

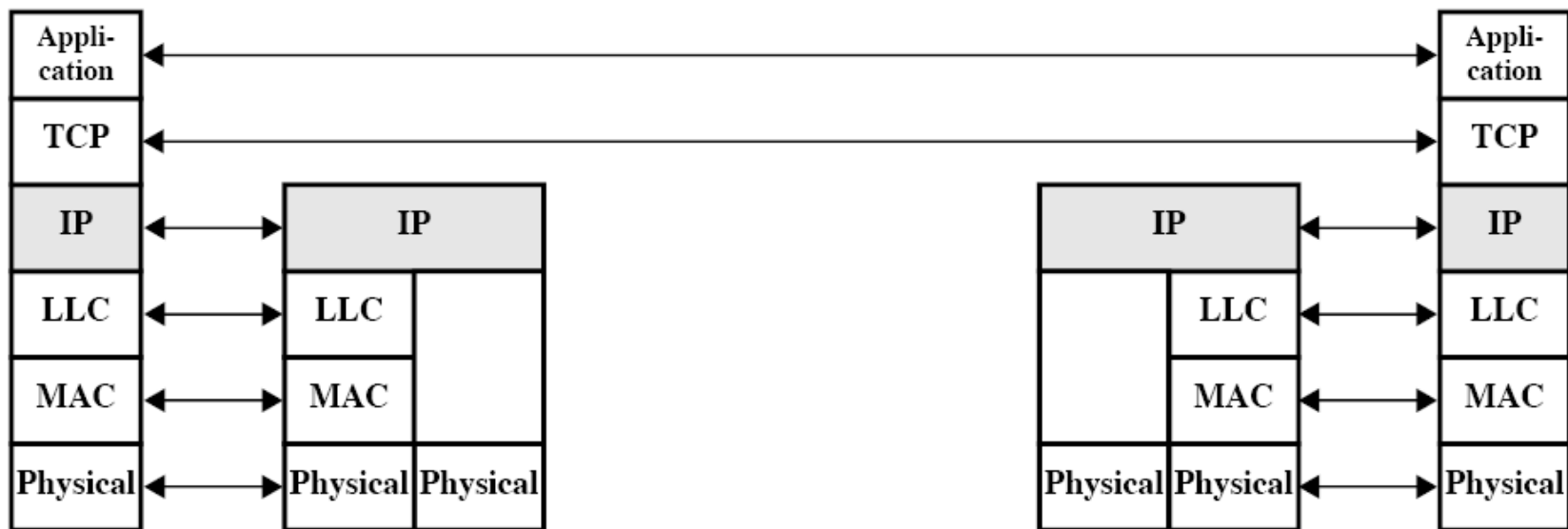
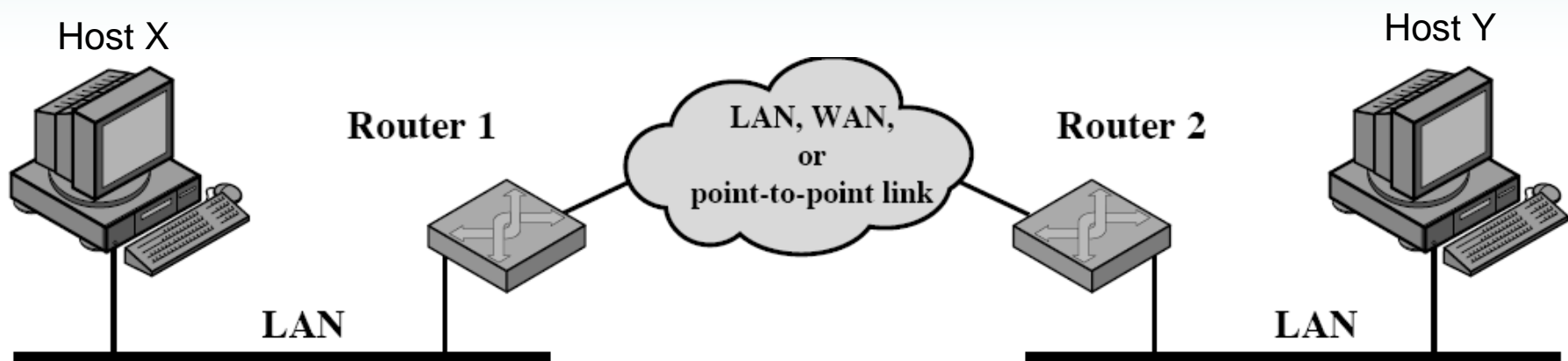
Internet Security

CSS 322 – Security and Cryptography

Contents

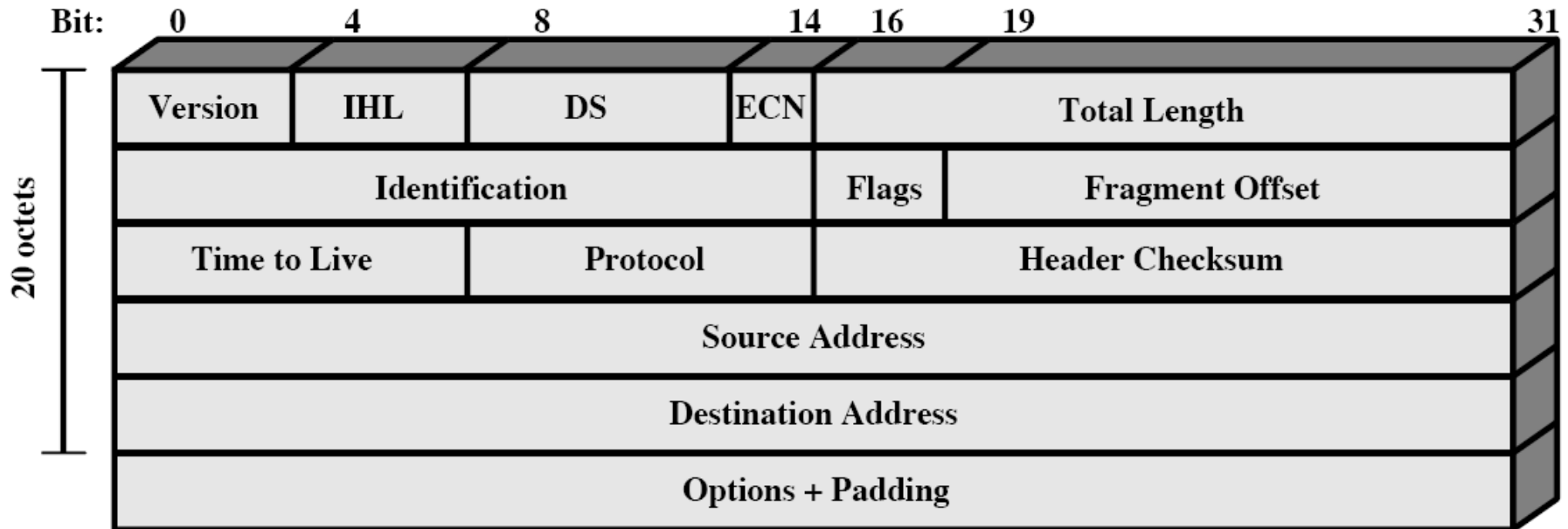
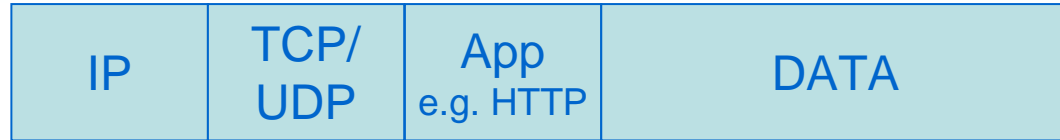
- Review of Internet Architecture
- Network Layer Security
 - IPsec
- Transport Layer Security
 - TLS
 - Used by HTTPS and others
- Email Security
 - PGP

Internet Architecture

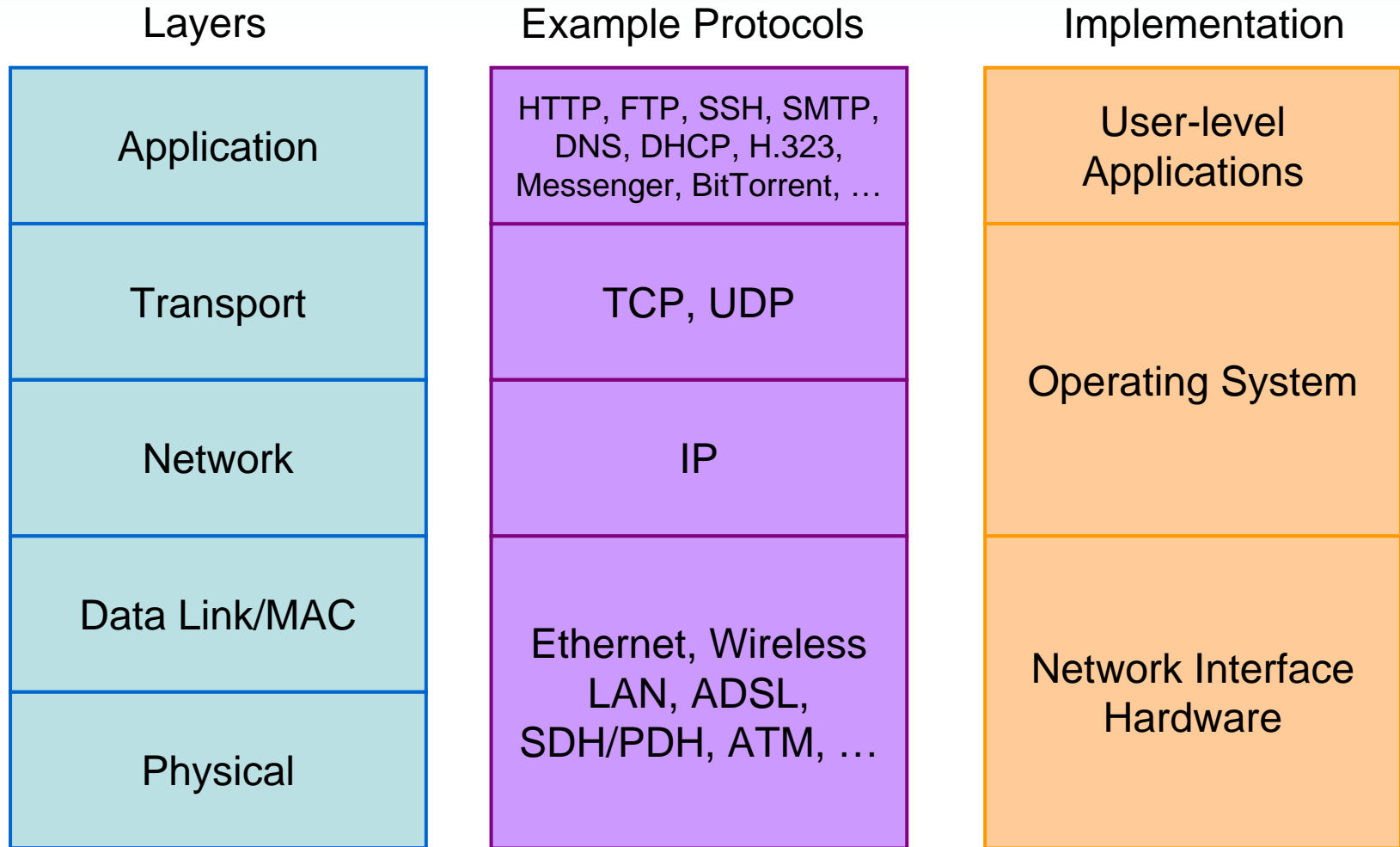


IPv4 Datagram Header

Packet format:



Internet Protocols



Security in Standard Internet Protocols

- The Internet was originally used by researchers, academics and government employees in 1970's and 1980's
 - No need for in-built security
 - Everyone was trustworthy; if you wanted security, simple to use proprietary application between users
 - As a result, most Internet protocols do not have any security mechanisms
 - IP, TCP, UDP, HTTP, FTP, SMTP, DNS, ...
- Growth and commercialisation of Internet in 1990's
 - Businesses, governments, consumers depend on Internet
 - Significant growth in malicious users
 - Financial, political, personal motivations
 - Security is now vital
- Most Internet security protocols are add-ons or enhancements to existing protocols
 - IP/IPsec; TCP/TLS; Telnet/SSH, FTP/SSH, ...

Internet Security Protocols/Standards

Internet Protocols

HTTP, FTP, SSH, SMTP,
DNS, DHCP, H.323,
Messenger, BitTorrent, ...

TCP, UDP

IP

Ethernet, Wireless
LAN, ADSL,
SDH/PDH, ATM, ...

Security Protocols and Standards

Secure Shell (SSH); Secure Electronic
Transactions (SET), DNSSEC, HTTPS, Secure
SMTP, PGP, S/MIME...

Secure Sockets Layer (SSL), also called
Transport Layer Security (TLS)

IPsec – optional addition to IPv4 (built-in
with IPv6)

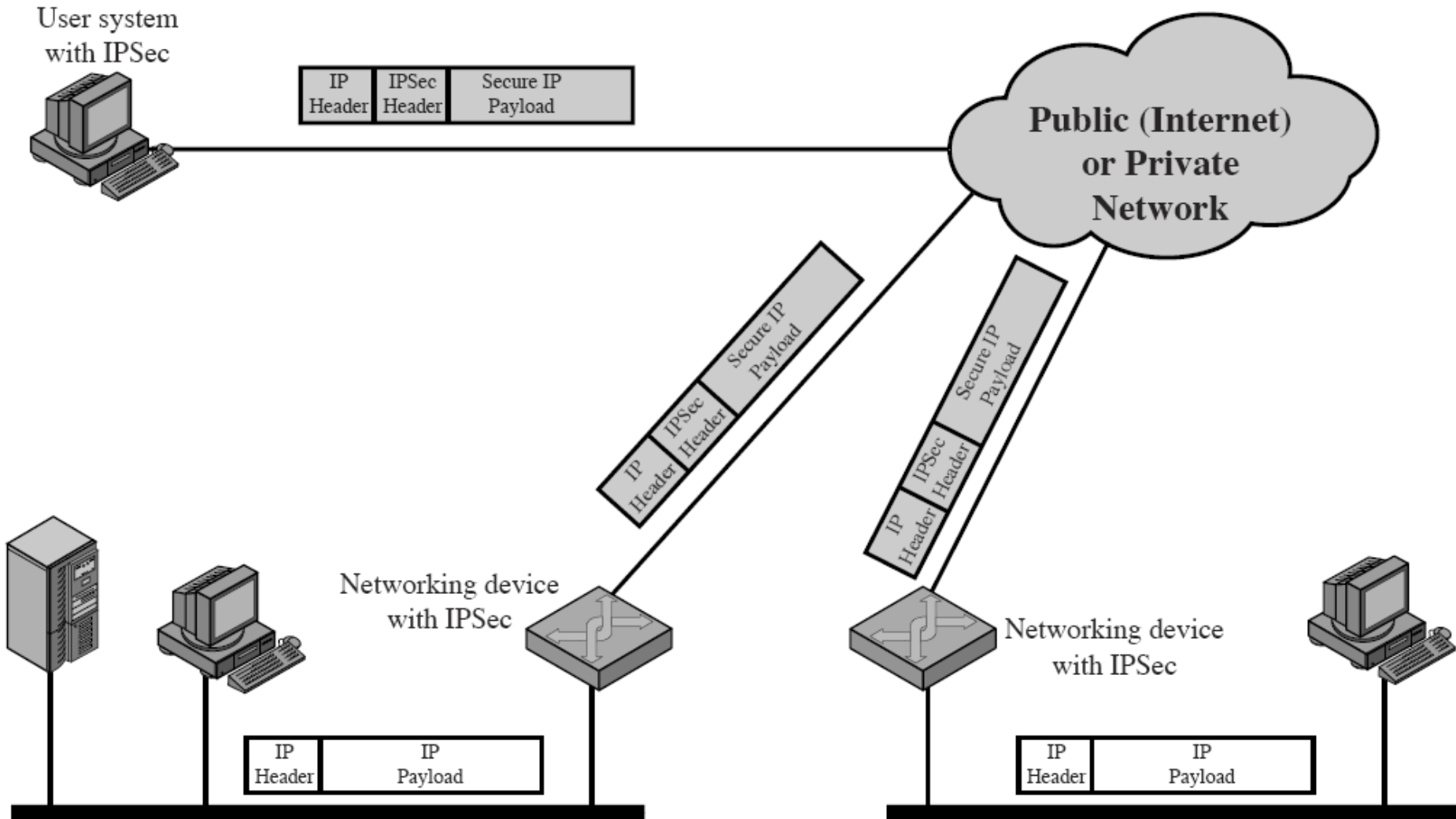
IPsec

Network Layer Security

IPsec

- Internet Engineering Task Force (IETF) defined RFC 2401 (Internet security architecture)
 - IPsec is optional for IPv4 and mandatory in IPv6
 - Mandatory: implementations must support it; but users do not have to use it
 - Implemented as extension headers for IP
- Functionality offered by IPsec:
 - Authentication: verify the sender of IP datagrams
 - Confidentiality: encrypt contents of IP datagrams
 - Data Integrity: guarantee integrity of IP datagrams
 - Key Management: secure exchange of keys
- Allows all traffic to be encrypted at IP (network layer) level
 - Can provide security for all Internet applications (web browsers, email, e-commerce, ...)
 - No need to change application or transport protocol software
 - Must have IPsec support on selected PCs, routers, firewalls

Example IPsec Scenario



IPsec Components

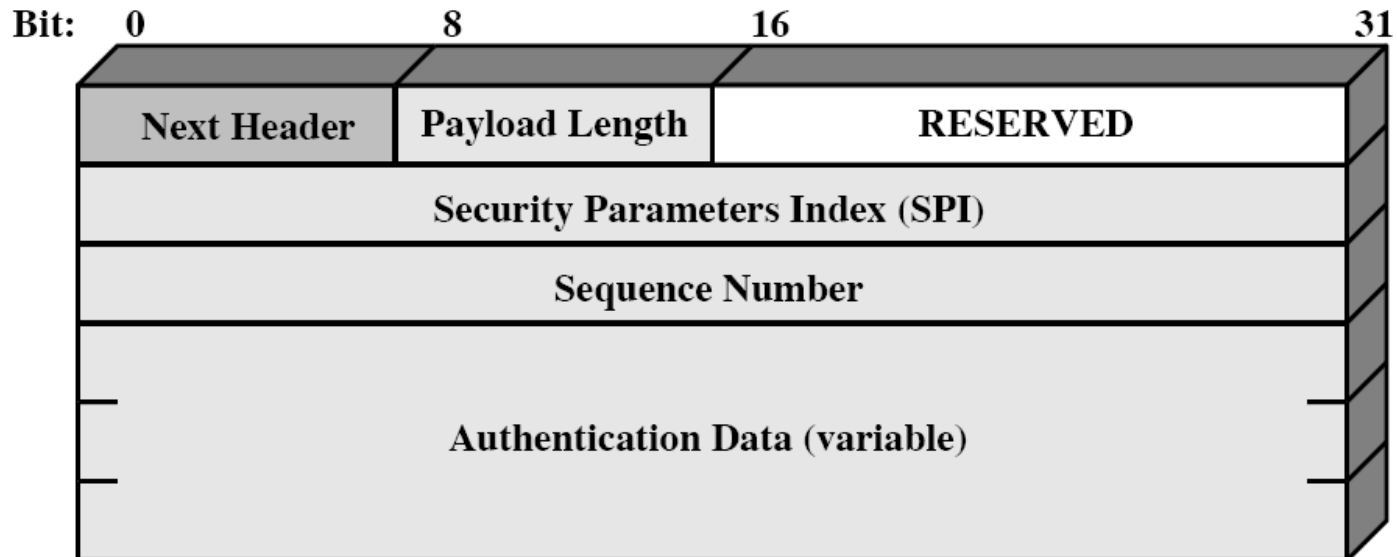
- Security Association (SA)
 - Sender and receiver must establish relationship, called Security Association
 - Traffic sent within that SA is given services agreed upon between sender and receiver
- Encapsulating Security Payload (ESP)
 - Allows for encryption of payload (e.g. TCP packet), as well encryption plus authentication of payload
- Authentication Header (AH)
 - Separate from ESP, allows for authentication-only of payload
- Key Management
 - Mechanisms for exchanging keys
 - Two automated protocols
 - Oakley: based on Diffie-Hellman secret key exchange
 - Internet Security Association and Key Management Protocol (ISAKMP): framework for using different algorithms for key exchange

Security Association

- SA is one-way: sender to receiver
 - That is, for traffic from A to B need one SA; for traffic from B to A need another SA
- SA is identified by:
 - *Security Parameters Index (SPI)*: carried in AH and ESP headers
 - Allows A and B to identify the agreed upon algorithms/parameters used for this SA
 - For a SPI, A and B store the relevant parameter values in a local database
 - Parameters include: sequence numbers, encryption/authentication algorithms and keys, lifetime of SA, protocol mode (tunnel or transport) and others
 - *IP Destination Address*
 - *Security Protocol Identifier*: indicates either AH or ESP (depend on which one is used)

Authentication Header

- AH provides two services for IP datagrams
 - Integrity: ensure payload is not changed
 - Authentication: verify the identity of user
- AH uses a Message Authentication Code
 - Users must share a secret key

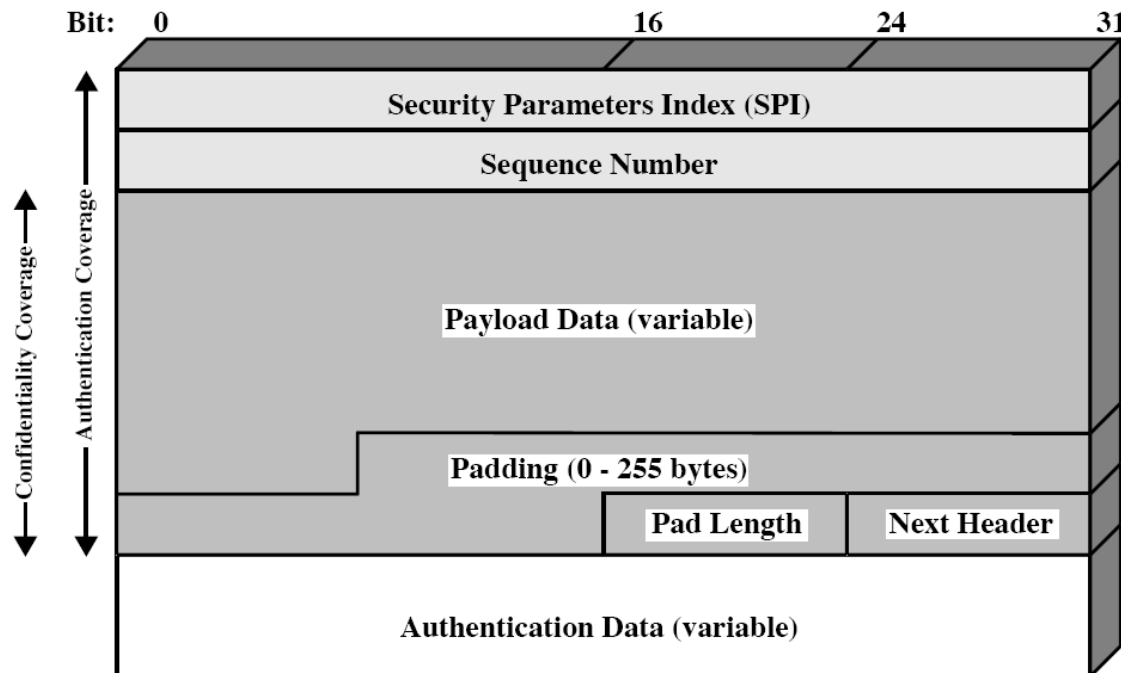


AH Services and Algorithms

- AH provides authentication
 - MAC requires sharing of secret key; the sender having the correct secret key authenticates that user
- AH provides integrity check of packet
 - HMAC-MD5 and HMAC-SHA1 must be supported (others are optional)
 - Sender calculates MAC from:
 - IP header fields that do not change (immutable) or are predictable
 - AH fields (except Authentication Data field)
 - Entire upper-layer packet (e.g. TCP header, HTTP header and HTTP data)
 - Only first 96-bits of MAC are sent (in Authentication Data field)
 - Receiver checks the MAC upon receipt of packet
- AH can prevent replay attacks
 - Sequence number in header is used to identify replayed packets

Encapsulating Security Payload

- ESP provides several services for IP datagrams
 - Encryption (confidentiality) of IP datagram
 - Authentication of IP datagram (optional)
 - Integrity of IP datagram



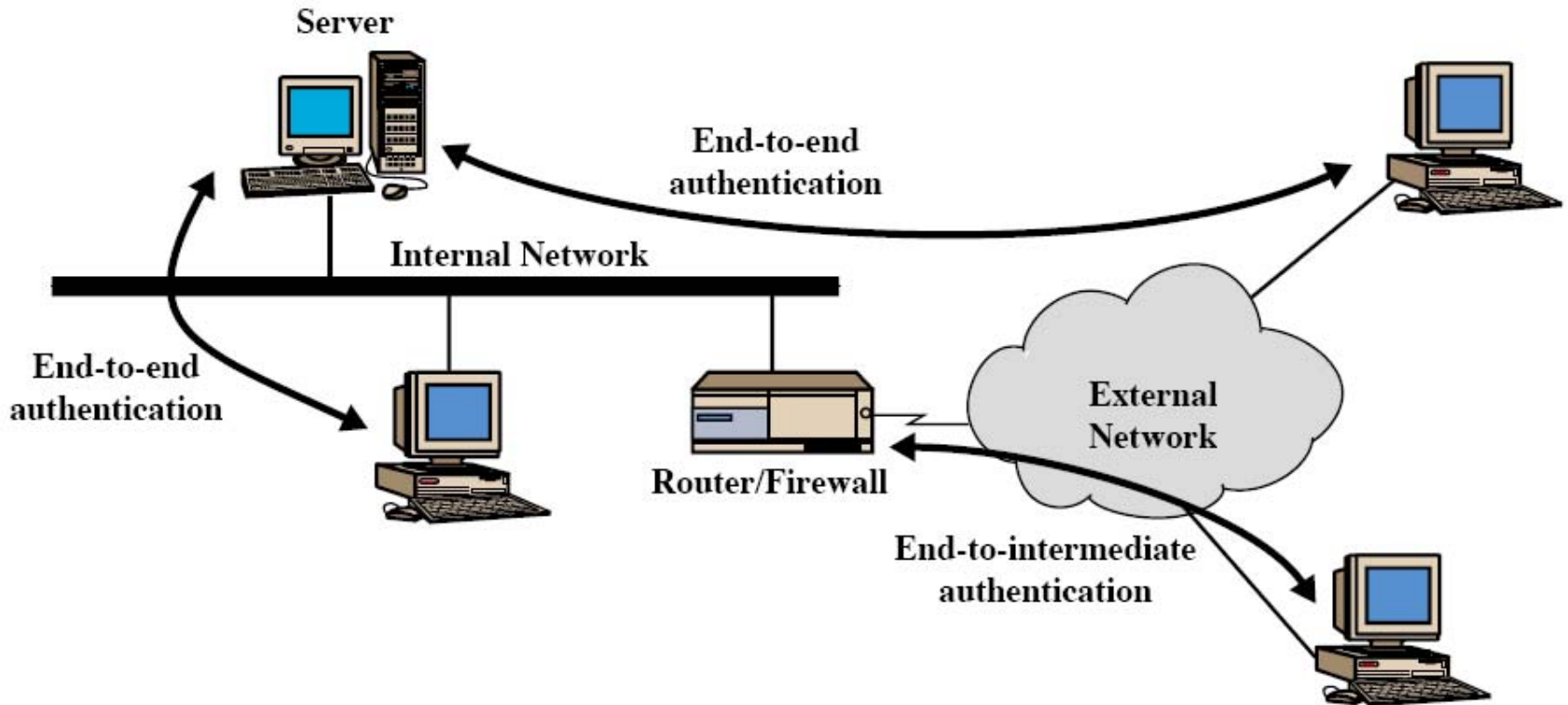
ESP Algorithms

- Encryption
 - Mandatory to support DES; many algorithms are optional:
 - 3DES, RC5, IDEA, CAST, Blowfish, ...
- Authentication
 - Same as AH: HMAC-MD5 and HMAC-SHA1 are mandatory

Protocol Modes

- Transport Mode
 - Apply encryption or authentication end-to-end
 - E.g. from PC to PC
 - Original IP header is not protected
 - Only protected TCP/UDP and application layer data
- Tunnel Mode
 - Apply encryption or authentication from intermediate device
 - E.g. from router to router or from router to PC
 - Original IP header is protected
 - Protect IP plus TCP/UDP plus application layer data
 - Often used for creating Virtual Private Networks (VPNs)

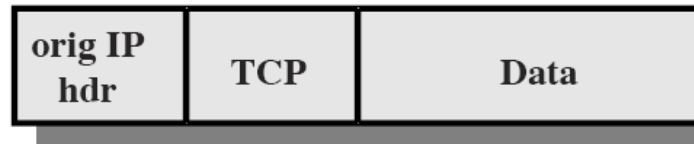
AH and Protocol Modes



- Transport: end-to-end
- Tunnelling: end-to-intermediate, or intermediate-to-intermediate

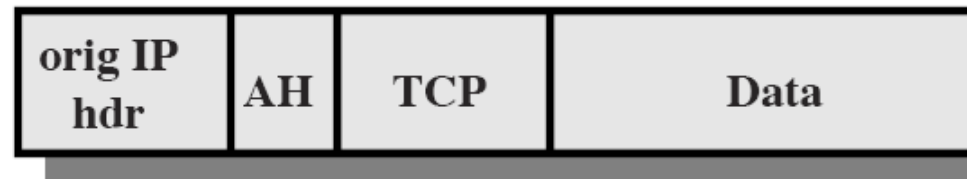
AH and Protocol Modes

- Original IP datagram (before IPsec)

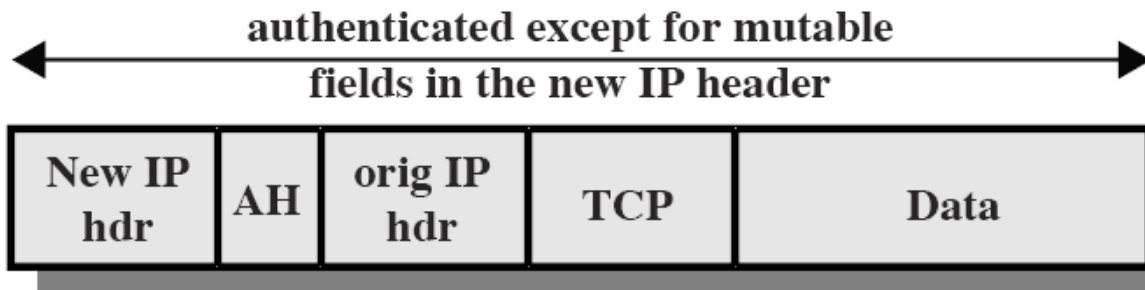


- AH with Transport Mode:

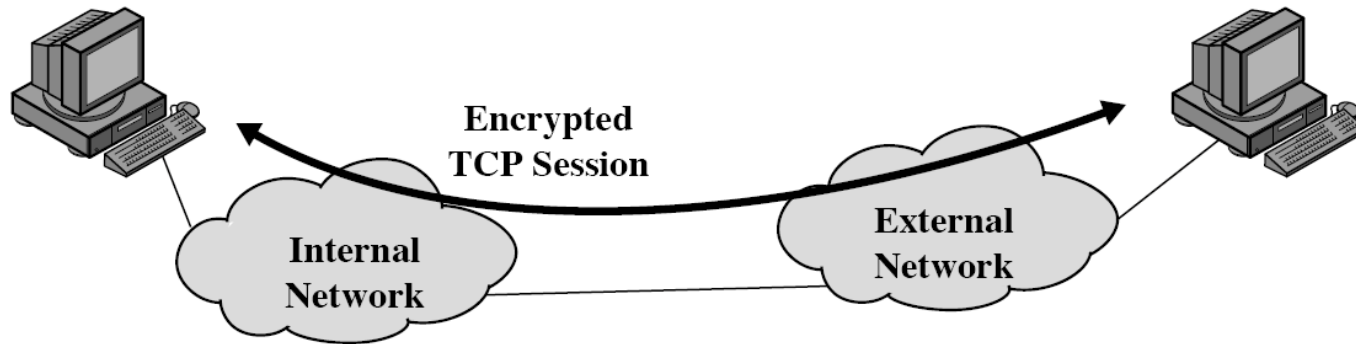
← authenticated except for mutable fields →



- AH with Tunnelling Mode:

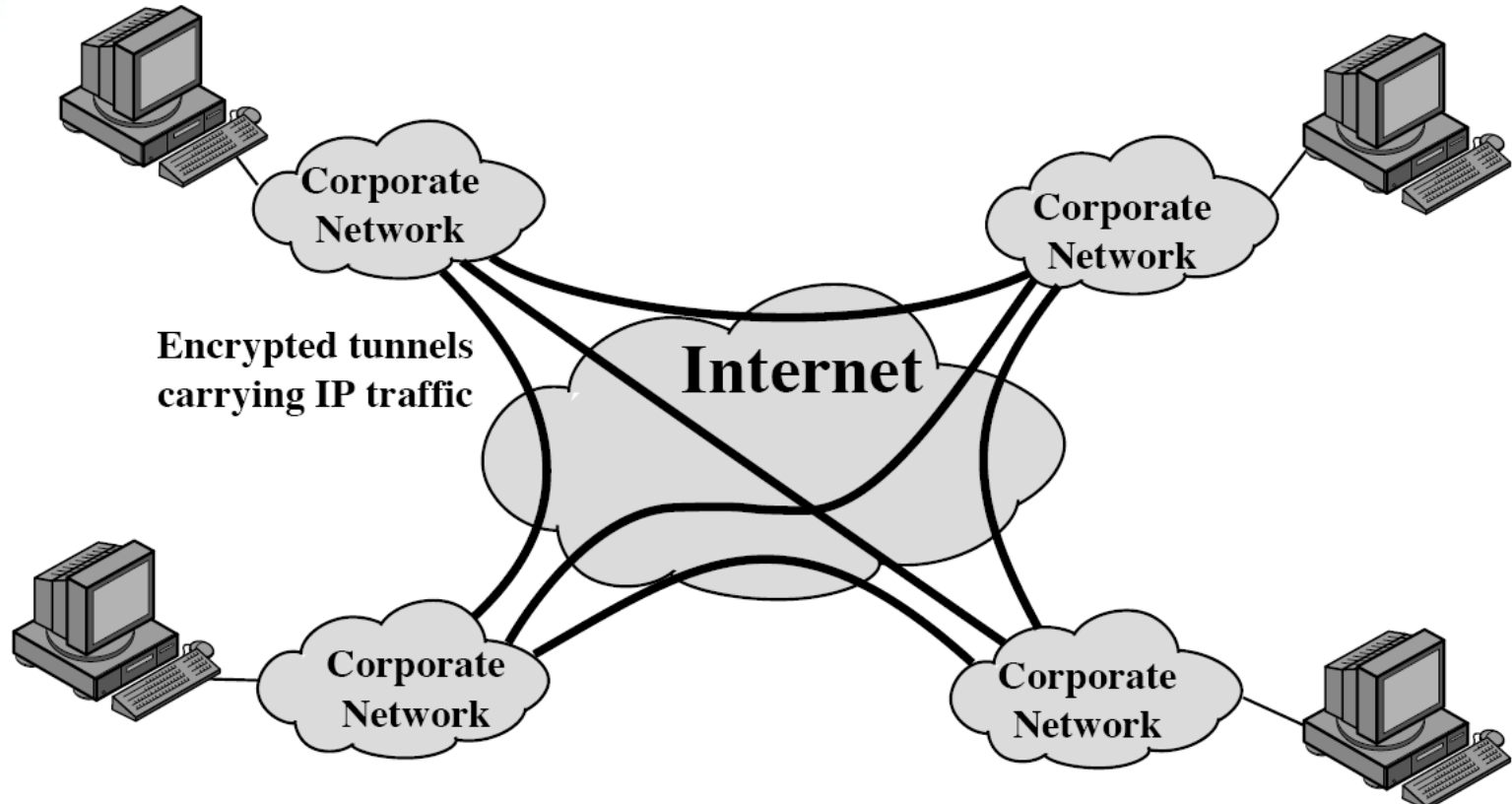


ESP and Transport Mode



- PCs support IPsec
- Encrypt traffic end-to-end; PC-to-PC

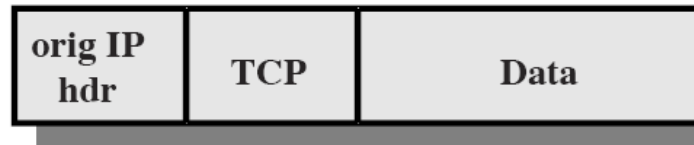
ESP and Tunneling Mode



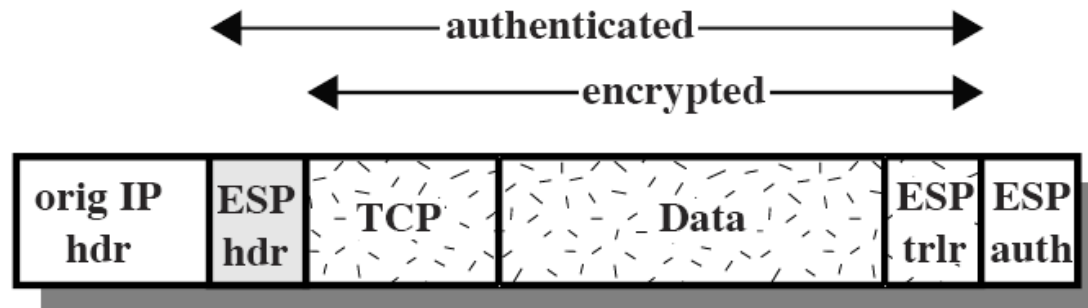
- Hosts/PCs send normal IP traffic (unencrypted)
- Routers at edge of local network creates an IPsec tunnel to other network

ESP and Protocol Models

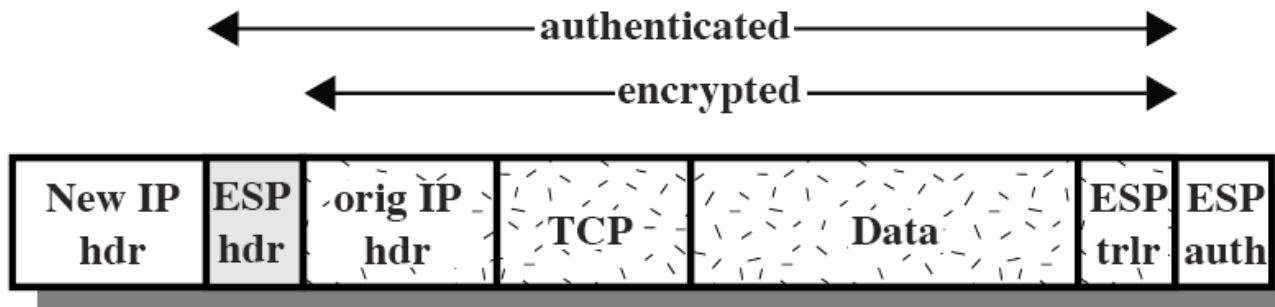
- Original IP datagram (before IPsec):



- ESP and Transport Mode:



- ESP and Tunnelling Mode



Summary of Protocol Modes

| | Transport | Tunnel |
|-----------------------|---|--|
| AH | Authenticate IP payload and selected parts of IP header | Authenticates entire inner IP packet (payload plus header) and parts of outer header |
| ESP | Encrypts IP payload | Encrypts entire inner IP packet |
| ESP with Auth. | Encrypts IP payload; authenticates IP payload | Encrypts entire inner IP packet; authenticates inner IP packet |

Summary of IPsec Services

| | AH | ESP (encrypt only) | ESP (encrypt + auth.) |
|--------------------------------------|----|--------------------|-----------------------|
| Access control | ✓ | ✓ | ✓ |
| Data integrity | ✓ | | ✓ |
| Data origin authentication | ✓ | | ✓ |
| Anti-replay | ✓ | ✓ | ✓ |
| Confidentiality | | ✓ | ✓ |
| Limited traffic flow confidentiality | | ✓ | ✓ |

Applications of IPsec

- Connecting branches/offices securely over the Internet
 - Create a Virtual Private Network using IPsec from Office A to Office B
 - Use of Internet to connect offices is cheaper than dedicated lines (e.g. DSL, E1, ATM)
 - Use ESP in tunnelling mode
- Secure remote access over Internet
 - Employee connects from home/hotel via a ISP to office
 - VPN from user PC to office router
 - Use ESP in tunnelling mode
- Web sites and e-commerce applications
 - IPsec can be used as an alternative or complement to HTTPS and similar protocols
 - Use ESP in transport mode

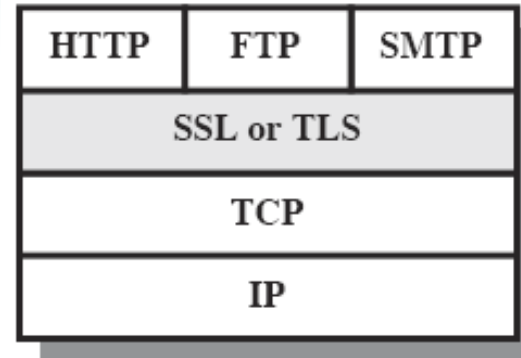
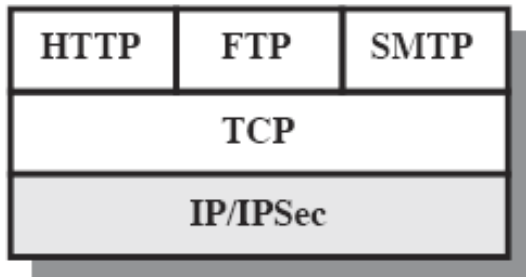
TLS

Transport Layer Security

Secure Socket Layer

- SSL originally developed by Netscape
 - SSL v3.1 is known as Transport Layer Security (TLS); developed by IETF
 - We will treat SSL and TLS as the same
- Provides security services between TCP and applications that use TCP
 - HTTP, FTP, SMTP, ...
- SSL is commonly used for Web security
 - HTTPS is simply HTTP on top of SSL

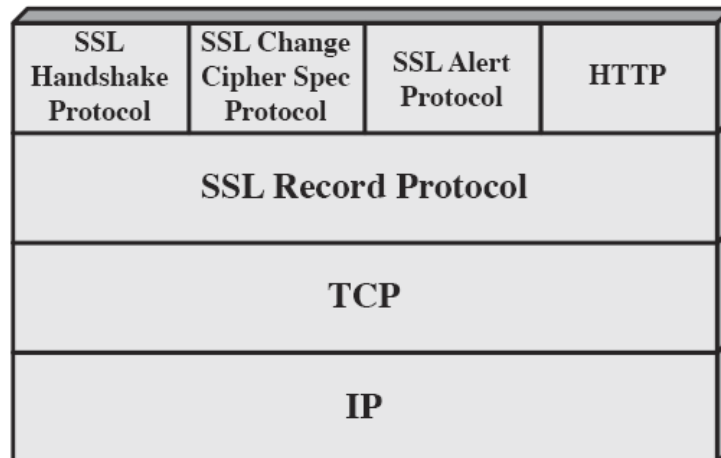
SSL versus IPsec



- IPsec is implemented in operating system at IP layer
 - Can be used by any Internet application
- SSL can only be used by applications that use TCP
 - Many real-time and messaging applications use UDP, not TCP
 - Implementation of SSL:
 - Option 1: Implement in operating system or common library so any application can use (e.g. OpenSSL library)
 - Option 2: Applications implement their own instance of SSL
 - E.g. web browsers like IE and Firefox, and web servers like Apache implement SSL

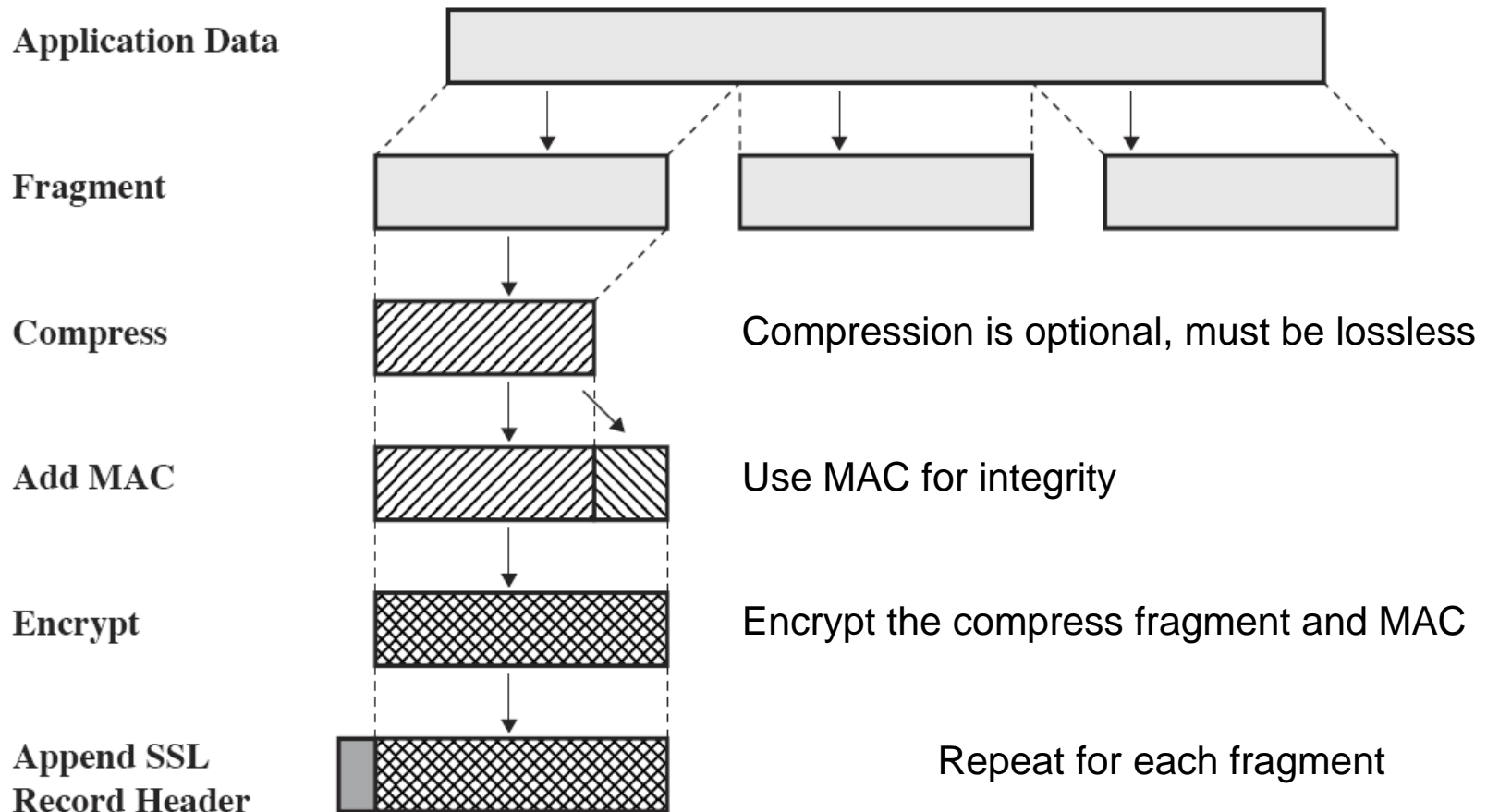
SSL Architecture

- SSL includes two layers:
 - Record Protocol: provides confidentiality and integrity of messages
 - Management layer:
 - Handshake protocol to agree upon parameters upon start
 - Change cipher protocol to change to the next cipher in the session
 - Alert protocol to alert the other side that something has happened
 - E.g. unexpected message, incorrect MAC, handshake failure, illegal parameter, bad certificate, certificate expired, ...



SSL Record Protocol

- Confidentiality provided using symmetric key encryption
- Integrity provided using Message Authentication Code



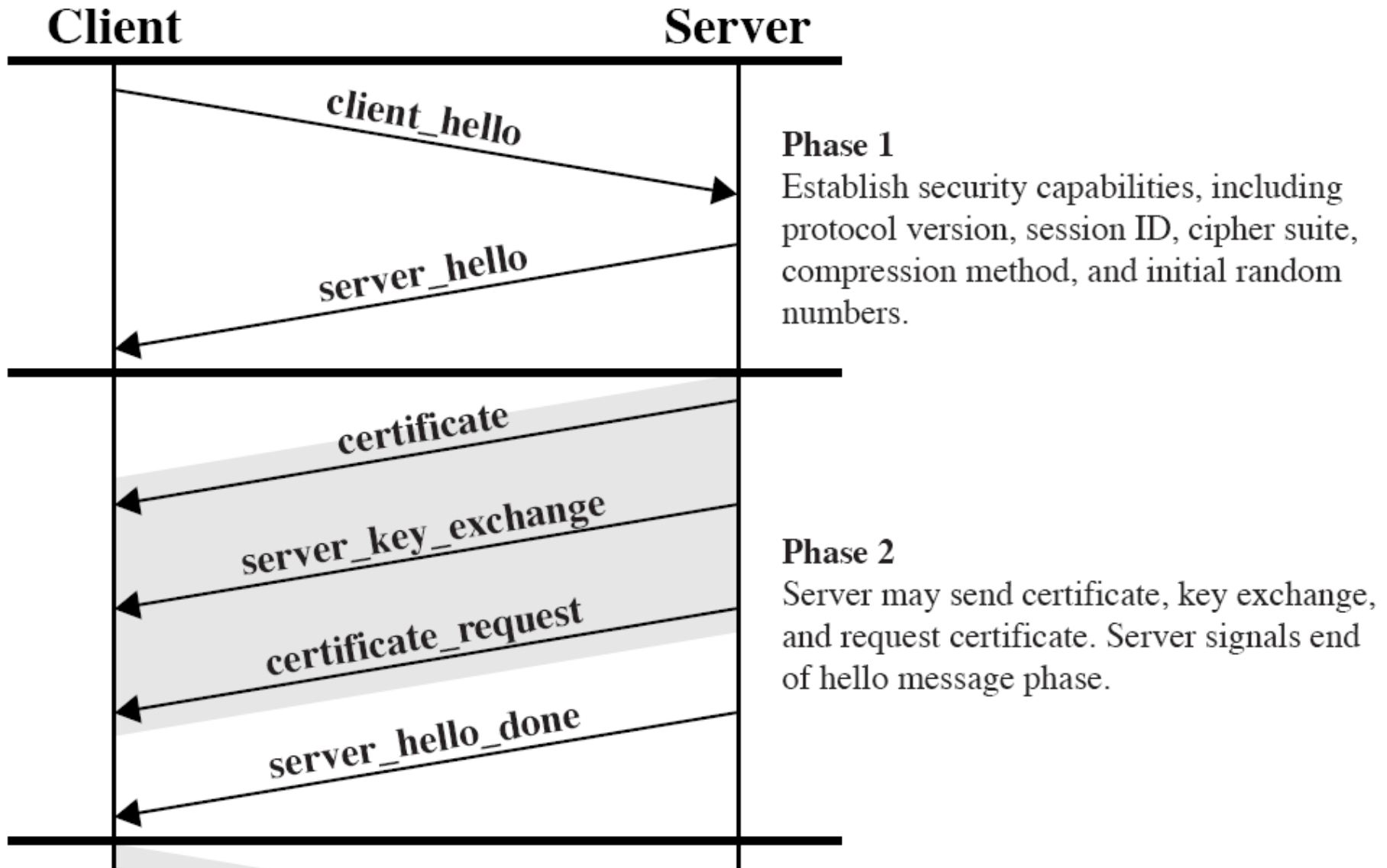
SSL Encrypt and MAC Algorithms

- Currently supported symmetric key algorithms for encryption:
 - Block ciphers
 - AES, IDEA, RC2, DES, 3DES, Fortezza
 - Stream ciphers
 - RC4
- MAC
 - MD5 or SHA1
 - TLS uses both MD5 and SHA1 and XORs the output together
 - Useful if one algorithm is considered insecure

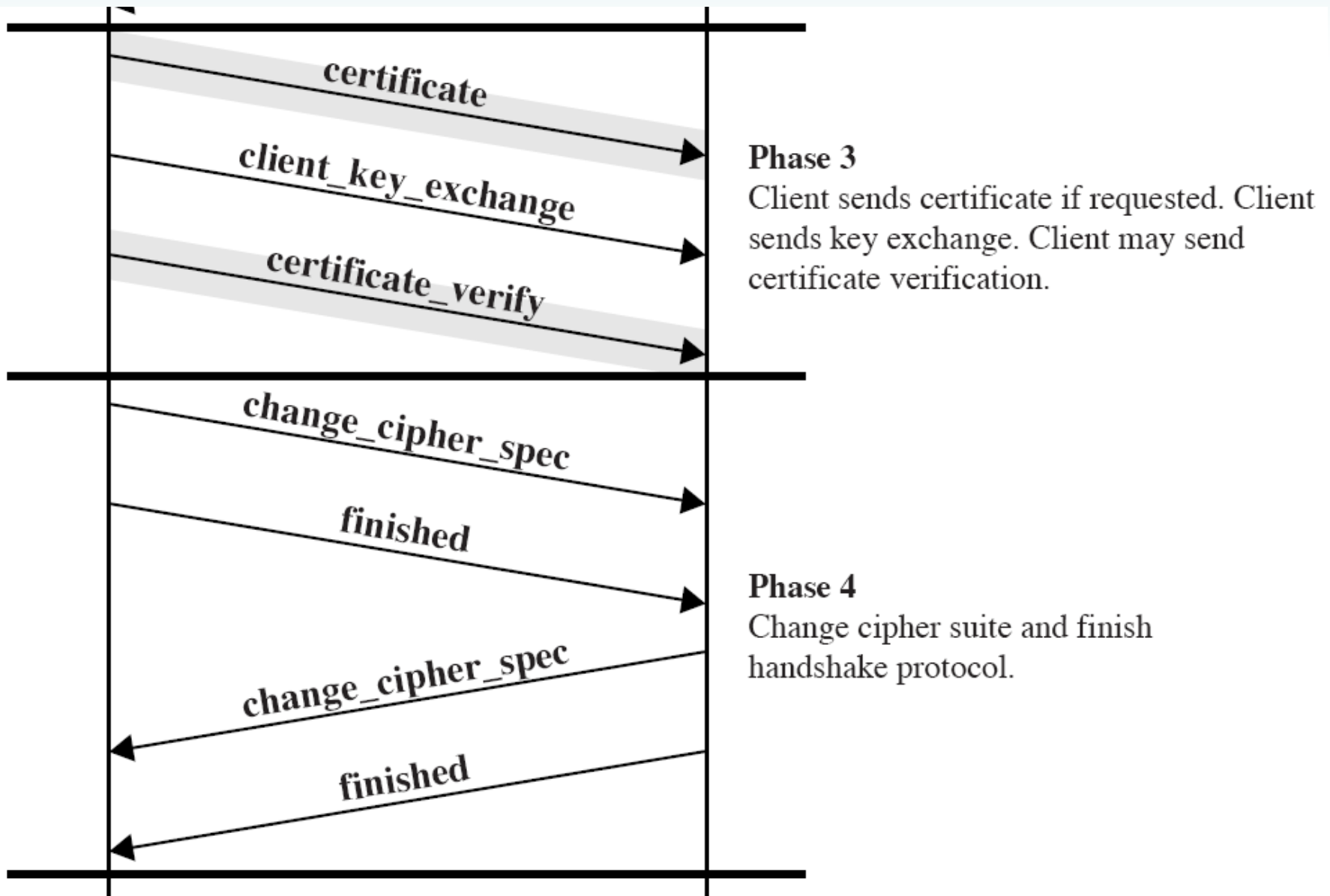
SSL Handshake Protocol

- Performed before any data is sent. Four phases:
 - Create connection and agree upon security capabilities
 - Send HELLO messages between client and server
 - HELLO messages can contain list of encryption, MAC and compression algorithms implemented
 - Server Authentication and Key Exchange
 - X.509 certificates are exchanged
 - A server key may be exchanged depending on exchange protocol
 - Key exchange methods supported:
 - RSA, Diffie-Hellman, Fortezza
 - Client Authentication and Key Exchange
 - Finish
 - Use Change Cipher Protocol to change from key exchange cipher to encryption cipher
 - Send final finish message to check that encryption cipher is correct

SSL Handshake Protocol



SSL Handshake Protocol



SSL and HTTPS

- Secure web transfer is a key application of SSL
 - HTTPS is simple HTTP using SSL
- HTTP servers normally accept connections on port 80
- HTTPS servers accept connections on port 443
 - The Web Server that supports SSL (e.g. Apache) must be configured with a public key certificate
 - Certificate should be signed by a CA for public use
 - Web browser can the verify the certificate from its in-built list of CAs