described as

$$c_1 = (k_{11}p_1 + k_{12}p_2 + k_{13}p_3) \bmod 26$$
$$c_2 = (k_{21}p_1 + k_{22}p_2 + k_{23}p_3) \bmod 26$$
$$c_3 = (k_{31}p_1 + k_{32}p_2 + k_{33}p_3) \bmod 26$$

$$(c_1\ c_2\ c_3) = (p\ p_2\ p_3)\begin{pmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{pmatrix} \bmod 26$$

C = **PK** mod 26

where **C** and **P** are row vectors of length 3 representing the plaintext and ciphertext, and **K** is a 3 * 3 matrix representing the encryption key. Operations are performed mod 26.

Example:

Plain Text : paymoremoney

$$\mathbf{K} = \begin{pmatrix} 17 & 17 & 5 \\ 21 & 18 & 21 \\ 2 & 2 & 19 \end{pmatrix}$$

The first three letters of the Plain Text are represented by

$$\begin{vmatrix} 15 \\ 0 \\ 24 \end{vmatrix} \text{ then, } K \begin{vmatrix} 15 \\ 0 \\ 24 \end{vmatrix} = \begin{vmatrix} 375 \\ 879 \\ 486 \end{vmatrix} \text{ mod26 } = \begin{vmatrix} 11 \\ 13 \\ 18 \end{vmatrix} = \text{LNS}$$

Cipher Text : LNSHDLEWMTRW

Exercise:

Plain Text : FINALYEAR

$$\begin{vmatrix} 2 & 5 & 3 \\ 3 & 1 & 4 \\ 9 & 7 & 6 \end{vmatrix}$$ Key :

Cipher Text : ?

Cipher Text : XAJOCVDAIUSGDAAUPIAGDGCSGDHAFQGSXI

Key : abishek

Plain Text : ?

Note: The letters M and N count as one letter

Example

Encrypt the message “meet me at the usual place at ten rather than eight oclock” using the Hill cipher with the key ( ). Show your calculations and the result.Show the calculations for the corresponding decryption of the ciphertext to recover the original plaintext.

1) mathematically give each letter a number

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

2) 1st pair from plain text "me" => $\begin{pmatrix}12\\4\end{pmatrix}$

$$\begin{pmatrix}9 & 4\\5 & 7\end{pmatrix}\begin{pmatrix}12\\4\end{pmatrix} => \begin{pmatrix}9x12+4x4\\5x12+7x4\end{pmatrix} = \begin{pmatrix}124\\88\end{pmatrix} => mod\ 26 => \begin{pmatrix}20\\10\end{pmatrix} => \begin{pmatrix}u\\k\end{pmatrix}$$

3) 2nd pair fro plain text "et"

$$\begin{pmatrix}9 & 4\\5 & 7\end{pmatrix}\begin{pmatrix}4\\19\end{pmatrix} => \begin{pmatrix}9x4+4x19\\5x4+7x19\end{pmatrix} = \begin{pmatrix}112\\153\end{pmatrix} => mod\ 26 => \begin{pmatrix}8\\23\end{pmatrix} => \begin{pmatrix}i\\x\end{pmatrix}$$

4) Cipher text for "meet" is "ukix"

5) To get plain text from cipher text, we need to find the inverse of K

6) |A| = (9x7 – 5x4) => 43

7) Adj (A) => $\begin{pmatrix}7 & -4\\-5 & 9\end{pmatrix} => \frac{1}{43}\begin{pmatrix}7 & -4\\-5 & 9\end{pmatrix} => \frac{1}{17}\begin{pmatrix}7 & -4\\-5 & 9\end{pmatrix}$ ($\because 43\ \%\ 26 = 17$)

8) Find the multiplier for 17, using 17 x X = 1 mod 26 => X = 23

9) $\begin{pmatrix}161 & -92\\-115 & 207\end{pmatrix} => mod\ 26 => \begin{pmatrix}5 & -14\\-11 & 25\end{pmatrix} => \begin{pmatrix}\mathbf{5} & \mathbf{12}\\\mathbf{15} & \mathbf{25}\end{pmatrix}$ ($\because Add\ 26\ for - ive\ values$)

10) P = CK^{-1} = > For the ciper text of "uk",

$$\begin{pmatrix}5 & 12\\15 & 25\end{pmatrix}\begin{pmatrix}20\\10\end{pmatrix} = \begin{pmatrix}5x20+12x10\\15x20+25x10\end{pmatrix} => \begin{pmatrix}220\\550\end{pmatrix} mod\ 26 => \begin{pmatrix}12\\4\end{pmatrix} = \begin{pmatrix}m\\e\end{pmatrix}$$

Hence the plain text is “me”

4. Polyalphabetic Ciphers

Another way to improve on the simple monoalphabetic technique is to use different monoalphabetic substitutions as one proceeds through the plaintext message. The general name for this approach is **polyalphabetic substitution cipher**.

All these techniques have the following features in common:

- A set of related monoalphabetic substitution rules is used.
- A key determines which particular rule is chosen for a given transformation.

5. Vigenere Cipher

Encryption and Decryption

Given a key letter X and plaintext letter Y, the ciphertext letter is at the intersection of the row labeled X and the column labled Y.

To encrypt a message, a key is needed that is as long as the message. Usually the key is repeating keyword.

Decryption is simple. The key letter again identifies the row. The position of the ciphertext letter in that row determines the column, and the plaintext letter is the top of the column.

Example:

Key : deceptive
Plain Text : we are discovered yourself

key: deceptivedeceptivedeceptive
plaintext: wearediscoveredsaveyourself
ciphertext: ZICVTWQNGRZGVTWAVZHCQYGLMGJ

Exercise:

Plaintext : cryptography and network security
Key : sectionb
Ciphertext : ?

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y
a	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
b	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
c	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A
d	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
e	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
f	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D
g	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E
h	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F
i	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G
j	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H
k	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I
l	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J
m	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K
n	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L
o	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
p	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N
q	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
r	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
s	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
t	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
u	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
v	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
w	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
x	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
y	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
z	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X

Vigenere Table

Note : Rows represents Plaintext and Columns represents the Key

keyword can be eliminated by using a nonrepeating keyword that is as long as the message itself.Vigenère proposed what is referred to as an **autokey system**, in which a keyword is concatenated with the plaintext itself to provide a running key. For our example,

key: deceptivewearediscoveredsav
plaintext: wearediscoveredsaveyourself

ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA

Exercise:
Plaintext : cryptography and network security
Key : sectionb
Ciphertext : ?

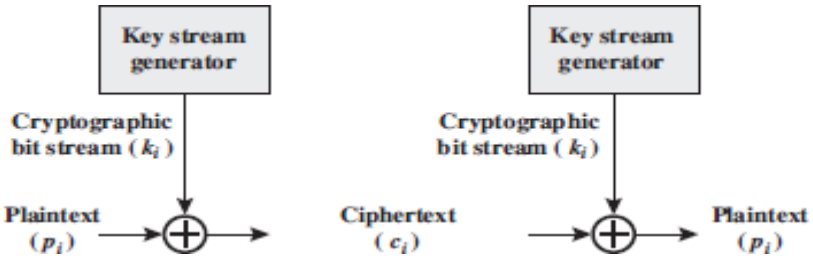
Vernam Cipher

The ultimate defense against such a cryptanalysis is to choose a keyword that is as long as the plaintext and has no statistical relationship to it. Such a system was introduced by an AT&T engineer named Gilbert Vernam in 1918.

$$c_i = p_i \oplus k_i$$

where

p_i = ith binary digit of plaintext
k_i = ith binary digit of key
c_i = ith binary digit of ciphertext
$\oplus$ = exclusive-or (XOR) operation



6. One-Time Pad

- improvement to the Vernam cipher that yields the ultimate in security
- using a random key that is as long as the message, so that the key need not be repeated
- the key is to be used to encrypt and decrypt a single message, and then is discarded.
- Each new message requires a new key of the same length as the new message **Example** ciphertext:ANKYODKYUREPFJBYOJDSPLREYIUNOFDOIUERFPLUYTS key: pxlmvmsydofuyrvzwc tnlebnecvgdupahfzzlmnyih plaintext: mr mustard with the candlestick in the hall ciphertext:ANKYODKYUREPFJBYOJDSPLREYIUNOFDOIUERFPLUYTS key: mfugpmiydgaxgoufhklllmhsqdqogtewbqfgyovuhwt plaintext: miss scarlet with the knife in the library **two fundamental difficulties**
- problem of making large quantities of random keys
- problem of key distribution and protection

Transposition Techniques

A very different kind of mapping is achieved by performing some sort of permutation on the plaintext letters

Rail Fence Technique

The simplest such cipher is the rail fence technique, in which the plaintext is written down as a sequence of diagonals and then read off as a sequence of rows.

For example, to encipher the message "meet me after the toga party" with a rail fence of depth 2, we write the following

m e m a t r h t g p r y e t e f e t e o a a t

The encrypted message is

MEMATRHTGPRYETEFETEOAAT

Pure Transposition Cipher

Write the message in a rectangle, row by row, and read the message off, column by column, but permute the order of the columns.

The order of the columns then becomes the key to the algorithm

Example

Key: 4 3 1 2 5 6 7

Plaintext: a t t a c k p

o s t p o n e d

u n t i l t w o

a m x y z

Ciphertext: TTNAAPTMTSUOAODWCOIXKNLYPETZ

Double Transposition

performing more than one stage of transposition Example

if the foregoing message is reencrypted using the same algorithm

Key: 4 3 1 2 5 6 7

Input: t t n a a p t

m t s u o a o

d w c o i x k

n l y p e t z

Output: NSCYAUOPTTWLTMDNAOIEPAXTTOKZ

This is a much less structured permutation and is much more difficult to cryptanalyze

Steganography

We conclude with a discussion of a technique that is, strictly speaking, not encryption, namely, steganography

A plaintext message may be hidden in one of two ways.

- The methods of steganography conceal the existence of the message
- The methods of cryptography render the message unintelligible to outsiders
  - by various transformations of the text

Various ways to conceal the message

Arrangement of words or letters within an apparently innocuous text spells out the real message

Character marking

Selected letters of printed or typewritten text are overwritten in pencil. The marks are ordinarily not visible unless the paper is held at an angle to bright light.

Invisible ink

A number of substances can be used for writing but leave no visible trace until heat or some chemical is applied

Pin punctures

Small pin punctures on selected letters are ordinarily not visible unless the paper is held up in front of a light.

Typewriter correction ribbon

Used between lines typed with a black ribbon, the results of typing with the correction tape are visible only under a strong light

Hiding a message by using the least significant bits of frames on a CD

- The Kodak Photo CD format's maximum resolution is 2048 by 3072 pixels, with each pixel containing 24 bits of RGB color information.

- The least significant bit of each 24-bit pixel can be changed without greatly affecting the quality of the image
- Thus you can hide a 2.3-megabyte message in a single digital snapshot

Number of drawbacks

- lot of overhead to hide a relatively few bits of information
- once the system is discovered, it becomes virtually worthless
- the insertion method depends on some sort of key

o Alternatively, a message can be first encrypted and then hidden using steganography

Advantage of steganography

- can be employed by parties who have something to lose should the fact of their secret communication be discovered
- Encryption flags traffic as important or secret or may identify the sender or receiver as someone with something to hide