Unit 1 Solution Set

1) What are Symmetric Ciphers? Explain Caesar cipher

Symmetric encryption uses the same key for both encryption and decryption. This means the same key transforms plaintext into ciphertext and also reverses the ciphertext back into plaintext.
Process:
Encryption: Plaintext → (Symmetric Key + Algorithm) → Ciphertext
Decryption: Ciphertext → (Same Symmetric Key + Algorithm) → Plaintext
Types: Substitution ciphers and transposition ciphers are classical symmetric encryption techniques.
Example in Use: Symmetric ciphers are still widely used in modern cryptographic systems, such as in securing communication or data transfer (e.g., AES, DES).

Caesar Cipher:
It is a simple substitution cipher in which each letter in the plaintext is shifted by a fixed number of positions down or up the alphabet. The key is the number of positions the alphabet is shifted.
Historical Use: Named after Julius Caesar, who is said to have used a shift of 3 to encrypt his military messages.
Weakness: It is easily broken by brute-force (trying all possible shifts) or frequency analysis because of its simplicity.
For e.g.

Plaintext: HELLO
Key (Shift): 3
Encryption: H becomes K, E becomes H, L becomes O, L becomes O, O becomes R.
Ciphertext: KHOOR
Decryption reverses this process using the same key.

2) What are the various types of Passive attacks?
Passive attacks in network security involve unauthorized monitoring of communication or systems without altering the information or interfering with data transmission. The goal of passive attacks is to gather sensitive information such as passwords, credit card details, or other private data without being detected.
There are two main types of passive attacks:

a) Release of Message Contents
b) Traffic Analysis

a) Release of Message Contents: In this type of attack, the attacker intercepts the content of communication between two parties without their knowledge. This could be email, instant messages, or other forms of communication.
An eavesdropper capturing the content of an email exchange to read sensitive business plans or personal information.

b) Traffic Analysis: This attack involves monitoring the patterns of communication to deduce valuable information from traffic, such as the frequency and timing of messages, the size of the messages, or the identities of the communicating parties.

Even if the content of the message is encrypted, an attacker could analyze traffic flow and volume to infer the presence of a sensitive conversation or predict when important communications are occurring.

Key Characteristics of Passive Attacks:

a) Stealth: Passive attacks are difficult to detect because they do not involve any alteration of data or noticeable disruption to the communication process.

b) Focus: They focus on obtaining information rather than causing immediate harm, making them a significant threat over time as sensitive data accumulates in the wrong hands.

3) Explain any three Active attacks

Active attacks involve direct manipulation of data streams or creation of false data streams to disrupt, alter, or intercept communication. These attacks affect the integrity and availability of information and can be detected due to their intrusive nature.

Below are four key types of active attacks:

a) Masquerade Attack: In a masquerade attack, an attacker pretends to be a legitimate user by using stolen credentials or impersonating an authorized entity. An attacker captures a valid user's authentication credentials and reuses them to gain unauthorized access to a system. Such attack allows unauthorized access, potentially leading to data theft or privilege escalation.

b) Modification of Messages: This attack involves altering a legitimate message in transit to produce an unauthorized outcome, such as changing the content or delaying/reordering the message. A message that grants permissions to one user might be altered to grant permissions to another unauthorized user. Such attacks lead to compromising data integrity and can lead to unauthorized actions or access.

c) Replay Attack: In a replay attack, an attacker captures a valid data transmission and replays it later to produce an unauthorized effect, such as re-initiating a transaction. An attacker captures a financial transaction and resends it to duplicate the payment without authorization. It can lead to fraudulent transactions or repeated actions without the user's consent.

d) Denial of Service (DoS) Attack: A DoS attack aims to make a network or service unavailable by overwhelming the target with excessive traffic or requests, disrupting normal service. Flooding a web server with requests until it becomes inaccessible to legitimate users. It disrupts service availability, causing system downtime and potentially significant financial or operational losses.

4) What are the security mechanisms to provide security at various levels of OSI model?

To provide security at various layers of the OSI model, specific and pervasive security mechanisms are incorporated to protect data and ensure secure communication.

Some of which are as follows

a) Routing Control: This mechanism ensures that data travels through secure routes to prevent unauthorized interception and ensures secure delivery of information.

b) Access Control: Enforces access rights to resources, ensuring that only authorized entities can access certain network devices or nodes.

c) Encipherment: Data encryption mechanisms are applied to prevent unauthorized access to sensitive information during data transmission.

d) Data Integrity: Mechanisms are in place to ensure the integrity of data being transmitted, confirming that data remains unaltered during transmission.

e) Authentication Exchange: Ensures the identity of communicating entities through information exchange mechanisms to avoid impersonation.

f) Traffic Padding: Adds extra bits to a data stream to prevent traffic analysis and protect against traffic monitoring attacks.

g) Digital Signature: Applied to verify the source and integrity of the data, ensuring that the data has not been tampered with during transmission.

h) Notarization: Uses a trusted third party to verify the integrity and authenticity of data exchanges, adding another layer of security.

5) What are the 5 components of a Symmetric cipher model?
A Symmetric Cipher Model uses a single key for both encryption and decryption. The following are the 5 main components of a symmetric cipher model:

a) Plaintext: This is the original, readable data or message that needs to be encrypted. It is the input to the encryption algorithm.

b) Encryption Algorithm: The encryption algorithm performs various transformations and substitutions on the plaintext, using the secret key, to convert it into ciphertext. This algorithm defines the specific process of encryption.

c) Secret Key: The secret key is a shared value known to both the sender and the receiver. It is used by both the encryption and decryption algorithms. The security of the cipher depends on keeping this key confidential.

d) Ciphertext: Ciphertext is the scrambled, unreadable form of the plaintext produced by the encryption algorithm. It is the output of the encryption process and is transmitted to the recipient.

e) Decryption Algorithm: The decryption algorithm is essentially the reverse of the encryption process. It takes the ciphertext and the same secret key used during encryption to convert the ciphertext back into the original plaintext.

6) How is encryption done using Playfair cipher?
The Playfair cipher is a digraph substitution cipher, meaning it encrypts pairs of letters (digraphs) instead of single letters. It uses a 5x5 grid of letters as the encryption key
Steps for Encryption:
Step 1: Create the 5x5 Grid:

First, a 5x5 grid (matrix) is created using a keyword. The keyword is written into the grid first, omitting repeated letters, and then the remaining letters of the alphabet are filled in. The letter "I" and "J" are usually combined to fit the alphabet into the 25 spaces.

Example: If the keyword is "MONARCHY", the grid might look like this:

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

Step 2: Prepare the Plaintext:

Break the plaintext into pairs of letters (digraphs). If a pair contains the same letter (e.g., "LL"), insert a filler letter (commonly "X") between them
Example: The plaintext "HELLO" becomes "HE LX LO".

Encryption Rules:

Rule 1: Same Row: If both letters in the digraph appear in the same row of the grid, replace them with the letters to their immediate right (wrap around to the left if needed).
Rule 2: Same Column: If both letters in the digraph appear in the same column, replace them with the letters directly below them (wrap around to the top if needed).
Rule 3: Rectangle: If the letters form a rectangle (they are neither in the same row nor column), replace them with the letters on the same row but at the opposite corners of the rectangle.
Rule 4: Same Letter: If a digraph consists of two identical letters, replace the second letter with "X", then encrypt according to the rules.

7) Discuss the various methods used in steganography
Steganography is the art of concealing a message within another medium, making it difficult to detect that a message exists at all. This is different from cryptography, which scrambles a message to make it unreadable, but doesn't hide its existence.
Historically, steganography has been used in various ways:

a) Character marking: Letters in printed or typed text could be marked with pencil, leaving subtle traces that were only visible under certain lighting conditions.
b) Invisible ink: Special substances could be used to write messages that were invisible until treated with heat or chemicals.
c) Pin punctures: Tiny holes could be punched in specific letters of a document, creating patterns that were only noticeable when held up to a light source.
d) Typewriter correction ribbon: A special correction ribbon could be used to type over existing text, leaving subtle traces that were difficult to detect.

8) Explain the DES technique
DES is a symmetric-key block cipher that was widely used for many years to encrypt digital data. It was developed by IBM
DES works as follows
   a) Input: The plaintext is divided into 64-bit blocks.
   b) Initial Permutation: The 64-bit block undergoes an initial permutation to rearrange the bits.
   c) Rounds: The data is processed through 16 rounds of encryption. Each round involves the following steps:
      i) Expansion: The 32-bit right half of the data is expanded to 48 bits.
      ii) XOR: The expanded right half is XORed with a 48-bit key.
      iii) Substitution: The result is divided into eight 6-bit blocks, each of which is substituted using a lookup table called an S-box.
      iv) Permutation: The substituted bits are permuted.
      v) Swapping: The left and right halves of the data are swapped.
   d) Final Permutation: The final result undergoes a final permutation that reverses the initial permutation.
   e) Key Generation
      DES uses a 56-bit key. This key is expanded into 16 48-bit subkeys, one for each round. The key generation process involves a series of left and right shifts and permutations.

9) Explain the Transposition cipher technique
Transposition ciphers are a type of encryption where the positions of the characters in the plaintext are shifted according to a defined system. Unlike substitution ciphers, which replace characters, transposition ciphers maintain the characters but rearrange them to produce the ciphertext.
Two common transposition techniques are
A) Rail Fence cipher
B) Simple Columnar cipher.
Rail Fence Cipher
This method involves writing the plaintext in a zigzag pattern, as if on a fence. The ciphertext is then formed by reading the letters row by row.

Example:
Plaintext: ATTACKATDAWN
Key (number of rails): 2

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A   T   C   A   D   W
  T   A   K   T   A   N
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Ciphertext: ATCADWTAKTAN

Simple Columnar Transposition Cipher
In this method, the plaintext is written in a rectangular grid, and the columns are rearranged according to a key. The ciphertext is formed by reading the letters column by column.

Example:
Plaintext: MEET ME AFTER THE WAR
Key: 3 2 1 4 6 5

M	E	E	T	M	E
A	F	T	E	R	T
H	E	W	A	R	X

Rearranging columns according to the key:

E	E	M	T	E	M
T	F	A	E	T	R
W	E	H	A	X	R

Reading row by row:
Ciphertext: EEMTEMTFAETRWEHAXR

10) What is cryptanalysis? How is it achieved?
Cryptanalysis is the study and practice of breaking cryptographic systems. It involves analysing cipher texts to extract the original plaintext without knowing the secret key.

Some common cryptanalytic techniques:

I. Brute Force Attack:
   i) Method: This involves trying every possible key until the correct one is found.
   ii) Effectiveness: Effective for short keys but becomes impractical for longer keys due to computational complexity.

II. Frequency Analysis:
   i) Method: Exploits the statistical properties of languages. For example, in English, certain letters and combinations of letters occur more frequently than others.
   ii) Effectiveness: Effective for simple substitution ciphers but less effective for more complex ones.

III. Known Plaintext Attack:
   i) Method: Assumes that an attacker has access to both the plaintext and the corresponding ciphertext.
   ii) Effectiveness: Can be very effective if the attacker can obtain a sufficient amount of plaintext-ciphertext pairs.

IV. Chosen Plaintext Attack:
   i) Method: Allows the attacker to choose the plaintext and obtain the corresponding ciphertext.
   ii) Effectiveness: Can be very effective for certain types of ciphers.

V. Chosen Ciphertext Attack:
   i) Method: Allows the attacker to choose the ciphertext and obtain the corresponding plaintext.
   ii) Effectiveness: Can be effective for certain types of ciphers, but is often more difficult to mount than a chosen plaintext attack.

11) What are the modes of operation?

Modes of operation are techniques used to apply a block cipher to data blocks of arbitrary length. They provide different security properties and trade-offs.

a) Electronic Codebook (ECB) Mode: Each block of plaintext is encrypted independently using the same key.
   Advantages: Simple to implement and efficient.
   Disadvantages: Susceptible to frequency analysis and pattern recognition attacks, especially for repetitive data.
b) Cipher Block Chaining (CBC) Mode: The previous ciphertext block is XORed with the current plaintext block before encryption.
   Advantages: Provides better security than ECB, as each ciphertext block depends on all previous plaintext blocks.
   Disadvantages: Requires initialization vector (IV) to be transmitted along with the ciphertext.
c) Cipher Feedback (CFB) Mode: A portion of the previous ciphertext is used as feedback to encrypt the current plaintext block.
   Advantages: Can be used for both encryption and decryption in a stream cipher-like manner.
   Disadvantages: Requires initialization vector (IV) to be transmitted along with the ciphertext.
d) Counter (CTR) Mode: A counter is used to generate a unique nonce for each block of plaintext. The nonce is XORed with the plaintext before encryption.
   Advantages: Highly efficient, parallel operations possible, and can be used for both encryption and decryption in a stream cipher-like manner.
   Disadvantages: Requires a secure random number generator to generate the counter.

12) Explain the Electronic Code Book(ECB) mode of operation

Electronic Codebook (ECB) Mode is a simple mode of operation for block ciphers. In this mode, each block of plaintext is encrypted independently using the same key.

It works as follows:

a) Divide the plaintext into blocks: The plaintext is divided into blocks of the same size as the block cipher's block size.

b) Encrypt each block individually: Each block is encrypted using the same encryption algorithm and key.
c) Combine the encrypted blocks: The encrypted blocks are combined to form the ciphertext.

Advantages:
a) Simple to implement: ECB is easy to understand and implement.
b) Efficient: It is computationally efficient, as each block can be encrypted independently.

Disadvantages:
a) Susceptible to frequency analysis: If the same plaintext block appears multiple times, the corresponding ciphertext blocks will also be identical. This can make it easier for attackers to identify patterns and break the cipher.
b) Lack of redundancy: ECB does not introduce any redundancy into the ciphertext, making it vulnerable to attacks that exploit the statistical properties of the plaintext.

13) How is the Counter mode of operation implemented?
Counter (CTR) Mode is a block cipher mode of operation that provides a stream cipher-like interface. It's particularly efficient and offers strong security properties.

Implementation Steps:
a) Initialization Vector (IV): Generate a random IV of the same size as the block cipher's block size.
b) Counter Generation: A counter is initialized to a known value. For each block of plaintext, the counter is incremented.

c) Encryption:
The counter value is encrypted using the block cipher and the secret key.
The encrypted counter value (called the "nonce") is XORed with the plaintext block to produce the ciphertext block.

d) Decryption:
The same counter sequence is used for decryption.
The ciphertext block is XORed with the encrypted counter value (nonce) to recover the original plaintext block.

Features of Counter mode:
a) Efficiency: CTR mode is highly efficient, as the encryption and decryption operations can be performed in parallel.
b) Security: CTR mode provides strong security, as each ciphertext block depends on a unique nonce.
c) Randomness: The randomness of the nonce ensures that the ciphertext is indistinguishable from random noise.

d) Stream Cipher-like Interface: CTR mode can be used as a stream cipher, allowing for the encryption and decryption of data blocks of any size.

14) Discuss briefly the AES

The Advanced Encryption Standard (AES) is a widely used symmetric block cipher that was established as a standard by NIST in 2001. AES is known for its security, efficiency, and flexibility.

Key Features of AES:

a) Symmetric Block Cipher: AES uses the same key for both encryption and decryption. It encrypts data in fixed-size blocks of 128 bits.

b) Key Sizes: AES supports three different key lengths, making it flexible for different security levels:
    i) 128-bit key (AES-128)
    ii) 192-bit key (AES-192)
    iii) 256-bit key (AES-256)

c) Rounds: AES consists of multiple encryption rounds, where each round involves several complex transformations:
    i) AES-128: 10 rounds
    ii) AES-192: 12 rounds
    iii) AES-256: 14 rounds

d) AES Encryption Process:
AES encrypts data through a series of transformations on blocks of 128 bits. The primary steps in each round of the encryption process are:
    i) SubBytes: This step substitutes each byte of the block with another byte using a predefined substitution table (S-Box).

    ii) ShiftRows: The rows of the block are shifted by a certain number of bytes to mix the data.

    iii) MixColumns: The columns of the block are mixed using a mathematical operation, further diffusing the data.

    iv) AddRoundKey: In this step, a round key (derived from the original key) is XORed with the current block to incorporate the encryption key.

    v) Key Expansion: AES generates a series of round keys from the original key for use in each encryption round.

15) Give the differences between Substitution and Transposition ciphers

Substitution Ciphers and Transposition Ciphers are two fundamental types of cryptographic techniques used to conceal messages. They differ in how they manipulate the plaintext to create the ciphertext.

Substitution Ciphers

a) Method: Each letter or character in the plaintext is replaced with a different letter or character according to a predetermined substitution rule.
b) Example: Caesar cipher, where each letter is shifted a fixed number of positions in the alphabet.
c) Key: The substitution rule, which can be a simple alphabet shift or a more complex substitution table.

Transposition Ciphers

a) Method: The order of the letters or characters in the plaintext is rearranged according to a predetermined permutation.
b) Example: Rail fence cipher, where the plaintext is written in a zigzag pattern and then read row by row.
c) Key: The permutation rule, which can be a simple columnar transposition or a more complex permutation scheme.