EMAIL SECURITY, IP SECURITY, WEB SECURITY & SYSTEM SECURITY

Syllabus: Transport Level Security: Web Security Requirements, Secure Socket Layer (SSL) and Transport Layer Security (TLS), Secure Shell(SSH) Electronic Mail Security: Pretty Good Privacy (PGP) and S/MIME.

Electronic Mail Security

In all distributed environments e-mail is the most heavily used network based application. It is also the only distributed application that is widely used across all architectures and vendor platforms. Users expect to be able to, and do send mail to others who are connected directly or indirectly to the Internet.

With the explosively growing reliance on e-mail for every conceivable purpose, there grows a demand for confidentiality and authentication services. Here are two schemes that provide these two services by name PGP (Pretty Good Privacy) and S/MIME (Secure Multipurpose and Internet Mail Extensions).

Pretty Good Privacy: PGP is an effort of a single person Phil Zimmerman. PGP provides confidentiality and authentication service that can be used for e-mail and file storage applications. In essence he selected

1. The best available cryptographic algorithms
2. Integrated these algorithms into a general purpose application
3. PGP is a freely available software
4. PGP runs on variety of platforms DOS/Windows/Unix/Mac and many more.

Notations:

K_s : Session key used for conventional encryption

KR_a : Private key of user A used in public key encryption

KU_a : Public key of user A used in public key encryption

EP: Public key encryption

DP: Public Key decryption

EC: Conventional encryption

DC: Conventional decryption

H: Hash function

||: concatenation

Z: Compression

R64: Radix 64 conversion

Operational Description:

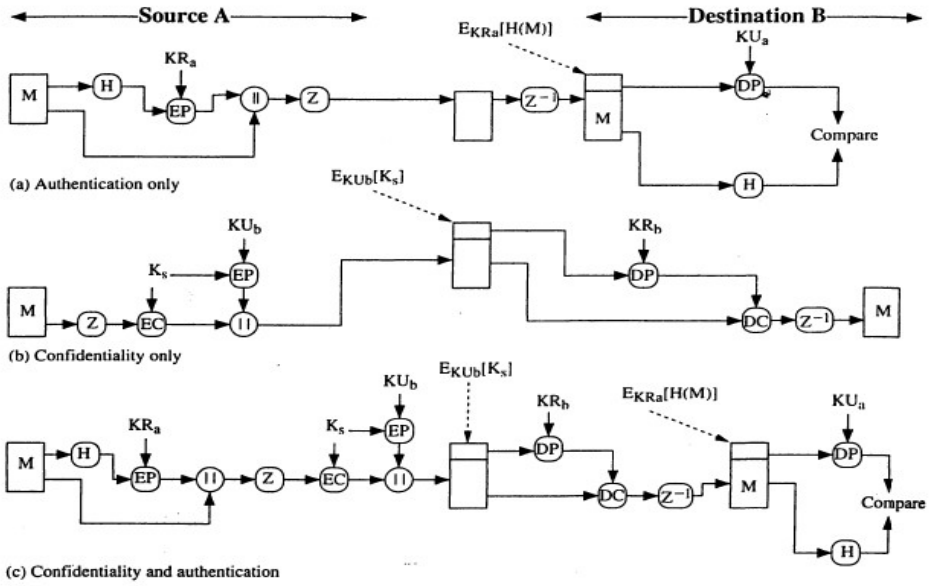
The actual operation of PGP implements the following five functions:

1. Digital Signature : Signature is created by using DSS or RSA algorithm. To create a signature, first a hash code is calculated on the message using SHA-1 or MD5. This hash code is encrypted with private key of the source KR_a using DSS or RSA.
2. Message encryption: A message is encrypted using CAST128 or IDEA or 3DES with a onetime session key. The session key is encrypted with receivers public key using public key encryption.
3. Compression: Messages are compressed for storage or transmission using ZIP. Compression must be provided always after authentication and before confidentiality serivce.

Why compression must be after authentication and before confidentiality?

- It is preferable to sign an uncompressed message so that one can store only the uncompressed message together with the signature for future verification. Suppose if one signed a compressed document, either he has to store compressed message for later verification or he has to decompress the message whenever verification is required. It is always preferable to authenticate the original contents of a message.
- Message encryption is applied after compression to strengthen cryptographic security. Because the compressed message has less redundancy than the original message, cryptanalysis is more.

4. E-mail Compatibility: When PGP is used at least part of the block to be transmitted is encrypted. If only the signature service is used, then the message digest is encrypted. If confidentiality service is used then the message plus signature must be encrypted. Many e-mail systems only permit ASCII text. To accommodate this restriction, PGP provides a service of converting the raw 8-bit stream to a stream of printable ASCII characters.
5. Segmentation and Reassembly: E-mail facilities are often restricted to a maximum length. To accommodate this restriction, PGP automatically subdivides a message that is too large into segments that are small enough to send via e-mail.



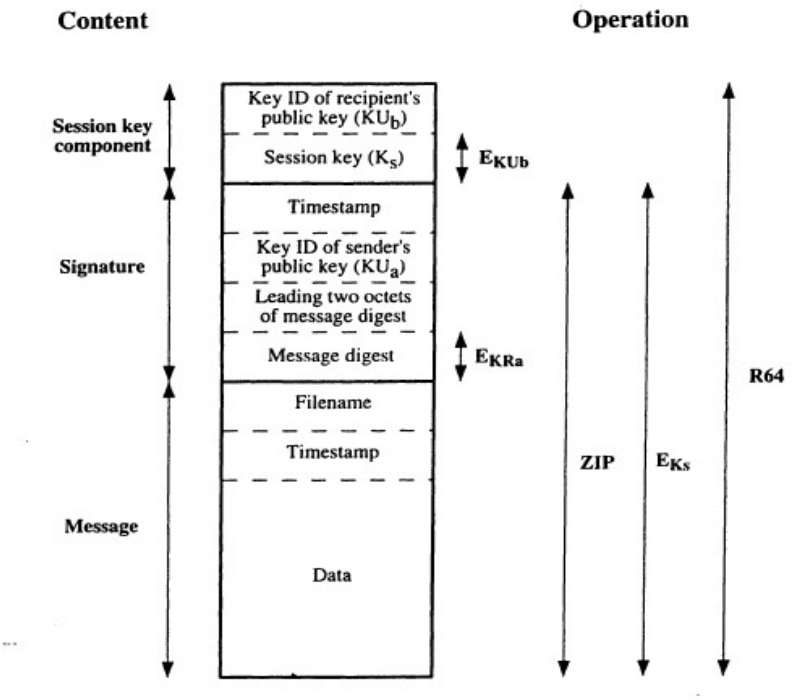
PGP Cryptographic Functions.

PGP Message Format:

A message consists of three components: a message component, signature component, session key component.

1. Message component includes the actual data to be stored or transmitted like file name, and a time stamp that specifies the time of creation.
2. Signature component includes the following components:

- Timestamp: The time at which the signature was made.
- Message Digest: The 160 SHA-1 message digest (hash code) encrypted with sender's private key.
- Leading two octets of message digest: To enable the recipient to determine if the correct public key was used to decrypt the message digest for authentication, by comparing this plain text copy of the first two octets with the first two octets of the message digest.
- Key Id of the sender's public key: Identifies the public key that should be used to decrypt the message digest and hence, identifies the private key that was used to encrypt the message digest. The message component and optional signature component may be compressed using ZIP and may be encrypted using a session key.



3. The session key component: It includes the session key and the identifier of the recipient's public key that was used by the sender to encrypt the session key.

All the three components are encoded with Radix 64 conversion.

PGP Key Rings:

PGP maintains a pair of data structures at each node, one to store the public and private key pairs owned by that node and one to store the public keys of other users known at this node. These data structures are known as private key ring and public key ring respectively.

Private Key Ring: Each row represents one of the public/private key pairs owned by this user. Each row contains the following entries:

- Timestamp: The date/time when this key pair was generated
- Key Id: The least significant 64 bits of public key for this entry
- Public Key: The public key of user
- Private Key: The encrypted version of private key
- User Id: User's e-mail address.

Private-Key Ring

Timestamp	Key ID*	Public Key	Encrypted Private Key	User ID*
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
T_i	$KU_i \bmod 2^{64}$	KU_i	$E_{H(P_i)}[KR_i]$	User *i*
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•

The private key ring can be indexed by either user id or key id.

Public Key Ring: This data structure is used to store public keys of other users that are known to this user.

Public-Key Ring

Timestamp	Key ID*	Public Key	Owner Trust	User ID*	Key Legitimacy	Signature(s)	Signature Trust(s)
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
T_i	$KU_i \bmod 2^{64}$	KU_i	$trust\_flag_i$	$User_i$	$trust\_flag_i$		
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•

* = field used to index table

Timestamp: The date/time when this entry was generated

Key Id: The least significant 64 bits of the public key for this entry

Public key: The public key of this entry

User Id: The owner of this key. Multiple user ids may be associated with a single public key.

Owner Trust: Represents Trust Flag value of owner.

Key Legitimacy: Key Trust Flag value

Signature: signature of the respective user

Signature Trust: signature of certification authority

PGP Message Generation:

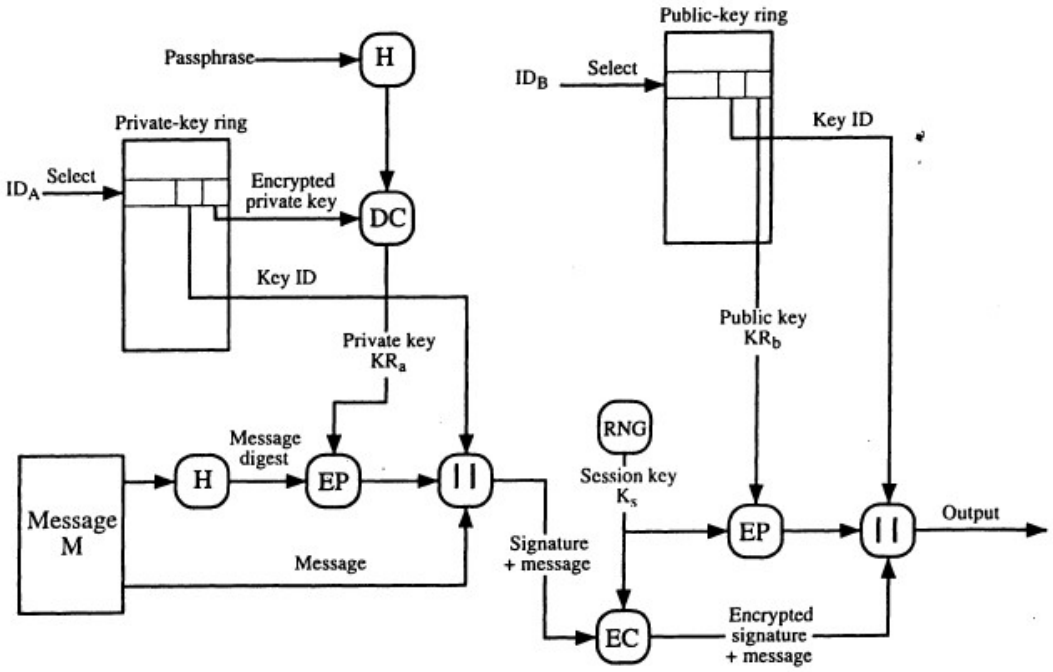
1. Sending the message

- PGP retrieves the sender's private key from the private key ring using the key id

- PGP prompts the user for the password to recover the encrypted private key which is stored in private key ring
- Then the signature is created with the retrieved private key.

2. Encrypting the message

- PGP generates a session key and encrypts the message
- PGP retrieves the recipient's public key from the public key ring using his/her key id.
- The session key component of the message is encrypted with the receiver's public key.



Now the sender forwards encrypted signature plus message and encrypted session key to the receiver.

PGP Message Reception:

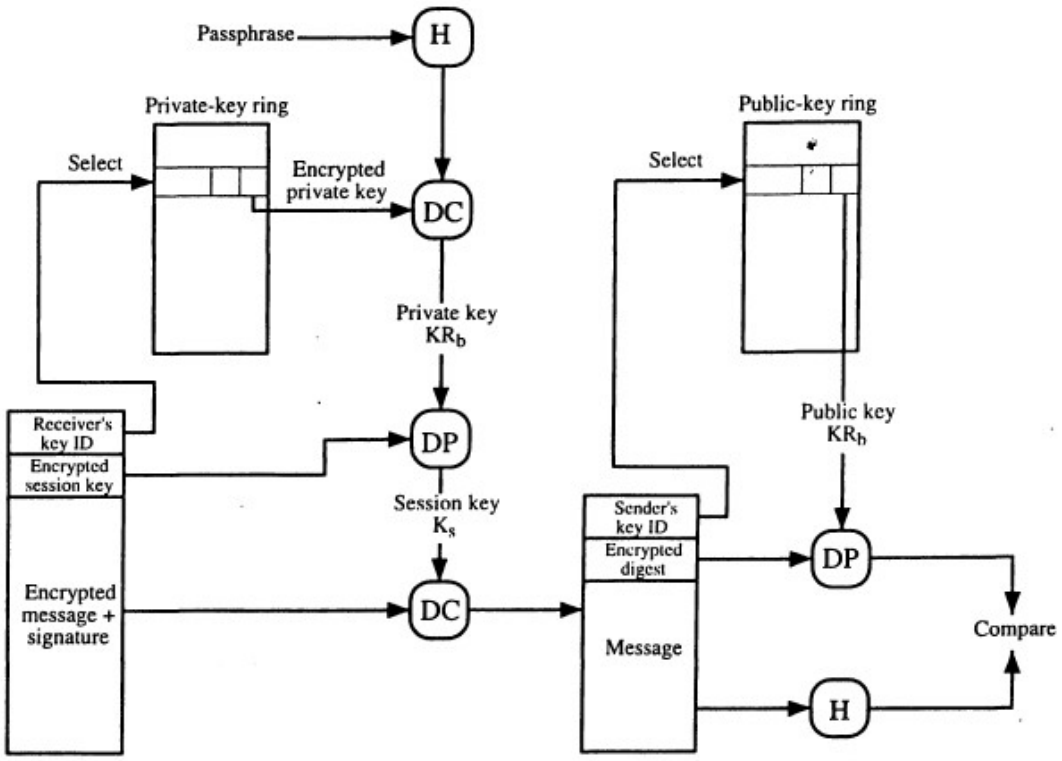
1. Decrypting the Message

- PGP retrieves the receiver's private key from the private key ring using key id field in the session key component of the message.
- PGP prompts the user for password to decrypt the encrypted private key which is stored in the private key ring.
- PGP recovers the session key by decrypting this using his private key.

2. Authenticating the Message

- PGP captures the sender's public key from the public key ring, using the key id field in the signature component of the message.

- Using the recovered public key receiver decrypts the message digest.
- PGP computes the message digest on the received message and compares this computed message digest with the decrypted message digest. If both are equal, then receiver accepts the message.



S/MIME: Secure Multipurpose Internet Mail Extension is a security enhancement to the MIME internet e-mail format standard based on RSA data security. MIME is an extension to the RFC 822 to address the limitations of the use of SMTP. Following are the limitations of SMTP:

- SMTP cannot transfer exe, and binary files
- SMTP cannot transfer textual data that includes national language characters
- SMTP servers rejects e-mail messages over a certain size
- SMTP gateways do not have compatibility between ASCII and EBCDIC formats
- SMTP gateways cannot handle non textual data

MIME consists of the following five headers:

- MIME version: Represents the version of MIME
- Content-Type: Describes the type of data contained in the body.

Type	Subtype	Description
Text	Plain	Unformatted text; may be ASCII or ISO 8859.
	Enriched	Provides greater format flexibility.
Multipart	Mixed	The different parts are independent but are to be transmitted together. They should be presented to the receiver in the order that they appear in the mail message.
	Parallel	Differs from Mixed only in that no order is defined for delivering the parts to the receiver.
	Alternative	The different parts are alternative versions of the same information. They are ordered in increasing faithfulness to the original, and the recipient's mail system should display the "best" version to the user.
	Digest	Similar to Mixed, but the default type/subtype of each part is message/rfc822.
Message	rfc822	The body is itself an encapsulated message that conforms to RFC 822.
	Partial	Used to allow fragmentation of large mail items, in a way that is transparent to the recipient.
	External-body	Contains a pointer to an object that exists elsewhere.
Image	jpeg	The image is in JPEG format, JFIF encoding.
	gif	The image is in GIF format.
Video	mpeg	MPEG format.
Audio	Basic	Single-channel 8-bit ISDN mu-law encoding at a sample rate of 8 kHz.
Application	PostScript	Adobe Postscript
	octet-stream	General binary data consisting of 8-bit bytes.

- Content-Transfer-Encoding: Indicates the type of transformation that has been used to represent the body of the message.

7bit	The data are all represented by short lines of ASCII characters.
8bit	The lines are short, but there may be non-ASCII characters (octets with the high-order bit set).
binary	Not only may non-ASCII characters be present, but the lines are not necessarily short enough for SMTP transport.
quoted-printable	Encodes the data in such a way that if the data being encoded are mostly ASCII text, the encoded form of the data remains largely recognizable by humans.
base64	Encodes data by mapping 6-bit blocks of input to 8-bit blocks of output, all of which are printable ASCII characters.
x-token	A named nonstandard encoding.

- Content Id: used to identify MIME entities uniquely
- Content-Description: A text description of the object with the body. This is useful when the object is not readable(audio)

S/MIME Functionality: It is very similar to PGP. Both offer the ability to sign and/or encrypt the messages. S/MIME provides the following functions:

- **Enveloped Data:** This consists of encrypted content of any type and encrypted content encryption keys for one or more recipients. The steps for developing enveloped data are:

a. Generates a pseudorandom session key for a particular symmetric key encryption
b. For each recipient, encrypt the session key with the recipient's public key
c. For each recipient, prepare a block such as recipient's info that contains the sender's public key certificate and the encrypted session key.
d. Encrypt the message content with the session key

- **Signed Data:** A digital signature is formed by taking the message digest of the content to be signed and then encrypting that with the private key of the signer. The content plus signature are then encoded using base 64 encoding. A signed data message can only be viewed by a recipient with S/MIME capability.
  i) Compute the message digest, or hash function of the content to be signed.
  ii) Encrypt the message digest with the signer's private key.
  iii) Prepare a block known as signerInfo that contains the signer's public key certificate and the encrypted message digest
- **Clear-Signed Data**: In signed data format, a digital signature of the content is formed. However in this case, only digital signature is encoded using base 64. So recipients without S/MIME capability can view the message contents but cannot verify the signature.
- **Signature and Enveloped Data**: Signed-only and encrypted-only entities may be nested, so that encrypted data may be signed and signed data or clear-signed data may be encrypted.

S/MIME Certificate Processing: S/MIME uses public key certificates that conform to version 3 of X.509. the key management scheme used by S/MIME is hybrid between X.509 hierarchy and PGP's web of trust. Certificates are used to verify incoming signatures and to encrypt outgoing messages.

Verisign Certificates: There are several companies that provide certification authority services. For example Nortel has designed an enterprise CA to provide S/MIME support within an organization. There are a number of Internet-based CA's including Verisign, GTE and the U.S Postal service. Verisign provides a CA service that is intended to be compatible with S/MIME. The information contained in a Digital ID depends on the type of Digital ID and its use. Each Digital ID contains the following:

- Owner's public key, Owner's name or alias
- Expiration date of the digital ID, Serial number of the Digital ID
- Name of the CA that issued the Digital ID
- Digital signature of the CA
- It also contains user supplied information like address
- E-mail address

- Basic registration information(country, zip code, age, and gender

Verisign provides three levels or classes of security for public key certificates. Here is a list of classes.

	Summary of Confirmation of Identity	IA Private-Key Protection	Certificate Applicant and Subscriber Private-Key Protection	Applications Implemented or Contemplated by Users
Class 1	Automated unambiguous name and e-mail address search	PCA: trustworthy hardware; CA: trustworthy software or trustworthy hardware	Encryption software (PIN protected) recommended but not required	Web browsing and certain e-mail usage
Class 2	Same as Class 1, plus automated enrollment information check plus automated address check	PCA and CA: trustworthy hardware	Encryption software (PIN protected) required	Individual and intra- and intercompany e-mail, on-line subscriptions, password replacement, and software validation
Class 3	Same as Class 1, plus personal presence and ID documents plus Class 2 automated ID check for individuals; business records (or filings) for organizations	PCA and CA: trustworthy hardware	Encryption software (PIN protected) required; hardware token recommended but not required	e-banking, corp. database access, personal banking, membership-based on-line services, content integrity services, e-commerce server, software validation; authentication of LRAAs; and strong encryption for certain servers

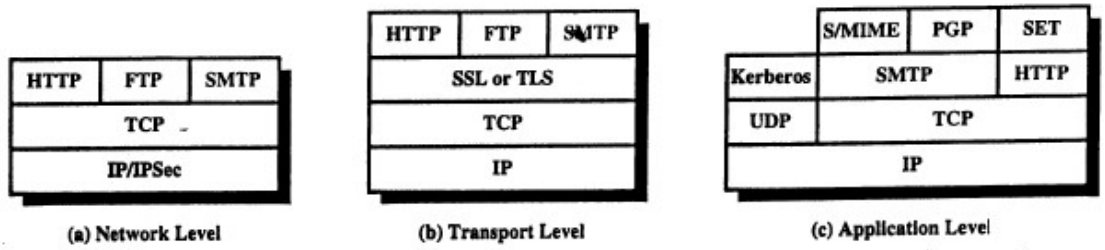
WEB SECURITY

The World Wide Web is fundamentally a client/server application running over the internet and TCP/IP intranets.

Web Security Threats: Web security threats are located at web server, web browser and network traffic between browser and server. These threats grouped into two categories passive and active threats. Following is the list of web threats:

	Threats	Consequences	Countermeasures
Integrity	• Modification of user data • Trojan horse browser • Modification of • memory • Modification of message traffic in transit	• Loss of information • Compromise of machine • Vulnerability to all other threats	Cryptographic checksums
Confidentiality	• Eavesdropping on the Net • Theft of info from server • Theft of data from client • Info about network configuration • Info about which client talks to server	• Loss of information • Loss of privacy	Encryption, Web proxies
Denial of Service	• Killing of user threads • Flooding machine with bogus threats • Filling up disk or memory • Isolating machine by DNS attacks	• Disruptive • Annoying • Prevent user from getting work done	Difficult to prevent
Authentication	• Impersonation of legitimate users • Data forgery	• Misrepresentation of user • Belief that false information is valid	Cryptographic techniques

Web Traffic Security Approaches: Several approaches are possible to provide web security. One way to provide web security is to use IP security. The advantage of using IP security is that it is transparent to end users and applications and provides security. It includes filtering capability so that only selected traffic need to be secured.

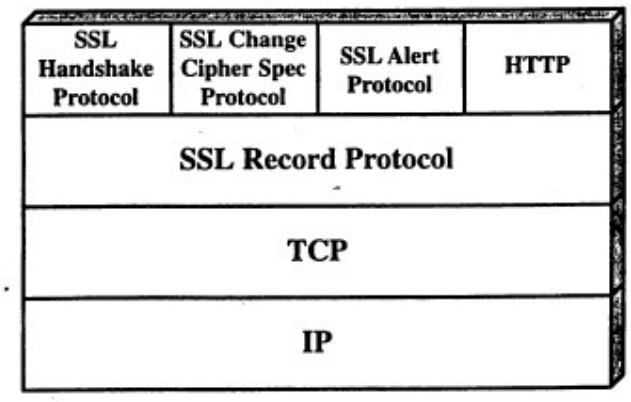


Another solution is to implement security at the top of TCP. SSL or TLS can be used to secure the web transactions. Application specific security services are embedded within the particular application. The advantage of this approach is that the service can be tailored to the specific needs of a given application. Ex: SET.

Secure Socket Layer and Transport Layer Security:

SSL was originated by Netscape. Version 3 of the protocol was designed with public review and input from industry. The first version of TLS can be viewed essentially an SSL version 3 .

SSL Architecture: SSL is designed to make use of TCP to provide a reliable end-to-end secure service. SSL is not a single protocol but it is a two layers of protocols. The SSL record protocol provides basic security services to various higher layer protocols. HTTP provides the transfer service for web client/server interaction and operates on top of SSL. Three higher layer protocols are defined as part of SSL: the Handshake protocol, the Change Cipher Spec protocol, and the Alert protocol.



Two important SSL concepts are SSL session and the SSL connection.

Connection: A connection is a transport that provides a suitable type of service. For SL, such connections are peer-to-peer relationships. The connections are transient. Every connection is associated with one session.

Session: An SSL session is an association between a client and a server. Sessions are created by the Handshake protocol. Session define a set of cryptographic security parameters which are shared with multiple connections. Security sessions are used to avoid the expensive negotiation of new security parameters for each connection.

There are number of states associated with each session. Once a session is established, there is a current operating state for both read and write. A session state is defined by the following parameters:

- Session Identifier: A sequence selected by the server to identify an active or resumable session state
- Peer certificate: An X.509 certificate of the peer.
- Compression method: The algorithm used to compress prior to encryption
- Cipher spec: Specifies the bulk data encryption algorithm used for MAC calculation.
- Master secret: The forty-eight byte secret shared between the client and server
- Is resumable: Indicates whether the session is used to initiate new connections.

A connection state is defined by the following parameters.

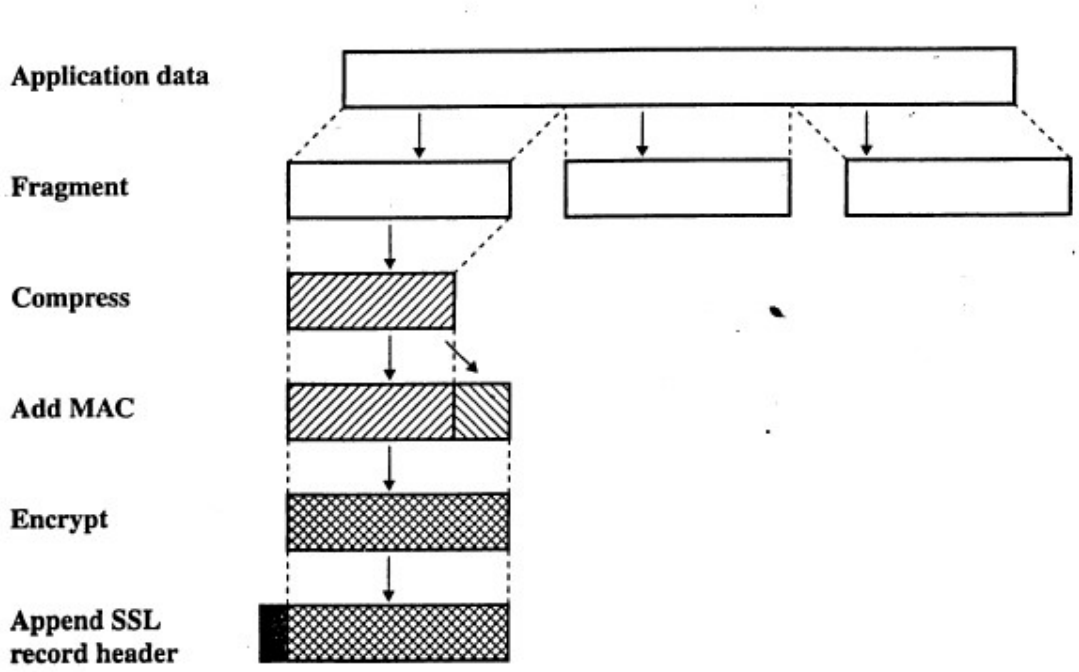
- Server and client random: byte sequences that are chosen by client and server for each connection
- Server write MAC secret: The secret key used in MAC operation on data sent by the server
- Client write MAC secret: The secret key used in MCA operation on data sent by the client.
- Server write key: The conventional encryption key for data encrypted by the server and decrypted by the client
- Client write Key: The conventional encryption key for data encrypted by the client and decrypted by the server.
- Initialization vector: when a block cipher uses CBC mode, an IV is used for each key. This is first initialized by handshake protocol.
- Sequence numbers: each party maintains separately sequence numbers for transmitted and received messages.

SSL Record Protocol:

The SSL record protocol provides two services for SSL connection.

- Confidentiality: Handshake protocol defines a shared secret key that is sued for conventional encryption of SSL payloads.
- Message Integrity: The Handshake protocol also defines a shared secret key that is used to form a MAC.

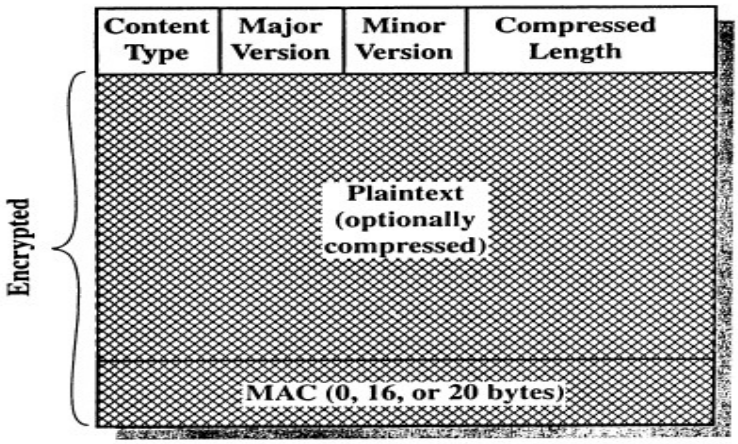
The Record protocol takes an application message to be transmitted, fragments the data into manageable blocks, optionally compresses the data, applies a MAC(using HMAC), encrypts (using IDEA, DES, 3DES, fortezza(used in smart card encryption)), adds a header, and transmits the resulting unit in a TCP segment. Received data are then decrypted, verified and decompressed and reassembled and then delivered to the higher level users.



SSL Record Protocol Operation.

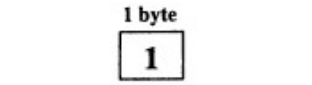
The final step of SSL record protocol processing is to prepend a header which contains the following fields:

- Content type(8 bits): The higher layer protocol used to process the enclosed fragment
- Major version(8 bits): Indicates a major version of SSL in use.it is 3.
- Minor version(8 bits): Indicates minor version of SSL in use. It is 0.
- Compressed length(16 bits): The length in bytes of the plain text fragment (or compressed fragment if compression is used) .

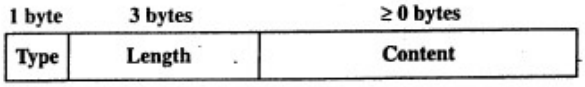


SSL Change Cipher Spec Protocol:

It is one of the three SSL-specific protocols that use the SSL record protocol, and it is simplest. It consists of a single message, which is a single byte with the value 1. The sole purpose fo this message is to cause the pending state to be copied into the current state, which updates the cipher suite to be used on this connection.



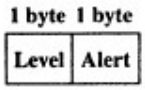
(a) Change Cipher Spec Protocol



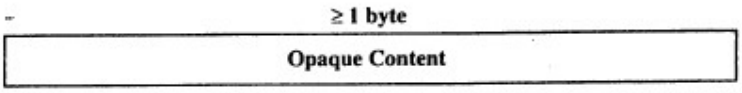
(c) Handshake Protocol

SSL Alert Protocol:

The alert protocol is used to convey SSL related alerts to the peer entity. Each message in this protocol consists of two bytes. The first byte takes the value warning (1) or fatal(2) to convey the security of message. If the level is fatal, SSL immediately terminates the connection. Other connections on the same session may continue, but no new connections on this session may be established. The second byte contains a code that indicates the specific alert. Here is a list of Fatal alerts:



(b) Alert Protocol



(d) Other Upper-Layer Protocol (e.g., HTTP)

- Unexpected_message: An inappropriate message was received

- Bad_record_mac: An incorrect mac was received.
- Decompression_failure: The received decompression function is improper.
- Handshake_failure: sender was unable to negotiate an acceptable set of security parameters.
- Illegal_parameter: A field in a handshake message was out of range

Rest of the alerts are:

- Close_notify: notifies the recipient that the sender will not send any more messages on this connection. Each party is required to send close_notify alert before closing the write side of a connection.
- No_certificate: no appropriate certificate is available
- Bad_certificate: A received certificate was corrupt.
- Unsupported_certificate: certificate is not supported
- Certificate_revoked: certificate is already revoked by its signer
- Certificate_expired: Certificate has expired.
- Certificate_unknown: Certificate CA is not known

SSL Handshake Protocol: The most complex part of SSL is the Handshake protocol. It allows the server and client to authenticate each other and to negotiate encryption and MAC algorithm and cryptographic keys to be used to protect data sent on the SSL record. The handshake protocol is used before any application data is transmitted. The handshake protocol consists of a series of messages exchanged by client and server. Each message has three fields:

- Type(1 byte): Indicates one of 10 messages
- Length (3 bytes): length of message in bytes.
- Content (>1 byte): the parameters associated with this message.

SSL Handshake protocol Message Types:

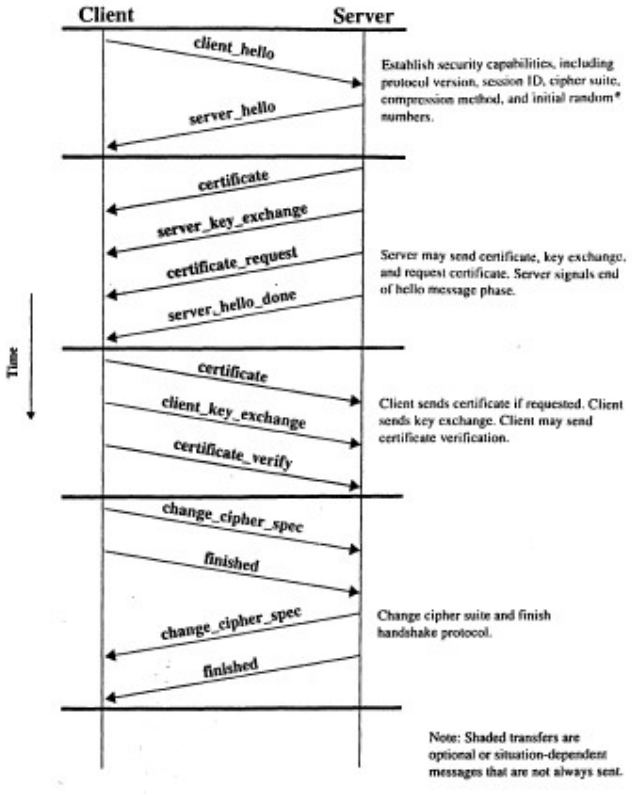
Message Type	Parameters
hello_request	null
client_hello	version, random, session id, cipher suite, compression method
server_hello	version, random, session id, cipher suite, compression method
certificate	chain of X.509v3 certificates
server_key_exchange	parameters, signature
certificate_request	type, authorities
server_done	null
certificate_verify	signature
client_key_exchange	parameters, signature
finished	hash value

Phase 1: Establishing security capabilities:

This phase is used to initiate logical connection and to establish the security capabilities that will be associated with it. The exchange is initiated by the client which sends a client_hello message with the following parameters:

- Version: Gives details of SSL version
- Random: A client generated pseudorandom number and timestamp
- Session ID: A variable length session identifier.
- CipherSuite: Contains a list that combination of cryptographic algorithms
- Compression method: List of compression methods that client supports.

After sending the client_hello message, the client waits for the server_hello message, which contains the same parameters as the client_hello message.



Phase 2. Server Authentication and Key Exchange: The server begins this phase by sending its certificate, if it needs to be authenticated; the message contains one or a chain of X.509 certificates. Next server_key_exchange message will best transmitted by the server. Server request client to forward client's public key certificate. The final message in phase 2 is server_done message which is sent by the server to indicate the end of server hello and associated messages. After sending this message, server will wait for a response from client. This message has no parameters.

Phase 3 Client Authentication and Key Exchange:

Upon receiving server_done message, the client verify that the server provided a valid certificate if required and check that the server_hello parameters are acceptable. If all is satisfactory, the client sends one or more messages back to the server.

If the server has requested a certificate, the client begins this phase by sending a certificate message. If no suitable certificate is available, the client sends a no_certificate alert instead.

Next is the client_key exchange message, which must be sent in this phase. The content of the message depends on the type of key exchange.

Finally in this pahse, the client sends a certificate_verify message to provide explicit verification of a client certificate.

Phase 4 Finish: IT completes the setting up of a secure connection. The client sends a change cipher spec message and copies the pending cipherspec into the current cipherspec. This message is not considered part of the Handshake protocol but is sent using the change cipher spec protocol. The client then immediately sends the finished message under the new algorithms, keys and secrets. The finished message verifies that the key exchange and authentication processes were successful.

Transport Layer Security(TLS):

TLS is very similar to SSL3. The TLS record format is the same as that of the SSL. Record format and the fields in the header have the same meanings. There are two differences between the SSLv3 and TLS MAC schemes: the actual algorithm and the scope of the MAC calculation. TLS makes use of the HMAC algorithm. TLS supports all of the alert codes defined in SSLv3 with the exception of no certificate. A number of additional codes are define in TLS:

- Decryption failed : cipher text decrypted in an invalid way
- Record_overflow: TLS record was receive with a payload
- Unknown_CA: CA is not trusted and is invalid
- Access_denied: A valid certificate was received, but when access control is applied, the sender decided not to proceed with the negotiation.
- Decode_error: A message could not be decoded because a field was out of its specified range or length of the message was incorrect
- Export_restriction: A negotiation not in compliance with export restrictions on key length was detected.

- Protocol version: The protocol version the client attempted to negotiate is recognized but not supported
- Insufficient_security: returned instead of handshake_failure when a negotiation has failed specifically because the server requires ciphers more secure than those supported by the client.
- Internal_error: an internal error unrelated to the peer or correctness of the protocol makes it impossible to continue.

IP SECURITY

Syllabus: IP Security Overview, IP Security Architecture, Authentication Header, Encapsulating Security Payload, Combining Security Associations and Key Management. **Intrusion detection**: Overview, Approaches for IDS/IPS, Signature based IDS, Host based IDS/IPS.

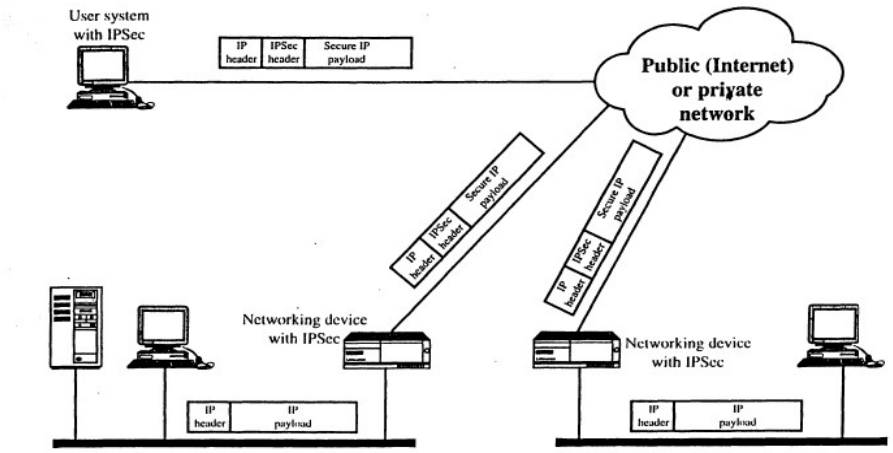
In 1994, the Internet Architecture Board issued a report entitled 'Security in the Internet Architecture". In the year 2001, CERT, Computer Emergency and Response Team analysed 52,000 types of attacks on the Internet. The most serious types of attacks are IP spoofing, eavesdropping and packet sniffing.

IP spoofing: Intruders create packets with false IP addresses and exploit applications that use authentication based on IP

Packet Sniffing: Attackers read transmitted information, including logon information and database contents.

Applications of IP Security:

IP security provides capability to secure communications across a LAN, across private and public WANs, and across the Internet.



An IP Security Scenario.

- **Secure Branch Office connectivity over the Internet:** A company can build a secure virtual private network over the Internet or over a public WAN. This enables the company to rely on the Internet and reduce its need for private networks.
- **Secure Remote access over the Internet**: An end user whose system is equipped with IP Security protocols can make a local call to an Internet Service Provider(ISP) and gain secure access to a company network.

- **Establishing extranet and Intranet connectivity with Partners**: IPSec can be used to secure communications with other organizations, ensuring authentication and confidentiality and providing a key exchange mechanism.
- **Enhancing Electronic Commerce Securit**y: Even though some web and e-commerce applications have built in security protocols, by using IPSec enhances that security.

Benefits of IP Security:

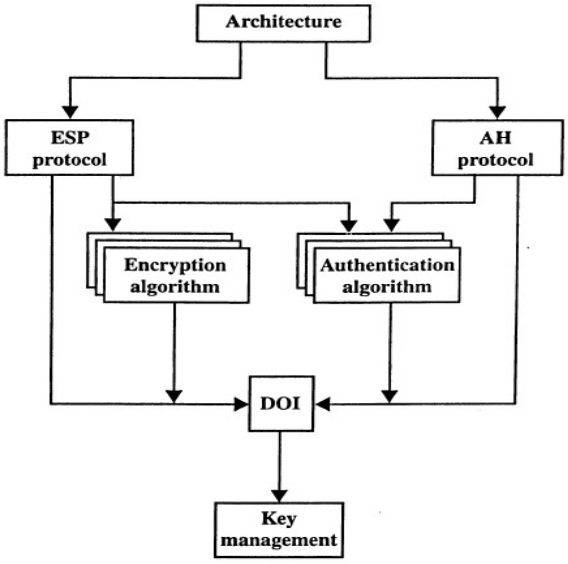
- When IPSec is implemented in a firewall or router, it provides strong security that can be applied to all traffic crossing the perimeter.
- Using IPSec, a firewall is resistant to bypass if all traffic from the outside must use IP, and the firewall is the only means of entrance from the Internet into the organization.
- IPSec is below transport layer and so it is transparent to applications and end users.

Routing Applications:

In addition to supporting end users and protecting premises systems and networks IPsec can play a vital role in the routing architecture required for internetworking.

- A router advertisement and neighbour advertisement comes from an authorized router
- A redirect message comes from the router to which the initial packet was sent
- A routing update is not forged.

IP SECURITY ARCHITECTURE:



IPSec Document Overview.

IP Security contains the following documents:

- IPSec Architecture: Covers the general concepts, security requirements, definitions, and mechanisms defining IPSec technology.

- Encapsulating Security Payload (ESP): Covers the packet format and general issues related the use of ESP for packet encryption and, optionally, authentication.
- Authentication Header(AH):Covers the packet format and general issues related to the use of AH for packet authentication.
- Encryption Algorithm: A set of documents that describe how various encryption algorithms are used for ESP
- Authentication Algorithm: A set if documents that describe how various authentication algorithms are used for AH and for the authentication option of ESP
- Key Management: Documents that describe key management schemes.
- Domain of Interpretation (DOI): Contains values needed for the documents relate to each other. These include identifiers for encryption and authentication algorithms.

IPSec Services: IPSec provides services at the IP layer by enabling a system to select required security protocols, determine the algorithms to use for the service. Two protocols are used to provide security: an authentication protocol (AH) and a combined protocol for encryption/authentication (ESP). the services are:

- Access Control
- Connectionless Integrity
- Data Origin Authentication
- Rejection of replayed packets
- Confidentiality
- Limited Traffic flow confidentiality

The following table lists various services provided by AH and ESP

IPSec Services

	AH	ESP (encryption only)	ESP (encryption plus authentication)
Access control	✔	✔	✔
Connectionless integrity	✔		✔
Data origin authentication	✔		✔
Rejection of replayed packets	✔	✔	✔
Confidentiality		✔	✔
Limited traffic flow confidentiality		✔	✔

Security Associations: A key concept that presents in both the authentication and confidentiality mechanisms for IP is the security association (SA). It is a one-way relation between a sender and a

receiver that affords security services to the traffic carried on it. A security association is uniquely identified by three parameters:

- Security Parameter Index (SPI): A bit string associated to this SA. This filed is present in AH and ESP.
- IP Destination Address: Only unicast addresses are allowed. This is the destination address of SA. Destination may be an end system, network system, firewall or router
- Security Protocol Identifier: Indicates whether the association is an AH or ESP.

SA Parameters:

In each IPSec implementation there is a nominal security association database that define the parameters associated with each SA:

- Sequence Number Counter: A 32-bit value is used to generate the sequence number field in AH or ESP headers.
- Sequence Counter Overflow: A flag which indicates the overflow of sequence numbers
- Anti-Replay Window: Used to find whenther an inbound AH or ESP packet is a replay.
- AH Information: Authentication algorithm, keys, key lifetimes and related parameters in AH
- ESP Information: Encryption and Authentication algorithms, keys, initialization values, key lifetimes, and related parameters.
- Lifetime of this Security Association: A time interval for each SA
- IPSec protocol Mode: Tunnel, transport, or wild card.
- Path MTU: maximum size of a packet.

SA Selectors: IPSec services are applied to IP traffic. Each SA has SPD(Security Policy Database. Each SPD is defined by a set of IP and upper layer protocol field values. The following selectors determine an SPD entry:

- Destination IP Address
- Source IP Address
- User ID: A user id from OS.
- Data Security Level: Used for systems providing information flow security(secret or unclassified)
- Transport Layer protocol:
- IPSec Protocol: (AH, ESP, AH/ESP)
- Source and Destination Ports
- IPV6 class: collected from IPV6 Header

- IPV6 flow Label
- IPV4 Type of Service(TOS)

Transport and Tunnel Modes: Both AH and ESP supports two modes.

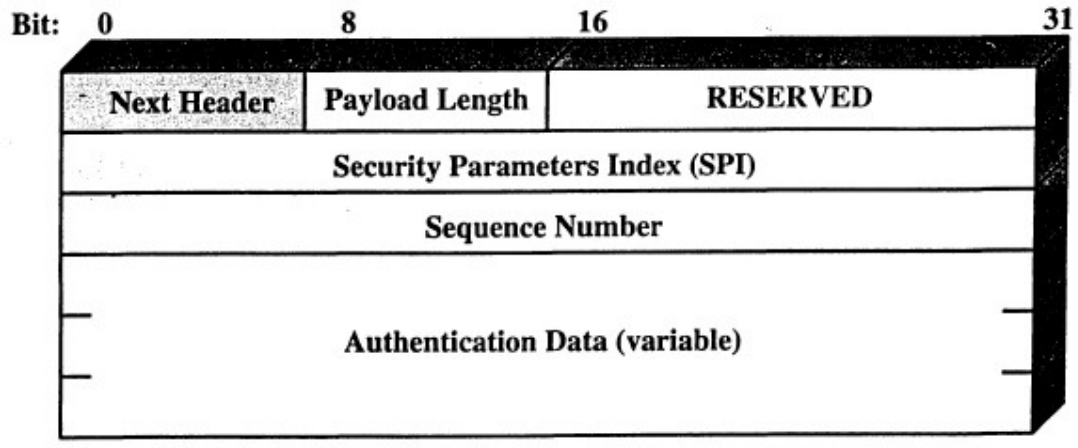
Transport Mode:

- Provides protection for upper layer protocols.
- That is transport mode protection extends to the payload of an IP packet. Ex: TCP,UDP,ICMP
- Transport mode is used to provide end-to-end communication between hosts

Tunnel Mode:

- Provides protection to the entire IP packet.
- After AH, ESP, these headers are added to the IP packet. So that the entire IP packet plus security files is treated as the payload of a new "outer" IP packet.
- The entire original, or inner packet travels through a tunnel from one peer to another peer

Authentication Header (AH): The AH provides support for data integrity and authentication of IP packets. The data integrity feature ensures that undetected modification to a packet's content in transit is not possible. The authentication feature enables an end system or network device to authenticate the user or application and filter traffic. It also prevents the address spoofing attacks. AH also guards against the replay attacks. Authentication is based on Message Authentication Code (MAC). The Authentication Header contains:



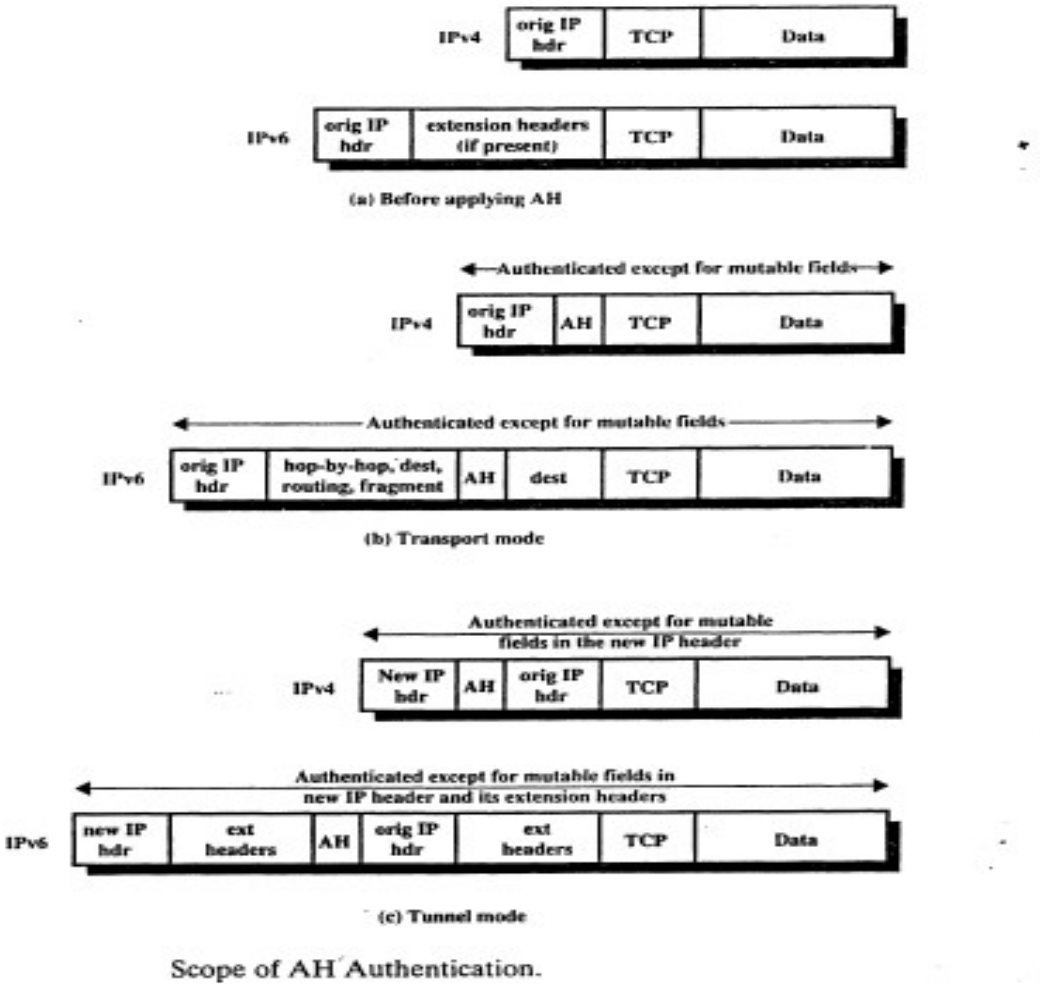
IPSec Authentication Header.

- Next Header (8 bits): Identifies the type of heard immediately following this header
- Payload Length (8 bits): Length of Authentication Header in 32 bit words.

- Reserved (16 bits): These 16 bits are reserved for future purpose.
- Security Parameter Index (32 bits): Identifies a Security Association (SA)
- Sequence Number (32 bits): A 32 bit increasing counter value
- Authentication Data (Variable): A variable length field (must be an integral number of 32-bit words) that contains the Integrity Check Value (ICV) or MAC for the corresponding packet.

AH in Transport and Tunnel Modes:

For transport mode AH using IPv4, the AH is inserted after the original IP header and before the IP payload. Authentication covers the entire packet, excluding mutable fields in the IPv4 header. In IPv6, the AH is viewed as an end-to-end payload; that is, it is not examined or processed by intermediate routers. Therefore, AH appears after IPv6 base header and hop-by-hop, routing and fragmentation extension headers. The destination options header can appear before or after the AH header.



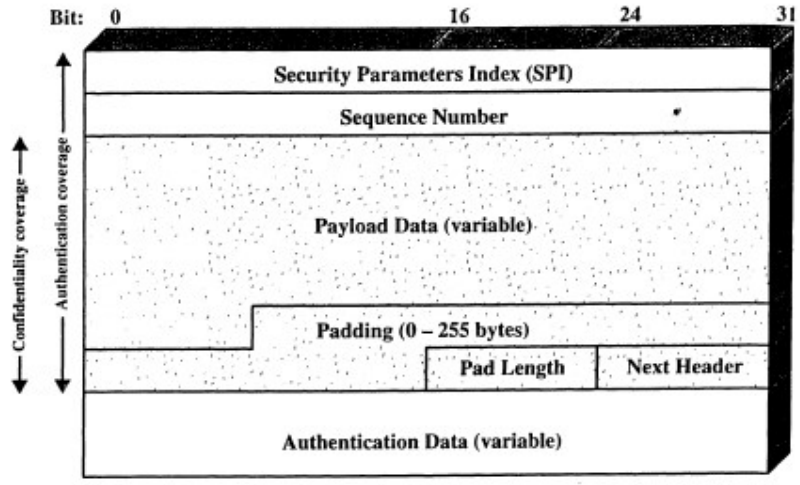
Scope of AH Authentication.

For tunnel mode AH, the entire original IP packet is authenticated and the AH is inserted between the original IP header and a new router IP header. The inner IP header carries the ultimate source and

destination addresses, while an outer IP header contain different IP addresses (firewalls or other security gateways). Therefore, with tunnel mode entire inner IP packet, including the entire inner IP header, is protected by AH. The outer IP header is protected except for mutable and unpredictable fields.

Encapsulating Security Payload: ESP provides confidentiality services including traffic flow confidentiality. ESP can also provide same authentication services as AH.

ESP Format: It contains the following fields:



IPSec ESP Format.

- Security Parameter Index (32 bits): Identifies a security association
- Sequence Number (32 bits): An increasing counter value which provides an anti-replay function.
- Payload Data (variable): This is a transport level segment (transport mode) or IP packet (tunnel mode) protected by encryption.
- Padding: This is of length 0 to 255 bytes
- Pad length (8 bits): Indicates the number of pad bytes immediately preceding this field.
- Next Header (8 bits): Identifies the type of data contained in the payload data field by identifying the first header in that payload.
- Authentication Data (variable): A variable-length field that contains the Integrity Check Value compared over the ESP packet minus the Authentication Data Field.

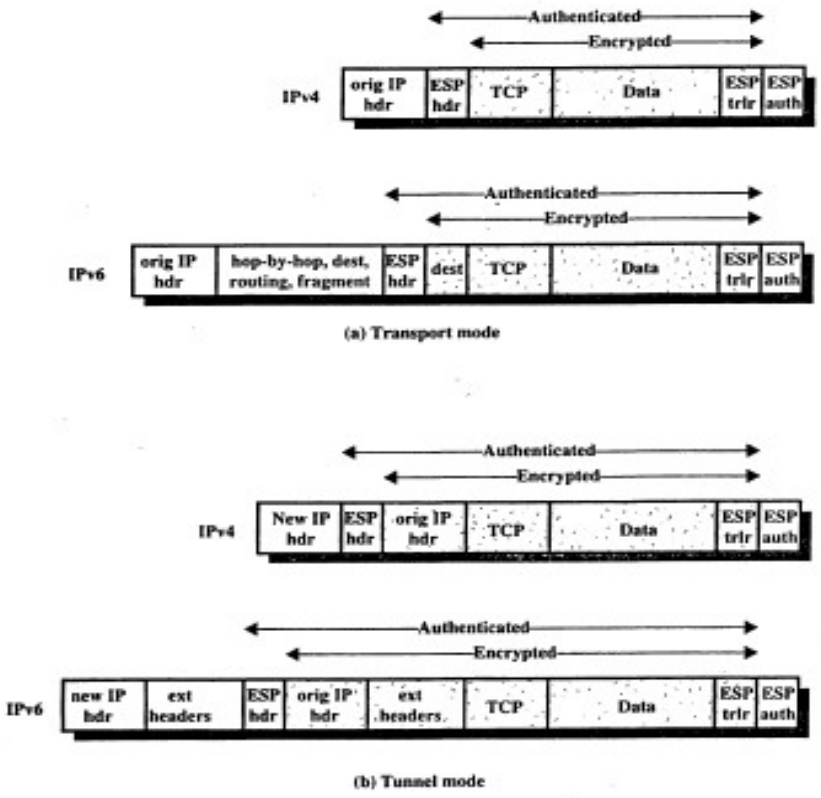
Encryption and Authentication Algorithms in ESP:

Encryption: 3DES, RC5, IDEA, 3key triple IDEA, CAST, Blowfish

Authentication: MAC, HMAC with MD5, HMAC with SHA I

Transport and Tunnel Modes:

Transport mode ESP is used to encrypt and optionally authenticate the data carried by IP(e.g., a TCP segment). For this mode using IPv4, the ESP header is inserted into the IP packet immediately prior to the transport-layer header and an ESP trailer is placed after the IP packet; if authentication is selected, the ESP authentication data field id added after the ESP trailer. The entire transport layer segment plus the ESP trailer are encrypted. Authentication covers all of the cipher text plus the ESP header. In IPv6, the ESP is viewed as an end-to-end payload; that is, it is not examined or processed by intermediate routers. Therefore, ESP appears after IPv6 base header and hop-by-hop, routing and fragmentation extension headers. The destination options header can appear before or after the ESP header. For IPv6 encryption covers the entire transport level segment plus the ESP trailer plus the destination options header if it covers after ESP.

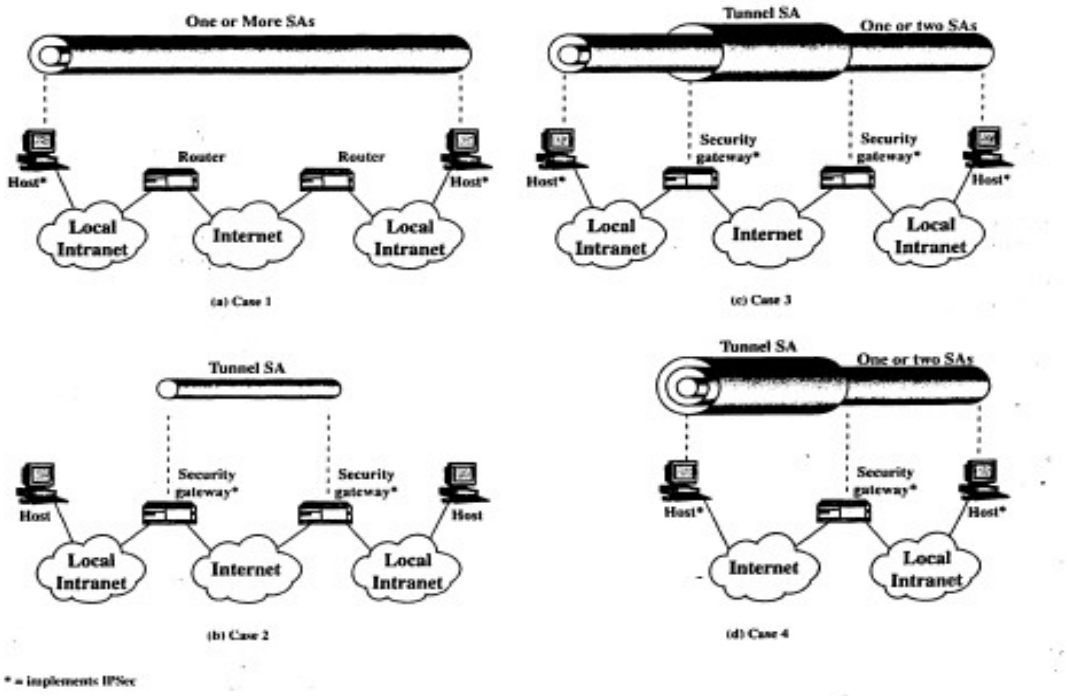


Scope of ESP Encryption and Authentication.

Tunnel mode ESP is used to encrypt an entire IP packet. For this mode, ESP header is prefixed to the packet and then packet plus the ESP trailer is encrypted. This method can be used to counter traffic analysis.

Basic combinations of security Associations:

IPSec architecture lists four examples of combinations of SAs that must support by IPSec hosts. The lower part of each case in the figure represents the physical connectivity of the elements; the upper part represents logical connectivity via one or more nested SAs, the mode may be either transport or tunnel; otherwise it must be tunnel mode.



Basic Combinations of Security Associations.

Case 1: Security is provided between end systems that implement IPSec. For any two end systems to communicate via an SA, they must share the appropriate secret keys. The following are the possible combinations:

- AH in transport mode
- ESP in transport mode
- AH followed by ESP in transport mode
- Any one of a, b, or c inside an AH or ESP in tunnel mode

Case 2: Security is provided only between gateways (routers, firewalls, etc.) and no hosts implement IPSec. It implements simple virtual private network support. The tunnel could support AH, ESP or ESP with its authentication.

Case 3: Built on case 2 by adding end-to-end security. The same combinations used in case 1 and case 2 are allowed here. The gateway-to-gateway tunnel provides either authentication or confidentiality or both for all traffic between end systems.

Case 4: Provides support for a remote host that uses the Internet to reach an organization's firewall and then gain access to some server or workstation behind the firewall. Only tunnel mode is required between the remote host and the firewall.

SYSTEM SECURITY

Intruders: An individual who gains, or attempts to gain, unauthorized access to a computer system or to gain unauthorized privileges on that system.

Password Capture:

- another attack involves **password capture**
  - watching over shoulder as password is entered
  - using a trojan horse program to collect
  - monitoring an insecure network login
    - eg. telnet, FTP, web, email
  - extracting recorded info after successful login (web history/cache, last number dialed etc)
- using valid login/password can impersonate user
- users need to be educated to use suitable precautions/countermeasures

Password Guessing:

- one of the most common attacks
- attacker knows a login (from email/web page etc)
- then attempts to guess password for it
  - defaults, short passwords, common word searches
  - user info (variations on names, birthday, phone, common words/interests)
  - exhaustively searching all possible passwords
- check by login or against stolen password file
- success depends on password chosen by user
- surveys show many users choose poorly

Password Management:

- front-line defense against intruders

- users supply both:
  - login – determines privileges of that user
  - password – to identify them
- passwords often stored encrypted
  - Unix uses multiple DES (variant with salt)
  - more recent systems use crypto hash function
- should protect password file on system

Password Studies:

- Purdue 1992 - many short passwords
- Klein 1990 - many guessable passwords
- conclusion is that users choose poor passwords too often
- need some approach to counter this

Managing Passwords-Education:

- can use policies and good user education
- educate on importance of good passwords
- give guidelines for good passwords
  - minimum length (>6)
  - require a mix of upper & lower case letters, numbers, punctuation
  - not dictionary words
- but likely to be ignored by many users

Computer Generated Passwords:

- let computer create passwords
- if random likely not memorisable, so will be written down (sticky label syndrome)
- even pronounceable not remembered
- have history of poor user acceptance
- FIPS PUB 181 one of best generators
  - has both description & sample code
  - generates words from concatenating random pronounceable syllables

Managing Passwords: Reactive Checking

- reactively run password guessing tools
  - note that good dictionaries exist for almost any language/interest group
- cracked passwords are disabled
- but is resource intensive

- bad passwords are vulnerable till found

Managing Passwords- Proactive Checking:

- most promising approach to improving password security
- allow users to select own password
- but have system verify it is acceptable
    - simple rule enforcement (see earlier slide)
    - compare against dictionary of bad passwords
    - use algorithmic (markov model or bloom filter) to detect poor choices

Intruders are classified into 3 categories

- **Masquerador:** An individual who is not authorized to use the computer and who penetrates a system's access conrols to exploit a legitimate user's account.
- **Misfeasor:** A legitimate user who accesses data, programs or resources for which such access is not authorized, or who is authorized for such access but misuses his or her privileges
- **Clandestine user**: An individual who seizes supervisory control of the system and uses this control to evade auditing and access controls or to suppress audit collection.

Intrusion Techniques:

- aim to gain access and/or increase privileges on a system
- basic attack methodology
    - target acquisition and information gathering
    - initial access
    - privilege escalation
    - covering tracks
- key goal often is to acquire passwords
- so then exercise access rights of owner

Intrusion Detection:

- inevitably will have security failures
- so need also to detect intrusions so can
    - block if detected quickly
    - act as deterrent
    - collect info to improve security
- assume intruder will behave differently to a legitimate user
    - but will have imperfect distinction between
- statistical anomaly detection
    - threshold

- profile based

- rule-based detection
  - anomaly
  - penetration identification

Audit Records:

- fundamental procedure for intrusion detection
- native audit records
  - part of all common multi-user O/S
  - already present for use
  - may not have info wanted in desired form
- detection-specific audit records
  - created specifically to collect wanted info
  - at cost of additional overhead on system

Statistical Anomaly Detection:

- threshold detection
  - count occurrences of specific event over time
  - if exceed reasonable value assume intrusion
  - alone is a crude & ineffective detector
- profile based
  - characterize past behavior of users
  - detect significant deviations from this
  - profile usually multi-parameter

Analysis:

- foundation of statistical approaches
- analyze records to get metrics over time
  - counter, gauge, interval timer, resource use
- use various tests on these to determine if current behavior is acceptable
  - mean & standard deviation, multivariate, markov process, time series, operational
- key advantage is no prior knowledge used

Rule-Based Intrusion Detection:

- observe events on system & apply rules to decide if activity is suspicious or not
- rule-based anomaly detection
  - analyze historical audit records to identify usage patterns & auto-generate rules for them

- then observe current behavior & match against rules to see if conforms
- like statistical anomaly detection does not require prior knowledge of security flaws

➢ rule-based penetration identification

- uses expert systems technology
- with rules identifying known penetration, weakness patterns, or suspicious behavior
- compare audit records or states against rules
- rules usually machine & O/S specific
- rules are generated by experts who interview & codify knowledge of security admins quality depends on how well this is done

Base Rate Fallacy:

➢ practically an intrusion detection system needs to detect a substantial percentage of intrusions with few false alarms

- if too few intrusions detected -> false security
- if too many false alarms -> ignore / waste time

➢ this is very hard to do

➢ existing systems seem not to have a good record

Distributed Intrusion Detection:

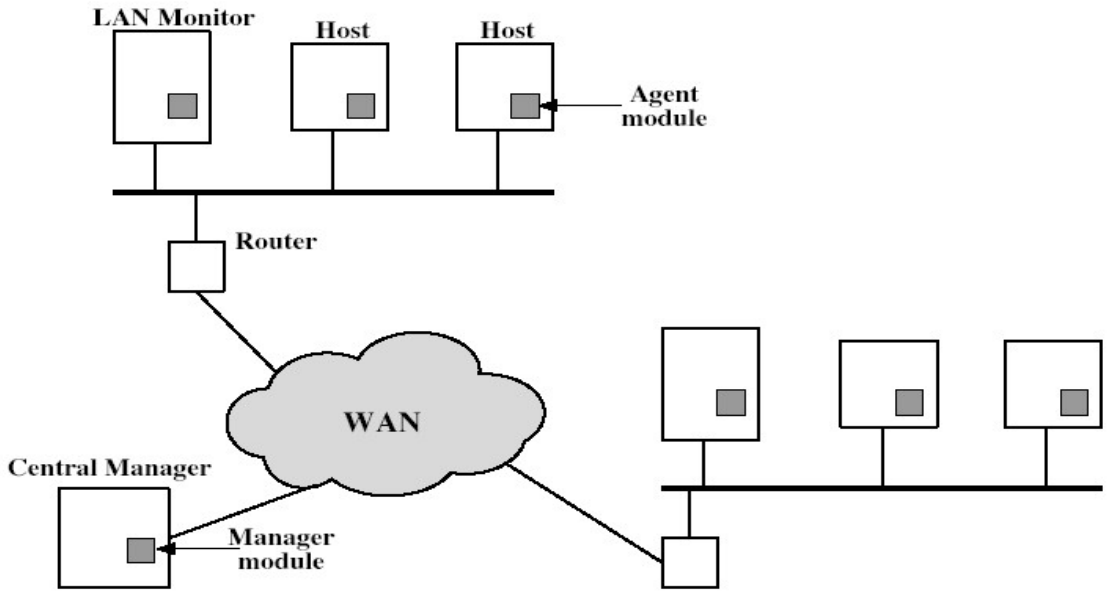
➢ traditional focus is on single systems

➢ but typically have networked systems

➢ more effective defense has these working together to detect intrusions

➢ issues

- dealing with varying audit record formats
- integrity & confidentiality of networked data
- centralized or decentralized architecture



Host Agent Module: Collects data on security related events on the host and transmit these to the central manager.

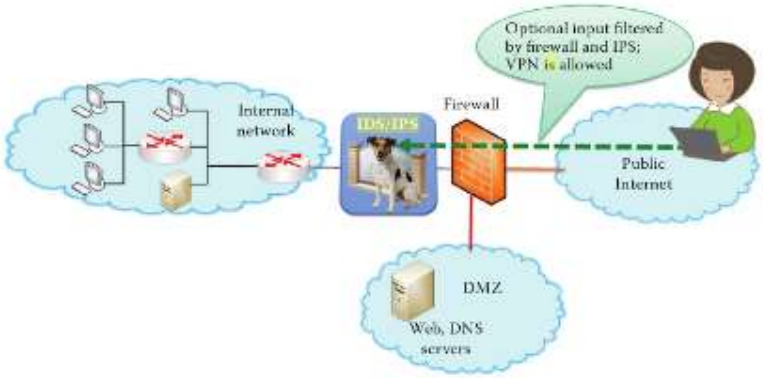
LAN Monitor agent module: Operates like a host agent module except that it analyses LAN traffic and reports the results to the central manager.

Central Manager Module: Receives reports from LAN monitor and host agents processes and correlates these reports to detect intrusion.

Honeypots:

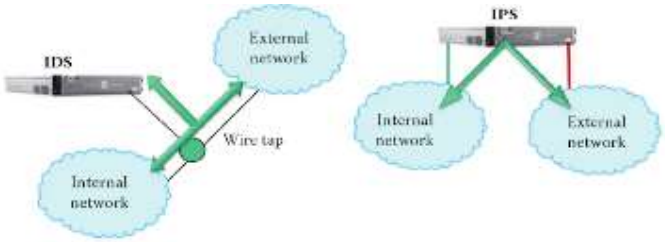
- decoy systems to lure attackers
  - away from accessing critical systems
  - to collect information of their activities
  - to encourage attacker to stay on system so administrator can respond
- are filled with fabricated information
- instrumented to collect detailed information on attackers activities
- single or multiple networked systems
- cf IETF Intrusion Detection WG standards

An Intrusion Detection/Prevention system provides a deep packet inspection at the entrance of network. This system is positioned behind the firewall as shown in the following diagram.



Positioning IDS/IPS in a system.

VPN (virtual private network) is permitted to pass firewall and IDS/IPS, since traffic is normally encrypted and authenticated. It provides deep inspection for the pay loads. IDS is based on out-of-band detection of intrusions and their reporting, and IPS in in-band-filtering to block intrusions. The following figure shows the difference between IDS and IPS.



Intrusion Detection System (IDS): The IDS is software or an appliance that detects a threat, unauthorized or malicious network traffic. IDS has their own predefined rule sets, through that it can inspect the configuration of endpoints to determine whether they may be susceptible to attack (this is known as host-based IDS), and also it can record activities across a network and compare it to known attacks or attack patterns (this is called network-based IDS). The purpose of intrusion detection is to provide monitoring, auditing, forensics, and reporting of network malicious activities.

- Preventing network attacks
- Identifying the intruders
- Preserving logs in case the incident leads to criminal prosecution

Intrusion Prevention System (IPS): The IPS are not only detect the bad packets caused by malicious codes, botnets, viruses and targeted attacks, but also it can take action to prevent those

network activity from causing damage on network. The attacker's main motive is to take sensitive data or intellectual property, through that they interested 4 in whatever they can get from customer data like employee information, financial records etc. The IPS is specified to provide protection for assets, resources, data, and networks.

- IPS stops the attack itself
- IPS changes the security environment