20BIT0340

Assessment – 3

Cryptography Analysis and Implementation

Objective: The objective of this assignment is to analyze cryptographic algorithms and implement them in a practical scenario.

DES

A symmetric encryption technique that uses 64-bit data blocks is called the Data Encryption Standard (DES). Here is a quick explanation of the DES algorithm's operation:

Key Generation: DES employs a 56-bit encryption key. However, the effective key size is decreased to 56 bits due to security concerns by using 8 of the 64 bits for parity tests. An algorithm that incorporates human input and a random component creates the key.

Key Expansion: For each encryption cycle, a separate 48-bit subkey is created from the 56-bit key. This expansion comprises a series of mathematical procedures that permute and transform the key.

Initial Permutation (IP): The bits in the 64-bit plaintext block are rearranged in accordance with a predetermined pattern.

Rounds of Encryption: DES uses 16 rounds of encryption. The following steps are involved in each round:

a. Expansion: Using a specified expansion function, the 32-bit right half of the data from the preceding round is enlarged to 48 bits.

b. Key Mixing: The relevant round subkey is XORed with the extended 48-bit data.

c. Substitution: Eight 6-bit blocks make up the final product. A predetermined S-box (substitution box), which converts each block's six bits into four bits using a lookup table, is used to substitute each block.

d. Permutation: Using a predetermined permutation pattern, the substituted data is then rearranged.

e. XOR and Swap: The data that has been permuted is XORed with the 32-bit left half of the data from the previous round. The next round's right half is the 32-bit block that was produced, and the left half is the preceding right half.

After the 16 cycles, the data is subjected to a final permutation (FP), which is the opposite of the initial permutation.

The same procedure is used to decrypt the ciphertext, but the subkeys are used in reverse.

Strengths:

1. Simplicity: DES has a relatively simple structure, making it easy to implement and understand.
2. Performance: DES was designed to be efficient in hardware implementations, which made it suitable for many applications at the time.

Weaknesses:

1. Key Length: The key length of 56 bits is considered short by today's standards, and it can be brute-forced within a reasonable amount of time using modern computing resources.
2. Vulnerability to Attacks: DES has been subjected to various cryptanalytic attacks over the years. The most significant attack is the exhaustive search, where all possible keys are tested until the correct one is found.
3. Security Margin: Due to advances in computing power, the security margin of DES has significantly decreased over the years. It is now recommended to use more robust encryption algorithms.

Common Use Cases:

1. Legacy Systems: DES may still be encountered in legacy systems that have not been updated or where compatibility with older systems is required.
2. Educational Purposes: DES is often used in academic settings to teach the fundamentals of cryptography and encryption algorithms.

Elliptic Curve Cryptography ECC

Key generation, key exchange, encryption, and decryption are all components of the elliptic curve cryptography (ECC) algorithm. The ECC algorithm is described in the following general terms:

Generating a Key:

Pick a base point on an elliptic curve that is specified over a finite field.

Pick a private key, which is a chance number that falls within a certain range.

By employing elliptic curve scalar multiplication, multiply the base point by the private key to create the public key.

Exchanging keys

Alice and Bob, two parties, concur on an elliptic curve and its base point.

Both Alice's public and private keys are generated.

Bob uses both his private key and public key in the same way.

Public keys are exchanged between Alice and Bob.

To obtain a shared secret point on the curve, each party multiplies their respective private key and the public key they got.

Encryption:

Bob is the recipient of a communication from Alice.

Alice creates a session key at random.

By dividing the base point by the session key, she calculates the coordinates of an ephemeral public key.

The shared secret point is calculated by Alice by dividing Bob's public key by her session key.

Alice uses the shared secret point to derive a symmetric encryption key.

She uses the symmetric encryption key to encrypt the communication.

Decryption:

Alice gives Bob the temporary public key and the encrypted message.

Bob multiplies his private key with Alice's transitory public key to determine the shared secret point.

Bob and Alice arrive at the same symmetric encryption key.

He uses the symmetric encryption key to decrypt the communication.

Strengths:

1. Security: ECC provides a high level of security with smaller key sizes compared to other public-key algorithms such as RSA. This makes ECC more efficient in terms of computational resources and bandwidth.
2. Key Size Efficiency: ECC provides an equivalent level of security with significantly smaller key sizes compared to other asymmetric algorithms, reducing the computational and storage requirements.

Weaknesses:

1. Implementation Complexity: ECC requires careful implementation and parameter selection to ensure security. Improper implementation can introduce vulnerabilities.
2. Patented Algorithms: Some ECC algorithms may be subject to patents, which can limit their use and adoption.

Common Use Cases:

1. Secure Communication: ECC is widely used in protocols such as Transport Layer Security (TLS) to secure communication channels over the internet.
2. Internet of Things (IoT): ECC's efficiency and security make it suitable for resource-constrained devices in IoT environments.
3. Digital Signatures: ECC is used for generating and verifying digital signatures, ensuring the integrity and authenticity of digital documents.

MD5 (Message Digest Algorithm 5)

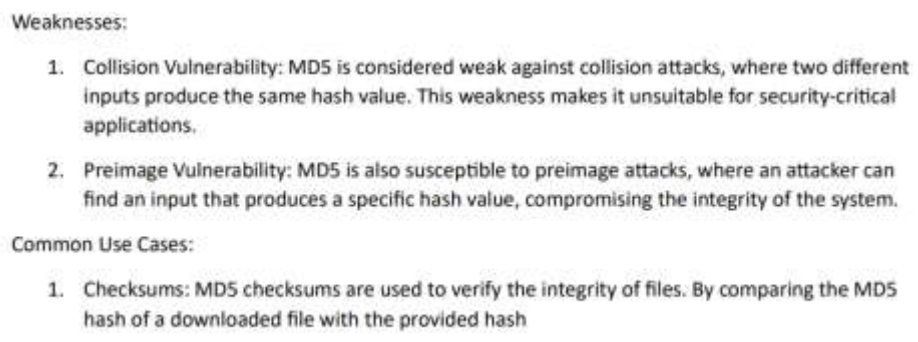
is a widely used cryptographic hash function that produces a 128-bit (16-byte) hash value. It takes an input message of any length and produces a fixed-size output, which is commonly represented as a 32-digit hexadecimal number.

The algorithm follows the following steps:

1. **Padding**: The input message is padded to make its length a multiple of 512 bits (64 bytes). The padding is done in such a way that the resulting message length is congruent to 448 modulo 512. The padding starts with a single bit "1" followed by a sequence of "0" bits until the length requirement is met. After that, the original message length is appended as a 64-bit representation.
2. **Initialization**: MD5 uses four 32-bit state variables (A, B, C, D) and a 64-element table (T[1..64]) containing precomputed values. The initial values of A, B, C, and D are fixed and serve as the initial state.
3. **Message Processing**: The padded message is divided into blocks of 512 bits. Each block is further divided into 16 words of 32 bits each (M[0..15]). The message is processed in a loop for each block.
4. **Round Function**: MD5 uses four basic functions (F, G, H, I) that operate on the state variables A, B, C, and D, as well as the current block's words. Each function takes three inputs (X, Y, Z) and produces a 32-bit output. The functions and their operations are as follows:
   - F(X, Y, Z) = (X AND Y) OR ((NOT X) AND Z)
   - G(X, Y, Z) = (X AND Z) OR (Y AND (NOT Z))
   - H(X, Y, Z) = X XOR Y XOR Z
   - I(X, Y, Z) = Y XOR (X OR (NOT Z))
5. **Round Operations**: Each block goes through four rounds of processing. In each round, a different function is used, and the results are combined with the state variables using modular addition. The block's 16 words are used as inputs to the functions in a predetermined order.
6. **Output**: After processing all the blocks, the resulting values of A, B, C, and D are concatenated, usually in little-endian format. The resulting 128-bit hash value represents the message's fingerprint.

Strengths:

1. Speed: MD5 is fast and efficient in terms of computation, making it suitable for applications where performance is critical.
2. Compatibility: MD5 is supported by many software systems and programming languages, making it easy to implement and use.


Weaknesses:

1. Collision Vulnerability: MD5 is considered weak against collision attacks, where two different inputs produce the same hash value. This weakness makes it unsuitable for security-critical applications.
2. Preimage Vulnerability: MD5 is also susceptible to preimage attacks, where an attacker can find an input that produces a specific hash value, compromising the integrity of the system.

Common Use Cases:

1. Checksums: MD5 checksums are used to verify the integrity of files. By comparing the MD5 hash of a downloaded file with the provided hash

IMPLEMENTING DES

CODE

```
#include <iostream>
#include <cstring>
#include <openssl/des.h>
// Function to encrypt using DES algorithm
void encryptDES(const unsigned char* plaintext, const unsigned char* key,
unsigned char* ciphertext) {
 DES_cblock keyEncrypt;
 DES_key_schedule schedule;
 // Prepare the key for encryption
 memcpy(keyEncrypt, key, 8);
 DES_set_odd_parity(&keyEncrypt);
 DES_set_key_checked(&keyEncrypt, &schedule);
 // Encrypt the plaintext
 DES_ecb_encrypt((DES_cblock*)plaintext, (DES_cblock*)ciphertext,
&schedule, DES_ENCRYPT);
}
// Function to decrypt using DES algorithm
void decryptDES(const unsigned char* ciphertext, const unsigned char* key,
unsigned char* plaintext) {
 DES_cblock keyEncrypt;
 DES_key_schedule schedule;
 // Prepare the key for decryption
 memcpy(keyEncrypt, key, 8);
 DES_set_odd_parity(&keyEncrypt);
DES_set_key_checked(&keyEncrypt, &schedule);
 // Decrypt the ciphertext
 DES_ecb_encrypt((DES_cblock*)ciphertext, (DES_cblock*)plaintext,
&schedule, DES_DECRYPT);
}
int main() {
 // Input plaintext and key
 const unsigned char plaintext[] = "Hello, DES!";
 const unsigned char key[] = "SecretKey";
 // Buffer to store the encrypted and decrypted data
 unsigned char ciphertext[32];
 unsigned char decryptedtext[32];
 // Encrypt the plaintext
 encryptDES(plaintext, key, ciphertext);
 // Decrypt the ciphertext
 decryptDES(ciphertext, key, decryptedtext);
 // Print the encrypted and decrypted messages
 std::cout << "Plaintext: " << plaintext << std::endl;
 std::cout << "Ciphertext: " << ciphertext << std::endl;
 std::cout << "Decrypted text: " << decryptedtext << std::endl;
 return 0;
}
```