Introduction to Computer Security

Chapter 22: Internet Security Protocols and Standards

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Outline

- Secure E-mail
- DomainKeys Identified Mail
- Secure Sockets Layer (SSL) and Transport Layer Security (TLS)
- HTTPS (HTTP over SSL)
- IPv4 and IPv6 Security

Secure E-mail

MIME

- Extension to the old RFC 822 specification of an Internet mail format
  - RFC 822 defines a simple heading with To, From, Subject
  - Assumes ASCII text format
- Provides a number of new header fields that define information about the body of the message

S/MIME

- Secure/Multipurpose Internet Mail Extension
- Security enhancement to the MIME Internet e-mail format
  - Based on technology from RSA Data Security
- Provides the ability to sign and/or encrypt e-mail messages

MIME and S/MIME Message Examples

MIME

```
From: John Doe <example@example.com>
MIME-Version: 1.0
Content-Type: multipart/mixed;
        boundary="XXXXboundary text"

This is a multipart message in MIME format.

--XXXXboundary text
Content-Type: text/plain

this is the body text

--XXXXboundary text
Content-Type: text/plain;
Content-Disposition: attachment;
        filename="test.txt"

this is the attachment text

--XXXXboundary text--
```

S/MIME

```
Content-Type: multipart/signed;
protocol="application/pkcs7-signature"; micalg="sha1";
boundary="----Alexis"

------Alexis
Content-Type: text/plain

This is an example of a clear signed message.

------Alexis
Content-Type: application/pkcs7-signature; name="smime.p7s"
Content-Transfer-Encoding: base64
Content-Disposition: attachment; filename="smime.p7s"

MIHmBgkqhkiG9w0BBwKggdgwgdUCAQMxCTAHBgUrDgMCGjALBgkqhkiG9w0BBwEx
gbcwgbQCAQOAFFJz90NbzoEOUQOJxop1+azsEdH9MAcGBSsOAwIaMA0GCSqGSIb3
DQEBAQUABIGAmO1mvk4maqMgb+aYomDTO5fPnRK/0p8w4ExJnai+MknjHmo5VX99
J0zxf+myPuBn1ajZKxoDIRSHpeMp8oToAKUgWNQm7b/yAqRmtCQvmaeI7rnMULVU
cfQfsI0Hz/ujJO2wUUMjFKmLgo7Q/C7++JTJTad9+SADRcNnVEWGjMg=

------Alexis--
```

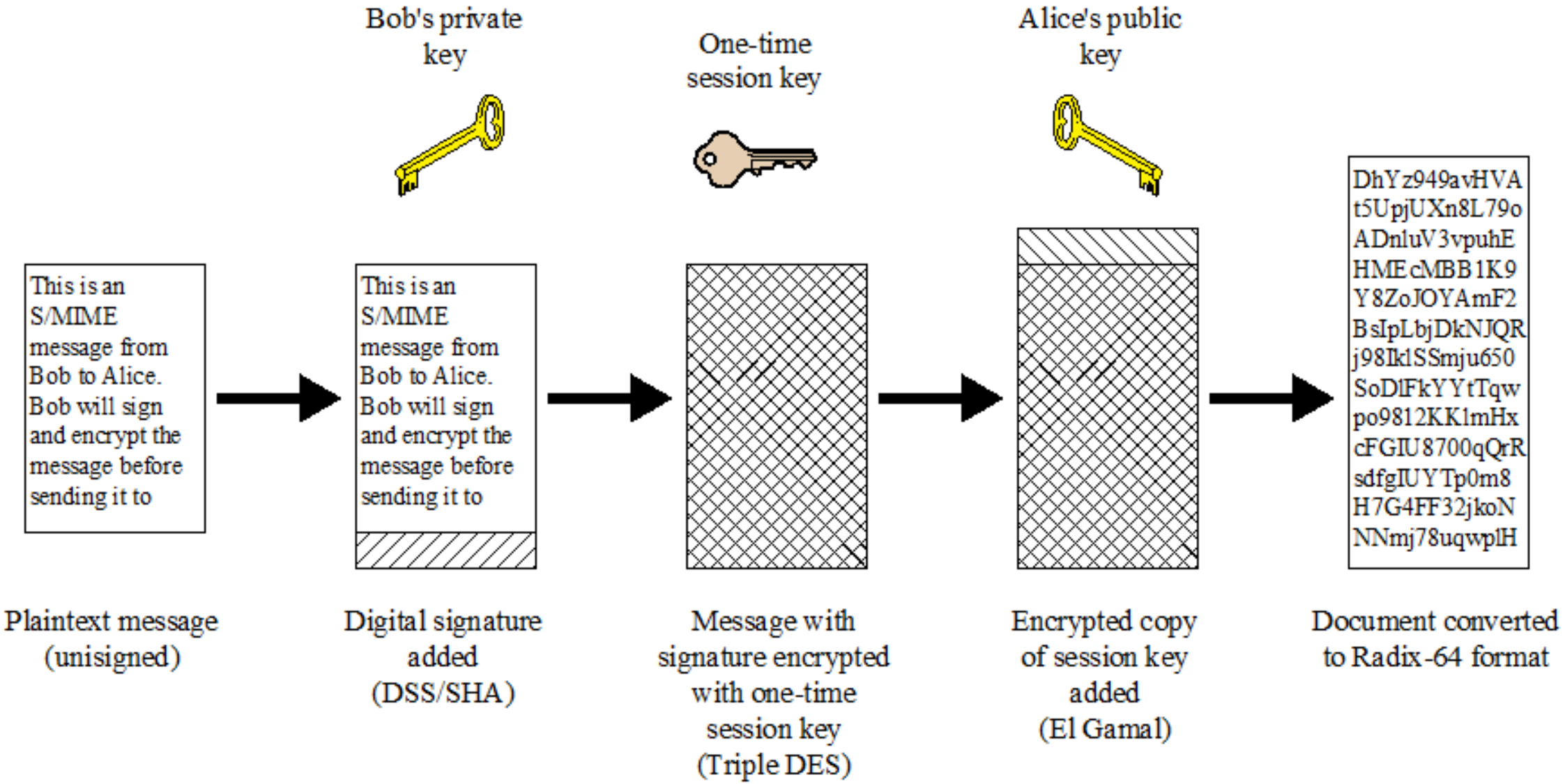
MIME Content Types

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.

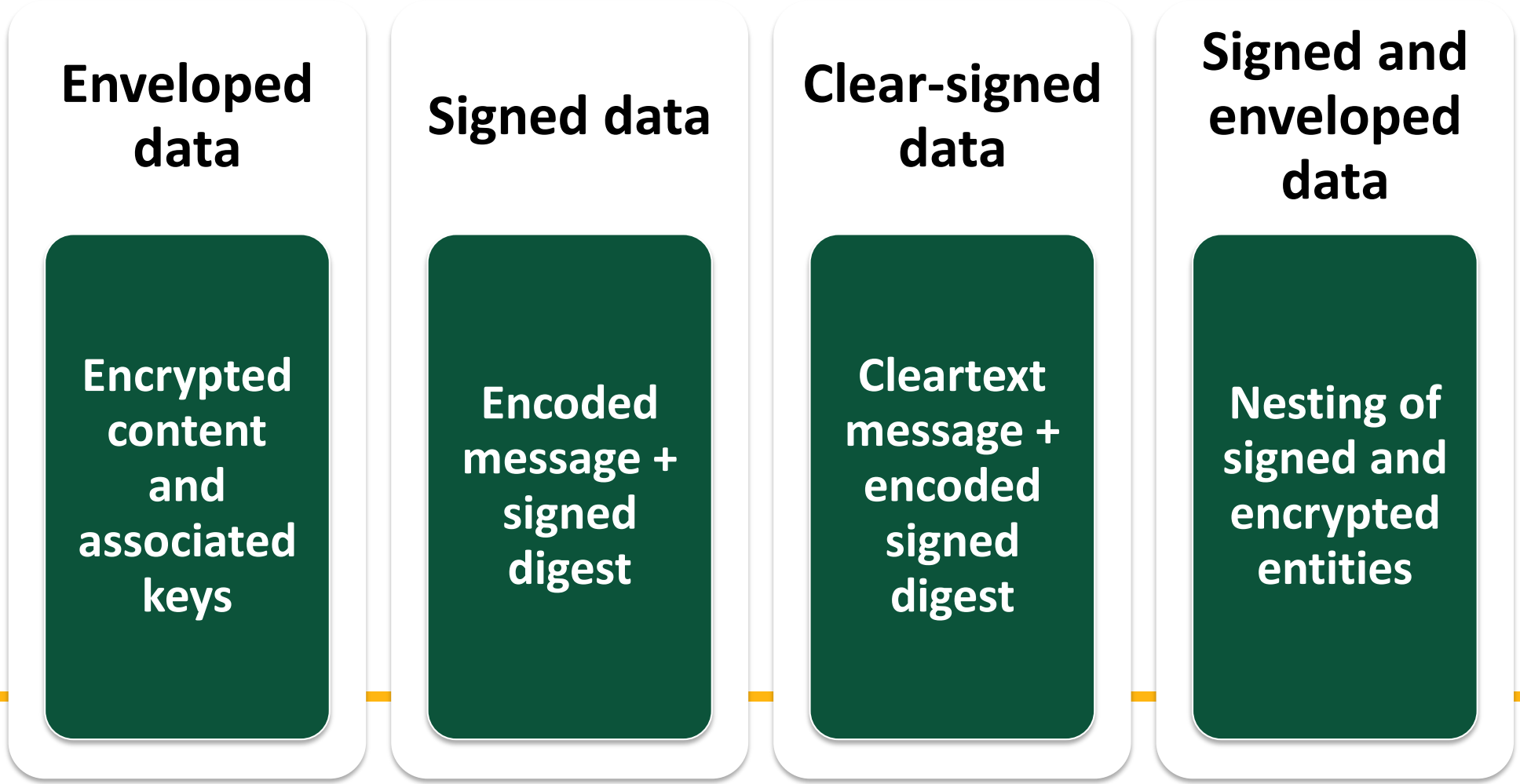
S/MIME Content Types

Type	Subtype	smime Parameter	Description
Multipart	Signed		A clear-signed message in two parts: one is the message and the other is the signature.
Application	pkcs7-mime	signedData	A signed S/MIME entity.
	pkcs7-mime	envelopedData	An encrypted S/MIME entity.
	pkcs7-mime	degenerate signedData	An entity containing only public-key certificates.
	pkcs7-mime	CompressedData	A compressed S/MIME entity.
	pkcs7-signature	signedData	The content type of the signature subpart of a multipart/signed message.

Typical S/MIME Process for Creating an S/MIME Message



S/MIME Functions



Enveloped Data Using Public-key Infrastructure

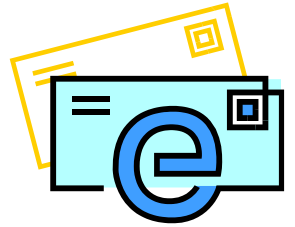
- Default algorithms used for encrypting S/MIME messages are 3DES and EIGamal
  - M → 3DES(M) → X + 3DES(M) → Elgamal (X + 3DES(M))
    - M: message
    - X: a session encryption key
    - Use recipient's EIGamal's public key to encrypt X+3DES(M)
    - ElGamal is based on the Diffie-Hellman public-key exchange algorithm
- Radix-64 is used to convert the ciphertext to ASCII format
- Basic tool that permits widespread use of S/MIME is the public-key certificate
- S/MIME uses certificates that conform to the international standard X.509v3

Signed and Clear-signed Data

- Signed data ➔ Base64(content + sig)
- Clear-signed data ➔ content + Base64(sig)
- Default algorithms used for signing messages
  - DSS(SHA-1(Message), DSS-private-key)
  - DSS: Digital Signature Standard; SHA: Secure Hash Algorithm
- Alternative
  - RSA(SHA-1/MD5(Message), RSA-private-key)
- Radix-64 or base64 mapping is used to map the signature and message into printable ASCII characters

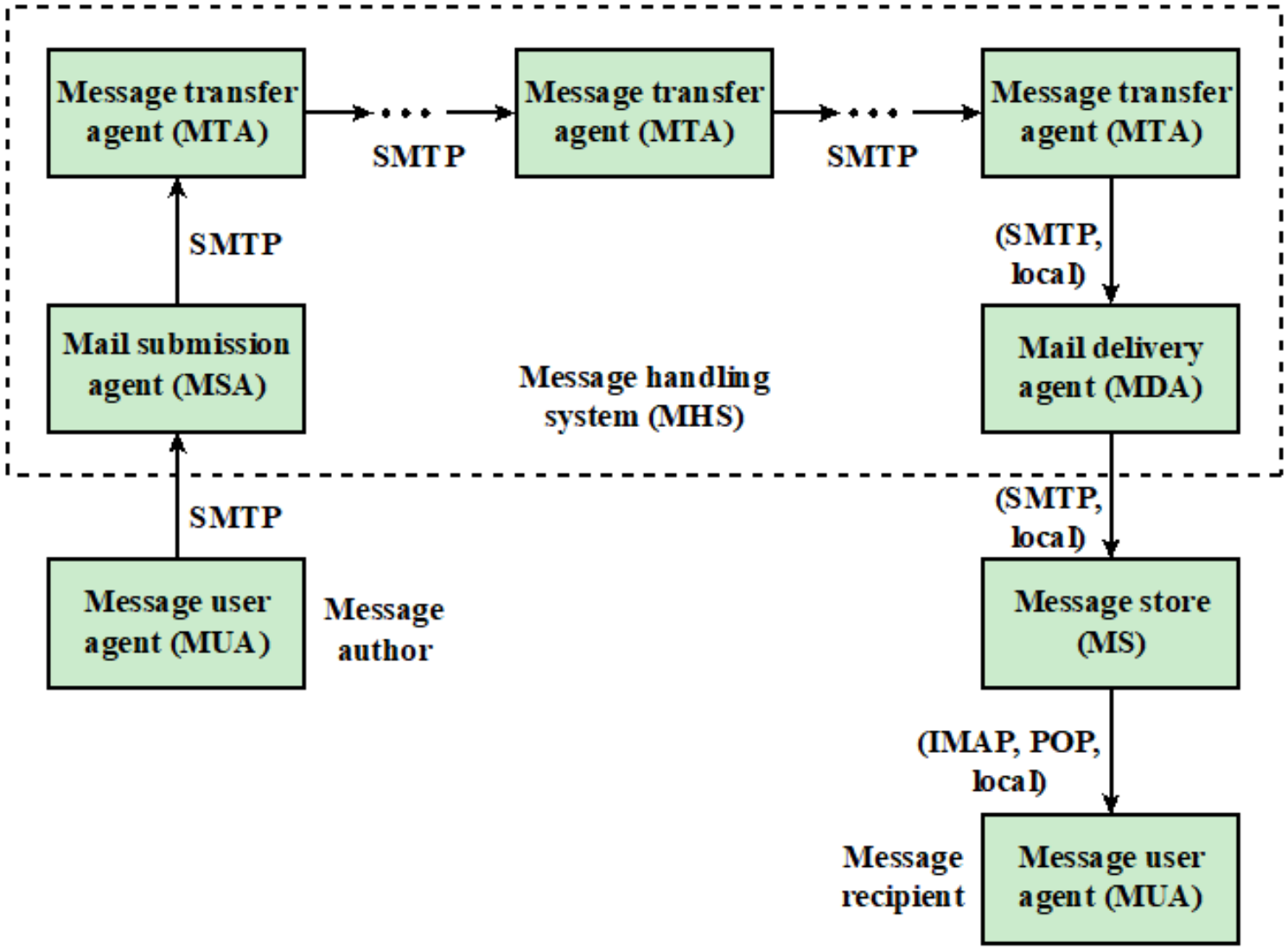
DomainKeys Identified Mail (DKIM)

- A specification of cryptographically signing e-mail messages
  - Permitting a signing domain to claim responsibility for a message in the mail stream
- A proposed Internet standard
  - RFC 4871: DomainKeys Identified Mail (DKIM) Signatures
- Has been widely adopted by a range of e-mail providers
  - e.g., gmail, yahoo, and many ISPs



Internet Mail Architecture

- User world: MUA
- Transfer world: MHS
  - Composed of MTAs

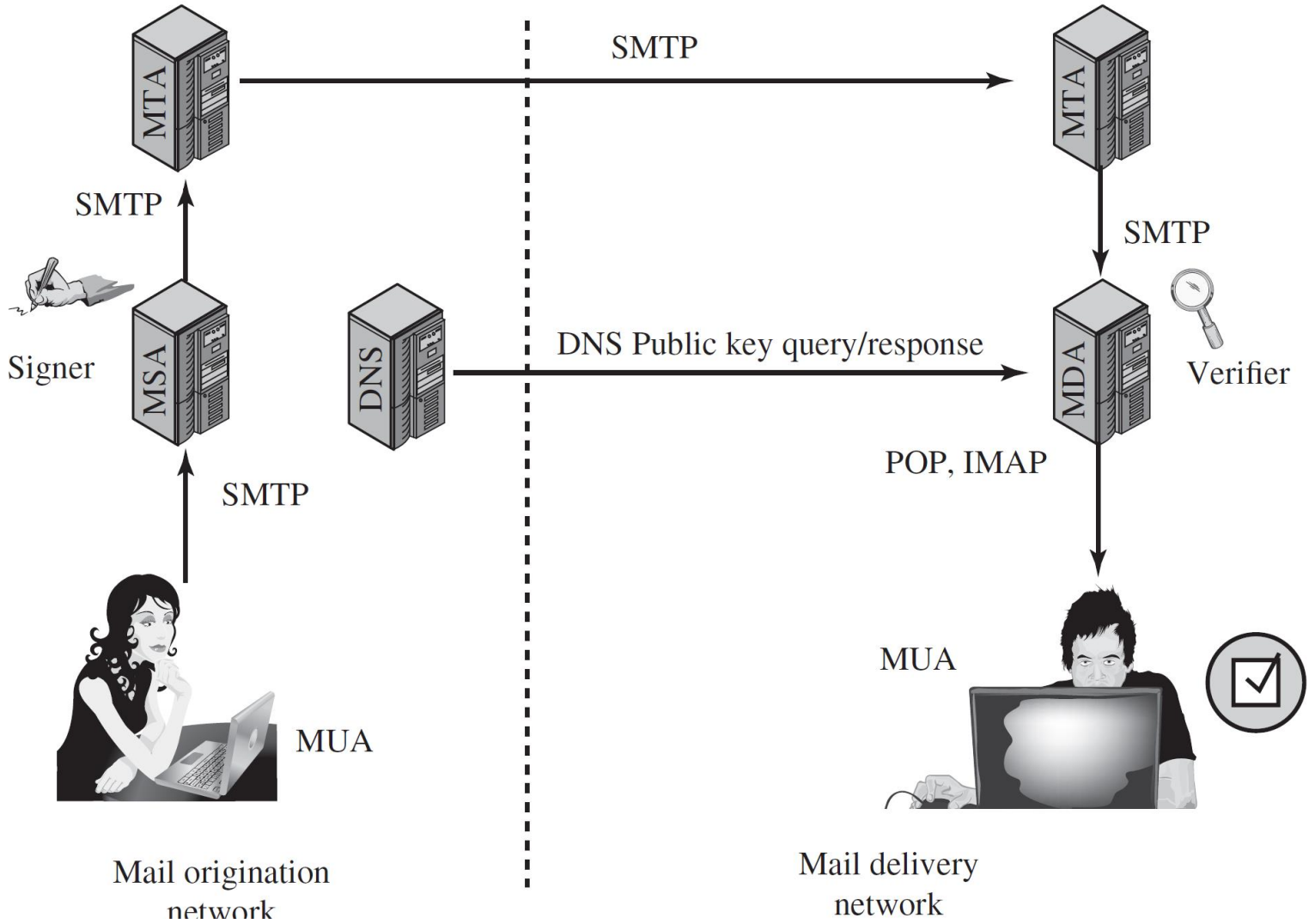


Why DKIM?

- An email authentication technique that is transparent to the end user

- Reasons
  - S/MIME depends on both the sending and receiving users employing S/MIME
    - But, the bulk of incoming mail does not use S/MIME
  - S/MIME signs only the message content
    - Header information concerning origin can be compromised
  - Transparent to the user; (s)he need take no action
  - Applied to all mail from cooperating domains
  - Preventing forgers from masquerading as good senders

Simple Example of DKIM Deployment

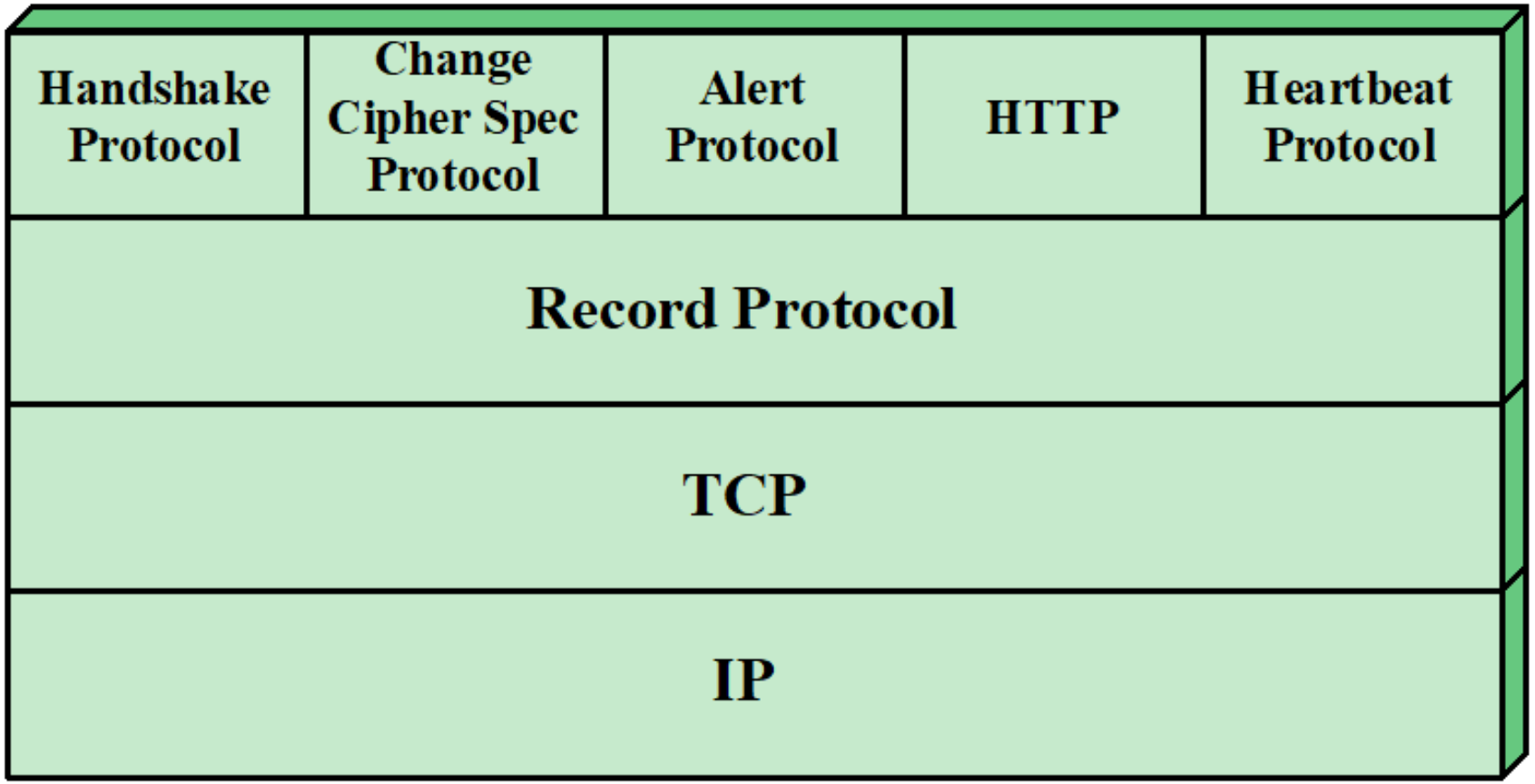


DNS = domain name system
MDA = mail delivery agent
MSA = mail submission agent
MTA = message transfer agent
MUA = message user agent

SSL and TLS

- Secure Socket Layer (SSL)
  - One of the most widely used security services
  - SSL3.0, SSL2.0 (deprecated in 2015)
- Transport Layer Security (TLS)
  - Becoming Internet standard RFC4346
  - General-purpose service: as a set of protocols that rely on TCP
  - TLS1.3, TLS1.2, TLS1.1 (new standards)
  - Two implementation choices
    - As part of the underlying protocol suite: transparent to apps
    - Be embedded in specific packages: e.g., most browsers come equipped with SSL

SSL/TLS Protocol Stack



TLS Concepts

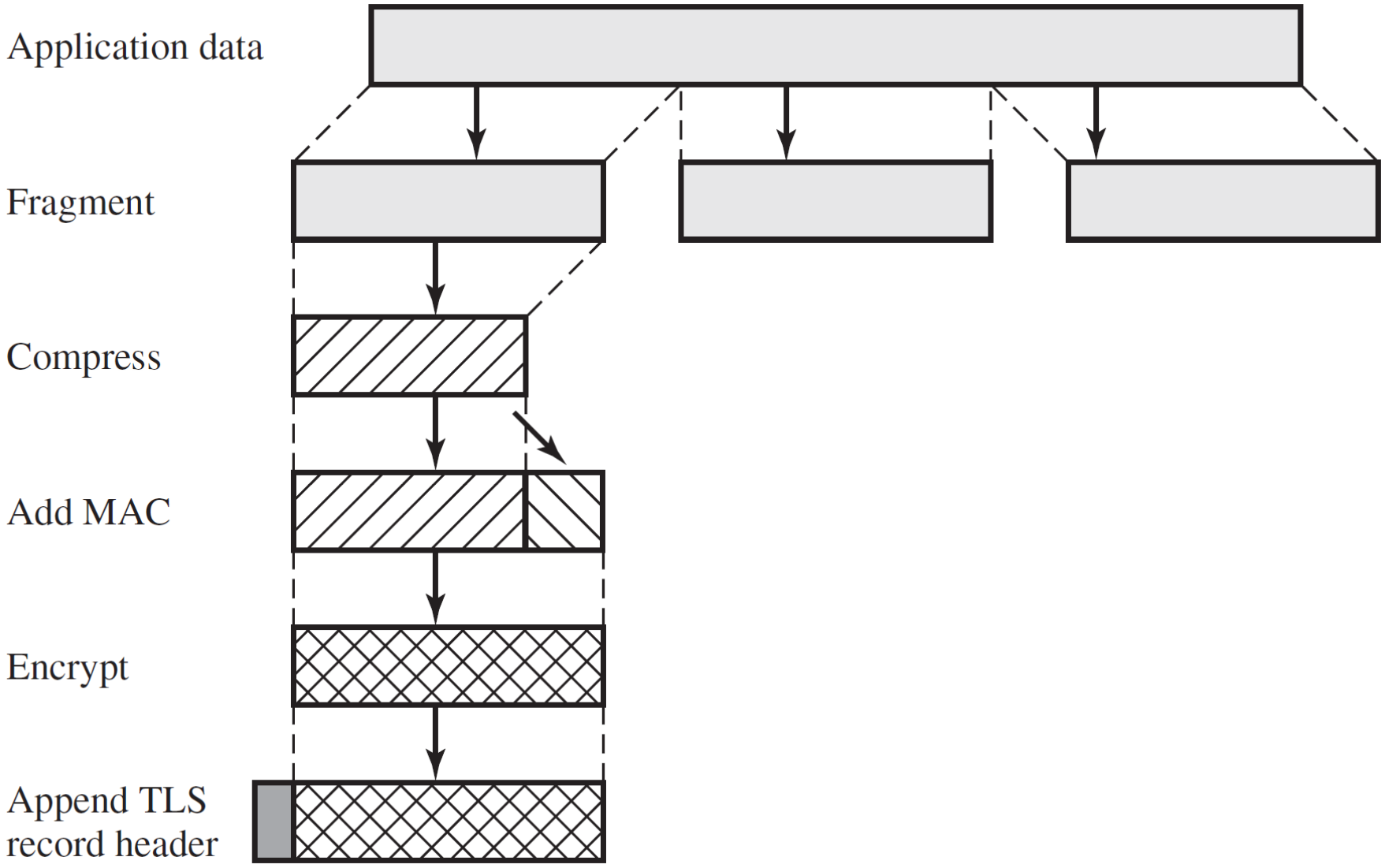
TLS Connection

- A transport (in the OSI layering model definition) that provides a suitable type of service
- Peer-to-peer relationships
- Transient
- Every connection is associated with one session

TLS Session

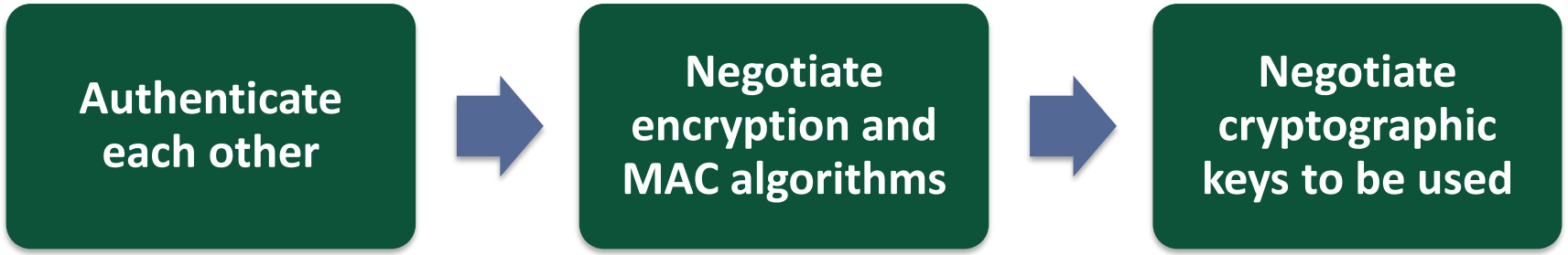
- An association between a client and a server
- Created by the handshake protocol
- Define a set of cryptographic security parameters
- Used to avoid the expensive negotiation of new security parameters for each connection

TLS Record Protocol Operation



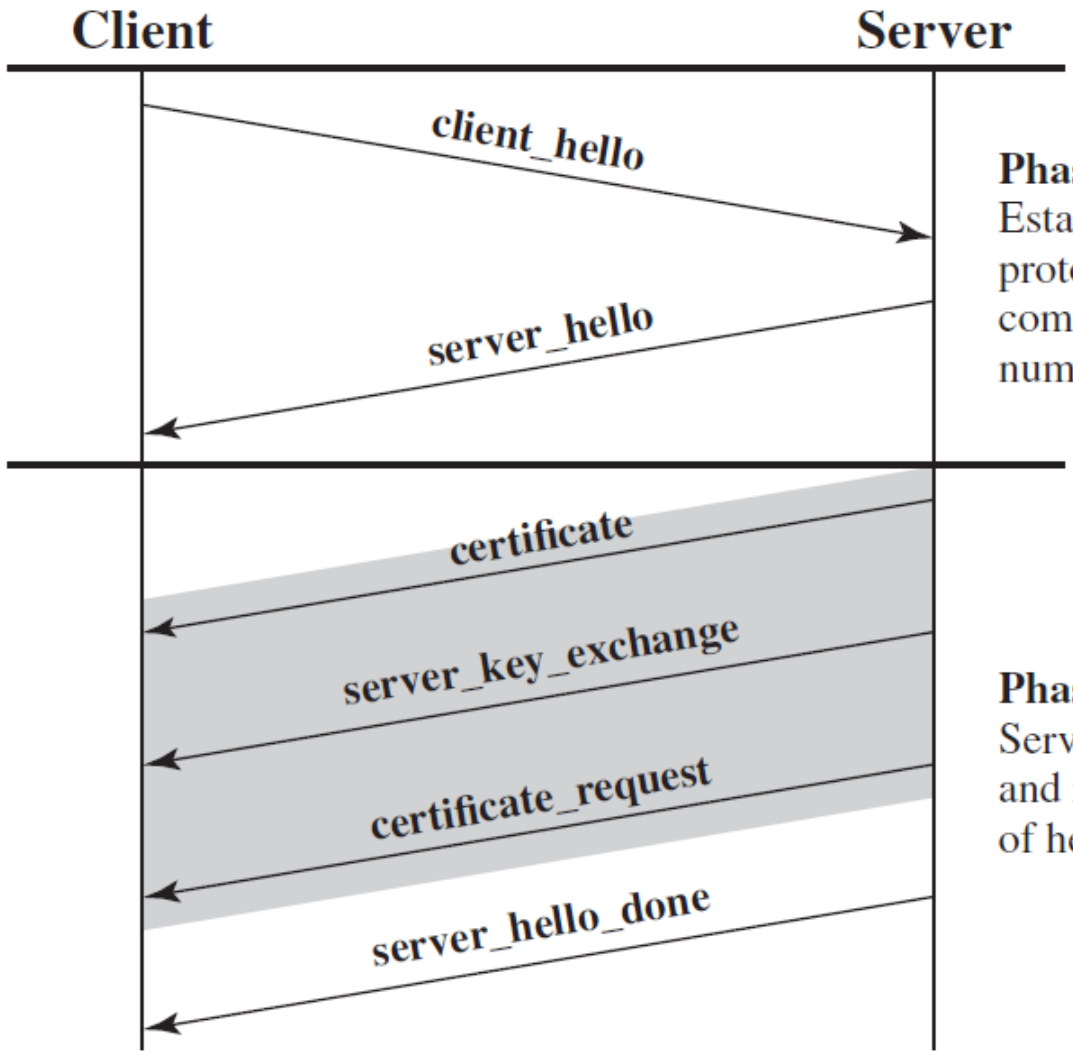
Handshake Protocol

- Most complex part of TLS
- Is used before any application data are transmitted
- Allows server and client to:



- Comprises a series of messages exchanged by client and server
- Exchange has four phases

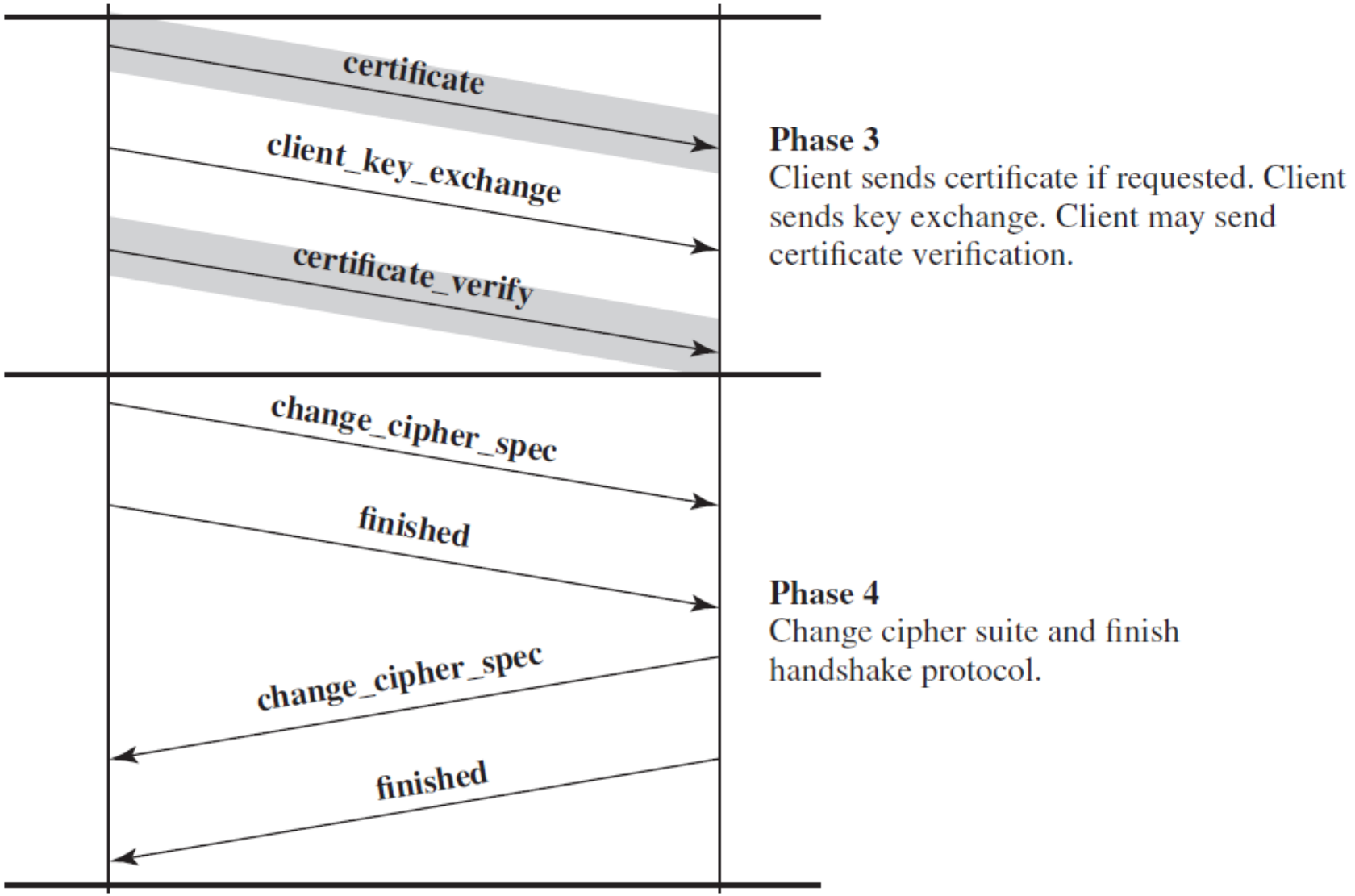
Handshake Protocol Action I



Phase 1
Establish security capabilities, including protocol version, session ID, cipher suite, compression method, and initial random numbers.

Phase 2
Server may send certificate, key exchange, and request certificate. Server signals end of hello message phase.

Handshake Protocol Action II



ClientHello (RFC)

```
CipherSuite TLS_RSA_WITH_NULL_MD5                = { 0x00,0x01 };
CipherSuite TLS_RSA_WITH_NULL_SHA                = { 0x00,0x02 };
CipherSuite TLS_RSA_WITH_NULL_SHA256             = { 0x00,0x3B };
CipherSuite TLS_RSA_WITH_RC4_128_MD5             = { 0x00,0x04 };
CipherSuite TLS_RSA_WITH_RC4_128_SHA             = { 0x00,0x05 };
CipherSuite TLS_RSA_WITH_3DES_EDE_CBC_SHA        = { 0x00,0x0A };
CipherSuite TLS_RSA_WITH_AES_128_CBC_SHA         = { 0x00,0x2F };
CipherSuite TLS_RSA_WITH_AES_256_CBC_SHA         = { 0x00,0x35 };
CipherSuite TLS_RSA_WITH_AES_128_CBC_SHA256      = { 0x00,0x3C };
CipherSuite TLS_RSA_WITH_AES_256_CBC_SHA256      = { 0x00,0x3D };
```

- struct {
  - ProtocolVersion client_version;
  - Random random;
  - SessionID session_id;
  - CipherSuite cipher_suites <2..2^16-2>;
  - CompressionMethod compression_methods <1..2^8-1>;} ClientHello;

ServerHello (RFC)

- struct {
  - ProtocolVersion server_version;
  - Random random;
  - SessionID session_id;
  - CipherSuite cipher_suite;
  - CompressionMethod compression_method;} ServerHello;

Change Cipher Spec Protocol

- One of four TLS specific protocols that use the TLS Record Protocol
- Is the simplest
- Consists of a single message which consists of a single byte with the value 1
- Sole purpose of this message is to cause pending state to be copied into the current state
- Hence updating the cipher suite in use

Alert Protocol

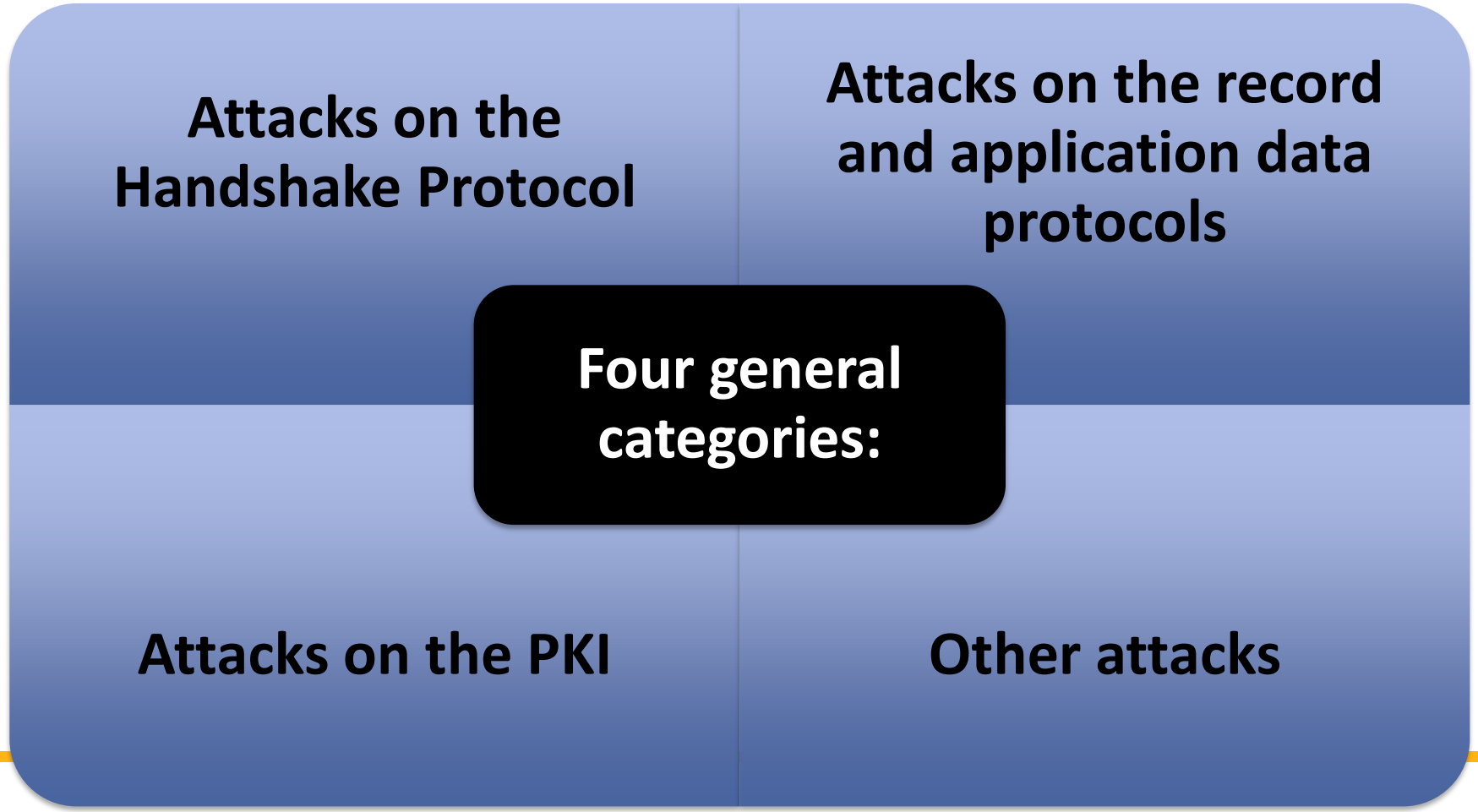
- Two bytes
  - First byte: warning (1), fatal (2)
    - For fatal, TLS implementation **terminates** the TLS connection.
    - For other TLS connections using the same TLS session, they may continue, but no new TLS connections may be established
  - Second byte: specific alert code (RFC5246-appendix)
    - close_notify(0), unexpected_message(10), etc.

Heartbeat Protocol

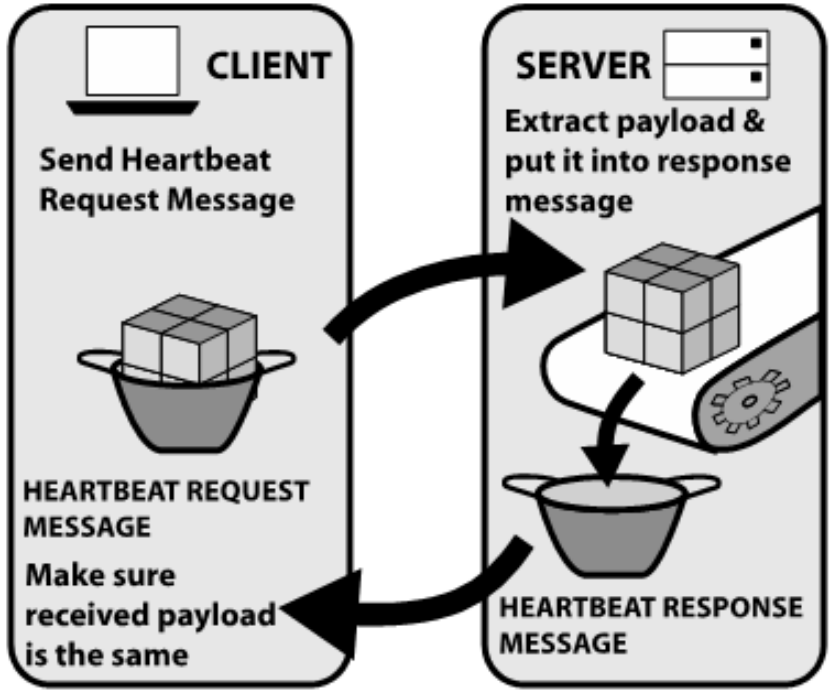
```
struct {
   HeartbeatMessageType type;
   uint16 payload_length;
   opaque payload[HeartbeatMessage.payload_length];
   opaque padding[padding_length];
} HeartbeatMessage;
```

- A periodic signal generated by hardware or software to indicate normal operation or to synchronize other parts of a system
- Typically used to monitor the availability of a protocol entity
- Defined in 2012 in RFC 6250
- Timer: 1s to 60s (RFC6347)
- Runs on top of the TLS Record Protocol
- Use is established during Phase 1 of the Handshake Protocol
- Each peer indicates whether it supports heartbeats
- Serves two purposes:
  - Assures the sender that the recipient is still alive
  - Generates activity across the connection during idle periods

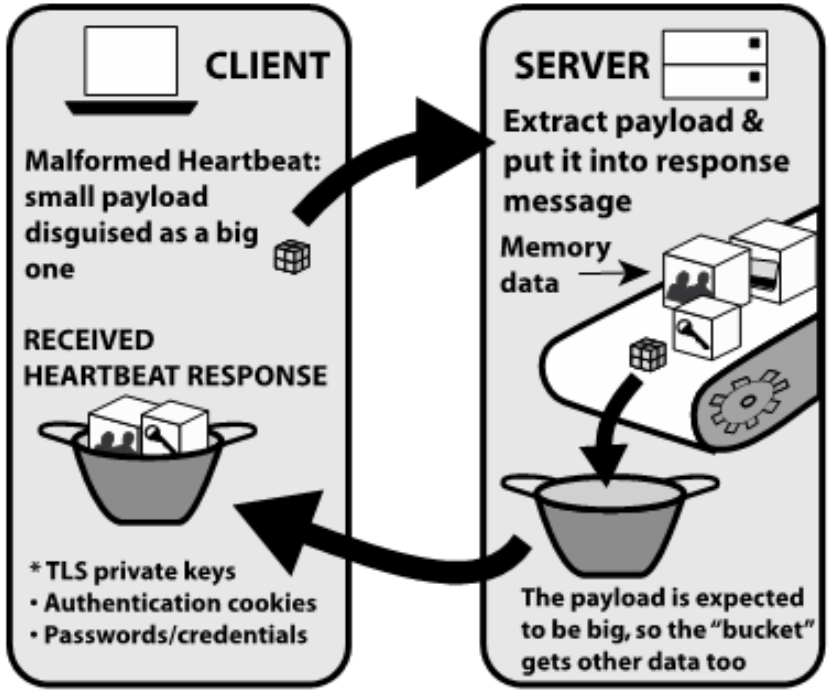
SSL/TLS Attacks



The Heartbleed Exploit (Source: BAE Systems)



(a) How TLS Heartbeat Protocol works

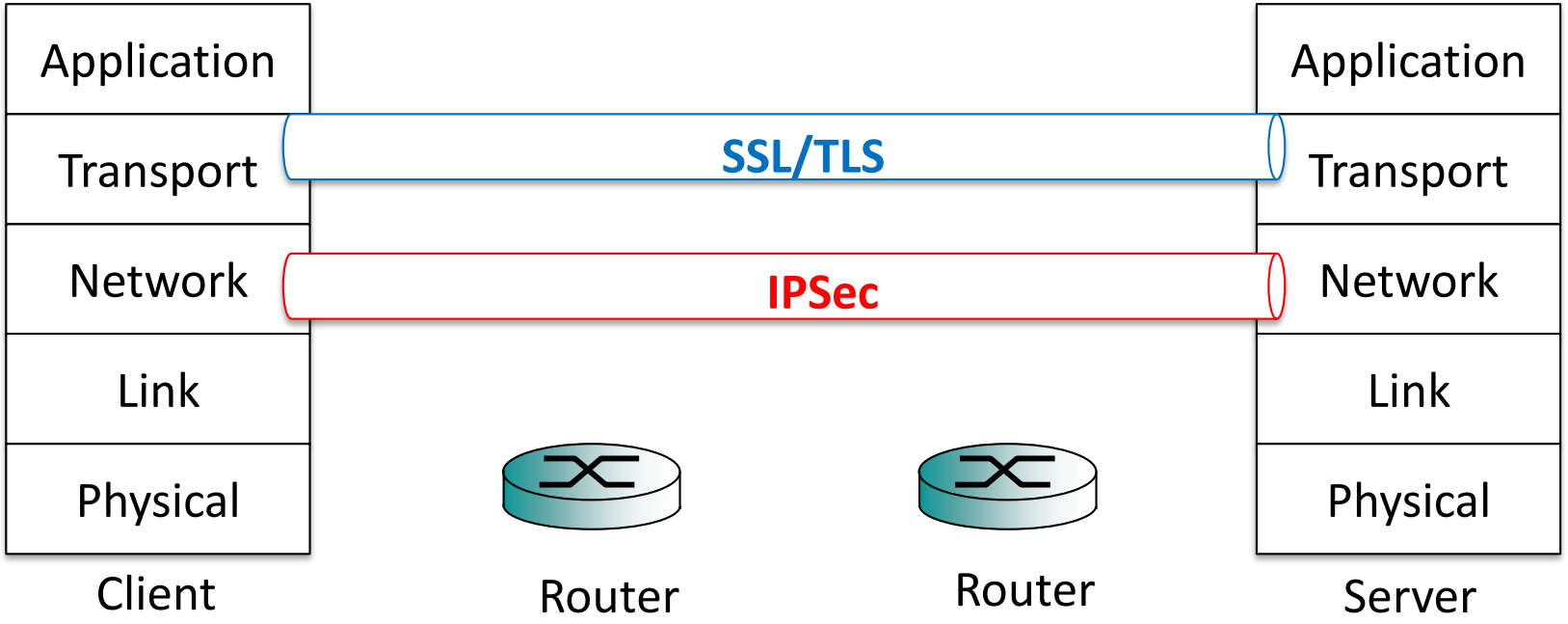


(b) How TLS Heartbleed exploit works

HTTPS (HTTP over SSL/TLS)

- Combination of HTTP and SSL
  - HTTP over TLS (RFC2818)
  - Secure communication between a Web browser and a Web server
- Built into all modern Web browsers
  - Search engines do not support HTTPS
  - URL addresses begin with https://
- Connection initiation and closure
  - HTTP client act as TLS client
  - TLS handshake ➔ HTTP request
  - Three levels: HTTP, TLS session, TCP

IPSec v.s. SSL/TLS



Applications of IPSec

- Secure branch office connectivity over the Internet
- Secure remote access over the Internet
- Establishing extranet and intranet connectivity with partners
- Enhancing electronic commerce security

Benefits of IPSec

- Strong security applied to all traffic at a firewall or router
- Resistant to bypass at a firewall
- Transparent to apps
  - No need to change software
- Transparent to end users
  - No need to train users on security mechanisms

Benefits of IPSec (Cont.)

- Routing apps: prevent attackers from disrupting communications or diverting some traffic
  - A router advertisement from an authorized router
  - A neighbor advertisement from an authorized router
  - A redirect message from the router to which the initial packet was sent
  - A routing update is nor forged

The Scope of IPSec

- Two main functions
  - Encapsulating Security Payload (ESP): a combined authentication/encryption function
  - A key exchange function
- VPN: both authentication and encryption are generally desired
- Authentication Header (AH): authentication-only function (deprecated)

Security Associations

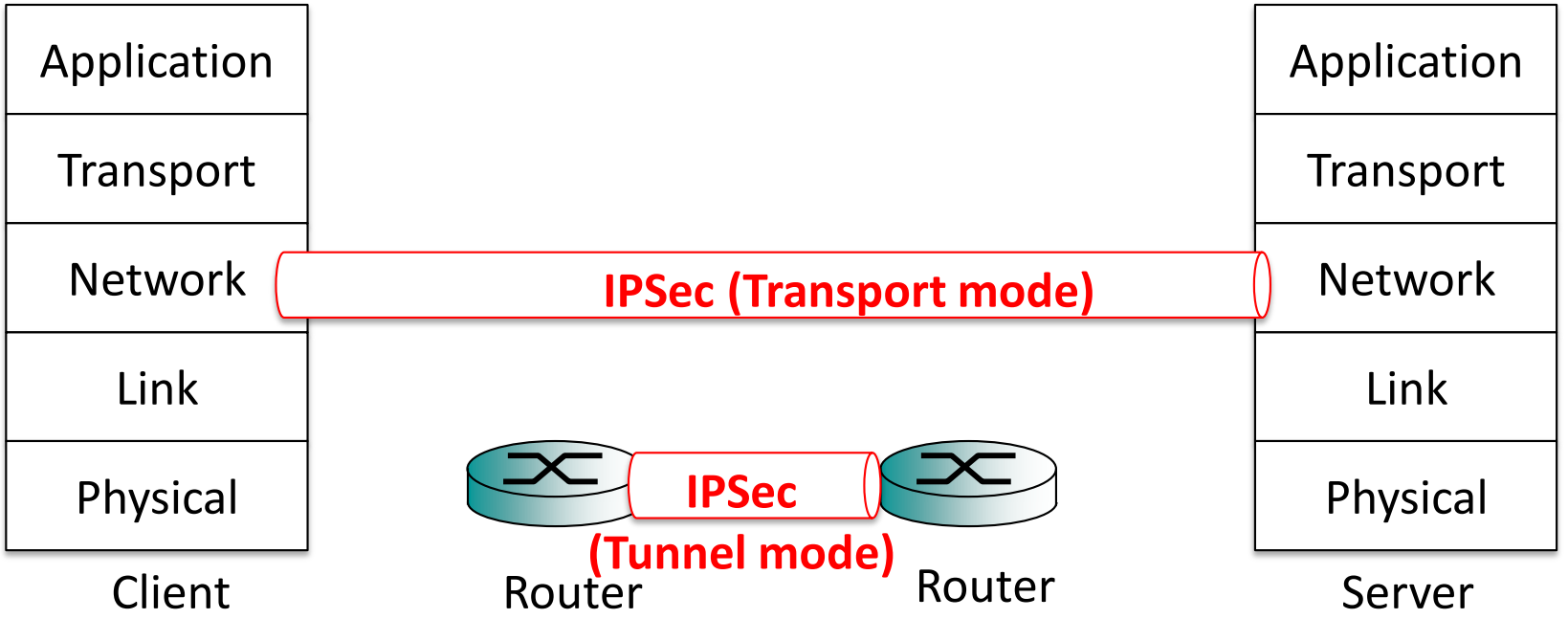
- A key concept of IPSec
  - One-way relationship between a sender and a receiver
  - Two-way secure exchange: two SAs are required
- Uniquely identified by three parameters
  - Security parameter index (SPI)
  - IP destination address
  - Protocol identifier: AH or ESP

Security Associations (Cont.)

- Characterized by the following parameters
  - Sequence number counter: 32-bit
  - Sequence counter overflow: A flag → whether overflow → an auditable event
  - Antireplay window: defining a sliding window
  - AH information
    - Algorithm, keys, key lifetimes, etc.
  - ESP information
    - Algorithm, keys, init values, key lifetimes, etc.
  - Lifetime of this security association
  - IPSec protocol mode: tunnel or transport
  - Path MTU

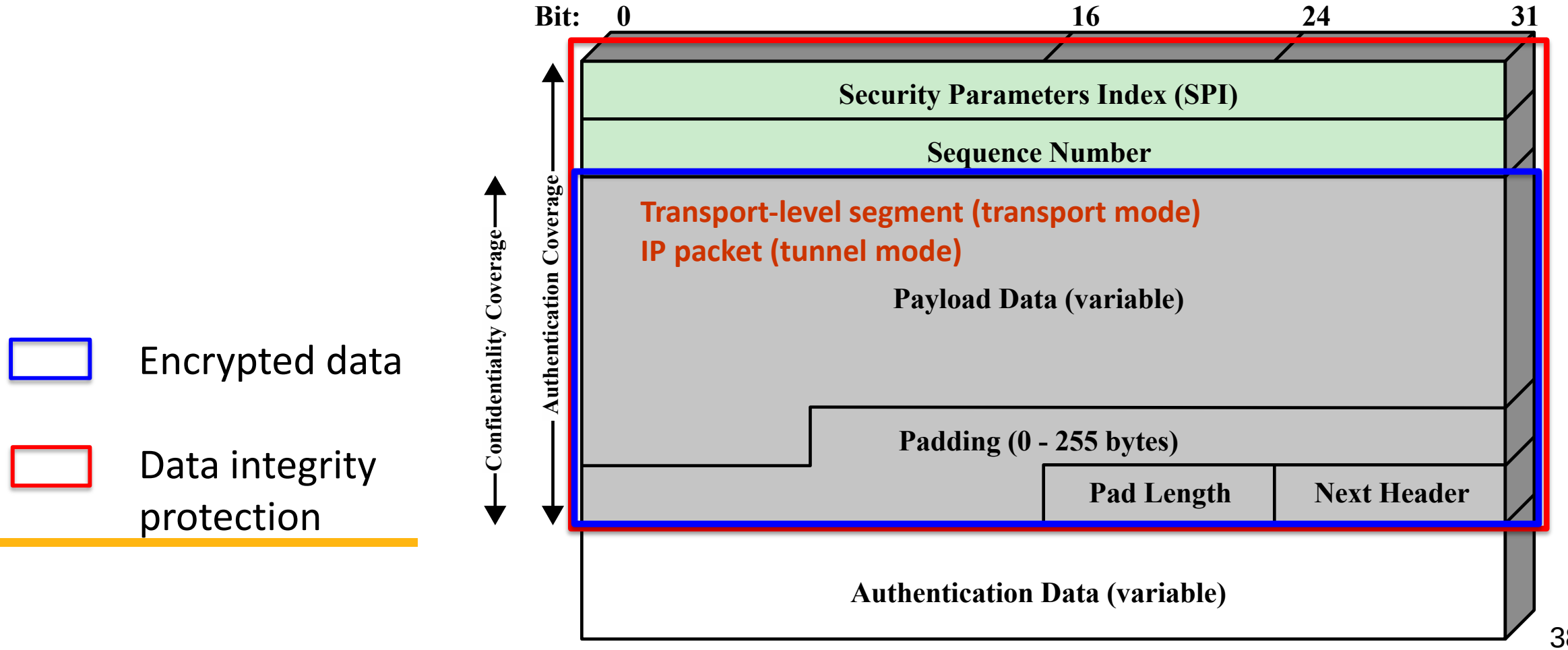
Two IPSec Operation Modes

- Transport and Tunnel modes



Encapsulating Security Payload

- Providing authentication and confidentiality services



Transport and Tunnel Modes

Transport Mode

- Provides protection to the payload of an IP packet
- Typically used for end-to-end communication between two hosts
- ESP protects the IP payload but not the IP header

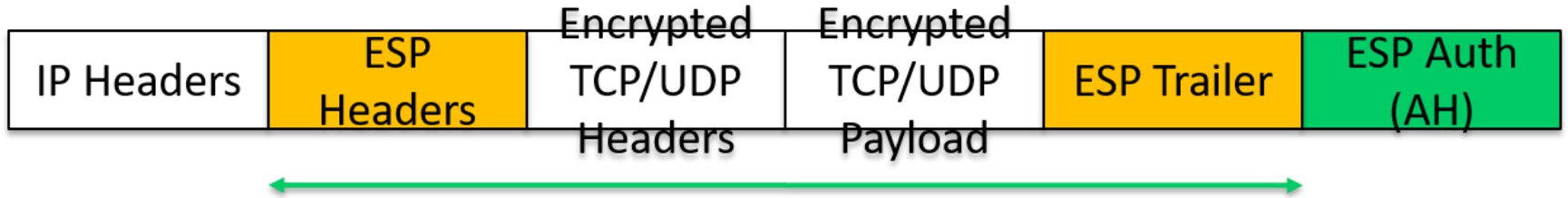
Tunnel Mode

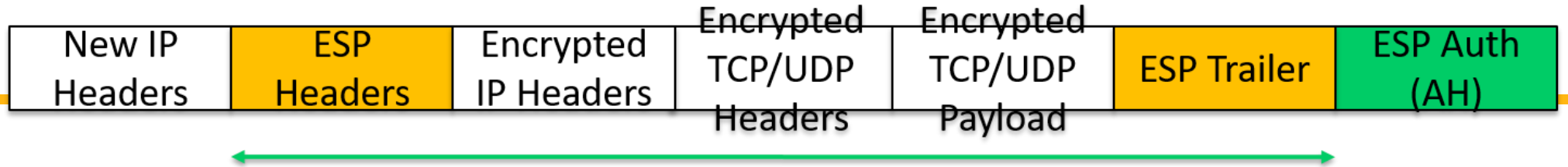
- Provides protection to the entire IP packet
- Entire original packet travels through a tunnel from one point to another
- Used when one or both ends of a security association are a security gateway
- Hosts on networks behind firewalls may engage in secure communications without implementing IPSec

IPSec: AH + ESP

- IP AH only

- IP AH + ESP
  - Transport mode
  - Tunnel mode





Questions?