Introduction to Cryptography

Cryptography, or **cryptology** is the practice and study of techniques for secure communication in the presence of adversarial behavior. More generally, cryptography is about constructing and analyzing protocols that prevent third parties or the public from reading private messages; various aspects of information security such as data confidentiality, data integrity, authentication, and non-repudiation are central to modern cryptography.

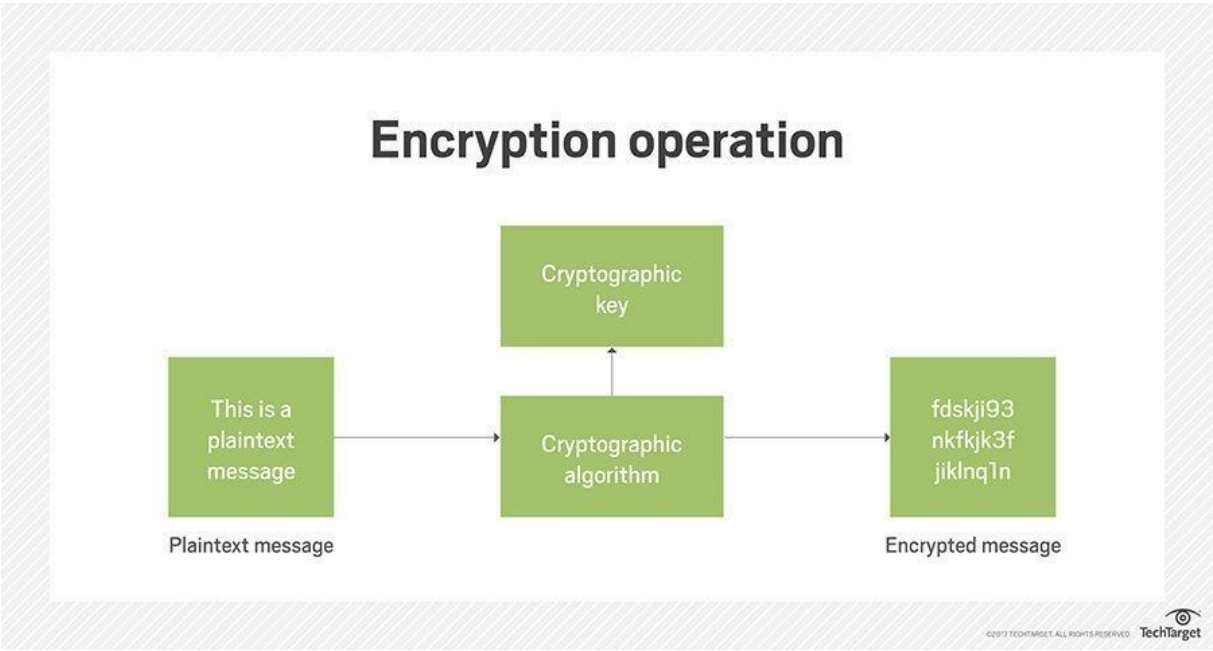
Modern cryptography exists at the intersection of the disciplines of mathematics, computer science, electrical engineering, communication science, and physics. Applications of cryptography include electronic commerce, chip-based payment cards, digital currencies, computer passwords, and military communications.

What is encryption?

Encryption is the method by which information is converted into secret code that hides the information's true meaning. The science of encrypting and decrypting information is called cryptography.

In computing, unencrypted data is also known as plaintext, and encrypted data is called ciphertext. The formulas used to encode and decode messages are called encryption algorithms, or ciphers.

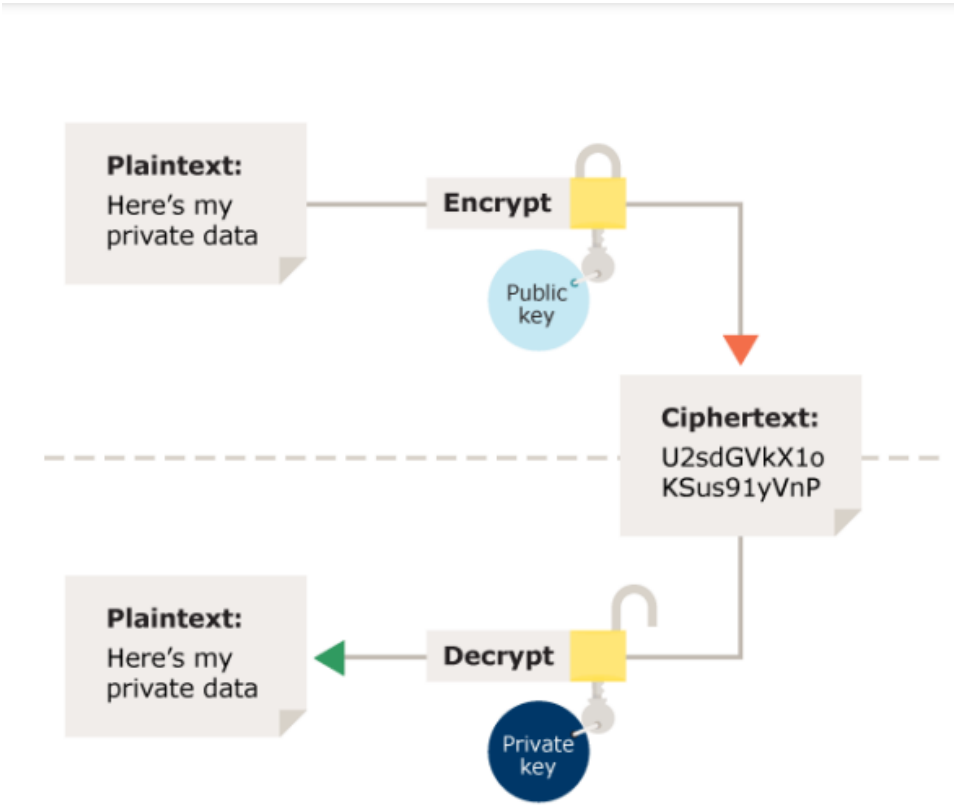
Example:



What is 'Decryption'

Definition: The conversion of encrypted data into its original form is called Decryption. It is generally a reverse process of encryption. It decodes the encrypted information so that an authorized user can only decrypt the data because decryption requires a secret key or password.

Description: One of the reasons for implementing an encryption-decryption system is privacy. As information travels over the Internet, it is necessary to scrutinise the access from unauthorized organisations or individuals. Due to this, the data is encrypted to reduce data loss and theft.



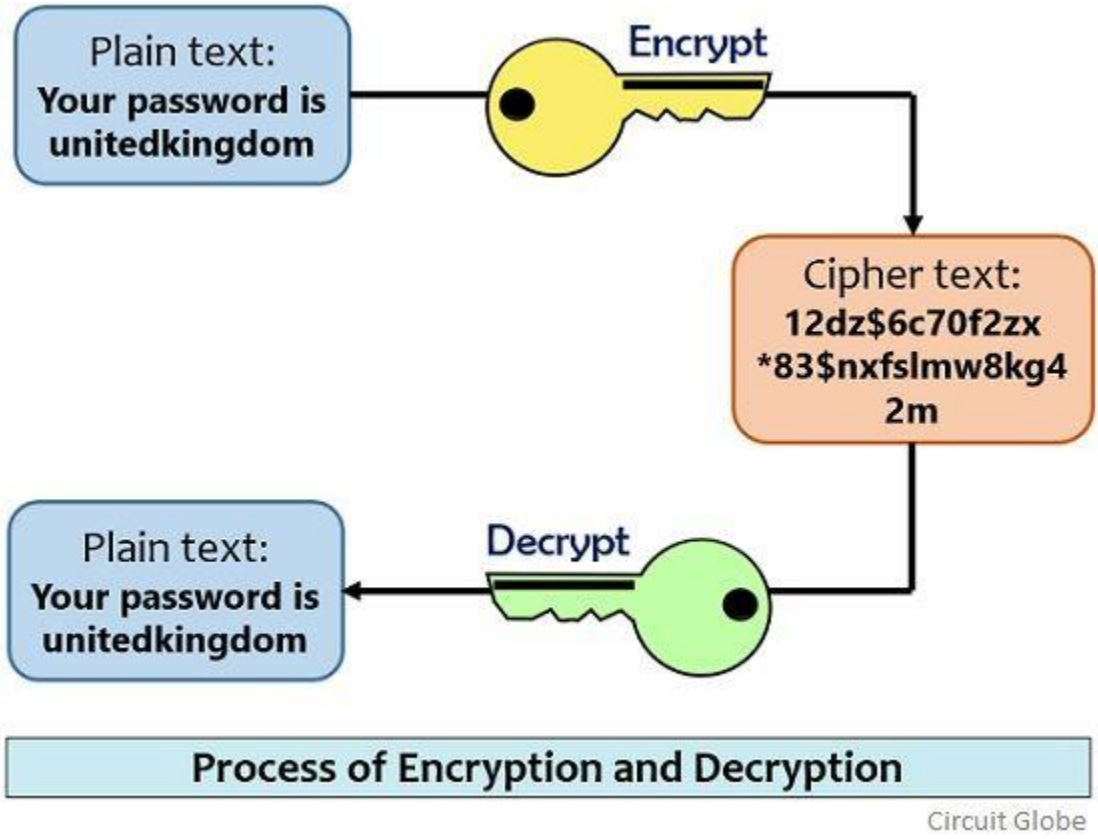
plaintext

In cryptography, plaintext usually means **unencrypted information pending input into cryptographic algorithms, usually encryption algorithms**. This usually refers to data that is transmitted or stored unencrypted.

What is 'Cipher text'

Definition: Cipher is an algorithm which is applied to plain text to get ciphertext. It is the unreadable output of an encryption algorithm. The term "cipher" is sometimes used as an alternative term for ciphertext. Ciphertext is not understandable until it has been converted into plaintext using a key.

Description: Earlier cipher algorithms were performed manually and were entirely different from modern algorithms which are generally executed by a machine.



Types Of Cryptography:

In general there are three types Of cryptography:

1. **Symmetric Key Cryptography:**
   It is an encryption system where the sender and receiver of message use a single common key to encrypt and decrypt messages. Symmetric Key Systems are faster and simpler but

the problem is that sender and receiver have to somehow exchange key in a secure manner. The most popular symmetric key cryptography system is Data Encryption System(DES).

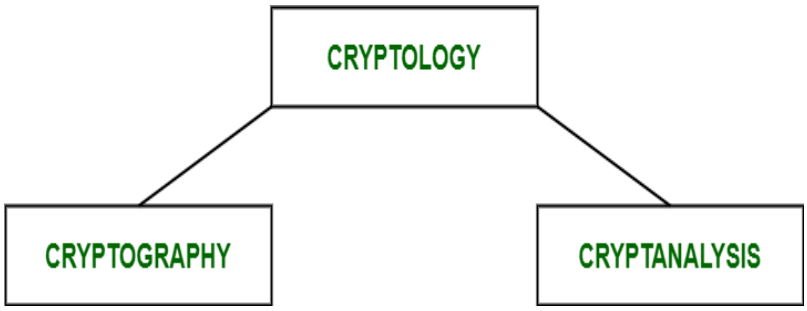
2. **Hash Functions:**
   There is no usage of any key in this algorithm. A hash value with fixed length is calculated as per the plain text which makes it impossible for contents of plain text to be recovered. Many operating systems use hash functions to encrypt passwords.
3. **Asymmetric Key Cryptography:**
   Under this system a pair of keys is used to encrypt and decrypt information. A public key is used for encryption and a private key is used for decryption. Public key and Private Key are different. Even if the public key is known by everyone the intended receiver can only decode it because he alone knows the private key.

Cryptology

Cryptology has two parts namely, **Cryptography** which focuses on creating secret codes and **Cryptanalysis** which is the study of the cryptographic algorithm and the breaking of those secret codes. The person practicing Cryptanalysis is called a **Cryptanalyst**.

It helps us to better understand the cryptosystems and also helps us improve the system by finding any weak point and thus work on the algorithm to create a more secure secret code.

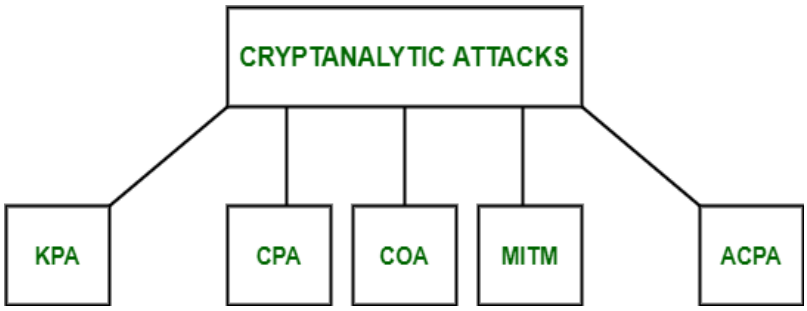
For example, a Cryptanalyst might try to decipher a ciphertext to derive the plaintext. It can help us to deduce the plaintext or the encryption key.



4. Parts Of Cryptology

To determine the weak points of a cryptographic system, it is important to attack the system. This attacks are called **Cryptanalytic attacks.** The attacks rely on nature of the algorithm and also knowledge of the general characteristics of the plaintext, i.e., plaintext can be a regular document written in English or it can be a code written in Java. Therefore, nature of the plaintext should be known before trying to use the attacks.

Types of Cryptanalytic attacks :



The Five Types of Cryptanalytic Attacks

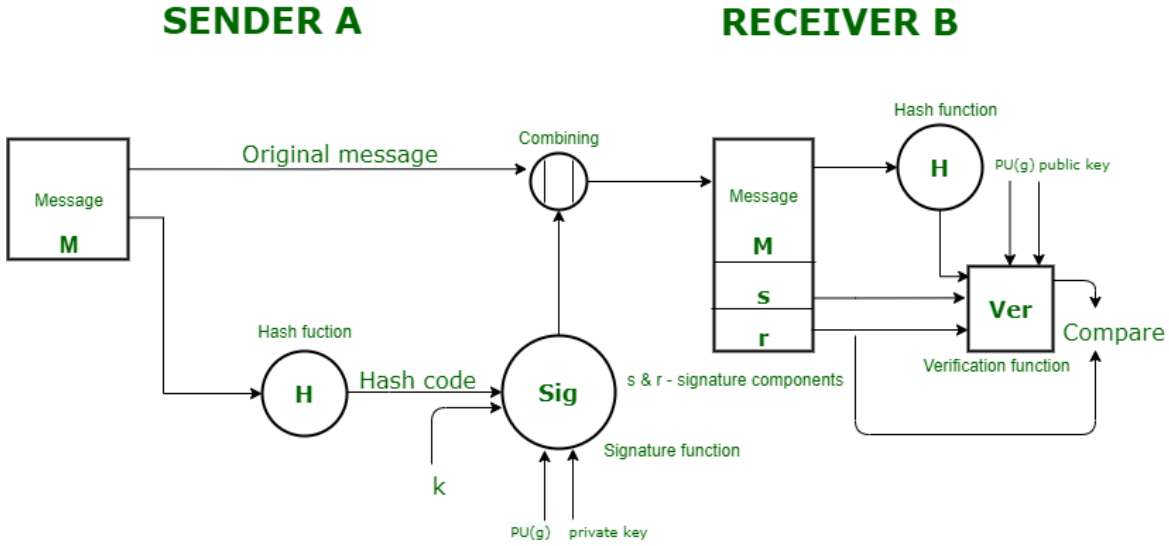
- **Known-Plaintext Analysis (KPA) :**
  In this type of attack, some plaintext-ciphertext pairs are already known. Attacker maps them in order to find the encryption key. This attack is easier to use as a lot of information is already available.
- **Chosen-Plaintext Analysis (CPA) :**
  In this type of attack, the attacker chooses random plaintexts and obtains the corresponding ciphertexts and tries to find the encryption key. Its very simple to implement like KPA but the success rate is quite low.
- **Ciphertext-Only Analysis (COA) :**
  In this type of attack, only some cipher-text is known and the attacker tries to find the corresponding encryption key and plaintext. Its the hardest to implement but is the most probable attack as only ciphertext is required.
- **Man-In-The-Middle (MITM) attack :**
  In this type of attack, attacker intercepts the message/key between two communicating parties through a secured channel.
- **Adaptive Chosen-Plaintext Analysis (ACPA) :**
  This attack is similar CPA. Here, the attacker requests the cipher texts of additional plaintexts after they have ciphertexts for some texts.

Network Security:

Digital Signature Standard (DSS)

As we have studied, signature is a way of authenticating the data coming from a trusted individual. Similarly, digital signature is a way of authenticating a digital data coming from a trusted source.

Digital Signature Standard (DSS) is a Federal Information Processing Standard(FIPS) which defines algorithms that are used to generate digital signatures with the help of Secure Hash Algorithm(SHA) for the authentication of electronic documents. DSS only provides us with the digital signature function and not with any encryption or key exchanging strategies.



Sender Side :
In DSS Approach, a hash code is generated out of the message and following inputs are given to the signature function –

1. The hash code.
2. The random number 'k' generated for that particular signature.
3. The private key of the sender i.e., PR(a).
4. A global public key(which is a set of parameters for the communicating principles) i.e., PU(g).

These input to the function will provide us with the output signature containing two components – 's' and 'r'. Therefore, the original message concatenated with the signature is sent to the receiver.

Receiver Side :
At the receiver end, verification of the sender is done. The hash code of the sent message is generated. There is a verification function which takes the following inputs –

1. The hash code generated by the receiver.
2. Signature components 's' and 'r'.
3. Public key of the sender.
4. Global public key.

The output of the verification function is compared with the signature component 'r'. Both the values will match if the sent signature is valid because only the sender with the help of it private key can generate a valid signature.

Electronic mail security (EMAIL Security)

Email security includes the techniques and technologies used to protect email accounts and communications. Email, which is an organization's largest attack surface, is the primary target of phishing attacks and can be used to spread malware.

Email is a critical component of organizational communication because it enables users to communicate quickly, easily, and with a variety of devices. Further, email can be used to send a number of different types of media, and communications can be tracked, stored, and organized according to attributes such as time and date stamps and size.

Types of Email Attacks

Cyber criminals use many different tactics to hack email, and some methods can cause considerable damage to an organization's data and/or reputation. Malware, which is malicious software used to harm or manipulate a device or its data, can be placed on a computer using each of the following attacks.

Phishing

A phishing attack targets users by sending them a text, direct message, or email. The attacker pretends to be a trusted individual or institution and then uses their relationship with the target to steal sensitive data like account numbers, credit card details, or login information.

Phishing comes in several forms, such as spear phishing, regular phishing, and whaling. Spear phishing targets a particular person, while a whaler targets someone high up in the organization by pretending to be someone they trust.

Spam

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Spoofing

Spoofing is a dangerous email threat because it involves fooling the recipient into thinking the email is coming from someone other than the apparent sender. This makes spoofing an effective business email compromise (BEC) tool. The email platform cannot tell a faked email from a real one because it merely reads the metadata—the same data the attacker has changed.

MIME Protocols

Multipurpose Internet Mail Extension (MIME) is a standard that was proposed by Bell Communications in 1991 in order to expand the limited capabilities of email.

MIME is a kind of add-on or a supplementary protocol that allows non-ASCII data to be sent through SMTP. It allows the users to exchange different kinds of data files on the Internet: audio, video, images, application programs as well.

Why do we need MIME?

Limitations of Simple Mail Transfer Protocol (SMTP):

1. SMTP has a very simple structure
2. Its simplicity however comes with a price as it only sends messages in NVT 7-bit ASCII format.
3. It cannot be used for languages that do not support 7-bit ASCII format such as French, German, Russian, Chinese and Japanese, etc. so it cannot be transmitted using SMTP. So, in order to make SMTP more broad, we use MIME.
4. It cannot be used to send binary files or video or audio data.

Purpose and Functionality of MIME –

Growing demand for Email Messages as people also want to express themselves in terms of Multimedia. So, MIME another email application is introduced as it is not restricted to textual data.

MIME transforms non-ASCII data at the sender side to NVT 7-bit data and delivers it to the client SMTP. The message on the receiver side is transferred back to the original data. As well as we can send video and audio data using MIME as it transfers them also in 7-bit ASCII data.

Features of MIME –

1. It is able to send multiple attachments with a single message.
2. Unlimited message length.
3. Binary attachments (executables, images, audio, or video files) may be divided if needed.
4. MIME provided support for varying content types and multi-part messages.

Working of MIME –
Suppose a user wants to send an email through a user agent and it is in a non-ASCII format so there is a MIME protocol that converts it into 7-bit NVT ASCII format. The message is transferred through the e-mail system to the other side in the 7-bit format now MIME protocol again converts it back into non-ASCII code and now the user agent of the receiver side reads it and then information is finally read by the receiver. MIME header is basically inserted at the beginning of any e-mail transfer.

MIME with SMTP and POP –

SMTP transfers the mail being a message transfer agent from the sender's side to the mailbox of the receiver side and stores it and MIME header is added to the original header and provides additional information. while POP being the message access agent organizes the mails from the mail server to the receiver's computer. POP allows the user agent to connect with the message transfer agent.

MIME Header:
It is added to the original e-mail header section to define transformation. There are five headers that we add to the original header:

1. **MIME-Version –** Defines the version of the MIME protocol. It must have the parameter Value 1.0, which indicates that message is formatted using MIME.
2. **Content-Type –** Type of data used in the body of the message. They are of different types like text data (plain, HTML), audio content, or video content.
3. **Content-Type Encoding –** It defines the method used for encoding the message. Like 7-bit encoding, 8-bit encoding, etc.
4. **Content Id –** It is used for uniquely identifying the message.
5. **Content description –** It defines whether the body is actually an image, video, or audio.

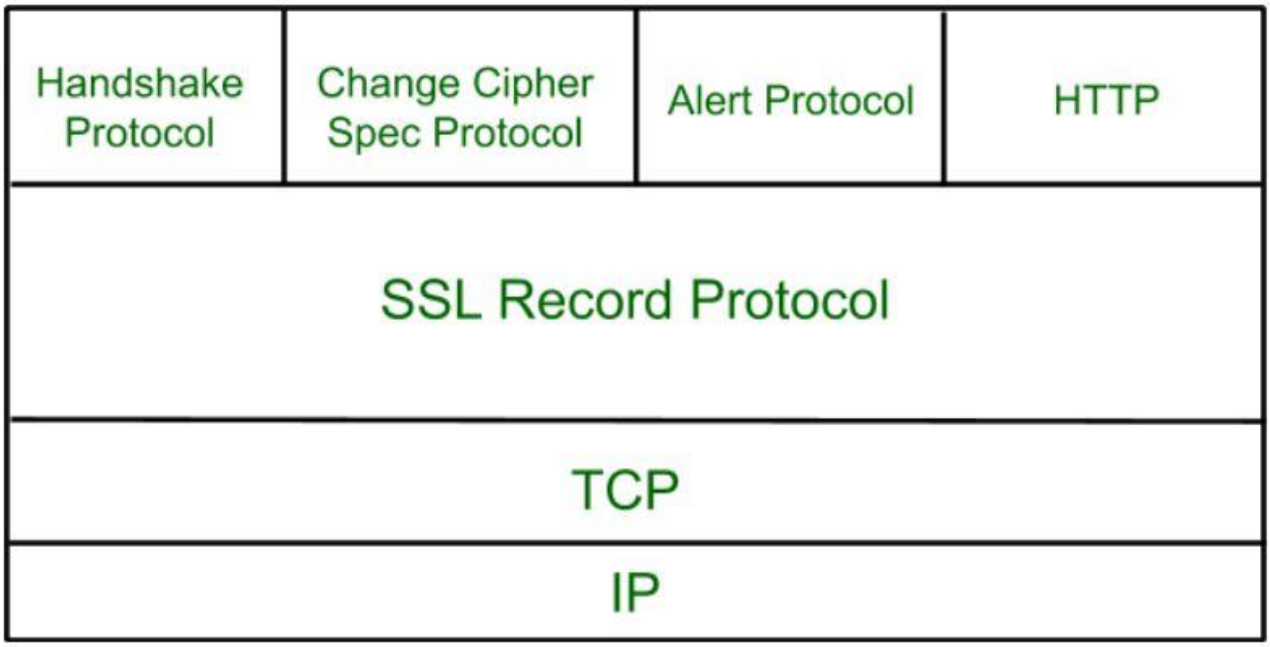
Secure Socket Layer (SSL)

Secure Socket Layer (SSL) provides security to the data that is transferred between web browser and server. SSL encrypts the link between a web server and a browser which ensures that all data passed between them remain private and free from attack.

Secure Socket Layer Protocols:

- SSL record protocol
- Handshake protocol
- Change-cipher spec protocol
- Alert protocol

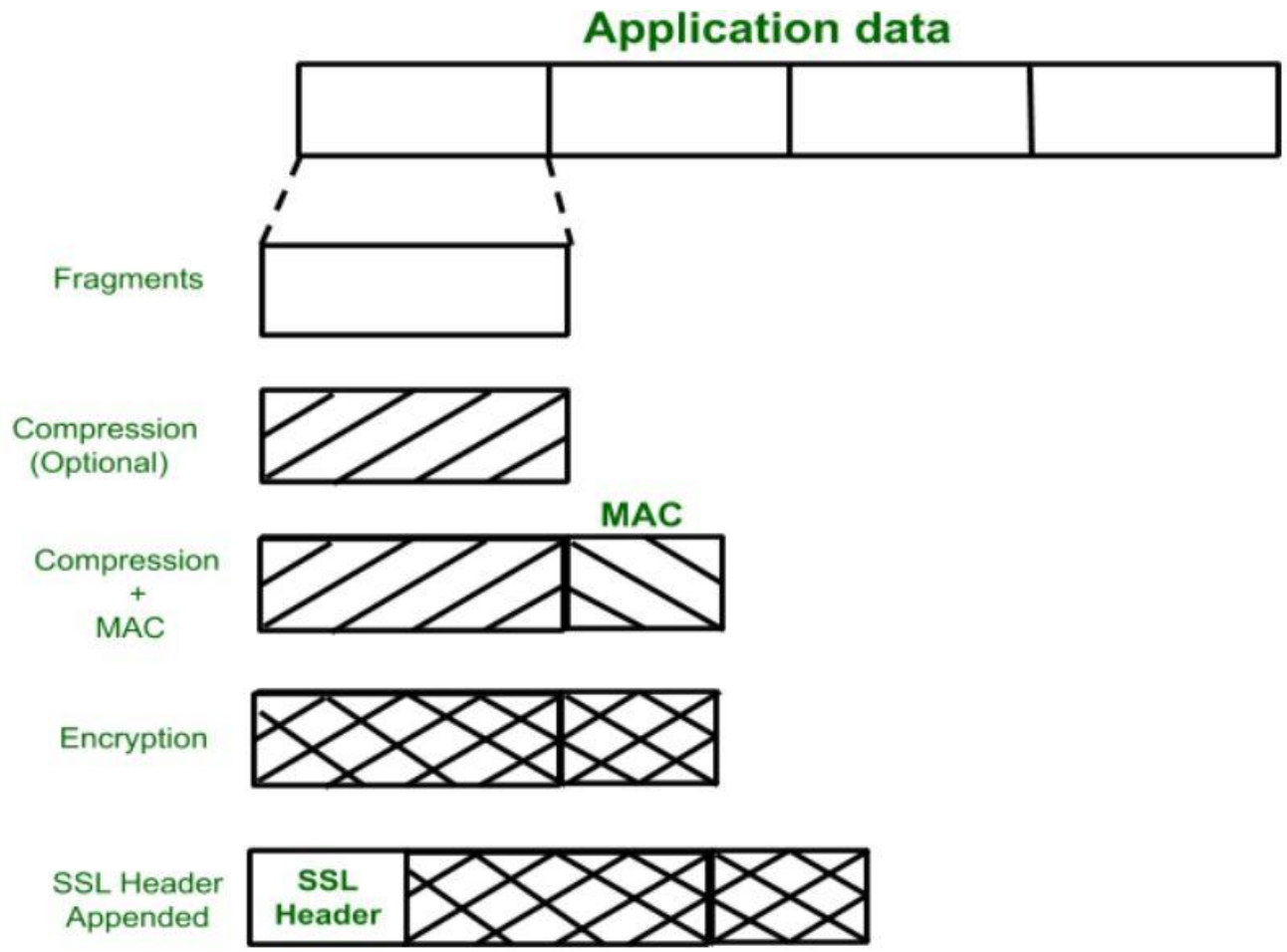
SSL Protocol Stack:



SSL Record Protocol:
SSL Record provides two services to SSL connection.

- Confidentiality
- Message Integrity

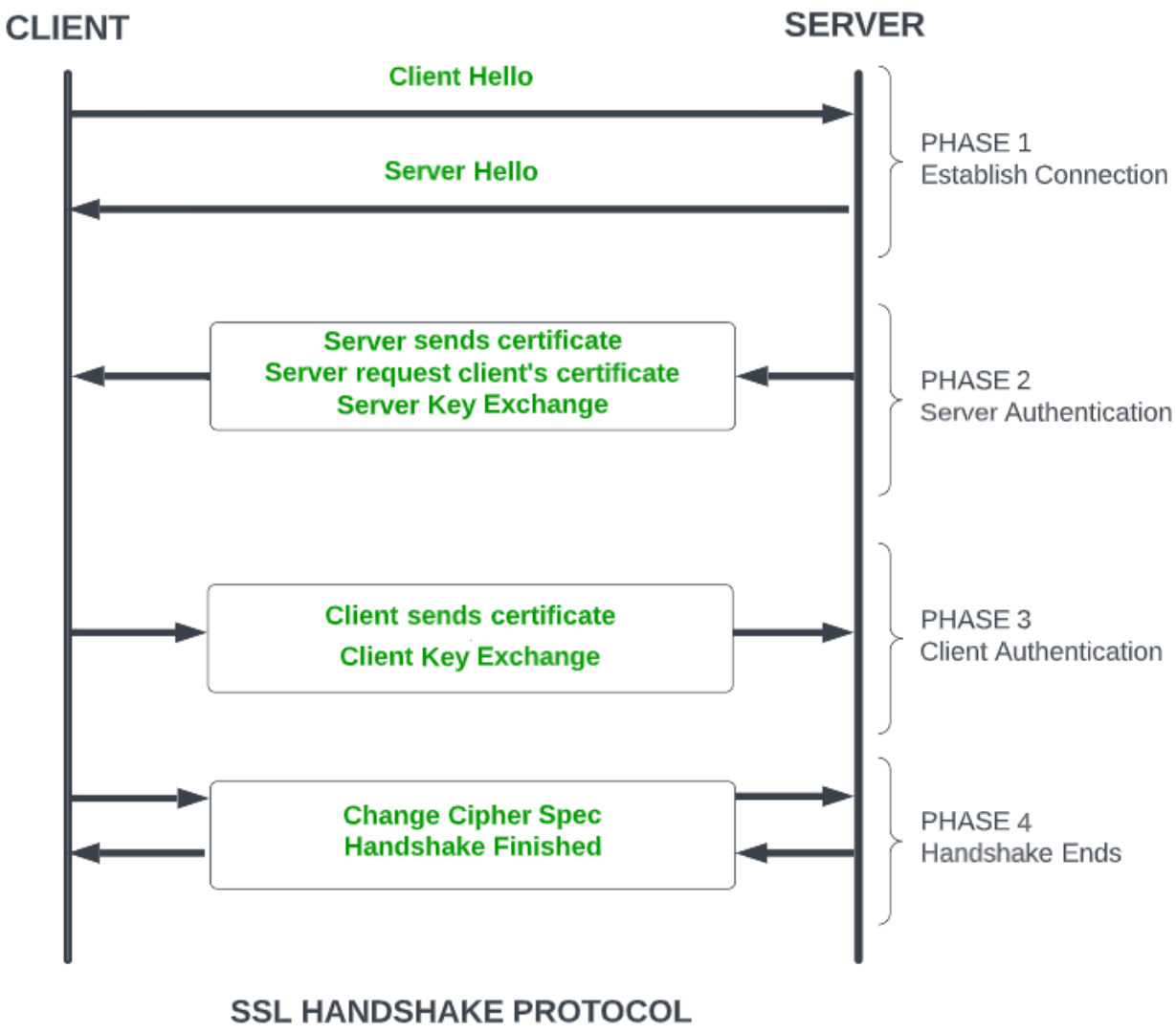
In the SSL Record Protocol application data is divided into fragments. The fragment is compressed and then encrypted MAC (Message Authentication Code) generated by algorithms like SHA (Secure Hash Protocol) and MD5 (Message Digest) is appended. After that encryption of the data is done and in last SSL header is appended to the data.



Handshake Protocol:

Handshake Protocol is used to establish sessions. This protocol allows the client and server to authenticate each other by sending a series of messages to each other. Handshake protocol uses four phases to complete its cycle.

- **Phase-1:** In Phase-1 both Client and Server send hello-packets to each other. In this IP session, cipher suite and protocol version are exchanged for security purposes.
- **Phase-2:** Server sends his certificate and Server-key-exchange. The server end phase-2 by sending the Server-hello-end packet.
- **Phase-3:** In this phase, Client replies to the server by sending his certificate and Client-exchange-key.
- **Phase-4:** In Phase-4 Change-cipher suite occurred and after this Handshake Protocol ends.



SSL Handshake Protocol Phases diagrammatic representation

Change-cipher Protocol:

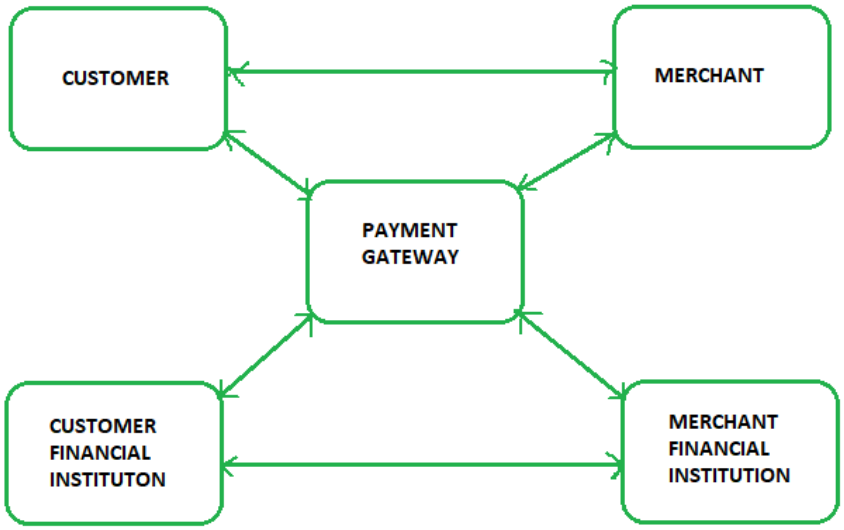
This protocol uses the SSL record protocol. Unless Handshake Protocol is completed, the SSL record Output will be in a pending state. After the handshake protocol, the Pending state is converted into the current state.
Change-cipher protocol consists of a single message which is 1 byte in length and can have only one value. This protocol's purpose is to cause the pending state to be copied into the current state.

Alert Protocol:

This protocol is used to convey SSL-related alerts to the peer entity. Each message in this protocol contains 2 bytes.

Secure Electronic Transaction (SET) Protocol

Secure Electronic Transaction or SET is a system that ensures the security and integrity of electronic transactions done using credit cards in a scenario. SET is not some system that enables payment but it is a security protocol applied to those payments. It uses different encryption and hashing techniques to secure payments over the internet done through credit cards. The SET protocol was supported in development by major organizations like Visa, Mastercard, Microsoft which provided its Secure Transaction Technology (STT), and Netscape which provided the technology of Secure Socket Layer (SSL).



Requirements in SET :
The SET protocol has some requirements to meet, some of the important requirements are :

- It has to provide mutual authentication i.e., customer (or cardholder) authentication by confirming if the customer is an intended user or not, and merchant authentication.
- It has to keep the PI (Payment Information) and OI (Order Information) confidential by appropriate encryptions.
- It has to be resistive against message modifications i.e., no changes should be allowed in the content being transmitted.
- SET also needs to provide interoperability and make use of the best security mechanisms.

Participants in SET :

In the general scenario of online transactions, SET includes similar participants:

1. **Cardholder –** customer
2. **Issuer –** customer financial institution
3. **Merchant**
4. **Acquirer –** Merchant financial
5. **Certificate authority –** Authority that follows certain standards and issues certificates to all other participants.

SET functionalities :

- **Provide Authentication**
    - **Merchant Authentication** – To prevent theft, SET allows customers to check previous relationships between merchants and financial institutions. Standard certificates are used for this verification.
    - **Customer / Cardholder Authentication** – SET checks if the use of a credit card is done by an authorized user or not using certificates.
- **Provide Message Confidentiality**: Confidentiality refers to preventing unintended people from reading the message being transferred. SET implements confidentiality by using encryption techniques. Traditionally DES is used for encryption purposes.
- **Provide Message Integrity**: SET doesn't allow message modification with the help of signatures. Messages are protected against unauthorized modification using RSA digital signatures with SHA-1 and some using HMAC with SHA-1,