CSCE 465 Computer & Network Security

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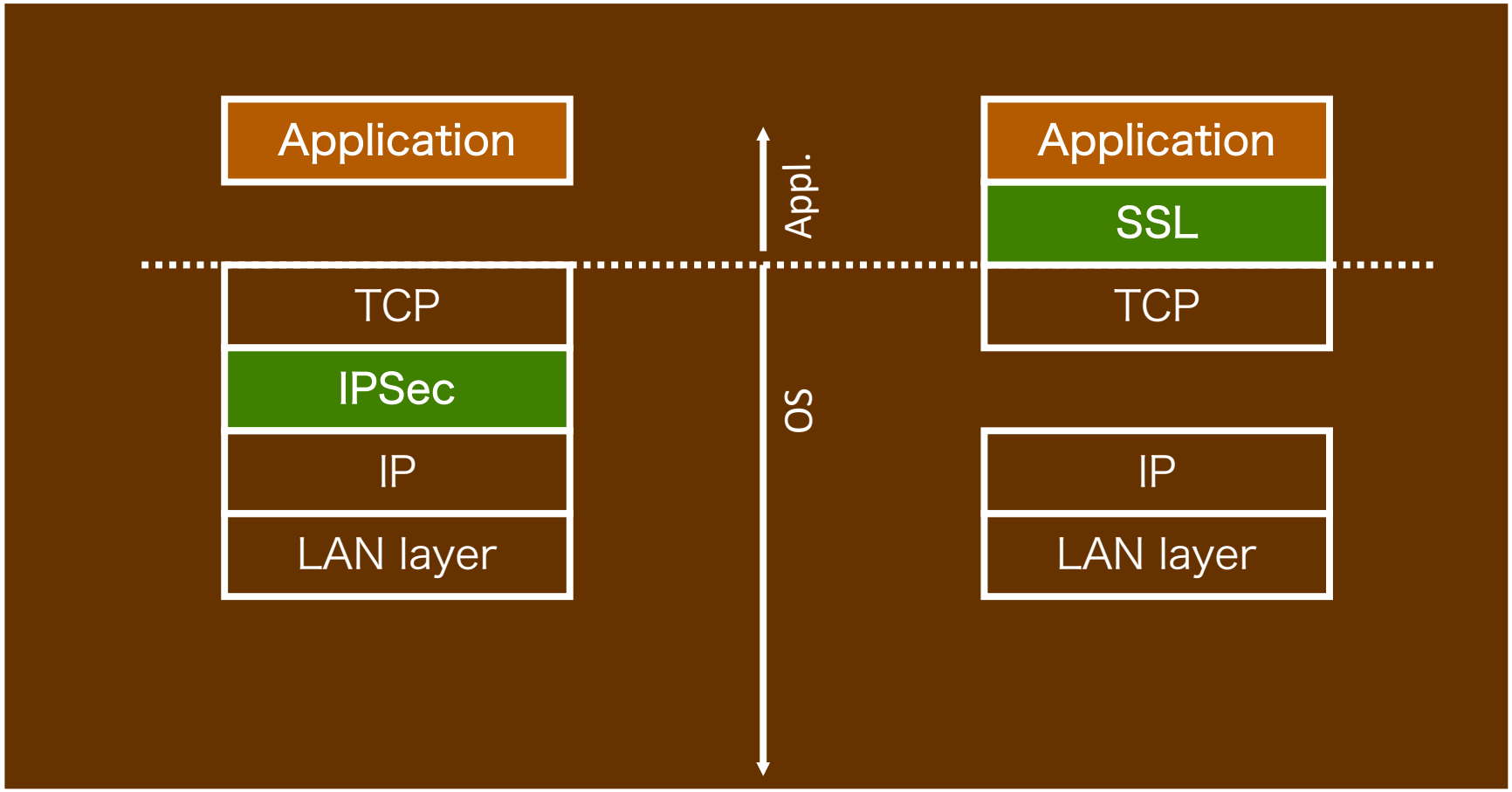
SSL/TLS

Roadmap

- Overview
- The SSL Record Protocol
- The SSL Handshake and Other Protocols

Overview of SSL

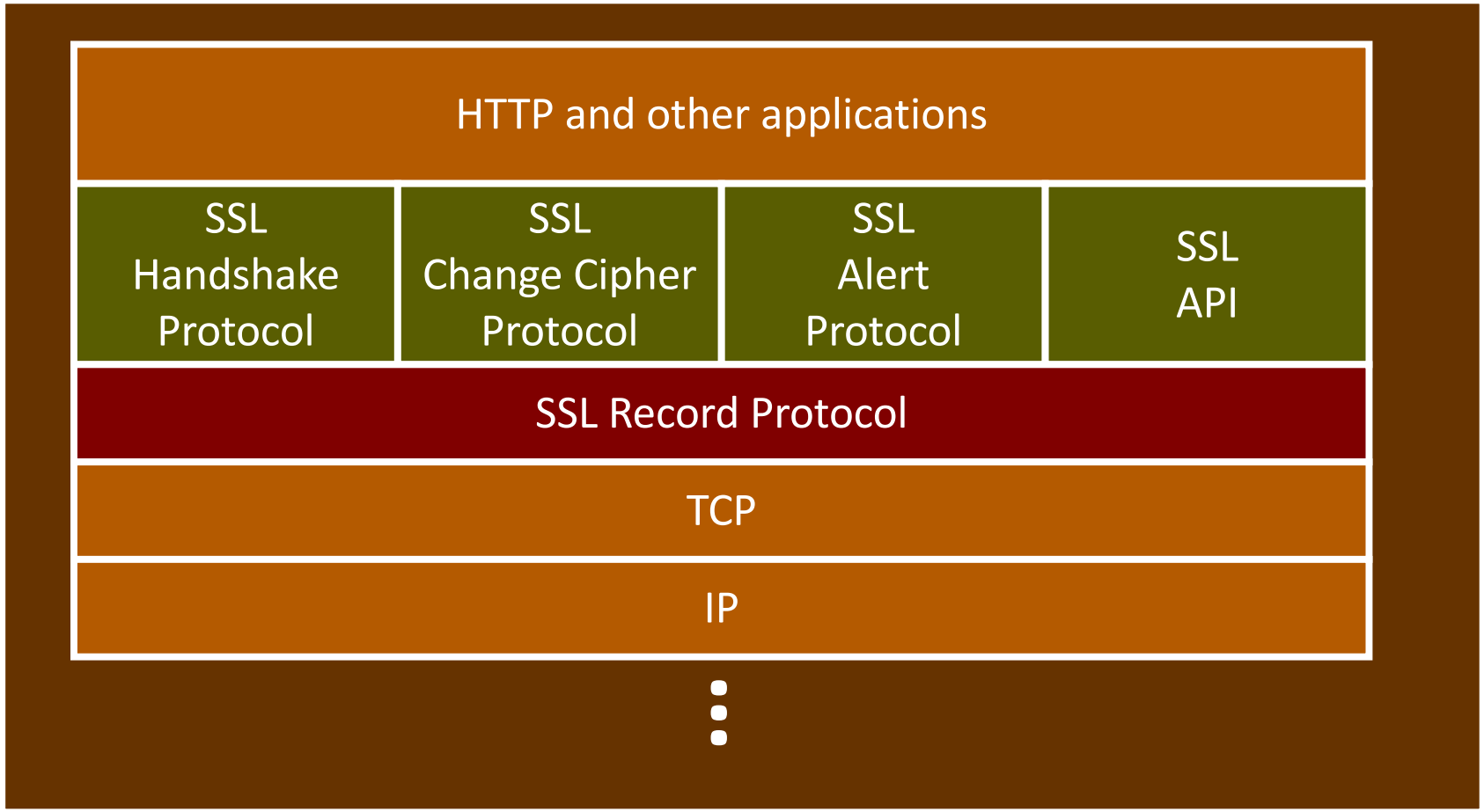
Reminder: What Layer?



Protocols

- Goal: application independent security
  - Originally for HTTP, but now used for many applications
  - Each application has an assigned TCP port, e.g., https (HTTP over SSL) uses port 443
- Secure Sockets Layer (SSL)
  - the de facto standard for web-based security
  - v3 was developed with public review
- Transport Layer Security (TLS)
  - TLS v1.0 very close to SSL v3.1
  - Currently, TLS 1.2 (SSL 3.3)

SSL Architecture



- Relies on TCP for reliable communication

Architecture (Cont'd)

- Handshake protocol: establishment of a session key
- Change Cipher protocol: start using the previously-negotiated encryption / message authentication
- Alert protocol: notification (warnings or fatal exceptions)
- Record protocol: protected (encrypted, authenticated) communication between client and server

SSL Services

- Peer authentication
- Negotiation of security parameters
- Generation / distribution of session keys
- Data confidentiality
- Data integrity

Connections and Sessions

- SSL *Session*
  - an association between peers
  - created through a handshake, negotiates security parameters, can be long-lasting
- SSL *Connection*
  - a type of service (i.e., an application) between a client and a server
  - transient
- Multiple connections can be part of a single session

Session Parameters

- Session ID
- X.509 public-key certificate of peer
- Compression algorithm to use
- Cipher specification: encryption algorithm, message digest, etc.
- Master (session) secret: 48-byte (384 bits) secret negotiated between peers

Connection Parameters

- Server and client nonces
- Server and client authentication keys
- Server and client encryption keys
- Server and client initialization vectors
- Current message sequence number

Ciphers Supported by SSL

- DES+HMAC/SHA-1
- 3DES+HMAC/SHA-1
- RC4+MD5
- RC2+MD5
- +others

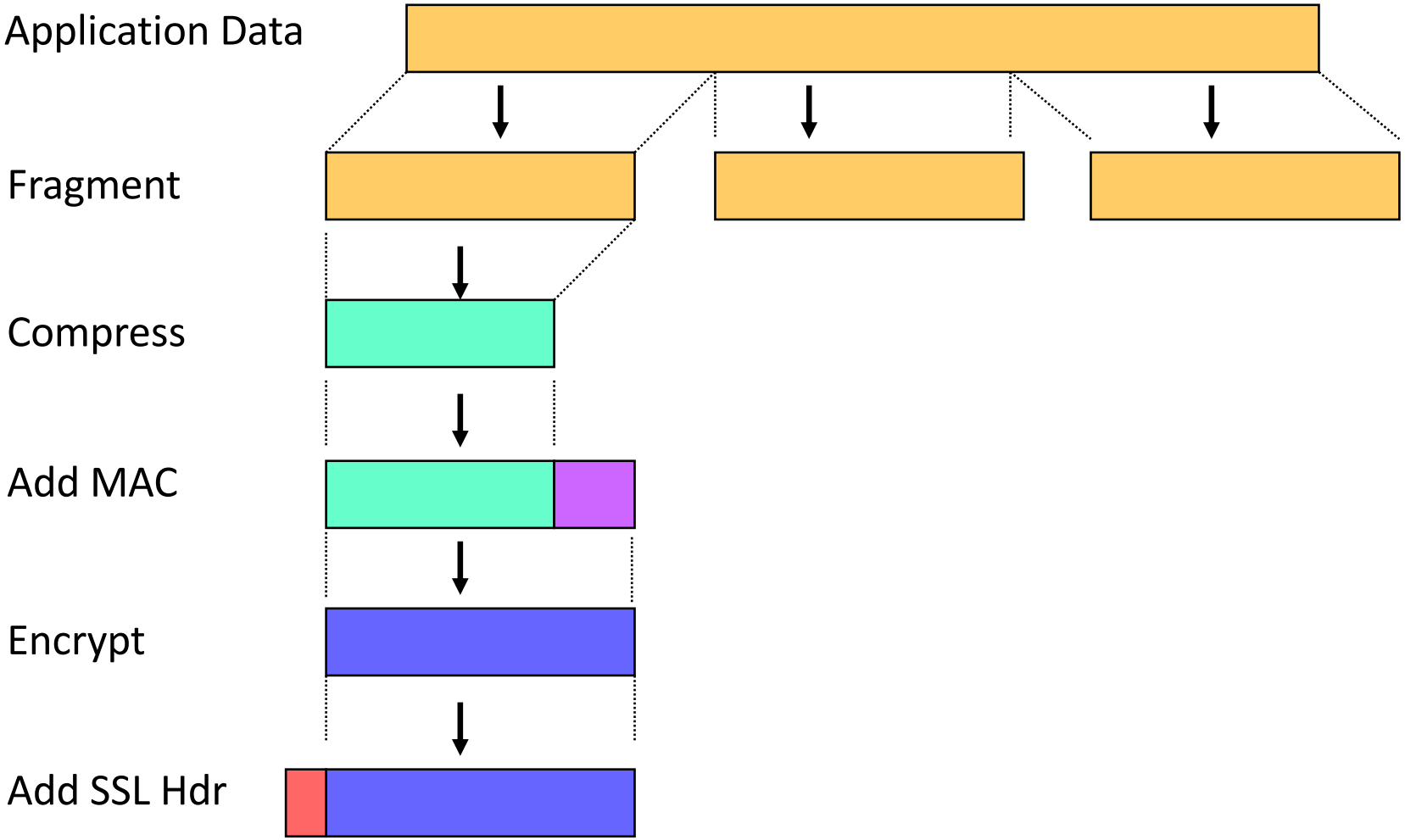
- RFC 3268: “AES Cipher suites for TLS”

The SSL Record Protocol

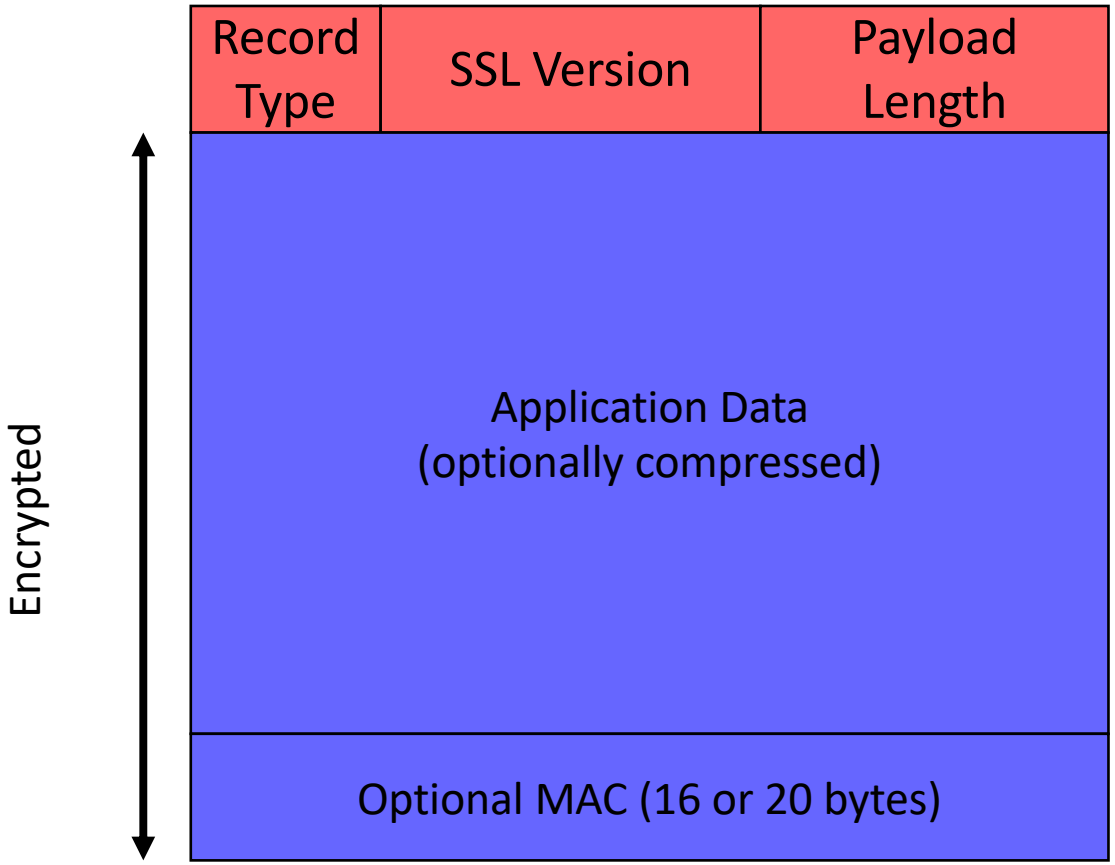
Protocol Steps

1. Fragment data stream into records
   - each with a maximum length of 2^{14} (=16K) bytes
2. Compress each record
3. Create message authentication code for each record
4. Encrypt each record

Steps… (cont'd)

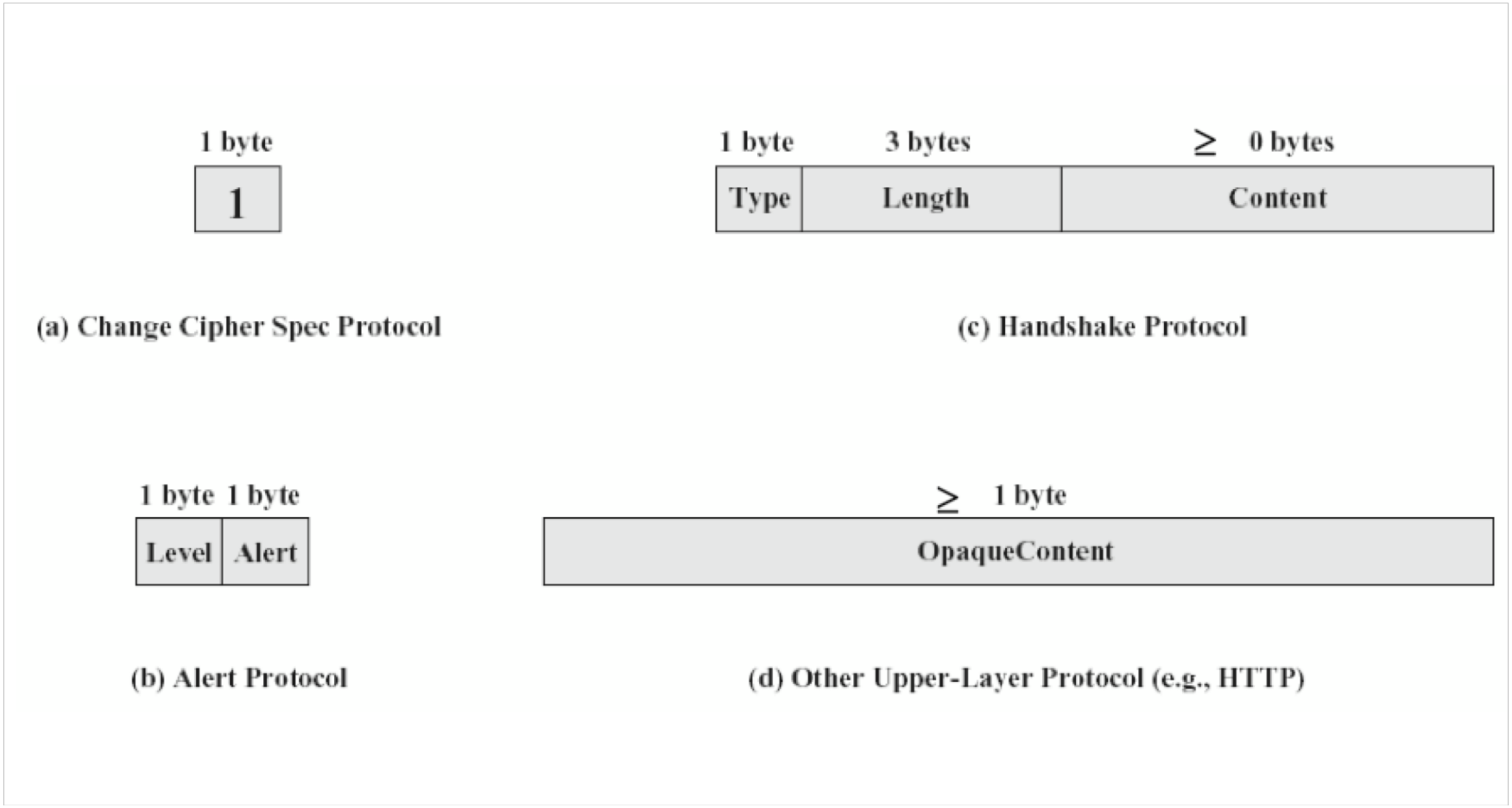

Application Data
Fragment
Compress
Add MAC
Encrypt
Add SSL Hdr

SSL Record Format



- There is, unfortunately, some version number silliness between v2 and v3; see text for (ugly) details

Possible Record “Payloads”



SSL Handshake Protocol

Phases of Protocol

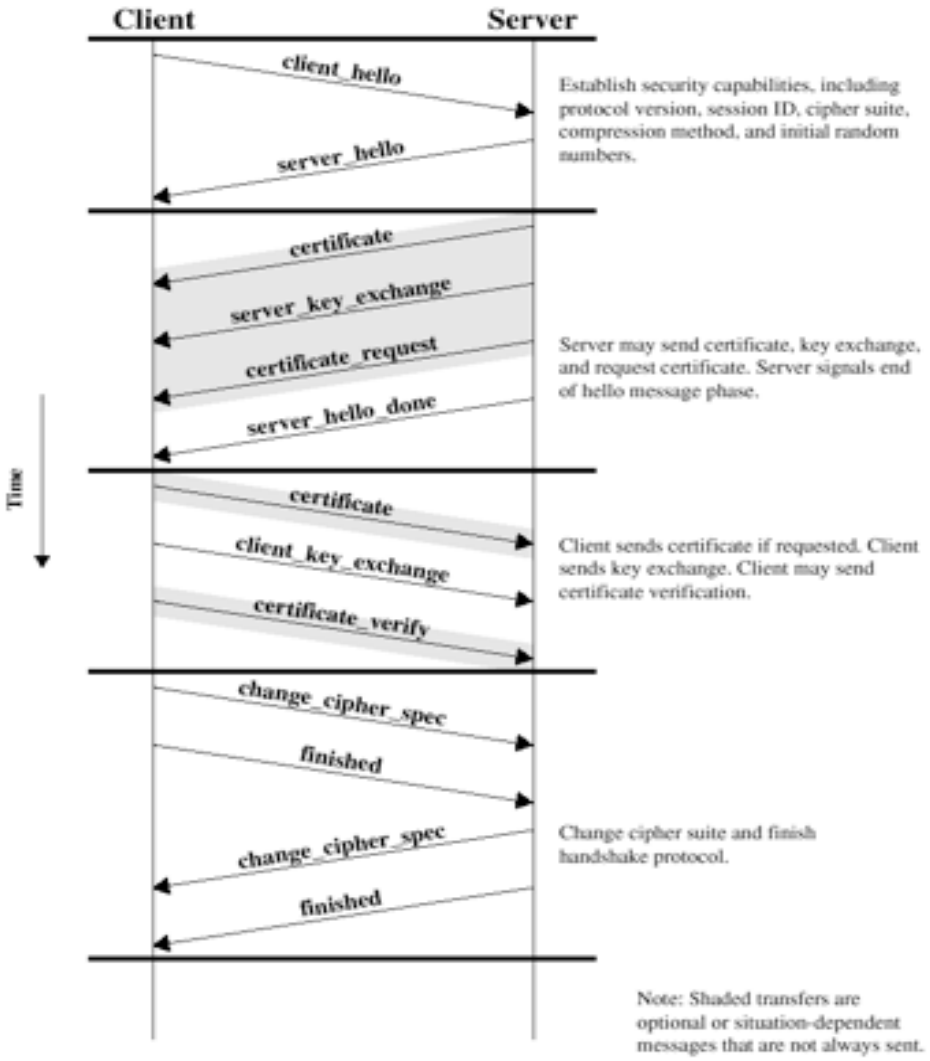
I. Establish security capabilities
   - version of SSL to use
   - cipher + parameters to use

II. Authenticate server (optional), and perform key exchange

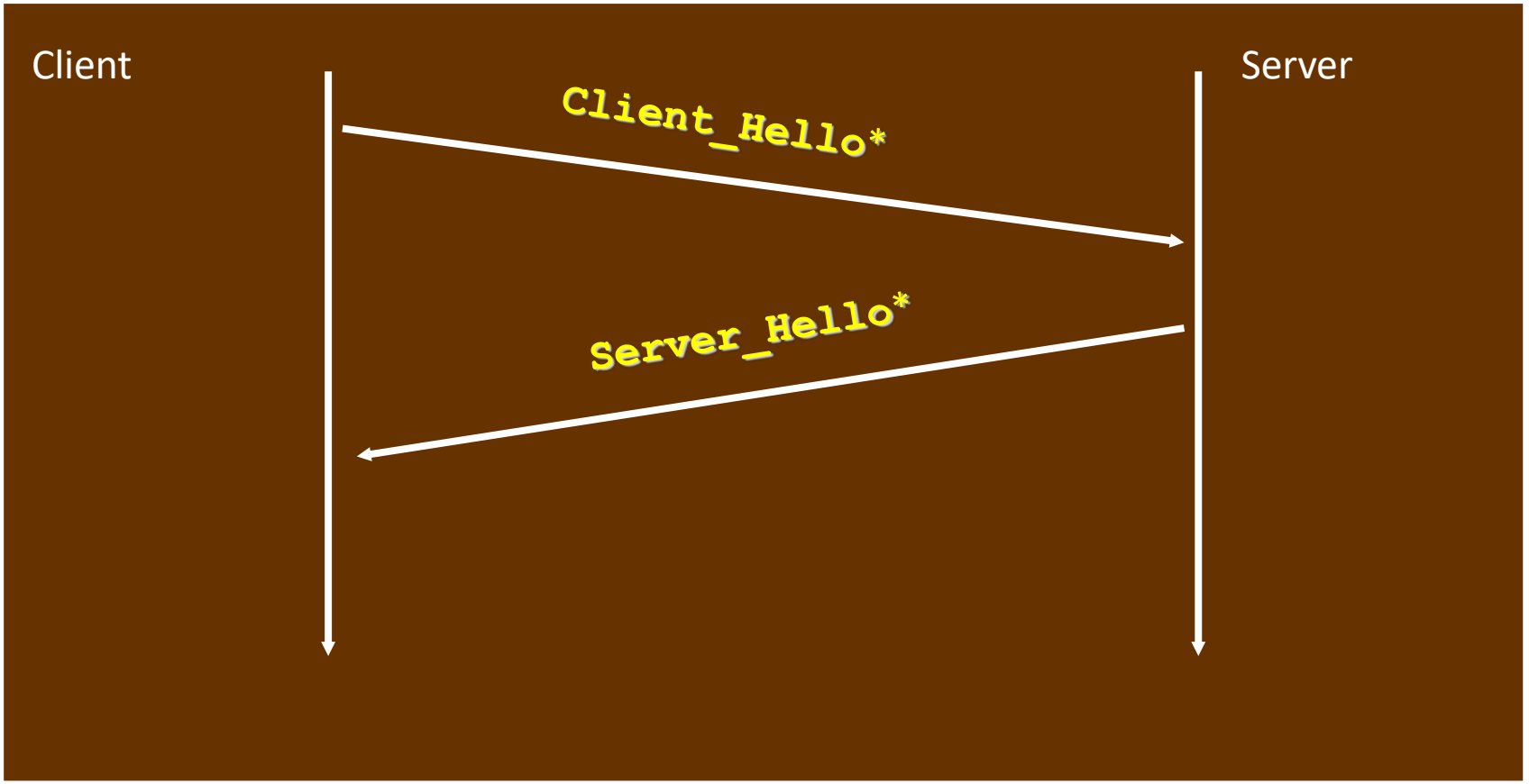
III. Authenticate client (optional), and perform key exchange

IV. Finish up

All the Messages



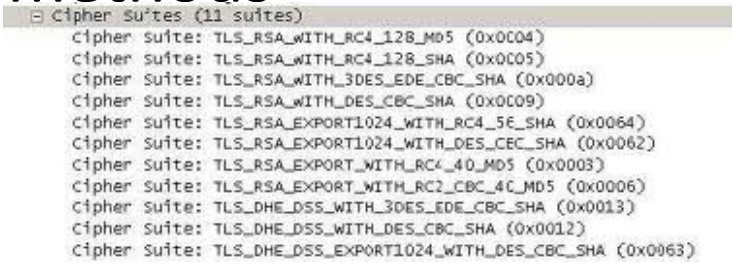
I. Establish Security Capabilities



- Messages marked with * are mandatory

`Client_Hello` Message

- Transmitted in plaintext
- Contents
  - highest SSL version understood by client
  - R_C: a 4-byte timestamp + 28-byte random number
  - session ID: 0 for a new session, non-zero for a previous session
  - list of supported cryptographic algorithms
  - list of supported compression methods



`Server_Hello` Message

- Also transmitted in plaintext
- Contents
  - minimum of (highest version supported by server, highest version supported by client)
  - R_S: 4-byte timestamp and 28-byte random number
  - session ID
  - a cryptographic choice selected from the client's list
  - a compression method selected from the client's list

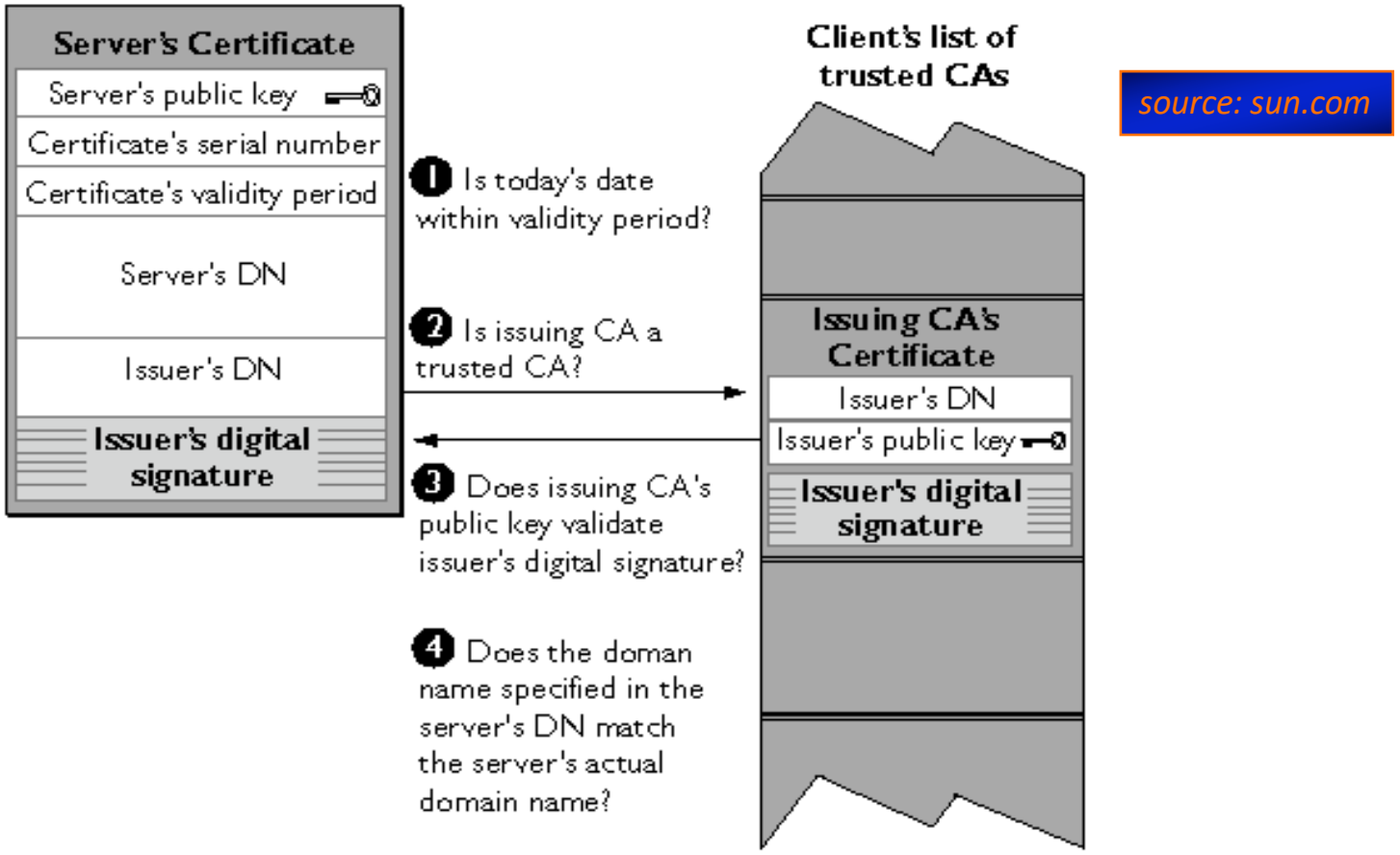
II. Server Auth. / Key Exchange

- The Server_Certificate message is optional, but almost always used in practice

`Server_Certificate` Message

- Contains a certificate with server's public key, in X.509 format
  - or, a chain of certificates if required
- The server certificate is necessary for any key exchange method except for anonymous Diffie-Hellman

Authenticating the Server



- Step #4: Domain name in certificate must match domain name of server (not part of SSL protocol, but clients should check this)

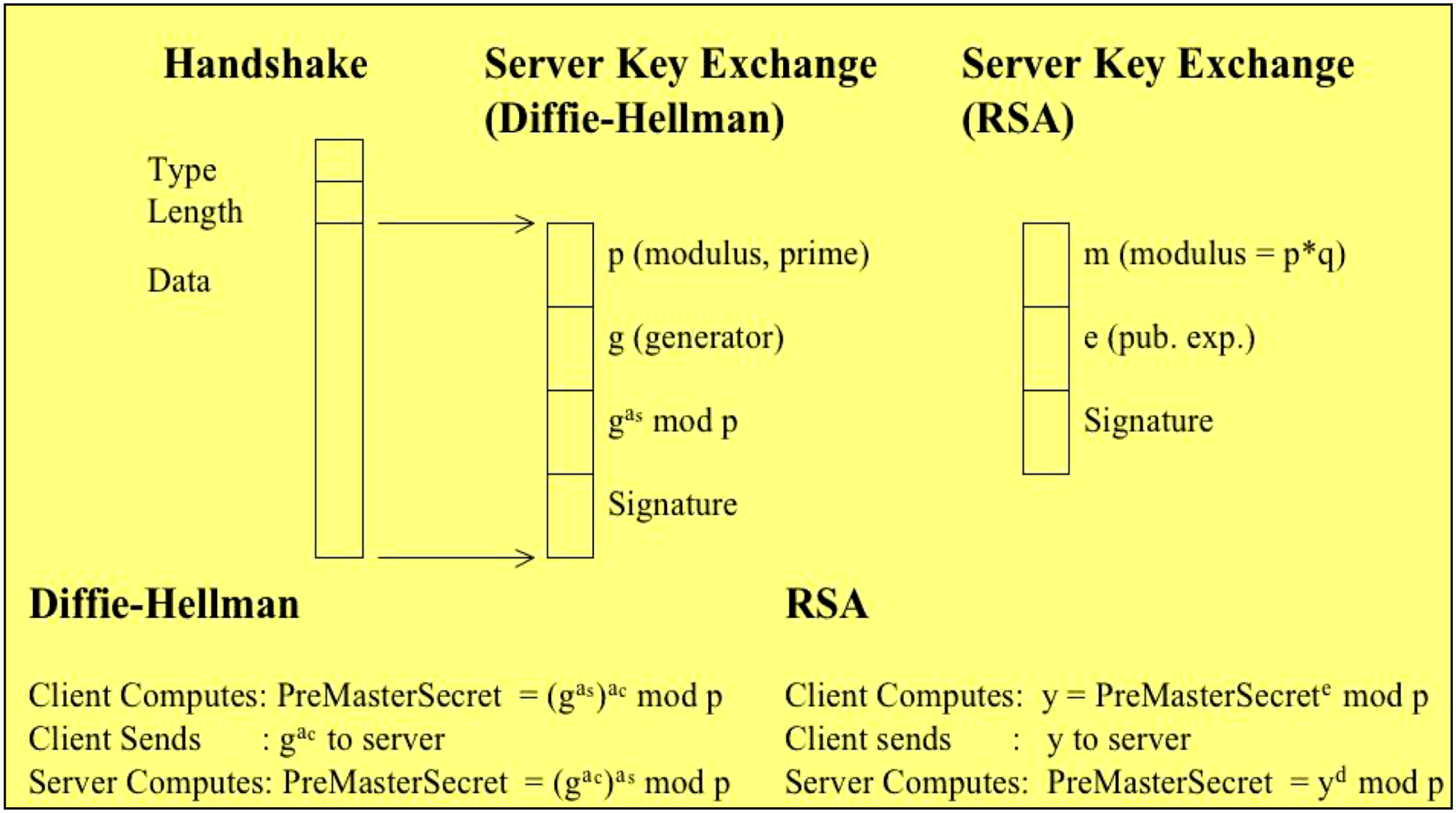
Key Exchange Methods Supported

- RSA (server must have a certificate)
- Ephemeral Public Key
  - public keys are exchanged, signed using long-term RSA keys
- (Fixed Diffie-Hellman
  - server provides the D-H public parameters in a certificate
  - client responds with D-H public key either in a certificate, or in a key exchange message
- Anonymous Diffie-Hellman)

`Server_Key_Exchange` Message

- Needed for…
  - anonymous D-H
  - ephemeral public key

Server Key Exchange



`Client_Certificate_Request` Msg.

- Normally not used, because in most applications
  - only the server is authenticated
  - client is authenticated at the application layer, if needed
- Two parameters
  - certificate type accepted, e.g., RSA/signature only, DSS/signature only, …
  - list of certificate authorities recognized (i.e., trusted third parties)

III. Client Auth. / Key Exchange

`Client_Certificate` Message

- Contains a certificate, or chain of certificates if needed

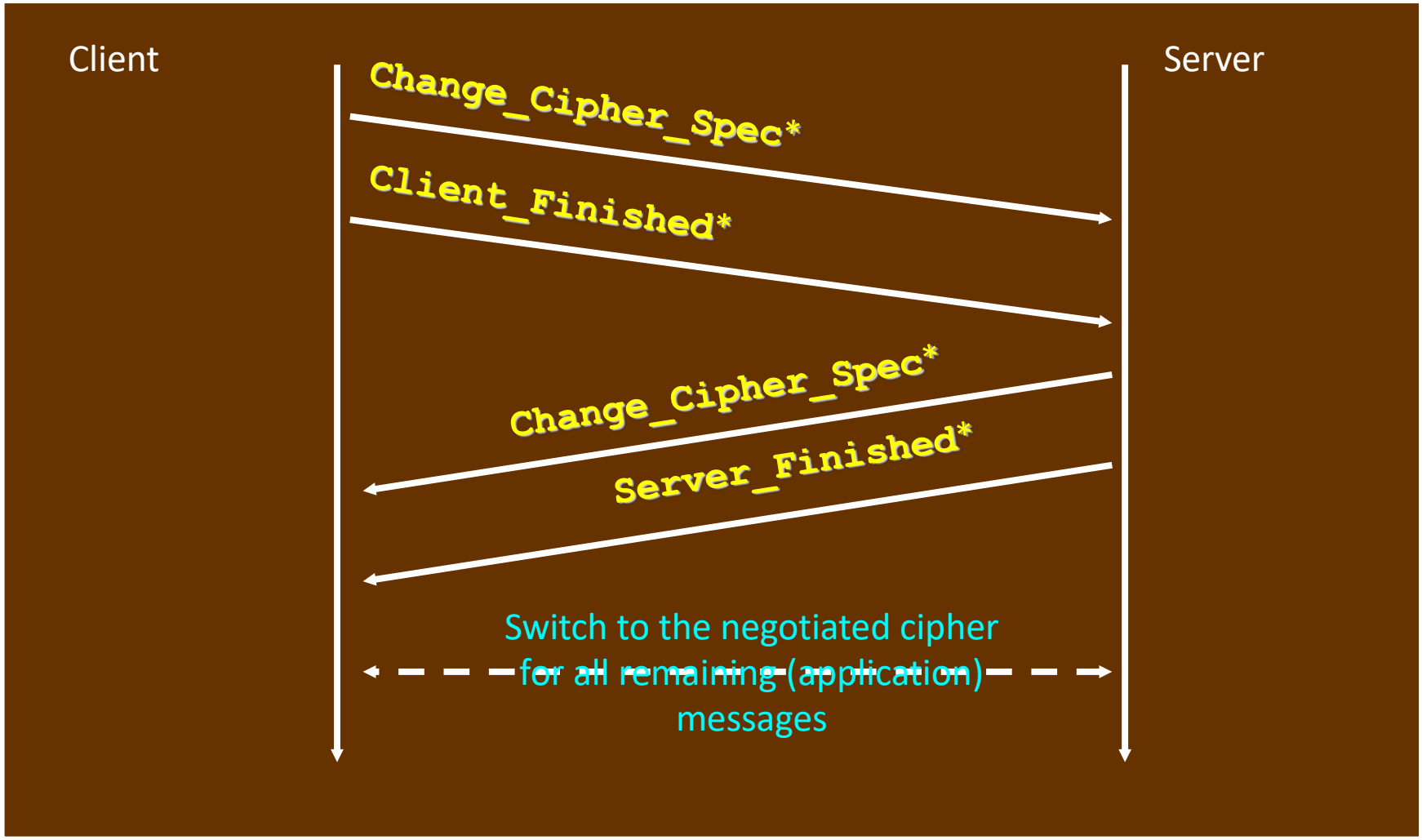
`Client_Key_Exchange` Message

- If using RSA, the pre-master secret S, encrypted with the server's public key
- If using D-H, the client's public key

`Client_Certificate_Verify` Msg

- Proves the client is the valid owner of a certificate (i.e., knows the corresponding private key)
- Only sent following any client certificate that has signing capability

IV. Finish Up


Client
Server
Change_Cipher_Spec*
Client_Finished*
Change_Cipher_Spec*
Server_Finished*
Switch to the negotiated cipher
for all remaining (application)
messages

`Change_Cipher_Spec` Msg

- Confirms the change of the current state of the session to a newly-negotiated set of cryptographic parameters
- **`Finished`** Messages
  - keyed hash of the previous handshake messages to prevent man-in-the-middle-attacks from succeeding

“Abbreviated” Protocol Possible

- Allows resumption of a previously-established session
  - does not require authentication of server or client
  - does not exchange keys
- Details omitted

Creating the "Master" Secret

- The master secret is a one-time (per session) 48-byte (= 16+16+16) value
- Parameters
  - the pre-master secret S has previously been communicated using RSA or D-H
  - the client nonce R_c
  - the server nonce R_s
- Computation: K =

  MD5 (S | SHA-1("A" | S | R_c | R_s)) |
  MD5 (S | SHA-1("BB" | S | R_c | R_s)) |
  MD5 (S | SHA-1("CCC" | S | R_c | R_s))

Cryptographic Parameters

- Generated from
  - the master secret K
  - Rc
  - Rs
- Values to be generated
  - client authentication and encryption keys
  - server authentication and encryption keys
  - client encryption IV
  - server encryption IV

Alert Protocol Examples

- Type 1: **`Fatal_Alert`**
  - ex.: **`Unexpected_Message`**, **`Bad_MAC`**, etc.
  - connection is immediately terminated
- Type 2: **`Warning`**
  - ex.: **`No_Certificate`**, **`Close_Notify`**

Summary

1. SSL is the de facto authentication/encryption protocol standard for HTTP
   – becoming popular for many other protocols as well
2. Allows negotiation of cryptographic methods and parameters