UNIT-V

Email Privacy: Pretty Good Privacy (PGP) and S/MIME. **IP Security:** IP Security Overview, IP Security Architecture, Authentication Header, Encapsulating Security Payload, Combining Security Associations and Key Management.

PRETTY GOOD PRIVACY:

In virtually all distributed environments, electronic mail is the most heavily used network-based application. But current email services are roughly like "postcards", anyone who wants could pick it up and have a look as it's in transit or sitting in the recipients mailbox. PGP provides a confidentiality and authentication service that can be used for electronic mail and file storage applications. With the explosively growing reliance on electronic mail for every conceivable purpose, there grows a demand for authentication and confidentiality services. The Pretty Good Privacy (PGP) secure email program, is a remarkable phenomenon, has grown explosively and is now widely used. Largely the effort of a single person, Phil Zimmermann, who selected the best available crypto algorithms to use& integrated them into a single program, PGP provides a confidentiality and authentication service that can be used for electronic mail and file storage applications. It is independent of government organizations and runs on a wide range of systems, in both free & commercial versions. There are **five** important services in PGP.

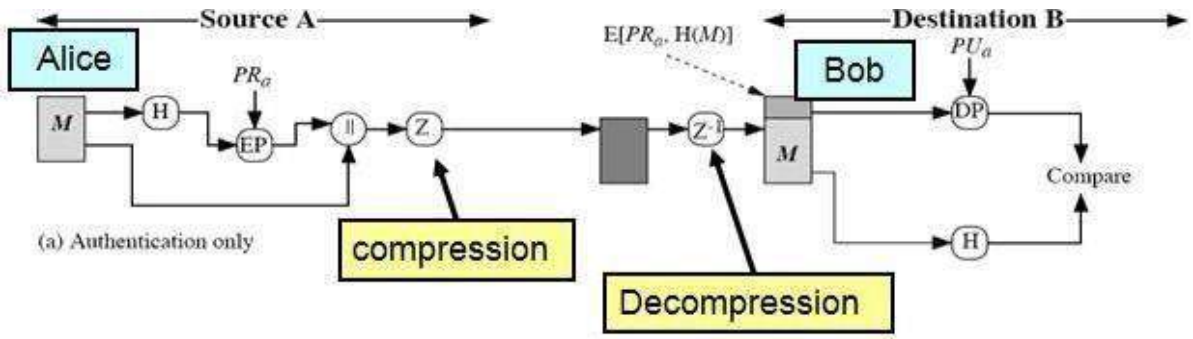
Authentication (Sign/Verify) Confidentiality (Encryption/Decryption) CompressionEmail compatibility Segmentation and Reassembly

The last three are transparent to the user

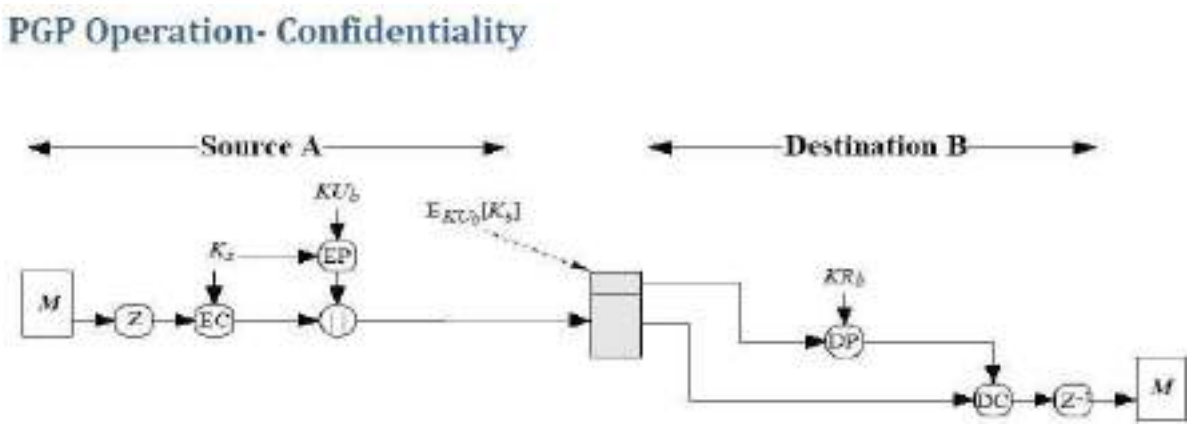
PGP Notations:

Ks	Session key used in Symmetric encryption Scheme
PRa	=private key of user A, used in public-key Encryption Scheme
PUa	=public key of user A, used in public-key Encryption Scheme
EP	= public-key encryption
DP	= public-key decryption
EC	= symmetric encryption
DC	= symmetric decryption
H	= hash function
||	= concatenation
Z	=compression using ZIP Algorithm
R64	= conversion to radix 64 ASCII format

PGP Notations:

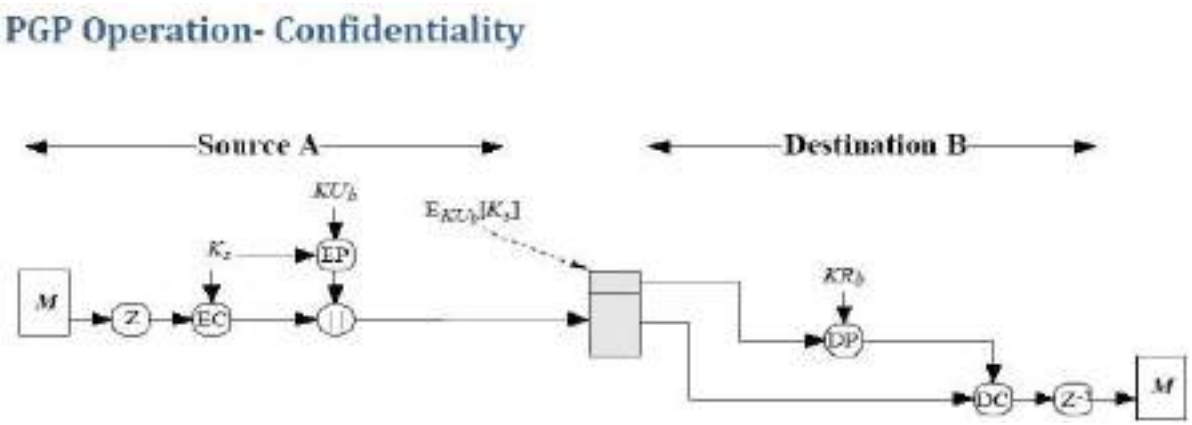


PGP Operation- Authentication:



1. sender creates message
2. use SHA-1 to generate 160-bit hash of message
3. signed hash with RSA using sender's private key, and is attached to message
4. receiver uses RSA with sender's public key to decrypt and recover hash code
5. receiver verifies received message using hash of it and compares with decrypted hash code

PGP Operation- Confidentiality:



Sender:

1. Generates message and a random number (session key) only for this message
2. Encrypts message with the session key using AES, 3DES, IDEA orCAST-128
3. Encrypts session key itself with recipient's public key using RSA
4. Attaches it to message

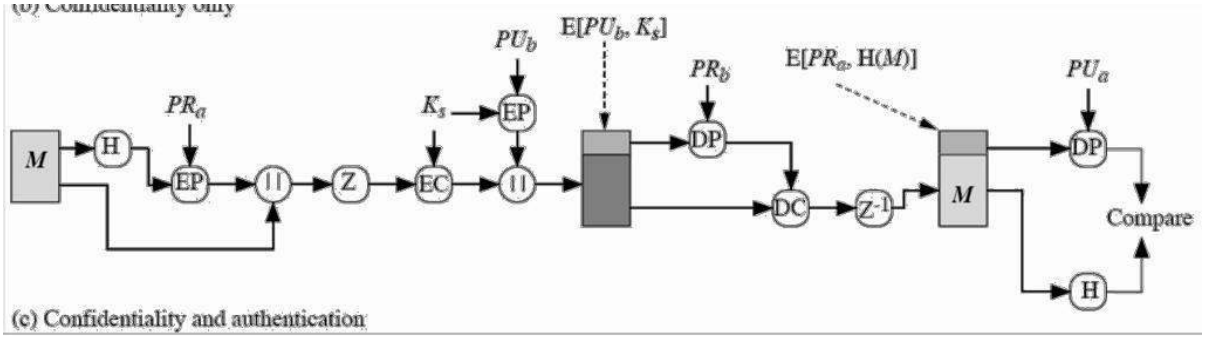
Receiver:

Recovers session key by decrypting using his private key

Decrypts message using the session key

Confidentiality service provides no assurance to the receiver as to the identity of sender (i.e. no authentication). Only provides confidentiality for sender that only the recipient can read the message (and no one else)

PGP Operation – Confidentiality & Authentication:



can use both services on same message o create signature & attach to message o

Encrypt both message & signature attach RSA/ElGamal encrypted session key

is called authenticated confidentiality.

PGP Operation – Compression

As a default, PGP compresses the message after applying the signature but before encryption. This has the benefit of saving space both for e-mail transmission and for file storage. The placement of the compression algorithm, indicated by Z for compression and Z-1 for decompression is critical. The compression algorithm used is ZIP.

The signature is generated before compression for two reasons:

1.so that one can store only the uncompressed message together with signature for later verification

2.Applying the hash function and signature after compression would constrain all PGP implementations to the same version of the compression algorithm as the PGP compression algorithm is not deterministic.

Message encryption is applied after compression to strengthen cryptographic security. Because the compressed message has less redundancy than the original plaintext, cryptanalysis is more difficult.

PGP Operation – Email Compatibility

When PGP is used, at least part of the block to be transmitted is encrypted, and thus consists of a stream of arbitrary 8-bit octets. However many electronic mail systems only permit the use of ASCII a stream of printable ASCII characters.

It uses radix-64 conversion, in which each group of text.

To accommodate this restriction, PGP provides these rvice of converting the raw 8-bit binary stream three octets of binary data is mapped into four ASCII characters. This format also appends a CRC to detect transmission errors. The use of radix 64 expands a message by 33%, but still an overall compression of about one-third can be achieved.

PGP Operation - Segmentation/Reassembly

E-mail facilities often are restricted to a maximum message length. For example, many of the facilities accessible through the Internet impose a maximum length of 50,000 octets. Any message longer than that must be broken up into smaller segments, each of which is mailed separately. To accommodate this restriction, PGP automatically subdivides a message that is too large into segmentsthat are small enough to send via e-mail. The segmentation is done after all of the other processing, including the radix-64 conversion. Thus, the session key component and signature component appearonly once, at the beginning of the first segment.

Reassembly at the receiving end is required before verifying signature or decryption

PGP Operations – Summary

Function	Algorithms Used	Description
Digital signature	DSS/SHA or RSA/SHA	A hash code of a message is created using SHA-1. This message digest is encrypted using DSS or RSA with the sender's private key, and included with the message.
Message encryption	CAST or IDEA or Three-key Triple DES with Diffie-Hellman or RSA	A message is encrypted using CAST-128 or IDEA or 3DES with a one-time session key generated by the sender. The session key is encrypted using Diffie-Hellman or RSA with the recipient's public key, and included with the message.
Compression	ZIP	A message may be compressed, for storage or transmission, using ZIP.
Email compatibility	Radix 64 conversion	To provide transparency for email applications, an encrypted message may be converted to an ASCII string using radix 64 conversion.
Segmentation	—	To accommodate maximum message size limitations, PGP performs segmentation and reassembly.

PGP Message Format

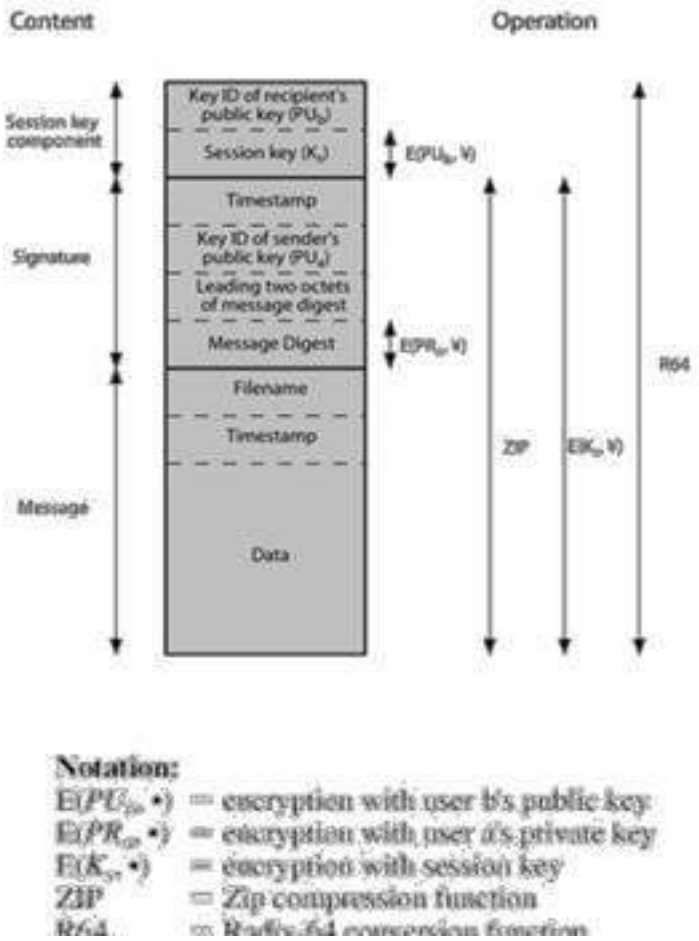
A message consists of three components: the message component, a signature (optional), and a session key component (optional). The *message component* includes the actual data to be stored or transmitted, as well as a filename and a timestamp that specifies the time of creation. The *signature component* includes the following:

Timestamp: The time at which the signature was made.

Message digest: The 160-bit SHA-1 digest, encrypted with the sender's private signature key.

Leading two octets of message digest: To enable the recipient to determine if the correct public keywas used to decrypt the message digest for authentication, by comparing this plaintext copy of thefirst two octets with the first two octets of the decrypted digest. These octets also serve as a 16-bitframe check sequence for the message.

Key ID of 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

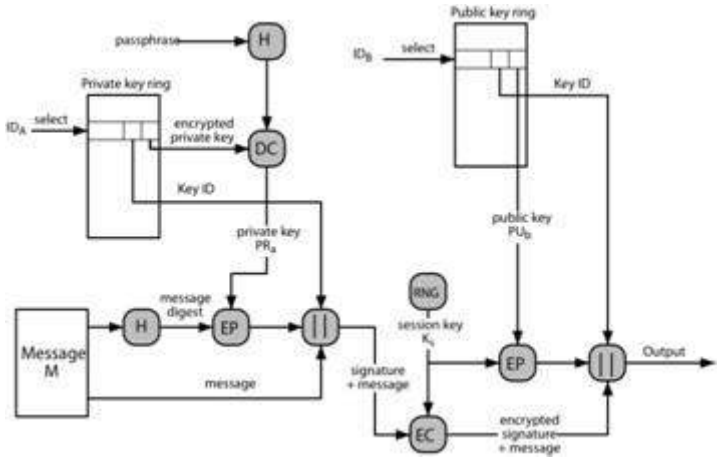


The *session key component* includes the session key and the identifier of the recipient's public key that was used by the sender to encrypt the session key. The entire block is usually encoded with radix-64 encoding.

PGP Message Transmission and Reception

Message transmission:

The following figure shows the steps during message transmission assuming that the message is to be both signed and encrypted.



The sending PGP entity performs the following steps:

Signing the message:

a. PGP retrieves the sender's private key from the private-key ring using your user id as anindex. If your user id was not provided in the command, the first private key on the ring is retrieved.

b. PGP prompts the user for the passphrase to recover the unencrypted private key.

c. Thesignature component of the message is constructed

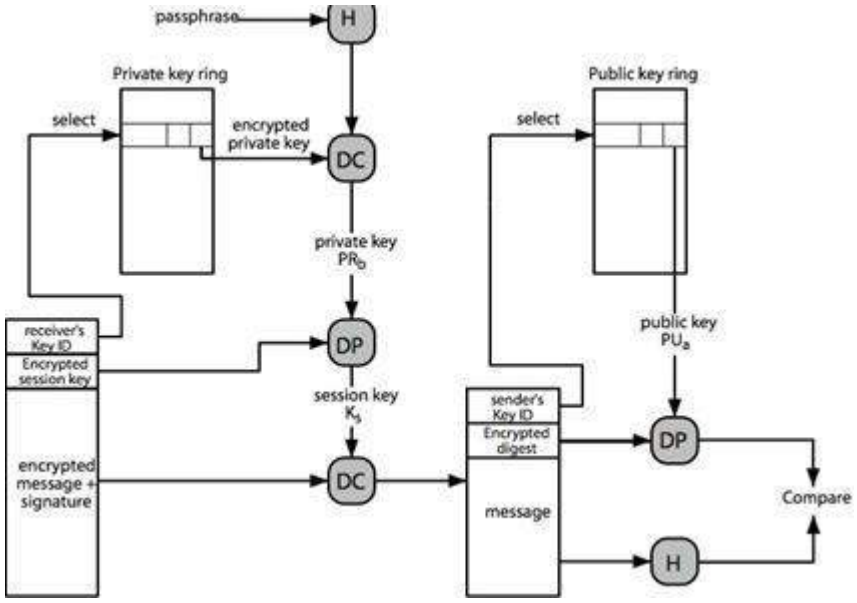
Encrypting the message:

a. PGP generates a session key and encrypts the message.

b. PGP retrieves the recipient's public key from the public-key ring using her_user id as an index.

c. The session key component of the message is constructed.

Message Reception :



The receiving PGP entity performs the following steps:

Decrypting the message:

a. PGP retrieves the receiver's private key from the private-key ring, using the Key ID field in the session key component of the message as an index.

b. PGP prompts the user for the passphrase to recover the unencrypted private key.

PGP then recovers the session key and decrypts the message.

Authenticating the message:

a. PGP retrieves the sender's public key from the public-key ring, using the Key ID field in the signature key component of the message as an index.

b. PGP recovers the transmitted message digest.

PGP computes the message digest for the received message and compares it to the transmitted message digest to authenticate

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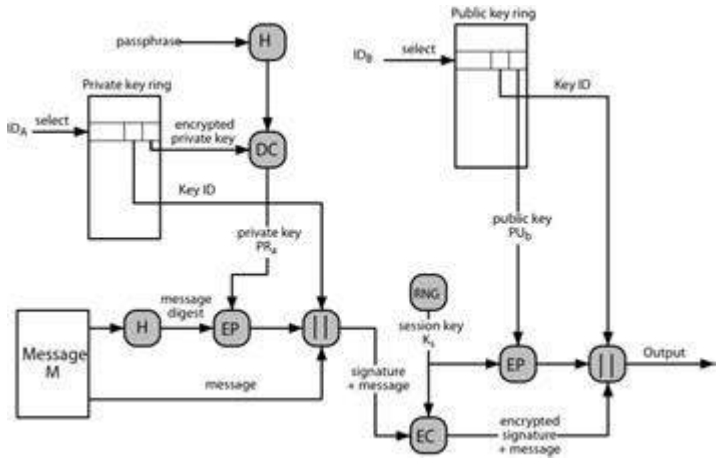
PGP Message Transmission and Reception



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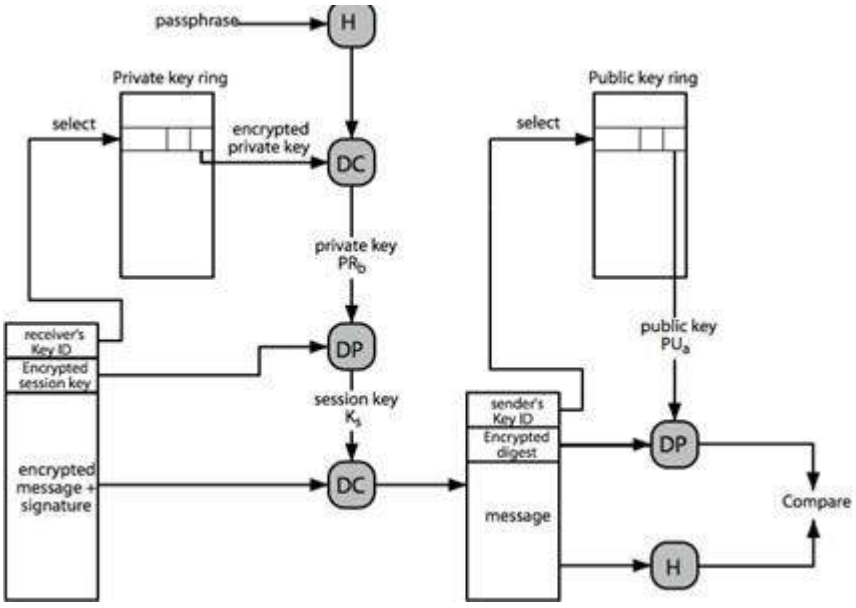

The receiving PGP entity performs the following steps:

Decrypting the message

a. PGP retrieves the receiver's private key from the private-key ring, using the Key ID field in the session key component of the message as an index.

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b. PGP then recovers the session key and decrypts the message.

Authenticating the message

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b. PGP recovers the transmitted message digest.

c.PGP computes the message digest for the received message and compares it to the transmitted message digest to authenticate.

S/MIME

- Stands for Secure/Multipurpose Internet Mail Extension
- Security enhancement to the MIME internet e-mail format

The MIME specification includes the following elements:

1.Five new message header fields are defined, which provide information about the body of the message.

2.A number of content formats are defined, thus standardizing representations that support multimedia electronic mail.

Transfer encodings are defined that protect the content from alteration by the mail system.

MIME - New header fields The five header fields defined in MIME are as follows:

MIME-Version: Must have the parameter value 1.0. This field indicates that the message conforms to RFCs 2045 and2046.

Content-Type: Describes the data contained in the body with sufficient detail that the receiving user agent can pick an appropriate agent or mechanism to represent the data to the user or otherwise deal with the data in an appropriate manner.

Content-Transfer-Encoding: Indicates the type of transformation that has been used to represent the body of the message in a way that is acceptable for mail transport.

Content-ID: Used to identify MIME entities uniquely in multiple contexts.

***Content-Description*:** A text description of the object with the body; this is useful when the object is not readable (e.g., audiodata).

MIME Content Types

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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.

MIME – Content Transferring Encoding

- Two types

– Quoted printable

- Used when data consists largely of octets.
- Limits message lines to 76 characters.

– Base64 transfer encoding
Common for encoding arbitrary binary data

S/MIME Functionality

S/MIME has a very similar functionality to PGP. Both offer the ability to sign and/or encrypt messages.

Functions

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.

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 base64 encoding. A signed data message can only be viewed by a recipient with S/MIME capability.

Clear-signed data: As with signed data, a digital signature of the content is formed. However, in this case, only the digital signature is encoded using base64. As a result, recipients without S/MIME capability can view the message content, although they cannot verify the signature.

Signed 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 – Cryptographic Algorithms

- Create message digest to form digital signature
  - Must use SHA-1, Should support MD5
- Encrypt message digest to form signature
  - Must support DSS, Should support RSA
- Encrypt session key for transmission
  - Should support Diffie-Hellman, Must support RSA
- Encrypt message for transmission with one-time session key
  - Must support triple DES, Should support AES, Should support RC2/40
- Create a message authentication code
  - Must support HMAC with SHA-1, Should support HMAC with SHA-1

S/MIME – User Agent Role

- Key generation
  - Generating key with RSA
- Registration
  - Register a user's public key must be registered with a certification authority
- Certificate storage and retrieval

Access to a local list of certificates in order to verify incoming signatures and encrypt outgoing

S/MIME – Enhanced Security Services

- Signed receipts
  - The receiver returns a signed receipt back to the sender to verify the message arrived
- Security labels
  - Permission, priority or role of message being sent
- Secure mailing lists
  - Sending to multiple recipients at once securely by using a public key for the whole mailing list.

MIME Transfer Encodings

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.

Native Form	The body to be transmitted is created in the system's native format. The native character set is used and, where appropriate, local end-of-line conventions are used as well. The body may be a UNIX-style text file, or a Sun raster image, or a VMS indexed file, or audio data in a system-dependent format stored only in memory, or anything else that corresponds to the local model for the representation of some form of information. Fundamentally, the data is created in the "native" form that corresponds to the type specified by the media type.
Canonical Form	The entire body, including "out-of-band" information such as record lengths and possibly file attribute information, is converted to a universal canonical form. The specific media type of the body as well as its associated attributes dictate the nature of the canonical form that is used. Conversion to the proper canonical form may involve character set conversion, transformation of audio data, compression, or various other operations specific to the various media types. If character set conversion is involved, however, care must be taken to understand the semanties of the media type, which may have strong implications for any character set conversion (e.g. with regard to syntactically meaningful characters in a text subtype other than "plain").

IP SECURITY OVERVIEW

Definition: Internet Protocol security (IPSec) is a framework of open standards for protecting communications over Internet Protocol (IP) networks through the use of cryptographic security services. IPSec supports network-level peer authentication, data origin authentication, data integrity, data confidentiality (encryption), and replay protection.

Need for IPSec

In Computer Emergency Response Team (CERT)'s 2001 annual report it listed 52,000 security incidents in which most serious types of attacks included IP spoofing, in which intruders create packets with false IP addresses and exploit applications that use authentication based on IP and various forms of eavesdropping and packet sniffing, in which attackers read transmitted information, including logon information and database contents. In response to these issues, the IAB included authentication and encryption as necessary security features in the next-generation IP i.e. IPv6.

Applications of IPSec

IPSec provides the capability to secure communications across a LAN, across private and publicwide area networks (WAN's), and across the Internet.

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 a business to rely heavily on the Internet and reduce its need for private networks, saving costs and network management overhead.

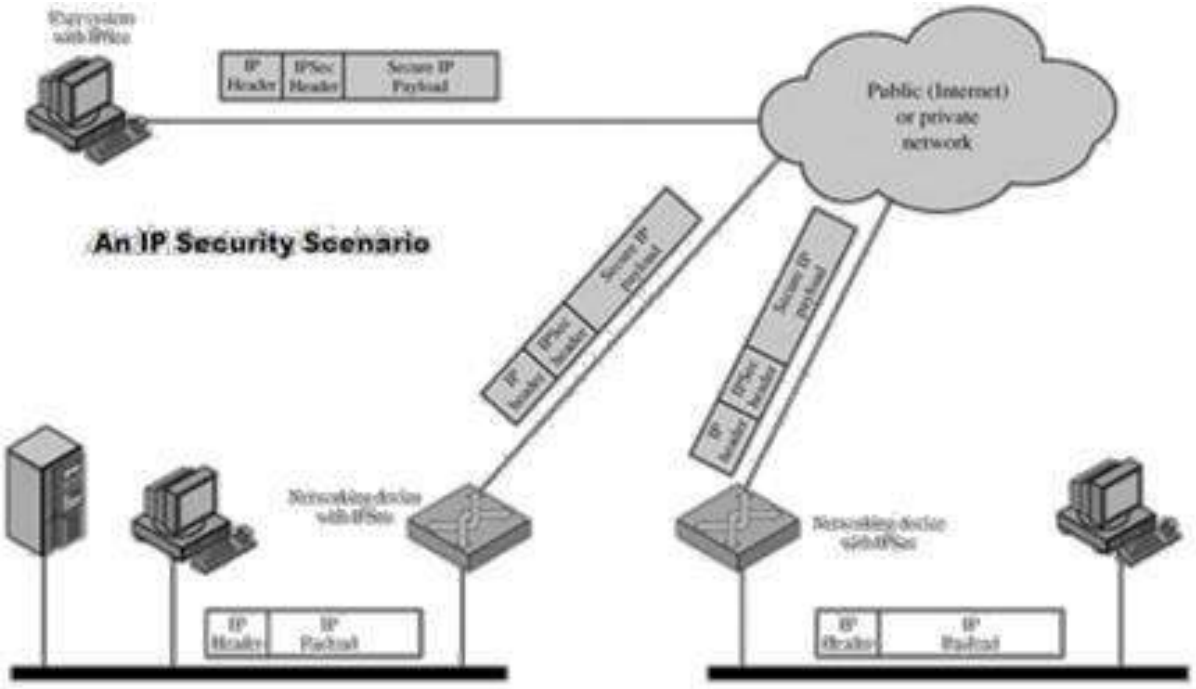
Secure remote access over the Internet: An end user whose system is equipped with IP security protocols can make a local call to an Internet service provider (ISP) and gain secure access to a company network. This reduces the cost of toll charges for travelling employees and telecommuters.

Establishing extranet and intranet connectivity with partners: IPSec can be used to secure communication with other organizations, ensuring authentication and confidentiality and providing a key exchange mechanism.

Enhancing electronic commerce security: Even though some Web and electronic commerce applications have built-in security protocols, the use of IPSec enhances that security.

The principal feature of IPSec enabling it to support varied applications is that it can encrypt and/or authenticate all traffic at IP level. Thus, all distributed applications, including remote logon, client/server, e-mail, file transfer, Web access, and so on, can be secured.

The following figure shows a typical scenario of IPSec usage. An organization maintains LANs at dispersed locations. Non secure IP traffic is conducted on each LAN.



The IPSec protocols operate in networking devices, such as a router or firewall that connect each LAN to the outside world. The IPSec networking device will typically encrypt and compress all traffic going into the WAN, and decrypt and decompress traffic coming from the WAN; these operations are transparent to workstations and servers on the LAN. Secure transmission is also possible with individual users who dial into the WAN. Such user workstations must implement the IPSec protocols to provide security.

Benefits of IPSec

The benefits of IPSec are listed below:

- IPSec in a firewall/router provides strong security to all traffic crossing theperimeter
- IPSec in a firewall is resistant to by pass
- IPSec is below transport layer(TCP,UDP), hence transparent to applications
- IPSec can be transparent to end users
- IPSec can provide security for individual users if needed (useful for offsite workers and setting up a secure virtual subnet work for sensitive applications)

Routing Applications:

IPSec also plays a vital role in the routing architecture required for internetworking. It assures that:

- router advertisements come from authorized routers
- neighbor advertisements come from authorized routers
- redirect messages come from the router to which initial packet was sent
- A routing update is not forged.

IP SECURITY ARCHITECTURE

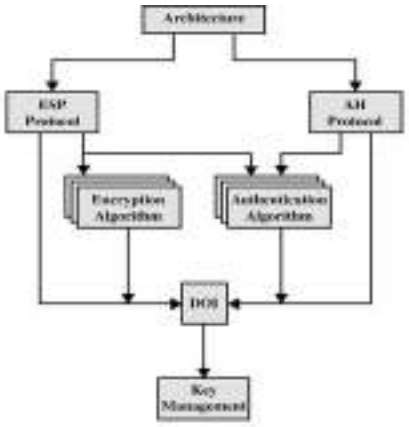
To understand IP Security architecture, we examine IPSec documents first and then move on to IPSec services and Security Associations.

IPSec Documents

The IPSec specification consists of numerous documents. The most important of these, issued in November of 1998, are RFCs 2401, 2402, 2406, and 2408:

- RFC 2401: An overview of a security architecture
- RFC 2402: Description of a packet authentication extension to IPv4 andIPv6
- RFC 2406: Description of a packet encryption extension to IPv4 andIPv6
- RFC 2408: Specification of key management capabilities

Support for these features is mandatory for IPv6 and optional for IPv4. In both cases, the security features are implemented as extension headers that follow the main IP header. The extension header for authentication is known as the Authentication header; that for encryption is known as the Encapsulating Security Payload (ESP) header. In addition to these four RFCs, a number of additional drafts have been published by the IP Security Protocol Working Group set up by the IETF. The documents are divided into seven groups, as depicted in following figure:



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 to theuse of the ESP for packet encryption and, optionally, authentication.

Authentication Header (AH): Covers the packet format and general issues related to the use of AHfor packet authentication.

Encryption Algorithm: Aset of documents that describe how various encryption algorithms are used for ESP.

Authentication Algorithm: A set of 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 other documents to relate to each other. These include identifiers for approved encryption and authentication algorithms, as well as operational parameters such as key lifetime.

IPSec Services

IPSec architecture makes use of two major protocols (i.e., Authentication Header and ESP protocols) for providing security at IP level. This facilitates the system to beforehand choose an algorithm to be implemented, security protocols needed and any cryptographic keys required to provide requested services. The IPSec services are as follows:

Connectionless Integrity:-Data integrity service is provided by IPSec via AH which prevents the data from being altered during transmission.

Data Origin Authentication :- This IPSec service prevents the occurrence of replay attacks, address spoofing etc.

Access Control:- The cryptographic keys are distributed and the traffic flow is controlled in both AH and ESP protocols, which is done to accomplish access control over the data transmission.

confidentiality:- Confidentiality on the data packet is obtained by using an encryption technique in which all the data packets are transformed into ciphertext packets which are unreadable and difficult to understand.

Limited Traffic Flow Confidentiality:- This facility or service provided by IPSec ensures that the confidentiality is maintained on the number of packets transferred or received. This can be done using padding in ESP

Replay packets Rejection:- The duplicate or replay packets are identified and discarded using the sequence number field in both AH and ESP.

	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

Since IPSEC is designed to be able to use various security protocols, it uses Security Associations (SA) to specify the protocols to be used. SA is a database record which specifies security parameters controlling security operations. They are referenced by the sending host and established by the receiving host. An index parameter called the Security Parameters Index (SPI) is used. SAs are in one direction only and a second SA must be established for the transmission to be bi-directional. A security association is uniquely identified by three parameters:

Security Parameters Index (SPI): A bit string assigned to this SA and having local significance only. The SPI is carried in AH and ESP headers to enable the receiving system to select the SA under which a received packet will be processed.

IP Destination Address: Currently, only unicast addresses are allowed; this is the address of the destination endpoint of the SA, which may be an end user system or a network system such as a firewall or router.

Security Protocol Identifier: This indicates whether the association is an AH or ESP security association.

SA Parameters

In each IPSec implementation, there is a nominal Security Association Database that defines the parameters associated with each SA. A security association is normally defined by the following parameters:

Sequence Number Counter: A 32-bit value used to generate the Sequence Number field in AH or ESP headers

Sequence Counter Overflow: A flag indicating whether overflow of the Sequence Number Counter should generate an auditable event and prevent further transmission of packets on this SA (required for all implementations).

Anti-Replay Window: Used to determine whether an inbound AH or ESP packet is a replay

AH Information: Authentication algorithm, keys, key lifetimes, and related parameters being used with AH (required for AH implementations).

ESP Information: Encryption and authentication algorithm, keys, initialization values, key lifetimes, and related parameters being used with ESP (required for ESP implementations).

Lifetime of This Security Association: A time interval or byte count after which an SA must be replaced with a new SA (and new SPI) or terminated, plus an indication of which of these actions should occur (required for all implementations).

IPSec Protocol Mode: Tunnel, transport, or wildcard (required for all implementations).

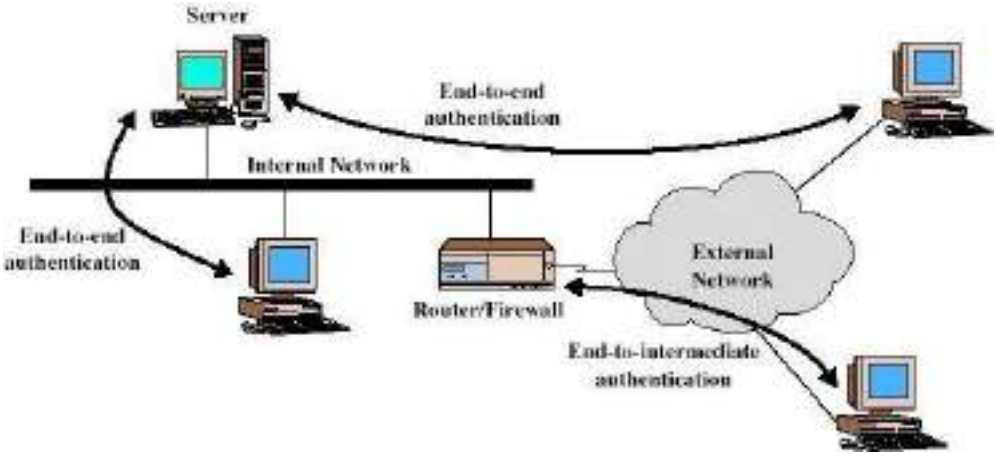
Path MTU: Any observed path maximum transmission unit (maximum size of a packet that can be transmitted without fragmentation) and aging variables (required for all implementations).

TRANSPORT AND TUNNEL MODE

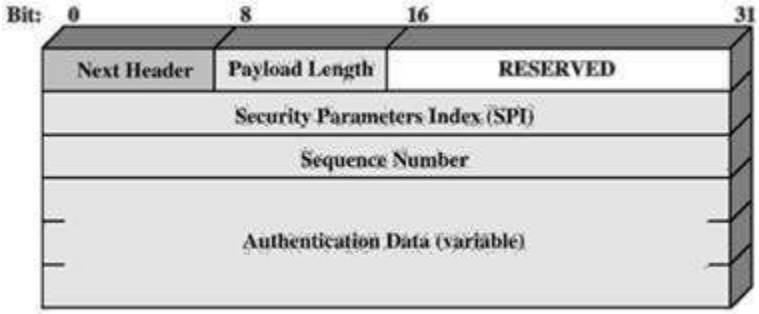
Both AH and ESP support two modes of use: transport and tunnel mode.

	Transport Mode SA	**Tunnel Mode SA**
AH	**Authenticates** IP payload and selected portions of IP header and IPv6 extension Headers	**Authenticates** entire inner IP packet plus selected portions of outer IP header
ESP	**Encrypts** IP payload and any IPv6 extesion header	**Encrypts** inner IP packet
ESP with authentication	**Encrypts** IP payload and any IPv6 extesion header. **Authenticates** IP payload but no IP header	**Encrypts** inner IP packet. **Authenticates** inner IP packet

AUTHENTICATION HEADER



The Authentication Header 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 accordingly; it also prevents the address spoofing attacks observed in today's Internet. The AH also guards against the replay attack. Authentication is based on the use of a message authentication code (MAC), hence the two parties must share a secret key. The Authentication Header consists of the following fields:



- **Next Header (8 bits):** Identifies the type of header immediately following this header.

Payload Length (8 bits): Length of Authentication Header in 32-bit words, minus 2. For example, the default length of the authentication data field is 96 bits, or three 32-bit words.

With a three-word fixed header, there are a total of six words in the header, and the Payload Length field hasa value of 4 .

- **Reserved (16 bits):** For future use.
- **Security Parameters Index (32 bits):** Identifies a security association.

Sequence Number (32 bits): A monotonically increasing counter value, discussed later.

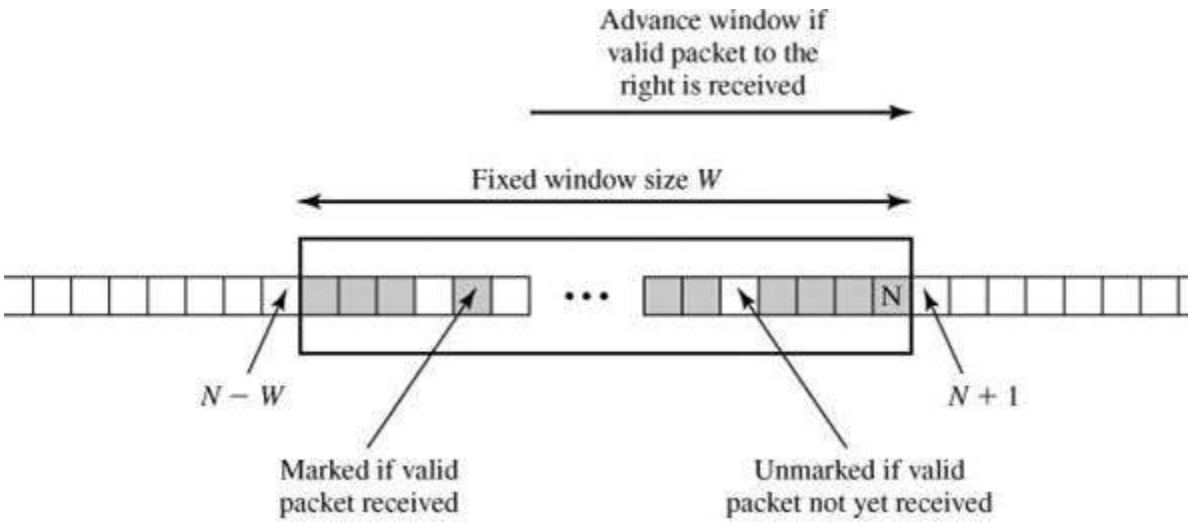
- **Authentication Data (variable):** A variable-length field (must be an integral number of 32-bit words) that contains the Integrity Check Value (ICV), or MAC, for this packet.

Anti-Replay Service

Anti-replay service is designed to overcome the problems faced due to replay attacks in which an intruder intervenes the packet being transferred, make one or more duplicate copies of that authenticated packet and then sends the packets to the desired destination, thereby causing inconvenient processing at the destination node. The Sequence Number field is designed to thwart such attacks.When a new SA is established, the sender initializes a sequence number counter to 0. Each time thata packet is sent on this SA, the sender increments the counter and places the value in the Sequence Number field. Thus, the first value to be used is 1. This value goes on increasing with respect to the number of packets being transmitted. The sequence number field in each packet represents the value of this counter. The maximum value of the sequence number field can go up to 232-1. If the limit of 232-1 is reached, the sender should terminate this SA and negotiate a new SA with a new key.

The IPSec authentication document dictates that the receiver should implement a window of size W, with a default of W = 64. The right edge of the window represents the highest sequence number, N, so far received for a valid packet. For any packet with a sequence number in the range from N-W+1 to N that has been correctly received (i.e., properly authenticated), the corresponding slot in the window is marked as shown.

Inbound processing proceeds as follows when a packet is received:



1. If the received packet falls within the window and is new, the MAC is checked. If the packet is authenticated, the corresponding slot in the window is marked.
2. If the received packet is to the right of the window and is new, the MAC is checked. If the packet is authenticated, the window is advanced so that this sequence number is the right edge of the window, and the corresponding slot in the window is marked.

3. If the received packet is to the left of the window, or if authentication fails, the packet is discarded; this is an auditable event.

Integrity Check Value:

ICV is the value present in the authenticated data field of ESP/AH, which is used to determine any undesired modifications made to the data during its transit. ICV can also be referred as MAC or part of MAC algorithm. MD5 hash code and SHA-1 hash code are implemented along with HMAC algorithms i.e.,

• HMAC-MD5-96

• HMAC-SHA-1-96

In both cases, the full HMAC value is calculated but then truncated by using the first 96 bits, which is the default length for the Authentication Data field. The MAC is calculated over.

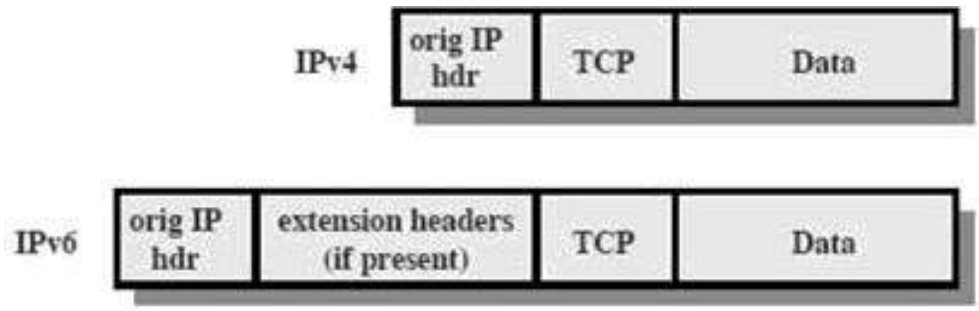
IP header fields that either do not change in transit (immutable) or that are predictable in valueupon arrival at the endpoint for the AH SA. Fields that may change in transit and whose value on arrival is unpredictable are set to zero for purposes of calculation at both source and destination.

The AH header other than the Authentication Data field. The Authentication Data field is set to zero for purposes of calculation at both source and destination.

The entire upper-level protocol data, which is assumed to be immutable in transit (e.g., a TCP segment or an inner IP packet in tunnel mode).

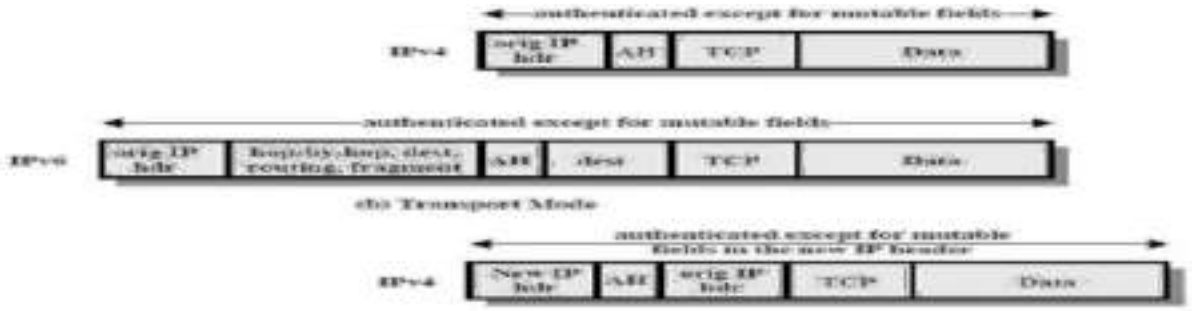
Transport and Tunnel Modes:

The following figure shows typical IPv4 and IPv6 packets. In this case, the IP payload is a TCP segment; it could also be a data unit for any other protocol that uses IP, such as UDP or ICM



(a) Before Applying AH

For transport mode AH using IPv4, the AH is inserted after the original IP header and before the IP payload (e.g., a TCP segment) shown below. Authentication covers the entire packet, excluding mutable fields in the IPv4 header that are set to zero for MAC calculation. In the context of IPv6, AH is viewed as an end-to-end payload; that is, it is not examined or processed by intermediate routers. Therefore, the AH appears after the IPv6 base header and the hop-by-hop, routing, and fragment extension headers. The destination options extension header could appear before or after the AH header, depending on the semantics desired. Again, authentication covers the entire packet, excluding mutable fields that are set to zero for MAC calculation.



For tunnel mode AH, the entire original IP packet is authenticated, and the AH is inserted between the original IP header and a new outer IP header. The inner IP header carries the ultimate source and destination addresses, while an outer IP header may contain different IP addresses (e.g., addresses of firewalls or other security gateways). With tunnel mode, the entire inner IP packet, including the entire inner IP header is protected by AH. The outer IP header (and in the case of IPv6, the outer IP extension headers) is protected except for mutable and un predictable fields.

IP sec can be used (both AH packets and ESP packets) in two modes.

ENCAPSULATING SECURITY PAYLOAD

The Encapsulating Security Payload provides confidentiality services, including confidentiality of message contents and limited traffic flow confidentiality. As an optional feature, ESP can also provide an authentication service.

ESP Format:

The following figure shows the format of an ESP packet. It contains the following fields:

Security Parameters Index (32 bits): Identifies a security association.

- **Sequence Number** (32 bits): A monotonically increasing counter value; this provides an anti-replay function, as discussed for AH.
- **Payload Data (variable):** This is a transport-level segment (transport mode) or IP packet (tunnel mode) that is protected by encryption.
- **Padding (0-255 bytes):** This field is used to make the length of the plaintext to be a multiple of some desired number of bytes. It is also added to provide confidentiality.
- **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 (for example, an extension header in IPv6, or an upper- layer protocol such as TCP).
- **Authentication Data (variable):** A variable-length field (must be an integral number of 32- bit words) that contains the Integrity Check Value computed over the ESP packet minus the Authentication Data field.

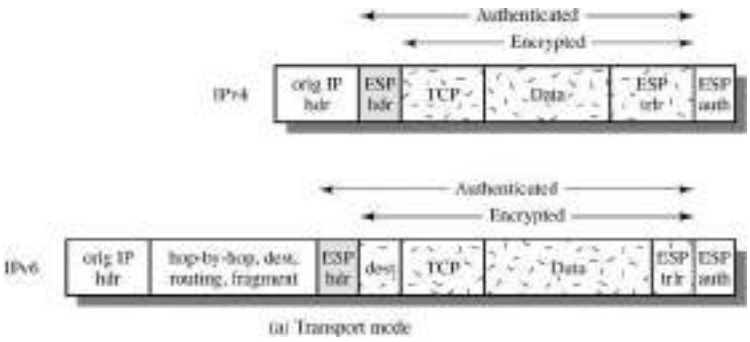
Adding encryption makes ESP a bit more complicated because the encapsulation *surrounds*

the payload rather than precedes it as with AH: ESP includes header and trailer

a) ESP followed by AH in transport mode (an ESP SA inside an AHSA)

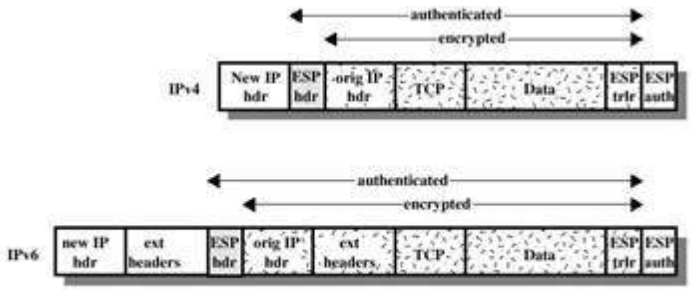
b) Any one of a, b, or c inside an AH or ESP in tunnel mode

Transport Mode ES



(a) Transport mode

Tunnel Mode ESP

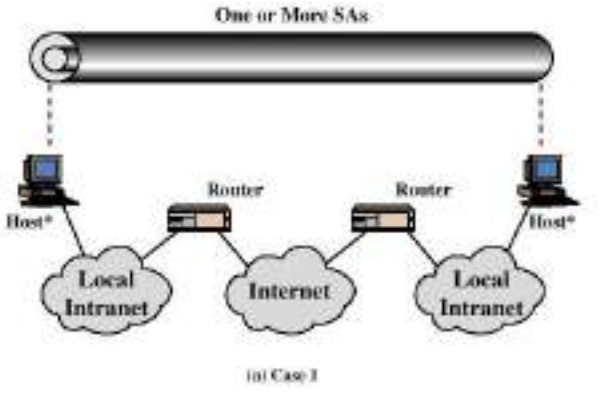


(b) Tunnel Mode

ASIC COMBINATIONS OF SECURITY ASSOCIATIONS

The IPSec Architecture document lists four examples of combinations of SAs that must be supported by compliant IPSec hosts (e.g., workstation, server) or security gateways (e.g. firewall, router).

case:-1



(a) Case 1

All 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. Among the possible combinations:

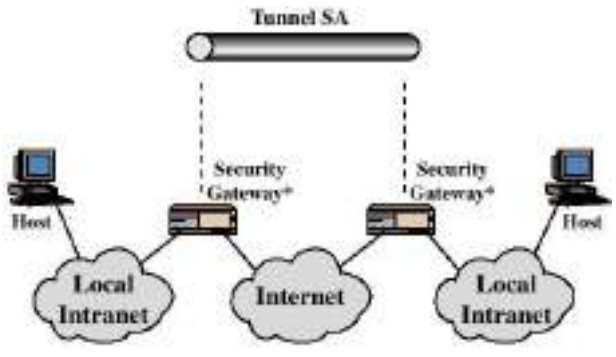
a) AH in transport mode

b) ESP in transport mode

c) ESP followed by AH in transport mode (an ESP SA inside an AHSA)

case:-2

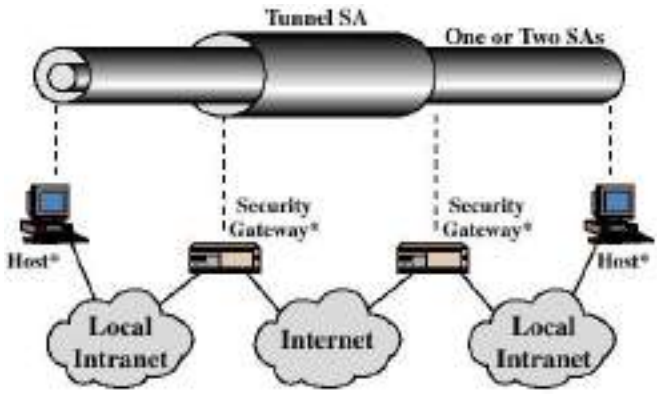
d) Any one of a, b, or c inside an AH or ESP in tunnel mode



(b) Case 2

Security is provided only between gateways (routers, firewalls, etc.) and no hosts implement IPSec. This case illustrates simple virtual private network support. The security architecture document specifies that only a single tunnel SA is needed for this case. The tunnel could support AH, ESP, or ESP with the authentication option. Nested tunnels are not required because the IPSec services apply to the entire inner packet

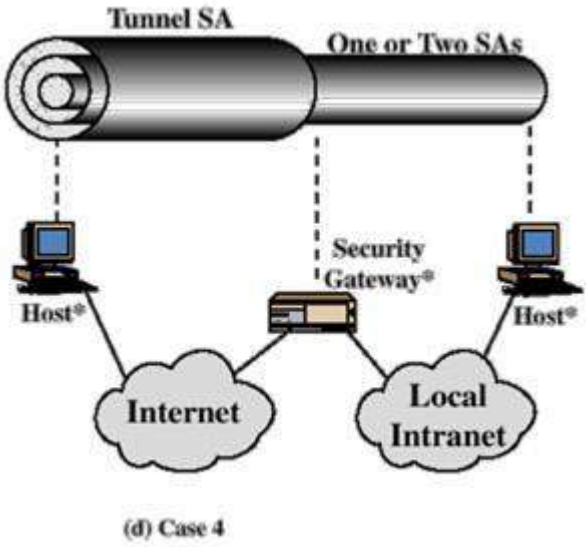
Case-3:-



(c) Case 3

The third combination is similar to the second, but in addition provides security even to nodes. This combination makes use of two tunnels first for gateway to gateway and second for node to node. Either authentication or the encryption or both can be provided by using gateway to gateway tunnel. An additional IPSec service is provided to the individual nodes by using node to node tunnel.

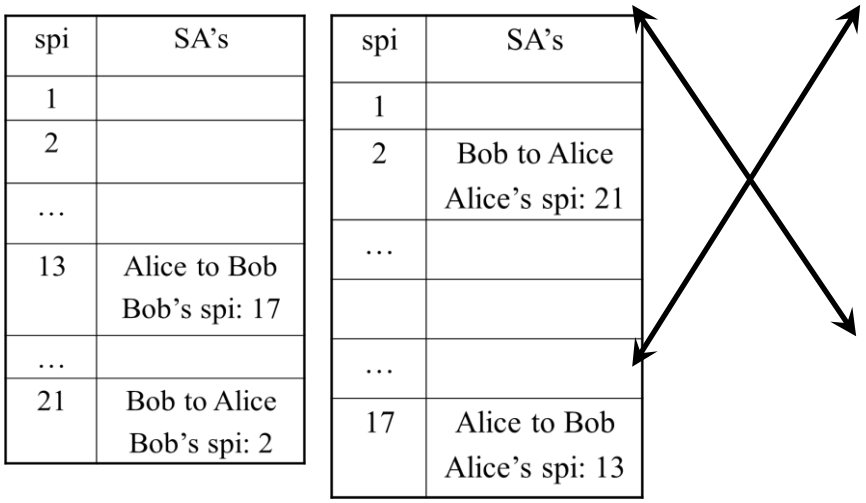
Case:-4



(d) Case 4

This combination is suitable for serving remote users i.e., the end user sitting anywhere in the world can use the internet to access the organizational workstations via the firewall. This combination states that only one tunnel is needed for communication between a remote user and an organizational firewall.

- Security Association Database (SAD) holds SA's
- Security Associations (SA) is a **one way**, cryptographically protected connection between a sender and a receiver that affords security services to traffic.



SA contains the fields:

- protocol identifier (ESP or AH)
- mode (tunnel or transport)
- algorithms for encryption/ decryption/ authentication and their respective keys
- lifetime
- SPI's
- sequence number

INTERNET KEY EXCHANGE (IKE)

Internet Key Exchange (IKE) is a key management protocol standard used in conjunction with the Internet Protocol Security (IPSec) standard protocol. It provides security for virtual private networks' (VPNs) negotiations and network access to random hosts. It can also be described as a method for exchanging keys for encryption and authentication over an unsecured medium, such as the Internet.

- Dynamic (automated) – On-demand creation of keys. Handled by IKE protocol
- IKE is a protocol that builds and manages IPSec SA's between two computers that implement IPSec.
- IKE is the only standard protocol for building IPSec SA's (Standard IPSec implementation must also implement IKE)
- IKE (like IPSec) is carried out either between a pair of hosts, a pair of security gateways or a host and a security gateway

Endpoint to Endpoint Transport

- Both endpoints of the IP connection implement IPsec
- Used with no inner IP header
- One of the protected points can be behind a NAT node

Expectations from IKE

- Secrecy and authenticity
- Protection against replay attacks
- Scalability (being suitable for big networks)
- Privacy and anonymity (protecting identity of players in the protocol)
- Protection against DOS
- Efficiency (both computational and minimal in the number of messages)
- Independence of cryptographic algorithms
- Minimize protocol complexity

KEY MANAGEMENT:

The key management portion of IPSec involves the determination and distribution of secret keys. The IPSec Architecture document mandates support for two types of key management:

Manual: A system administrator manually configures each system with its own keys and with the keys of other communicating systems. This is practical for small, relatively static environments.

Automated: An automated system enables the on-demand creation of keys for SAs and facilitates the use of keys in a large distributed system with an evolving configuration.

The default automated key management protocol for IPSec is referred to as ISAKMP/Oakley and consists of the following elements:

Oakley Key Determination Protocol: Oakley is a key exchange protocol based on the Diffie-Hellman algorithm but providing added security. Oakley is generic in that it does not dictate specific formats.

Internet Security Association and Key Management Protocol (ISAKMP): ISAKMP provides a framework for Internet key management and provides the specific protocol support, including formats, for negotiation of security attributes.

Oakley Key Determination Protocol:

Oakley is a refinement of the Diffie-Hellman key exchange algorithm. The Diffie-Hellman algorithm has two attractive features:

Secret keys are created only when needed. There is no need to store secret keys for a longperiod of time, exposing them to increased vulnerability.

The exchange requires no pre-existing infrastructure other than an agreement on the global parameters.

However, Diffie-Hellman has got some weaknesses:

- No identity information about the parties is provided.
- It is possible for a man-in-the-middle attack

It is computationally intensive. As a result, it is vulnerable to a clogging attack, in which an opponent requests a high number of keys.

Oakley is designed to retain the advantages of Diffie-Hellman while countering its weaknesses.

Features of Oakley:

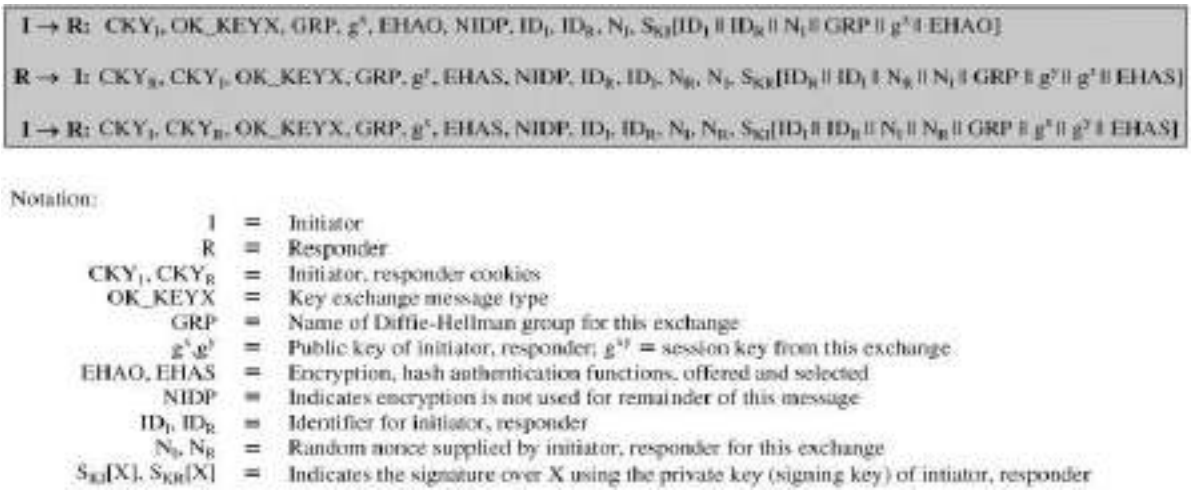
The Oakley algorithm is characterized by five important features:

1. It employs a mechanism known as cookies to thwart clogging attacks.
2. It enables the two parties to negotiate a group; this, in essence, specifies the global parameters of the Diffie-Hellman key exchange.
3. It uses nonces to ensure against replay attacks.
4. It enables the exchange of Diffie-Hellman public key values.
5. It authenticates the Diffie-Hellman exchange to thwart man-in-the-middle attacks.

In clogging attacks, an opponent forges the source address of a legitimate user and sends a public Diffie-Hellman key to the victim. The victim then performs a modular exponentiation to compute the secret key. Repeated messages of this type can clog the victim's system with useless work. The cookie exchange requires that each side send a pseudorandom number, the cookie, in the initial message, which the other side acknowledges. This acknowledgment must be repeated in the first message of the Diffie-Hellman key exchange. The recommended method for creating the cookie is toperform a fast hash (e.g., MD5) over the IP Source and Destination addresses, the UDP Source and Destination ports, and a locally generated secret value. Oakley supports the use of different groups for the Diffie-Hellman key exchange. Each group includes the definition of the two global parameters and the identity of the algorithm. Oakley employs nonces to ensure against replay attacks. Each nonce is a locally generated pseudorandom number. Nonces appear in responses and are encrypted during certain portions of the exchange to secure their use. Three different authentication methods can be used with Oakley are digital signatures, public-key encryption and Symmetric-key encryption.

Aggressive key exchange:

Aggressive key exchange is a technique used for exchanging the message keys and is so called because only three messages are allowed to be exchanged at any time.



Example of Aggressive Oakley Key Exchange

In the first step, the initiator (I) transmits a cookie, the group to be used, and I's public Diffie- Hellman key for this exchange. I also indicates the offered public-key encryption, hash, and authentication algorithms to be used in this exchange. Also included in this message are the identifiers of I and the responder (R) and I's nonce for this exchange. Finally, I appends a signature using I's private key that signs the two identifiers, the nonce, the group, the Diffie- Hellman public key, and the offered algorithms. When R receives the message, R verifies the signature using I's public signing key. R acknowledges the message by echoing back I's cookie, identifier, and nonce, aswell as the group. R also includes in the message a cookie, R's Diffie-Hellman public key, the selected algorithms (which must be among the offered algorithms), R's identifier, and R's nonce for this exchange. Finally, R appends a signature using R's private key that signs thetwo

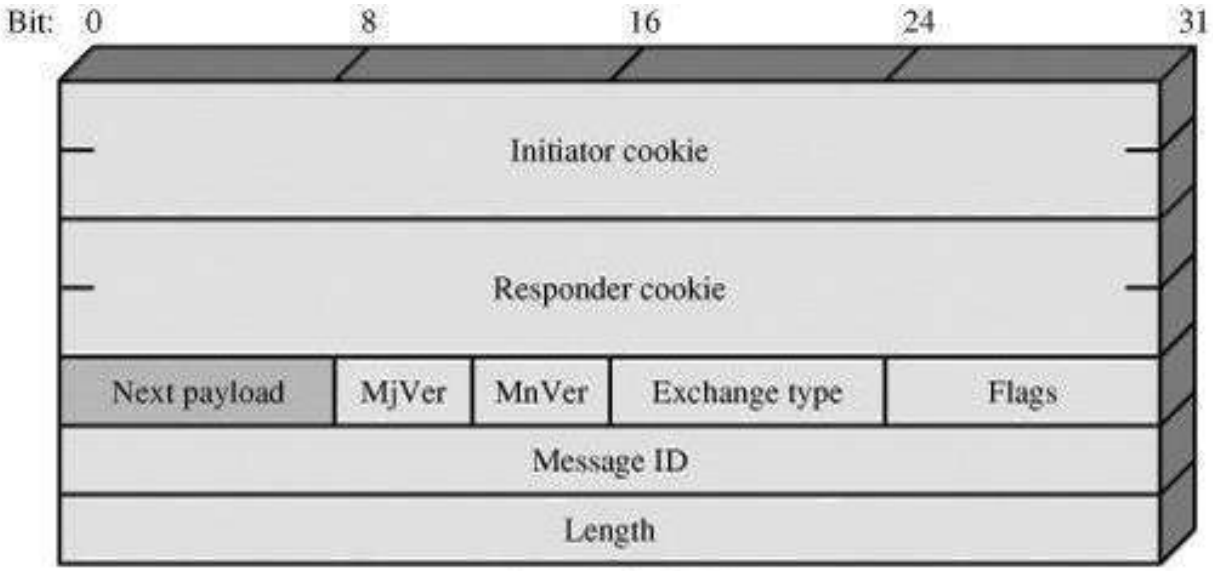
identifiers, the two nonces, the group, the two Diffie-Hellman public keys, and the selected algorithms.

When I receives the second message, I verifies the signature using R's public key. The nonce values in the message assure that this is not a replay of an old message. To complete the exchange, I must send a message back to R to verify that I has received R's public key.

ISAKMP

ISAKMP defines procedures and packet formats to establish, negotiate, modify, and delete security associations. As part of SA establishment, ISAKMP defines payloads for exchanging key generation and authentication data.

ISAKMP Header Format:



(a) ISAKMP header

An ISAKMP message consists of an ISAKMP header followed by one or more payloads and must follow UDP transport layer protocol for its implementation. The header format of an ISAKMP header is shown below:

Initiator Cookie (64 bits): Cookie of entity that initiated SA establishment, SA notification, orSA deletion.

Responder Cookie (64 bits): Cookie of responding entity; null in first message from initiator.

Next Payload (8 bits): Indicates the type of the first payload in the message

Major Version (4 bits): Indicates major version of ISAKMP in use.

Minor Version (4 bits): Indicates minor version in use.

Exchange Type (8 bits): Indicates the type of exchange. Can be informational,

Aggressive, authentication only, identity protection or base exchange(S).

Flags (8 bits): Indicates specific options set for this ISAKMP exchange. Two bits so far defined:

The Encryption bit is set if all payloads following the header are encrypted using

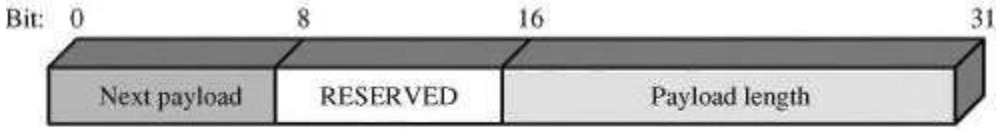
The encryption algorithm for this SA. The Commit bit is used to ensure that encrypted material is not received prior to completion of Astablishment.

Message ID (32 bits): Unique ID for this message.

Length (32 bits): Length of total message (header plus all payloads) in octets.

ISAKMP Payload Types

All ISAKMP payloads begin with the same generic payload header shown below.



(b) Generic payload header

The Next Payload field has a value of 0 if this is the last payload in the message; otherwise its value is the type of the next payload. The Payload Length field indicates the length in octets of this payload, including the generic payload header. There are many different ISAKMP payload types. They are:

a. The SA payload is used to begin the establishment of an SA. The Domain of Interpretation parameter identifies the DOI under which negotiation is taking place. The Situation parameter defines the security policy for this negotiation; in essence, the levels of security required for encryption and confidentiality are specified (e.g., sensitivity level, security compartment)

b. The Proposal payload contains information used during SA negotiation. The payload indicates the protocol for this SA (ESP or AH) for which services and mechanisms are being negotiated. The payload also includes the sending entity's SPI and the number of transforms. Each transform is contained in a transform payload.

c. The Transform payload defines a security transform to be used to secure the communications channel for the designated protocol. The Transform # parameter serves to identify this particular payload so that the responder may use it to indicate acceptance of this transform. The Transform-ID and Attributes fields identify a specific transform (e.g., 3DES for ESP, HMAC-SHA- 1-96 for AH) with its associated attributes (e.g., hash length).

d. The Key Exchange payload can be used for a variety of key exchange techniques, including Oakley, Diffie-Hellman, and the RSA-based key exchange used by PGP. The Key Exchange data field contains the data required to generate a session key and is dependent on the key exchange algorithm used.

e. The Identification payload is used to determine the identity of communicating peers and maybe used for determining authenticity of information. Typically the ID Data field will contain an IPv4 or IPv6address.

f. The Certificate payload transfers a public-key certificate. The Certificate Encoding field indicates the type of certificate or certificate-related information, which may include SPKI, ARL, CRL, PGP info etc. At any point in an ISAKMP exchange, the sender may include a Certificate Request payload to request the certificate of the other communicating entity.

g. The Hash payload contains data generated by a hash function over some part of the message and/or ISAKMP state. Thispayload may be used to verify the integrity of the data in a message or to authenticate negotiating entities.

h. The Signature payload contains data generated by a digital signature function over some part of the message and/or ISAKMP state. This payload is used to verify the integrity of the data in a message and may be used for nonrepudiation services.

i. The Nonce payload contains random data used to guarantee liveness during an exchange and protect against replay attacks.

j. The Notification payload contains either error or status information associated with this SA orthis SA negotiation. Some of the ISAKMP error messages that have been defined are Invalid Flags, Invalid Cookie, Payload Malformed etc.

k. The Delete payload indicates one or more SAs that the sender has deleted from its database and that therefore are no longer valid.

ISAKMP Exchanges

ISAKMP provides a framework for message exchange, with the payload types serving as thebuilding blocks. The specification identifies five default exchange types that should be supported.

1. Base Exchange: allows key exchange and authentication material to be transmitted together.

2. This minimizes the number of exchanges at the expense of not providing identity protection.

The first two messages provide cookies and establish an SA with agreed protocol and transforms; both side use a nonce to ensure against replay attacks. The last two messages exchange the key main user IDs, with an authentication mechanism used to authenticate keys, identities, and thenonces from the first two messages.

2.Identity Protection Exchange: expands the Base Exchange to protect the users' identities.

(b) Identity Protection Exchange

(1)**I**⟶**R**: SA	Begin ISAKMP-SA negotiation
(2)**R**⟶**E**: SA	Basic SA agreed upon
(3)**I**⟶**R**: KE; NONCE	Key generated
(4)**R**⟶**E**: KE; NONCE	Key generated
(5)*__I__⟶**R**: ID_I; AUTH	Initiator identity verified by responder
(6)*__R__⟶**E**: ID_R; AUTH	Responder identity verified by initiator; SA established

The first two messages establish the SA. The next two messages perform key exchange, with nonces for replay protection. Once the session key has been computed, the two parties exchange encrypted messages that contain authentication information, such as digital signatures and optionally certificates validating the public keys.
Authentication Only Exchange: used to perform mutual authentication, without a key exchange
The first two messages establish the SA. In addition, the responder uses the second message to convey its ID and uses authentication to protect the message. The initiator sends the third message to transmit its authenticated ID.
Aggressive Exchange: minimizes the number of exchanges at the expense of not providing identity protection.

(d) Aggressive Exchange

(1)**I**⟶**R**: SA; KE; NONCE; ID_I	Begin ISAKMP-SA negotiation and key exchange
(2)**R**⟶**E**: SA; KE; NONCE; ID_R; AUTH	Initiator identity verified by responder; Key generated; Basic SA agreed upon
(3)*__I__⟶**R**: AUTH	Responder identity verified by initiator; SA established