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CSCI 454/554 Computer and Network Security

Topic 8.3 SSL/TLS

Outline

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1. Overview
2. The SSL Record Protocol
3. The SSL Handshake and Other Protocols

Overview of SSL

Reminder: What Layer?

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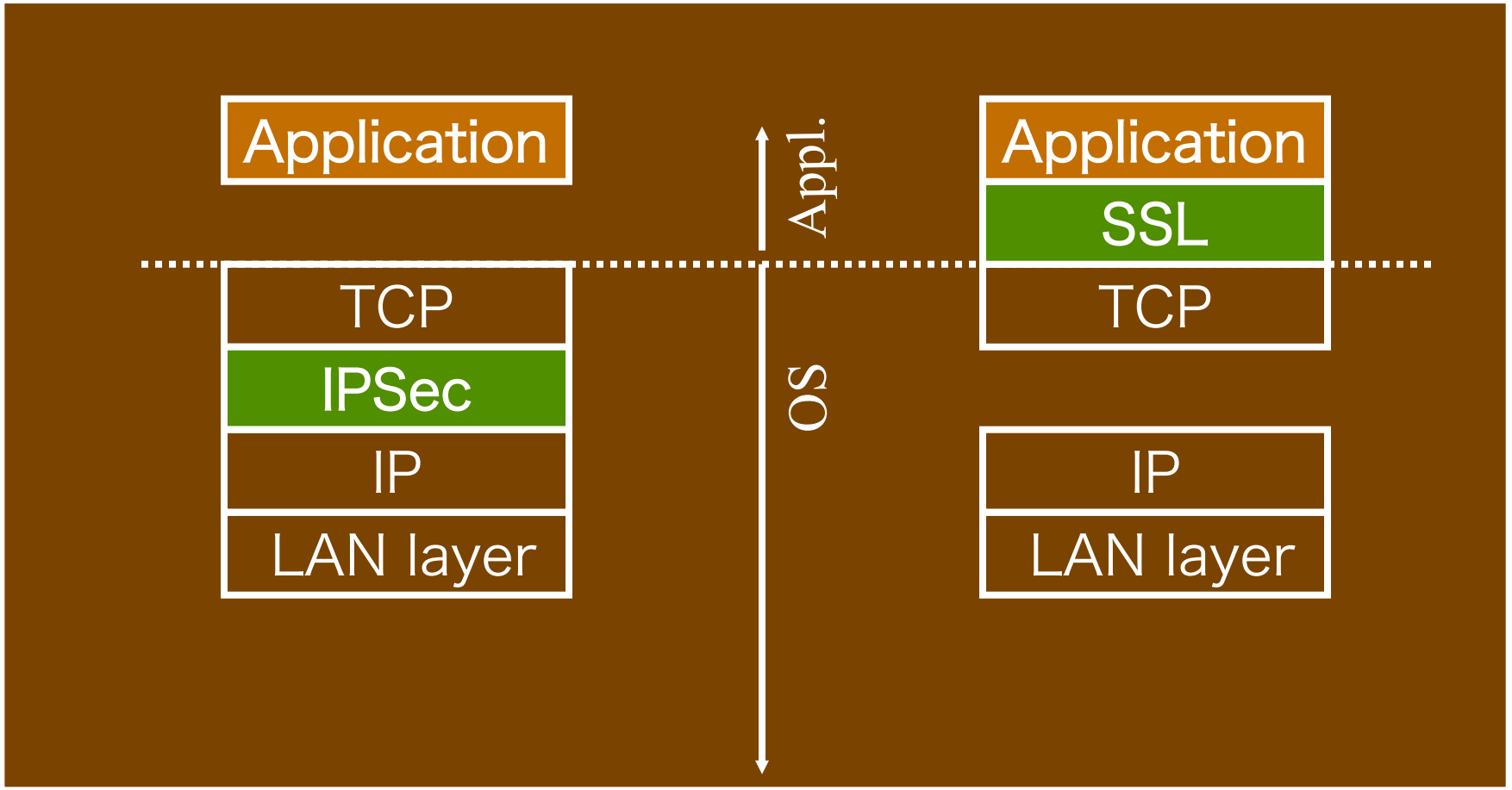

Protocols

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- 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

Protocol over SSL/TLS

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Keyword	Decimal	Description
nsiiops	261/tcp	IIOP Name Service over TLS/SSL
https	443/tcp	http protocol over TLS/SSL
ddm-ssl	448/tcp	DDM-SSL
smtps	465/tcp	smtp protocol over TLS/SSL
nntps	563/tcp	nntp protocol over TLS/SSL
sshell	614/tcp	SSLshell
ldaps	636/tcp	ldap protocol over TLS/SSL
ftps-data	989/tcp	ftp protocol, data, over TLS/SSL
ftps	990/tcp	ftp, control, over TLS/SSL
telnets	992/tcp	telnet protocol over TLS/SSL
imaps	993/tcp	imap4 protocol over TLS/SSL
ircs	994/tcp	irc protocol over TLS/SSL
pop3s	995/tcp	pop3 protocol over TLS/SSL

SSL Architecture

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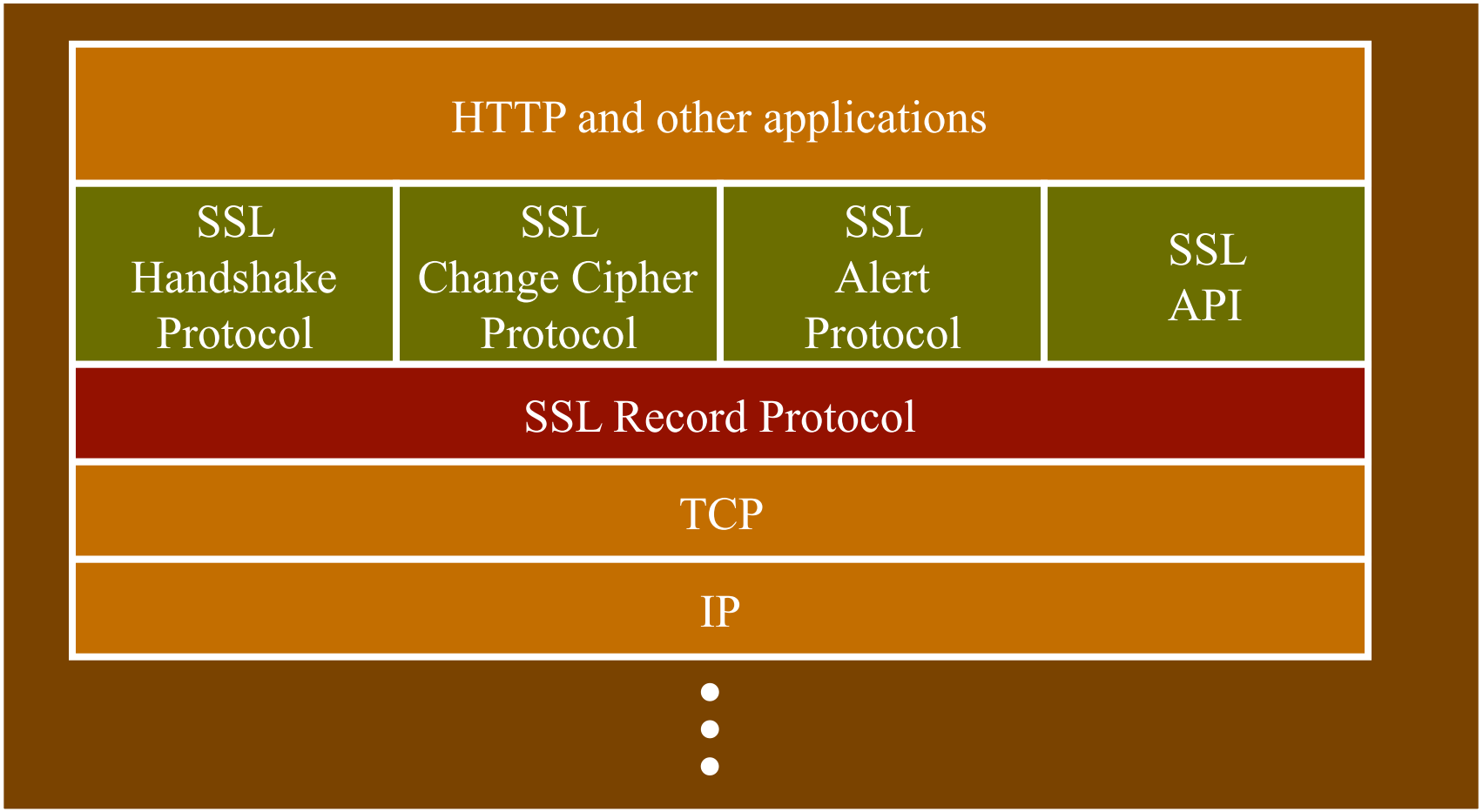

- Relies on TCP for reliable communication

Architecture (Cont'd)

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- 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

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

Connections and Sessions

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- 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

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- 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

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- 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

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

The SSL Record Protocol

Protocol Steps

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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)

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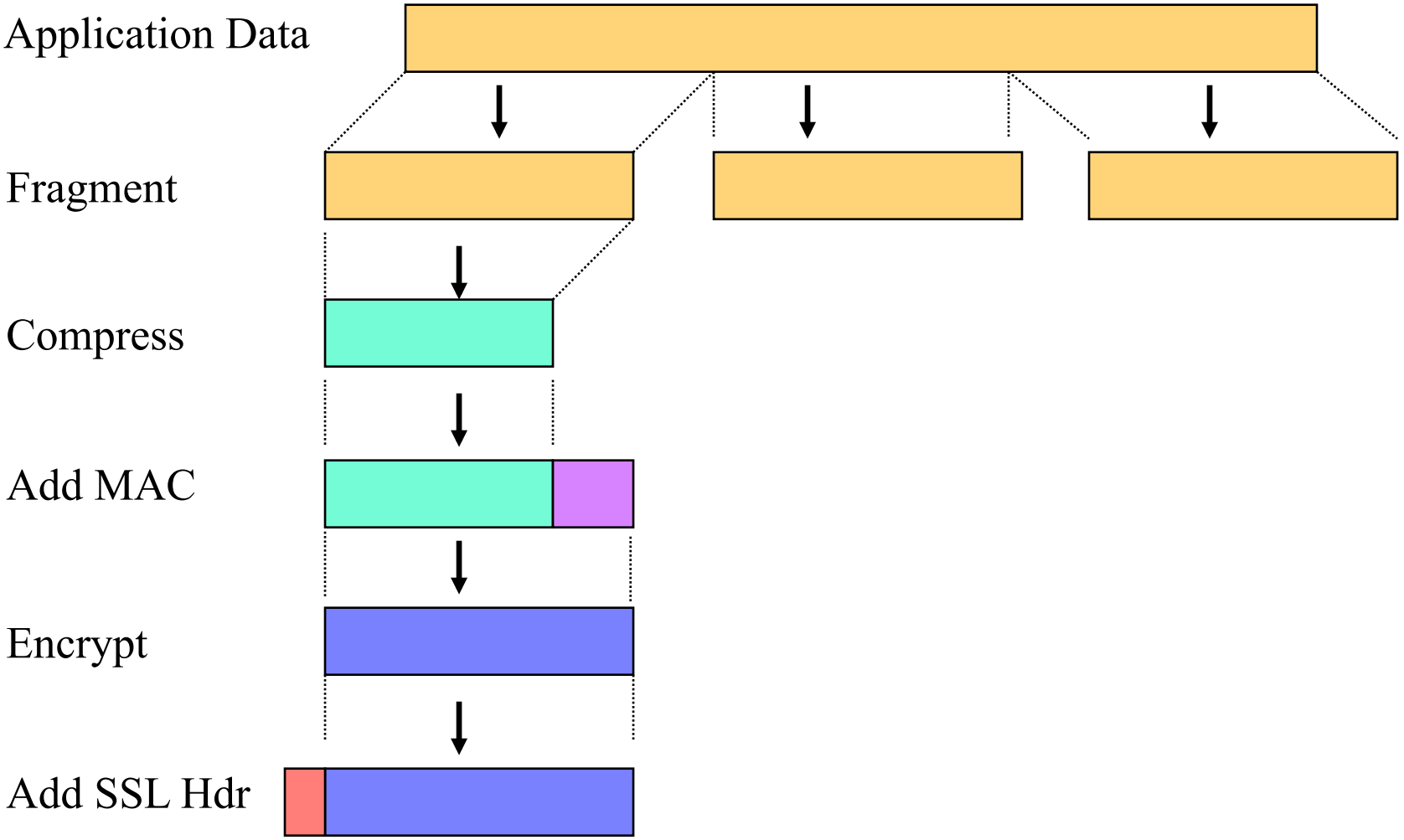

SSL Record Format

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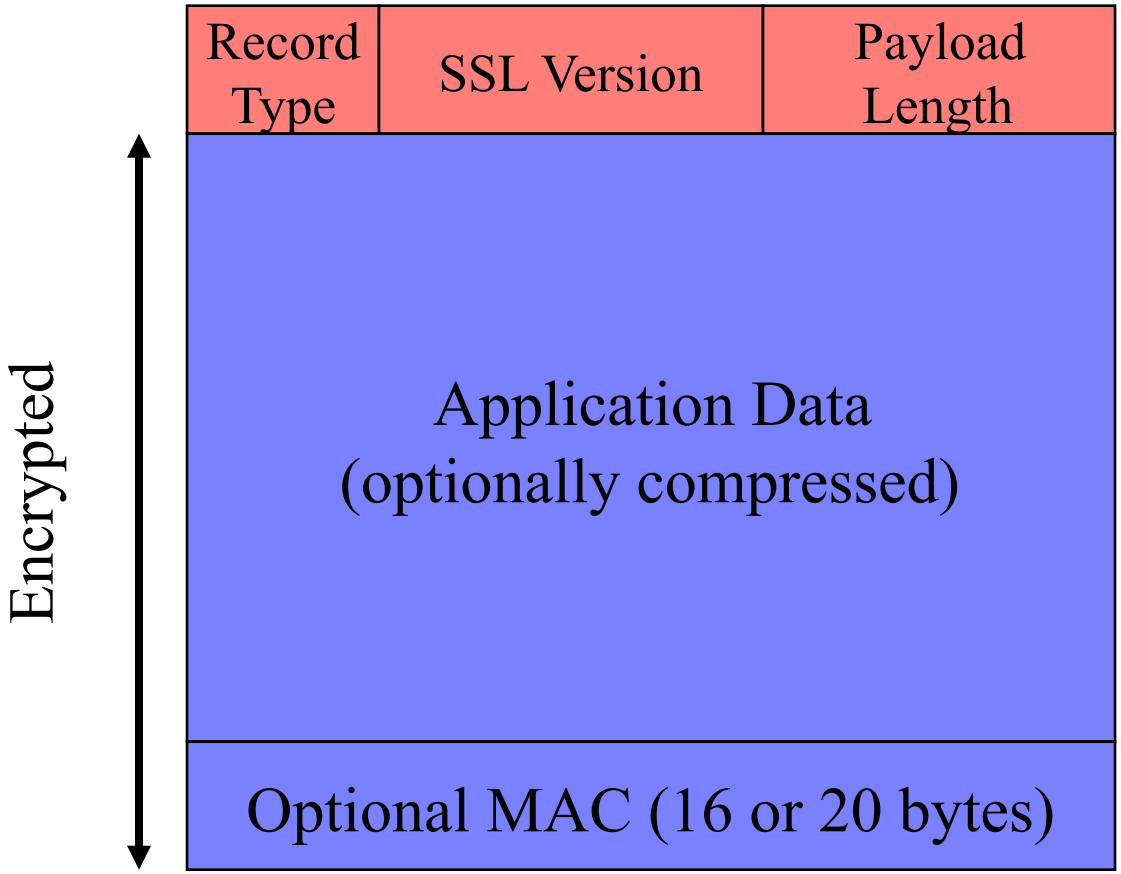
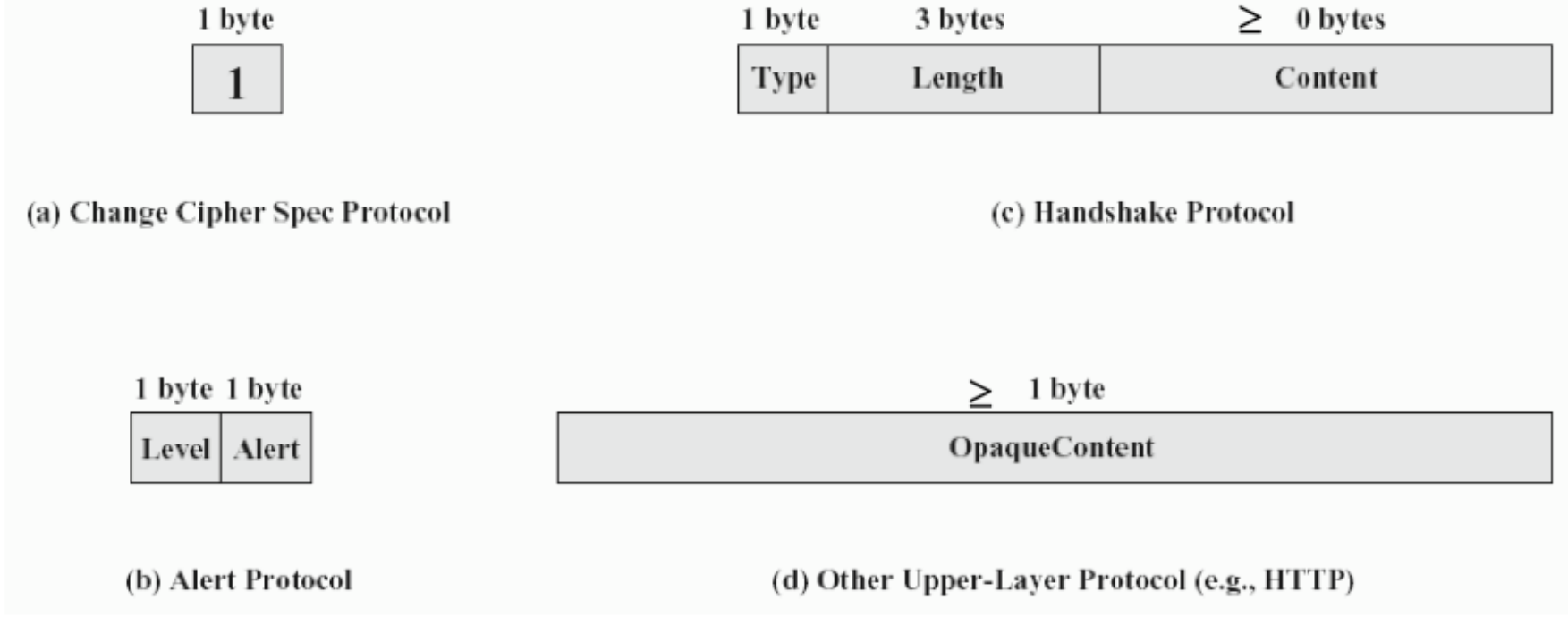


- There is, unfortunately, some version number silliness between v2 and v3; see text for (ugly) details

Possible Record "Payloads"



SSL Handshake Protocol

Phases of Protocol

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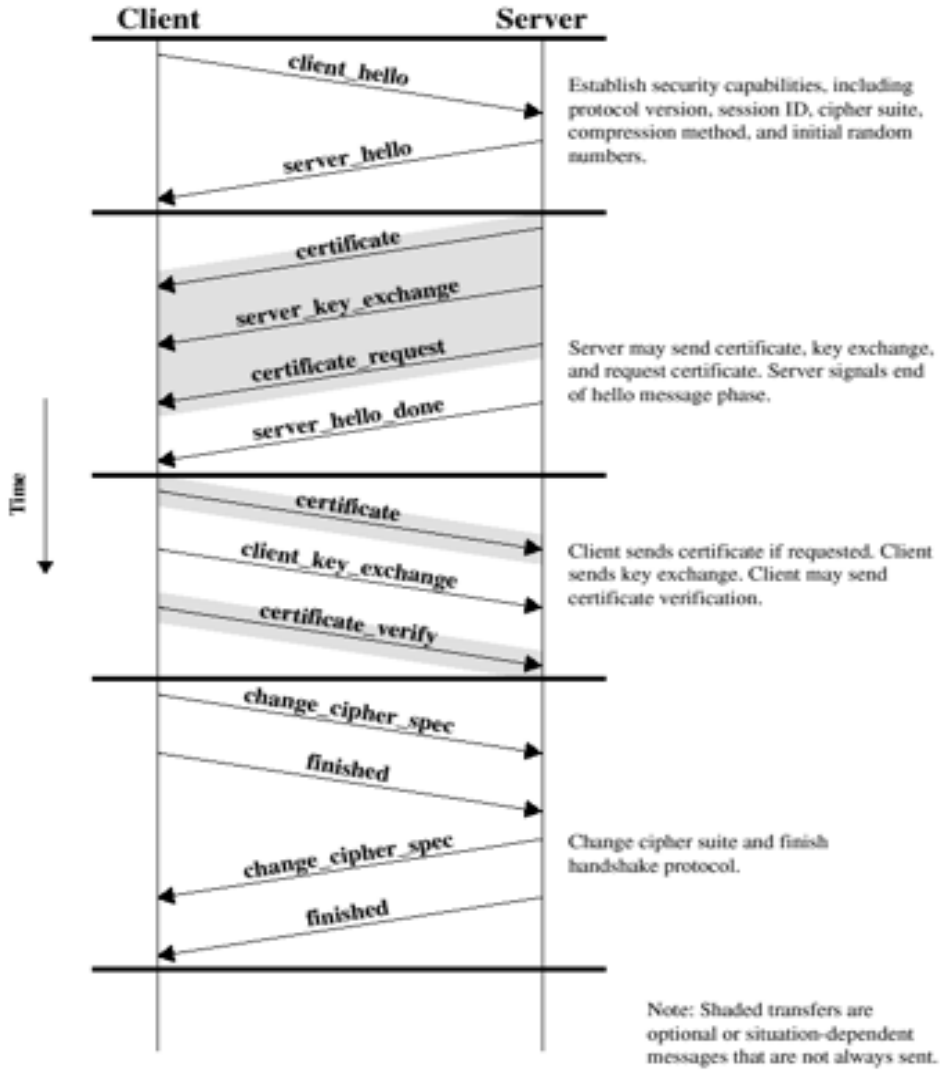
I. Establish security capabilities
   - version of SSL to use
   - cipher + parameters to use

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

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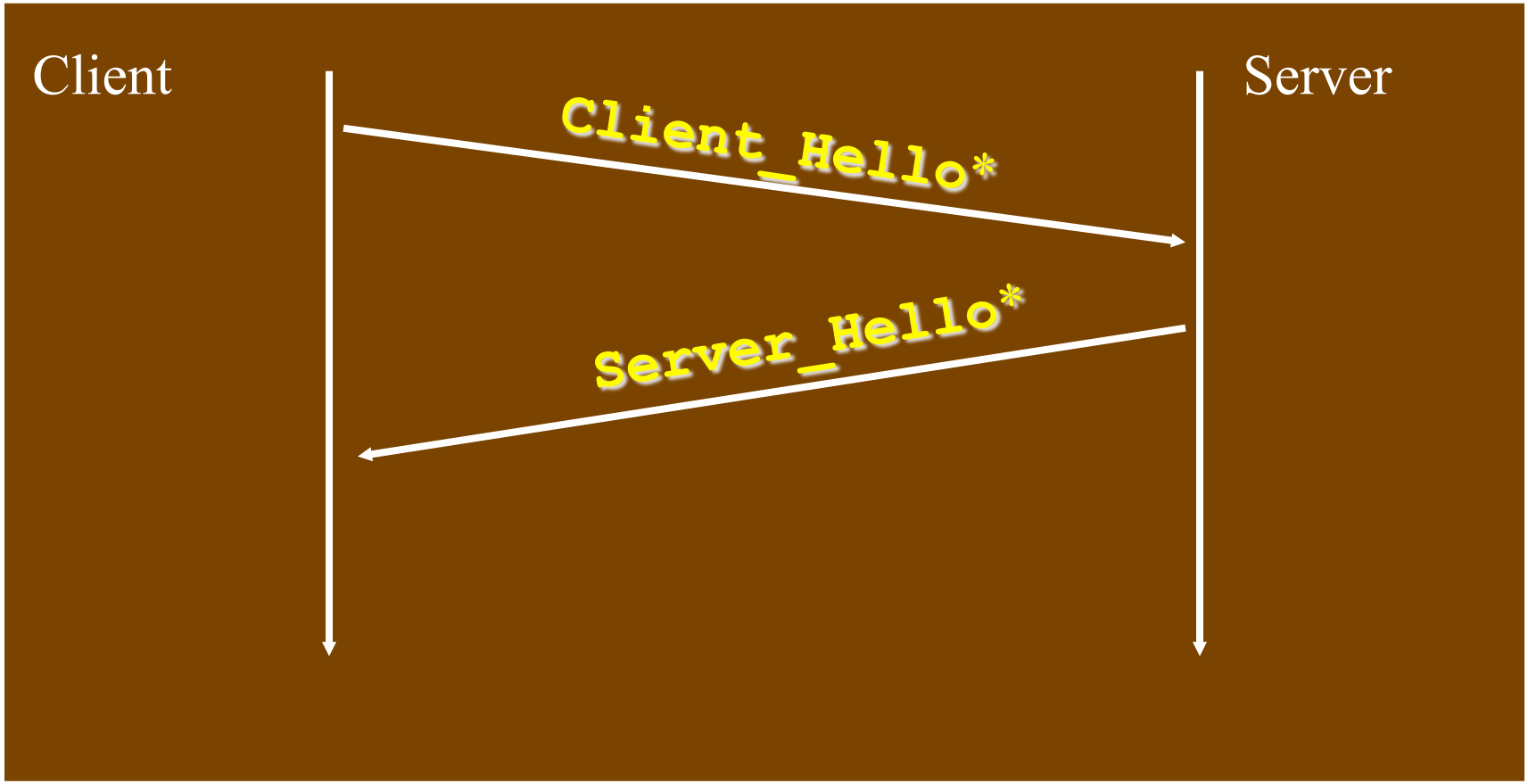

- Messages marked with * are mandatory

Client_Hello Message

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- 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

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- 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

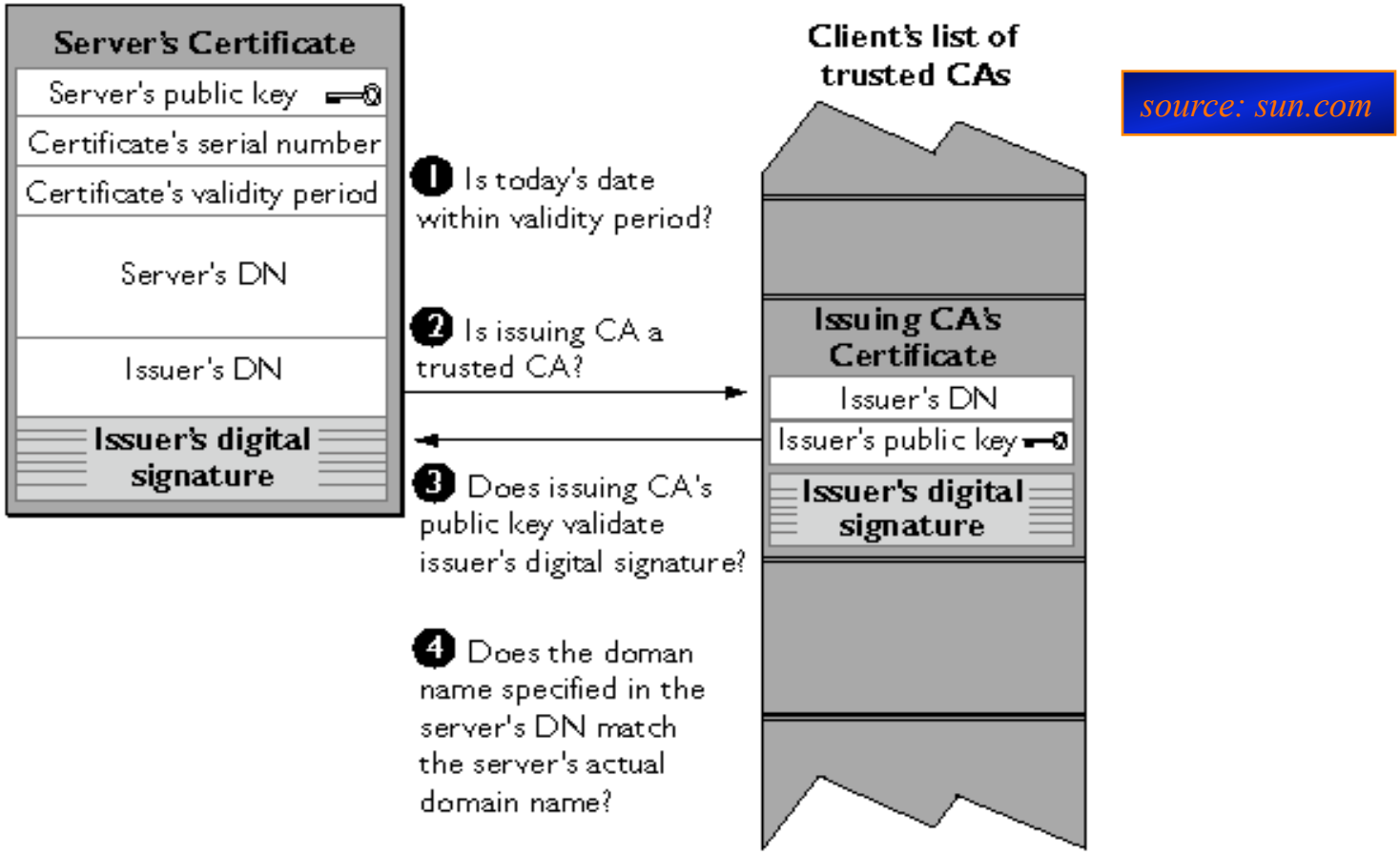
II. Server Auth. / Key Exchange

- 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



source: sun.com

- 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

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- 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
  - Diffie-Hellman without authentication
  - Susceptible to Man-in-the-middle attack

Server_Key_Exchange Message

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

Server Key Exchange

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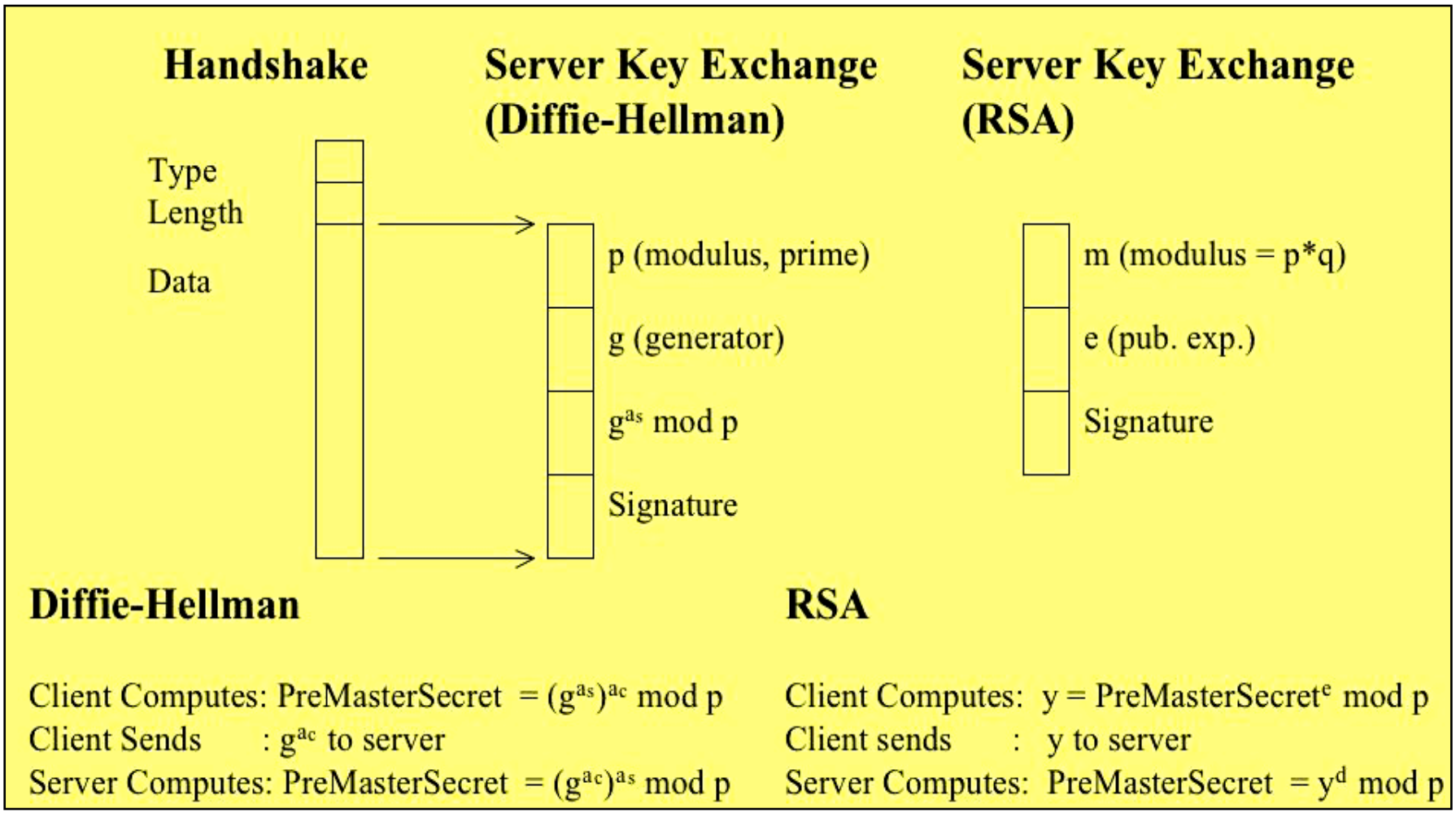

Client_Certificate_Request Msg.

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- 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

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- 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

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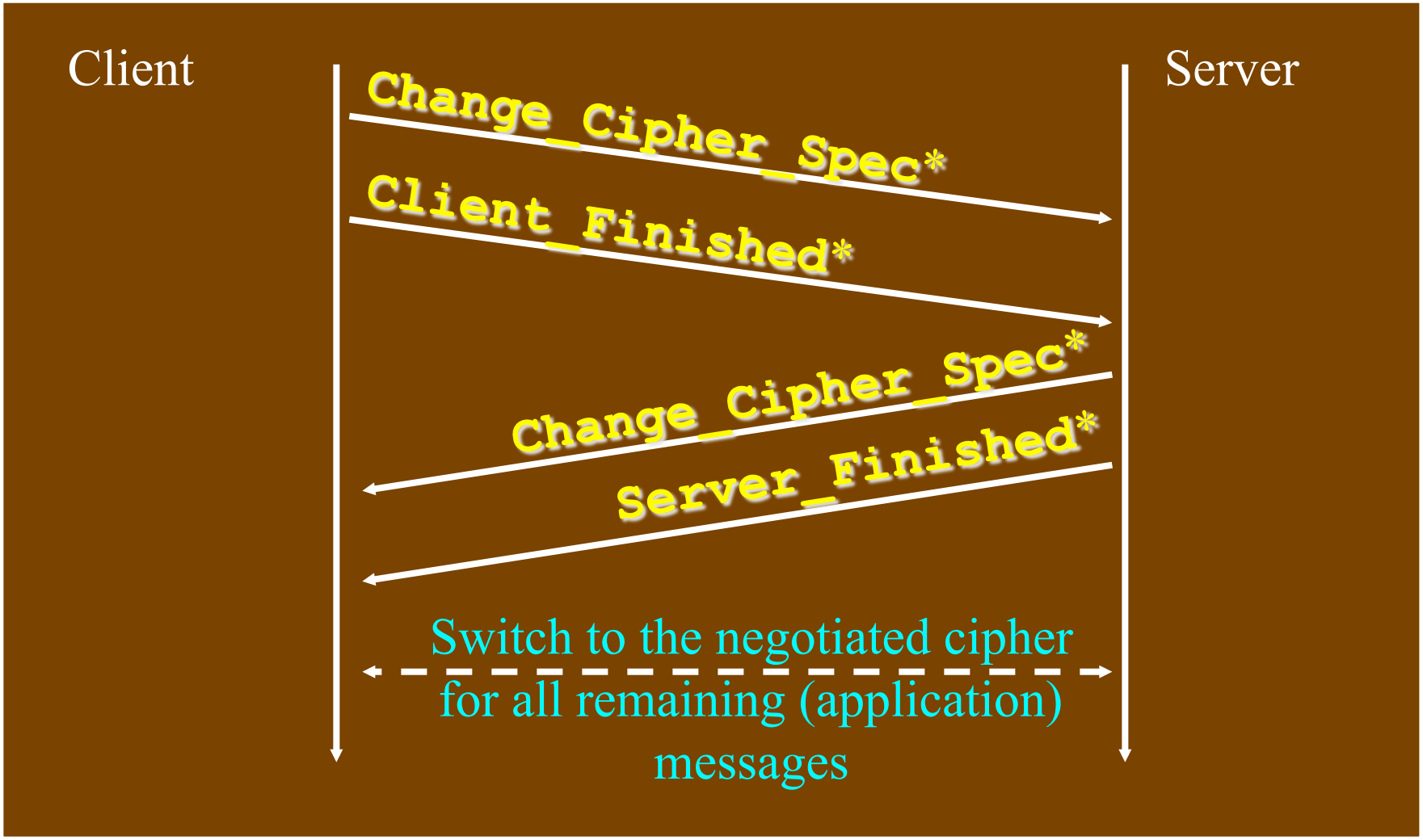
- Proves the client is the valid owner of a certificate (i.e., knows the corresponding private key)
- Only sent following any client certificate that has signing capability


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

IV. Finish Up

Change_Cipher_Spec Msg

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- 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

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- 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

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- 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

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- 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

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

Summary

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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