DI-FCT-UNL
Segurança de Redes e Sistemas de Computadores
*Network and Computer Systems Security*

Mestrado Integrado em Engenharia Informática
MSc Course: Informatics Engineering
1º Semestre, 2019/2020

# Transport Layer Security (TLS), HTTPS and WEB/HTTPS Security

# Outline

- WEB security issues
  - Web traffic security threats: the role of SSL and TLS
  - TCP/IP Stack and TLS
  - Security properties and services addressed by TLS
  - TLS operation and TLS based programming
- TLS: Session-Security vs. Transport Security Layers
  - TLS architecture and protocol stack
  - TLS protocol versions
  - TLS configurability and flexibility issues
  - TLS Ciphersuites
  - Analysis of TLS Sub-Protocols: RLP, CSP, AP, HP and HB
- TLS vs. HTTPS
- TLS Practical Security: Weak Ciphersuites and Security Tradeoffs
- Web Security and Threats beyond TLS

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# HTTP, Web Security, HTTPS and TLS

- Web Browsers, Web Servers, Web Apps and Web-Based Contents and Services
  - More and more easy to program, develop, configure, deploy and deploy, but ... underlying software (runtime SW stack) can be complex and may hide many potential security flaws
    - Web Security Threats and Web Software Vulnerabilities

- More and more critical applications managing sensitive data and traffic are Web based: require Web Interaction Security not provided by HTTP
  - Web Traffic Security Protection (end-to-end security assumptions)

HTTPS / TLS Approach

# TLS and the scope of HTTPS for "Web Encryption"

- More and more critical applications manage sensitive data
  - More and more Web Traffic Security, primarily supported by HTTPS (and TLS)
  - HTTPS is (and will be more and more) the unified application-level security support layer to protect web (http) traffic

See, Ex., Google, HTTPS Effort:
https://transparencyreport.google.com/https/overview?hl=en

# TLS

- Initial motivation: Protection of HTTP Communication
- … but designed as a generic solution (transport+session layer security) to support any application level protocol
- Usually implementations offer fast development and prototyping to migrate TCP/IP Based Applications and Protocols to adopt TLS

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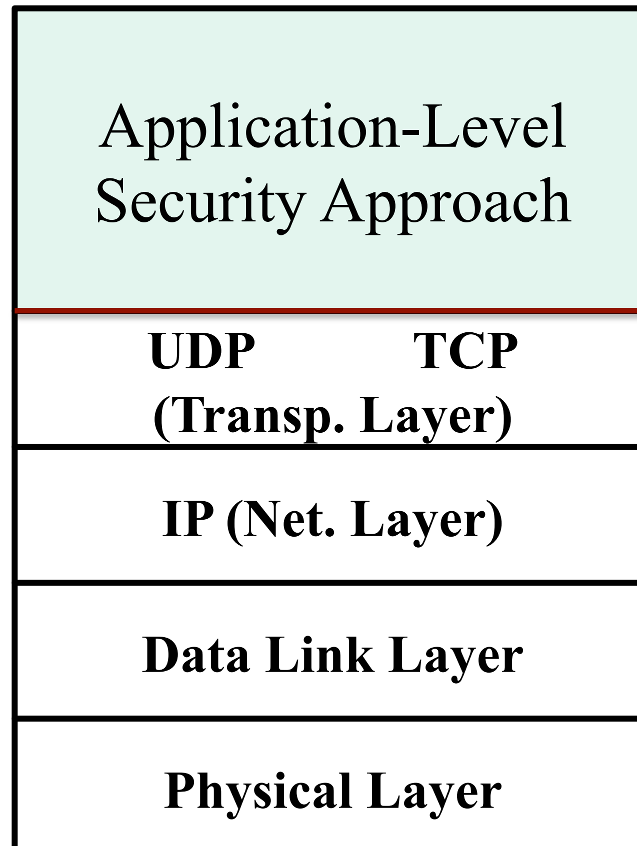
# Protection of Application-Level Protocols and TCP/IP Security Stack Approaches

- Protection at Application Level: App. Protocol + Session Control Services
- Some examples;
  - SSH, SCP
  - DNSSEC
  - Kerberos and Kerberized Applications
  - S/MIME, PGP
  - DMARC, DKIM
  - POP3-AUTH, POP3S, IMAP-S (ex., SASL, APOP Ext.)

  Email Security Protocols

  - ...... (many)



# TLS Level Approach

Transport Layer Security (TLS) Approach

TLS/TCP: TLS
TLS/UDP: DTLS

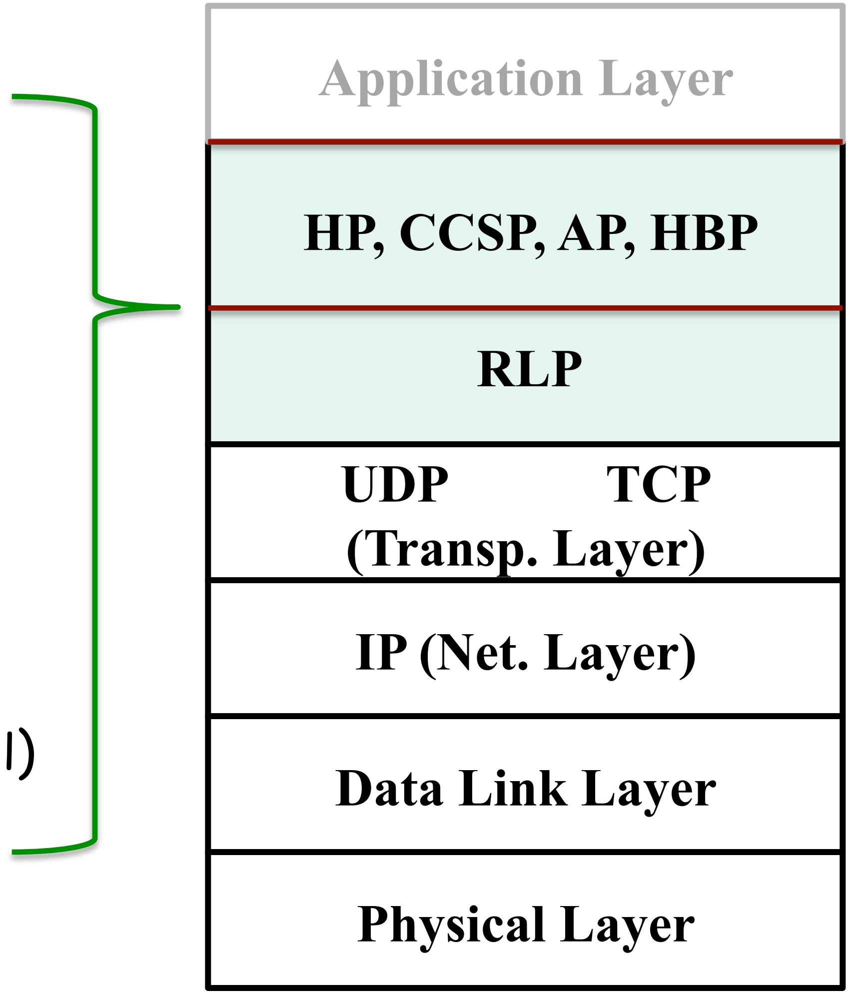
TLS as a Security (Sub)Stack providing:

**Secure Transport**

- RLP (Record Layer Protocol)

**Session Control Services**

- HP (Handshake Protocol)
- CCSP (Change Cipher Spec Protocol)
- AP (Alert Protocol)
- HBP (Heart Beat Protocol)



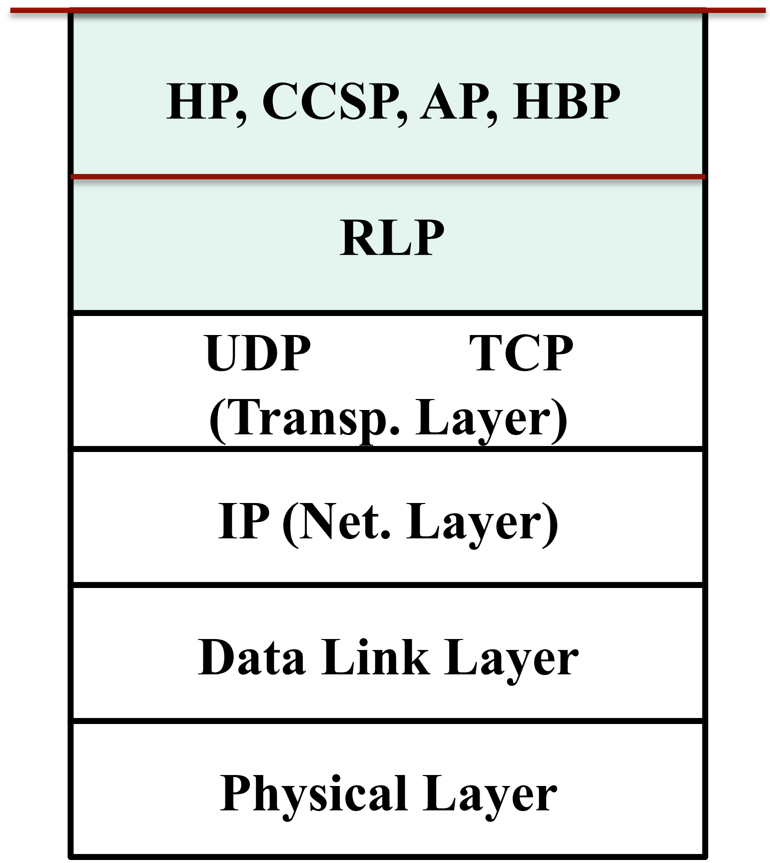
# TLS Level Programming Approcah

TLS Programming Level APIs

Examples:

- Java JSSE (Java Secure Socket Extension)
  - https://docs.oracle.com/javase/8/docs/
  - https://docs.oracle.com/javase/8/docs/technotes/guides/security/jsse/JSSERefGuide.html
- Openssl library for TLS Sockets (C, C++)
  - https://www.openssl.org
- MS TLS .NET Framework
  https://docs.microsoft.com/en-us/dotnet/framework/network-programming/tls

TLS-Enabled Prigramming Abstraction:
TLS-based APIs



# Other Programming Level Approaches

Examples:

- Java RMI/TLS
- https://docs.oracle.com/javase/8/docs/api/javax/rmi/ssl/package-summary.html

Java WebSockets using TLS

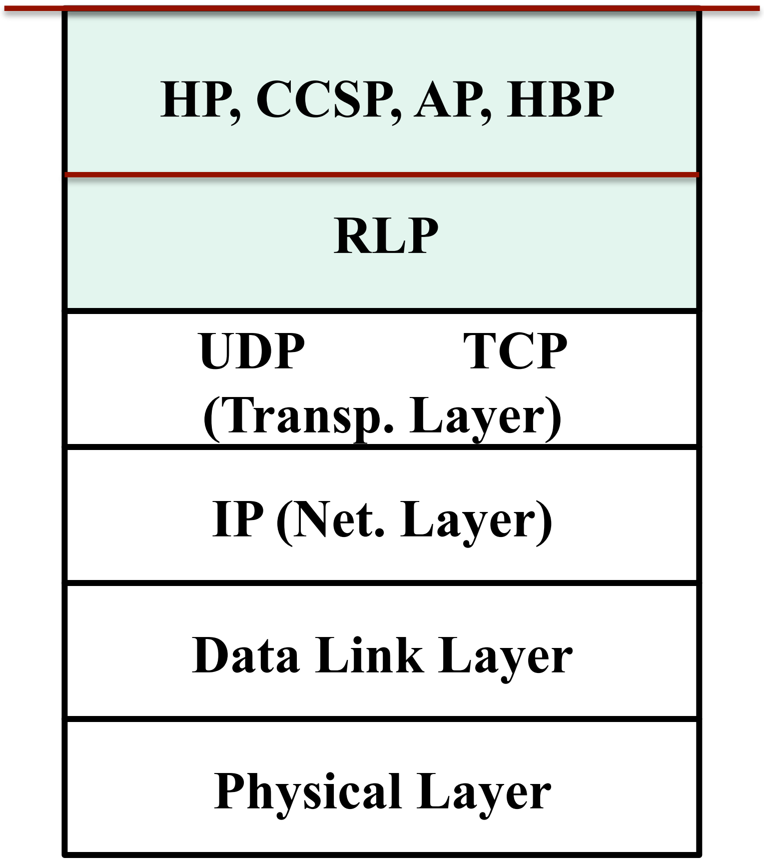
Web Services and RESTful Web enabled services

REST / TLS

WS / TLS

TLS-enabled Web Service Endpoints (Rest, WS) using Web App Programming Frameworks (ex: SPRING Framework)

Other Programming-Level Support Possibilities



# SASL and GSS Approaches

SASL: Simple Authentication and Security Layer (rfc 2222)

Used for example by:

LDAP (v3), IMAP (v4)

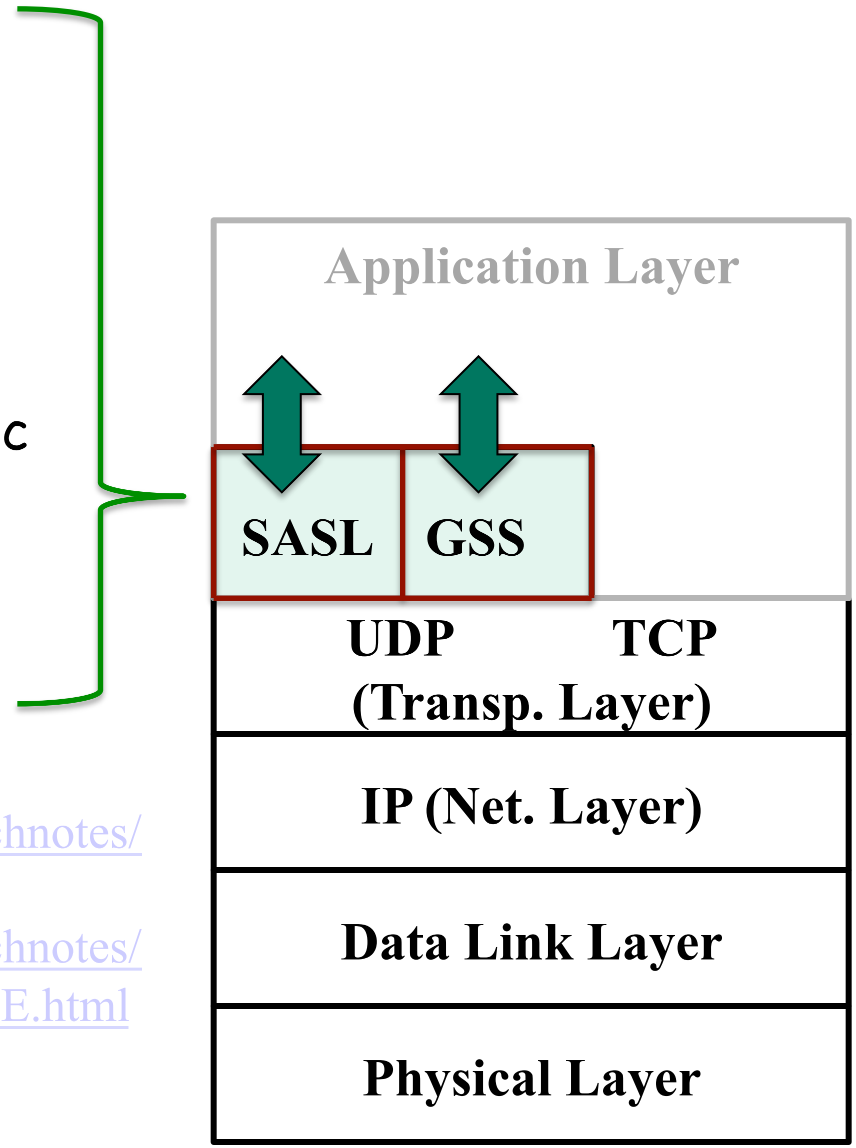
Ex: Java SASL API

GSS: Generic Security Service (rfc 2743)

Ex: Java GSS API

See more in:

- https://docs.oracle.com/javase/8/docs/
- https://docs.oracle.com/javase/8/docs/technotes/guides/security/index.html
- https://docs.oracle.com/javase/8/docs/technotes/guides/security/jgss/tutorials/JGSSvsJSSE.html



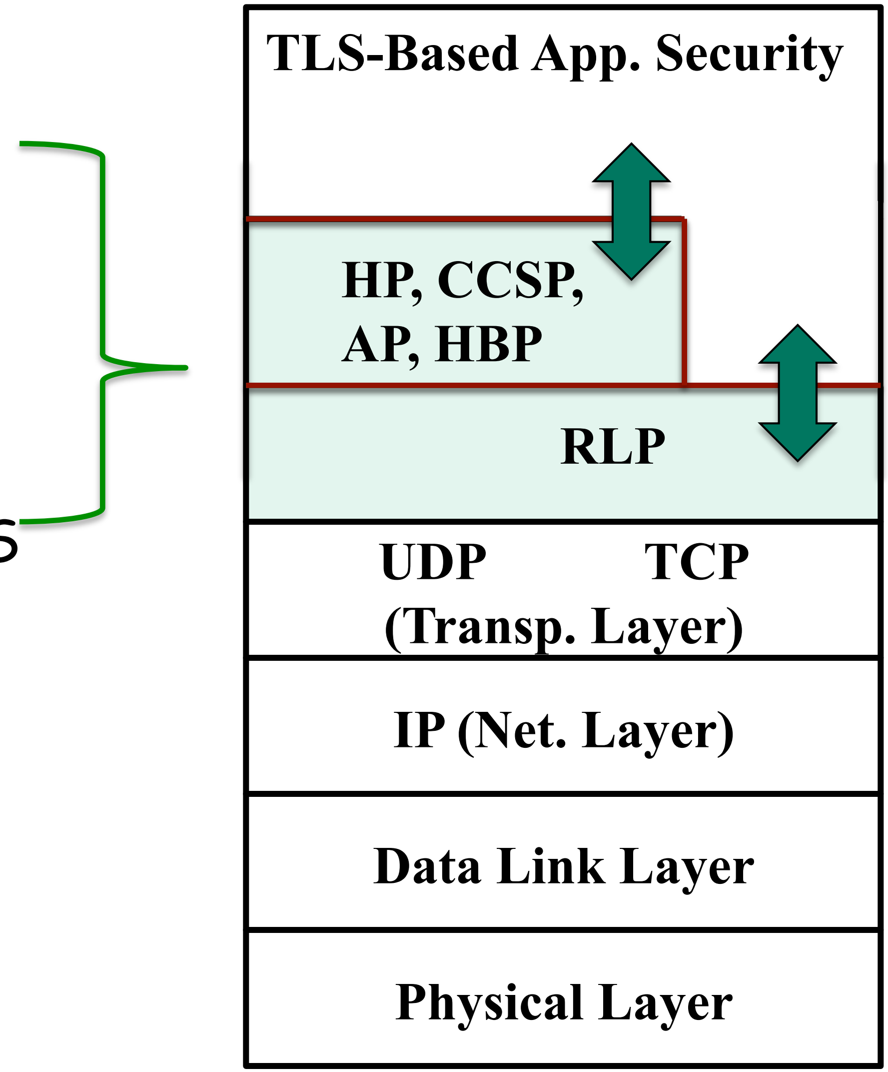
# TLS-Based Application Security Approach

- TLS-Enabled Application Security

HTTPS

STARTTLS POP3S, IMAP and ACAP (…. > rfc 8314)

Kerberos V5 w/ STARTTLS Extension (rfc 6251)

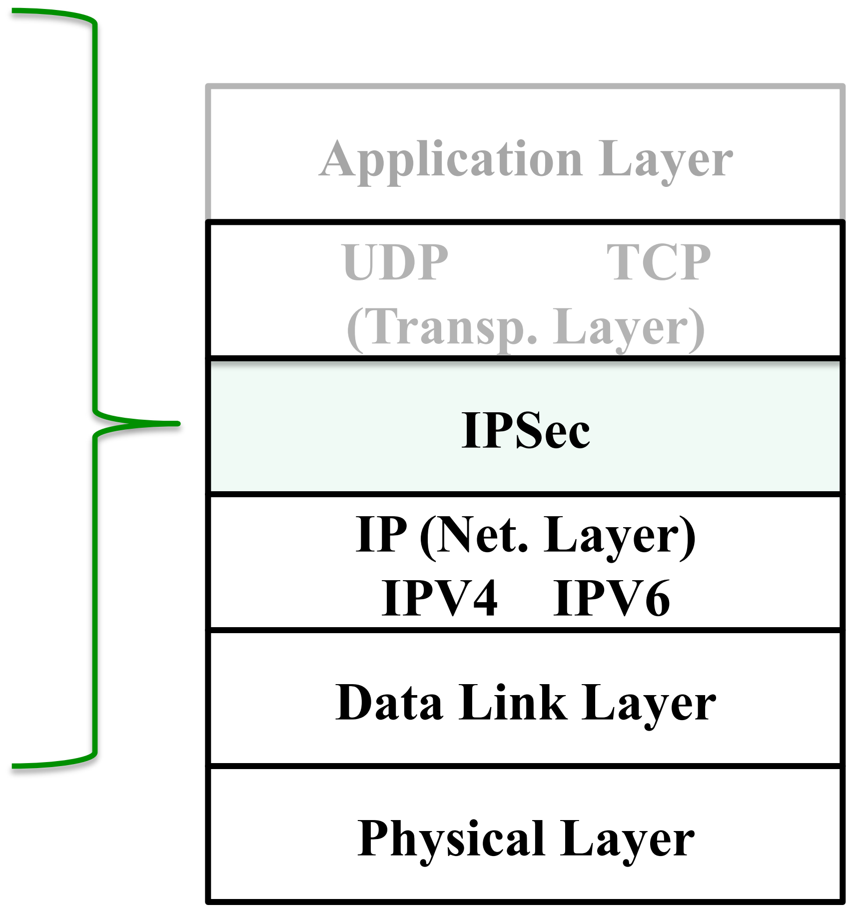


# IP Security Level Approach

IP Security Level Approach (IPSec)

Also a Security (Sub)Stack:

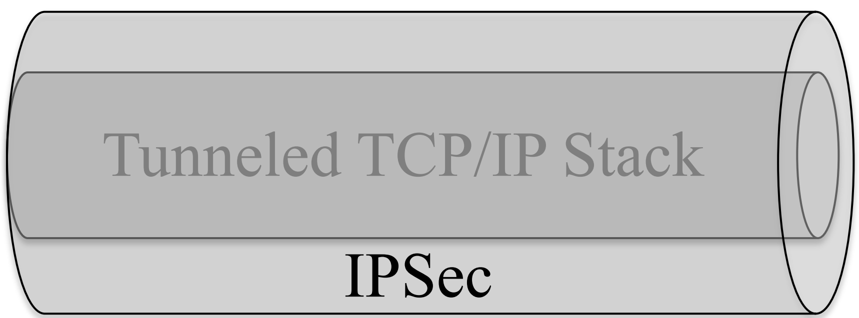
- AH (Auth. Header Protocol)
- ESP (Encap. Security Protocol)
- IKE (Internet Key Exchange Prot)
- ISAKMP (Internet Security Association and Key Management Protocol)

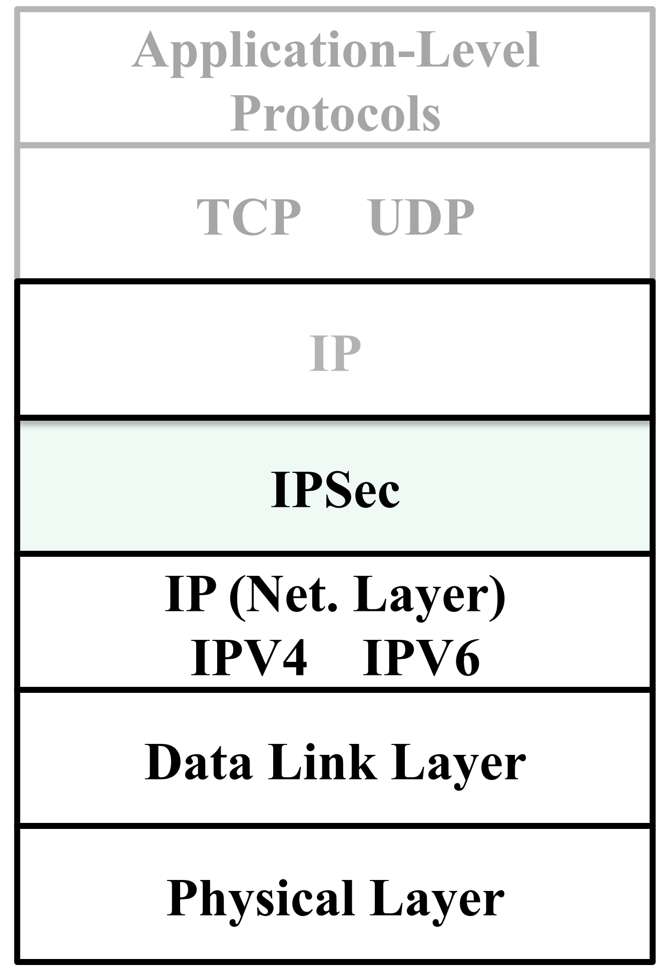


# Stack Tunneling with IP Security Level Approach

IP Security Level Approach (IPSec)

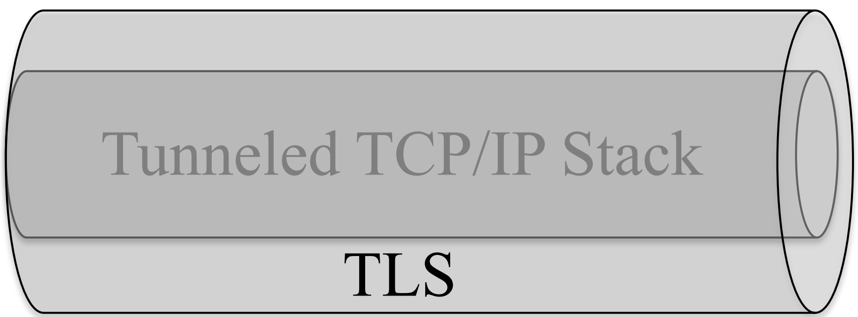
Tunneling with an overlayed TCP/IP Stack



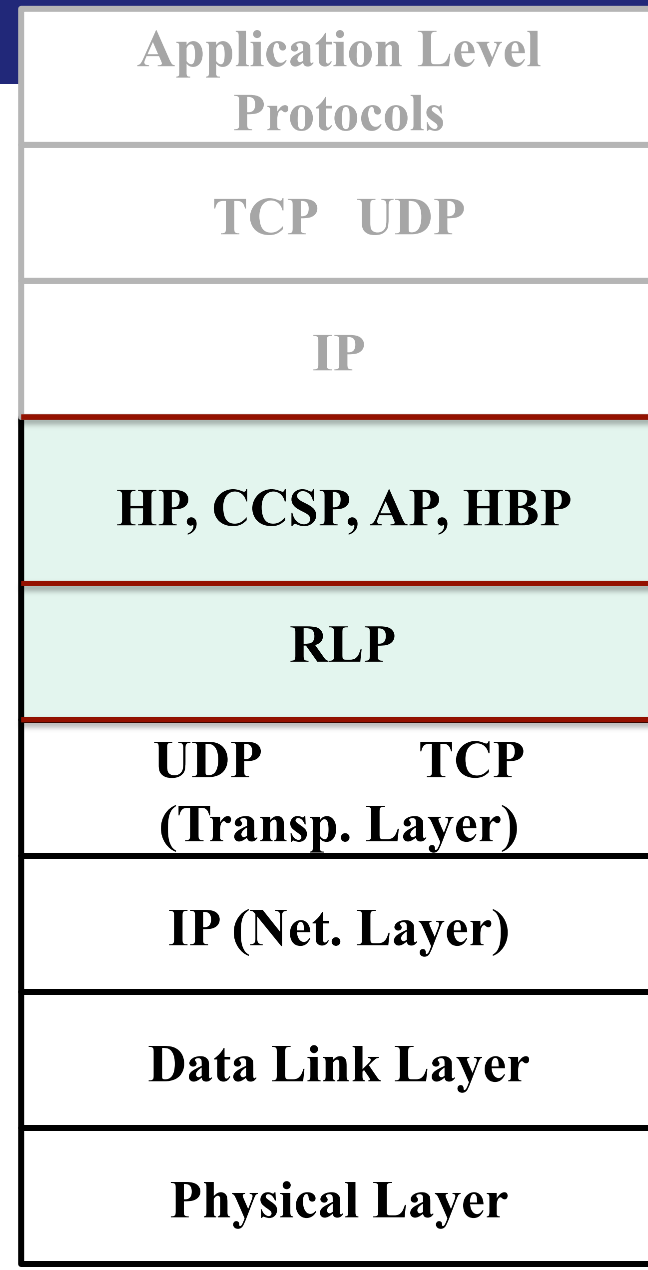
# Tunneling with a TLS Level Approach

Tunneling w/ Transport Layer Security (TLS) Approach




Obs)
Can also address tunneling Strategies w/ other security levels (ex., SSH Tunneling)

IPSec, TLS and SSH tunneling Strategies are used, for example to support Secure VPNs



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# TLS: Protection provided in summary

Security Properties Addressed by TLS:

- Integrity (message and data flow-integrity)
  - Including msg ordering control and session (connection-oriented) integrity
- Confidentiality (message and data confidentiality)
  - Session or Connection Oriented Confidentiality
  - But not necessarily Traffic Confidentiality
- Authentication (peer authentication and message authentication)
- Secure establishment and management control of Session Keys and Security Association Parameters

- What about Availability protection ? (discussion)

| | Threats | Consequences | Countermeasures |
|---|---|---|---|
| **Integrity** | • Modification of user data<br>• Trojan horse browser<br>• Modification of memory<br>• Modification of message traffic in transit | • Loss of information<br>• Compromise of machine<br>• Vulnerabilty to all other threats | Cryptographic checksums |
| **Confidentiality** | • Eavesdropping on the net<br>• Theft of info from server<br>• Theft of data from client<br>• Info about network configuration<br>• Info about which client talks to server | • Loss of information<br>• Loss of privacy | Encryption, Web proxies |
| **Denial of Service** | • Killing of user threads<br>• Flooding machine with bogus requests<br>• Filling up disk or memory<br>• Isolating machine by DNS attacks | • Disruptive<br>• Annoying<br>• Prevent user from getting work done | Difficult to prevent |
| **Authentication** | • Impersonation of legitimate users<br>• Data forgery | • Misrepresentation of user<br>• Belief that false information is valid | Cryptographic techniques |

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| **Authentication** | • Impers... users<br>• Data f | | |

Secure Hash Functions,
MACs (CMACs or HMACs)

Symmetric Encryption, w/ defined Modes and Encryption Padding

X509v3 Certificates, Digital Signatures / Asymmetric Cryptography

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Secure Hash Functions,
MACs (CMACs or HMACs)

SESSION CIPHERSUITES

Symmetric Encryption,
w/ defined Modes and Encryption Padding

TLS not effective only by itself

TLS Handshake (for Key-Establishment and Agreement of Session Security Association Parameters, Protocol Versionm Ciphersuites and TLS processing extensions

# TLS-Stack and Role of TLS Sub-Protocols

**HP: Handshake Protocol**

- Authentication, Agreement and Establishment of Cryptographic Keys, Security Association Parameters and Extensions for TLS Sessions

**AP: Alert Protocol**

- Reaction to events and exceptions in TLS flows, aborting, resuming or restarting HP

**CCSP: Change Cipher Spec. Protocol**

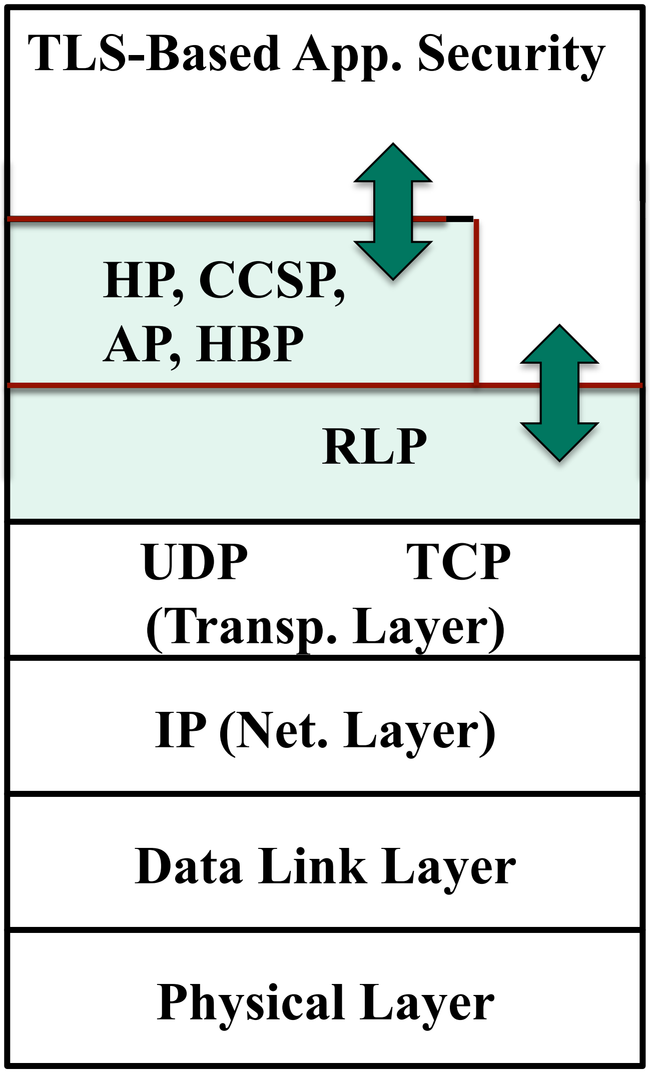
- Sync. of established session security parameters

**Heartbeat Protocol**

- Keep-Alive Control of established sessions

**RLP: Record Layer Protocol**

- Secure transport TLS payload format



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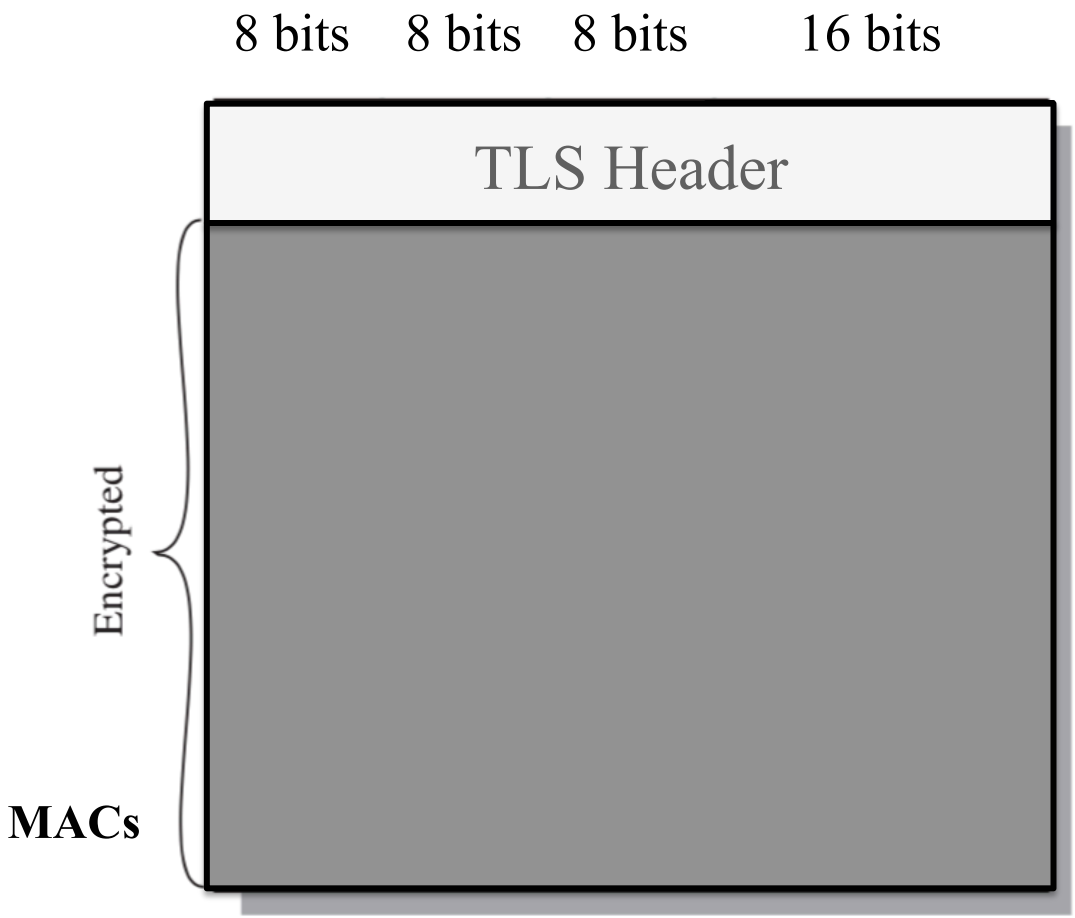
# RLP Message Format




**Content types**

| Hex | Dec | Type |
|---|---|---|
| 0x14 | 20 | ChangeCipherSpec |
| 0x15 | 21 | Alert |
| 0x16 | 22 | Handshake |
| 0x17 | 23 | Application |
| 0x18 | 24 | Heartbeat |

**Versions**

| Major version | Minor version | Version type |
|---|---|---|
| 3 | 0 | SSL 3.0 |
| 3 | 1 | TLS 1.0 |
| 3 | 2 | TLS 1.1 |
| 3 | 3 | TLS 1.2 |
| 3 | 4 | TLS 1.3 |

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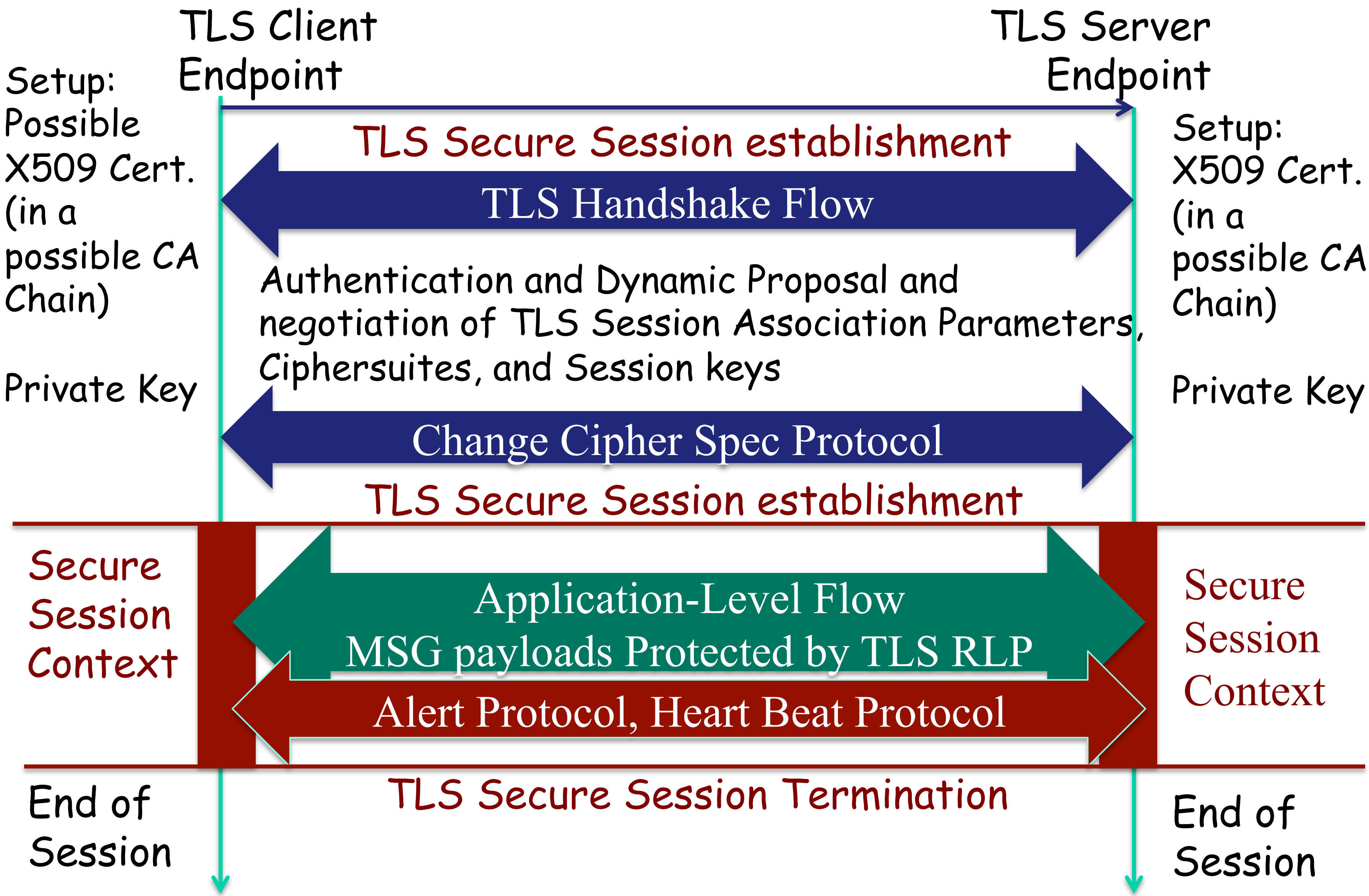
# TLS Operation and Generic Traffic Flow



# TLS Operation and Flexibility Issues
(imply on possible different required setups)

- Client TLS and Server TLS endpoints can map or not Client Side and Server Side App. Endpoints
  - In TLS a Client TLS Endpoint initiates the Handshake Process
    … But it can be the Server Side App Endpoint
- TLS protocol can be supported in different versions
- Peer-Authentication of Endpoints can be:
  - Unilateral Authentication
    - Server Only or Client Only Authentication
  - Mutual Authentication
    - Client and Server mutually authenticated
- Peer-Authentication Type and Key + SA Establihment can be different, according to the negotiated handshake
- Agreed TLS ciphersuites (for all the cryptographic methids that will be used) depend on the handshake negotiation

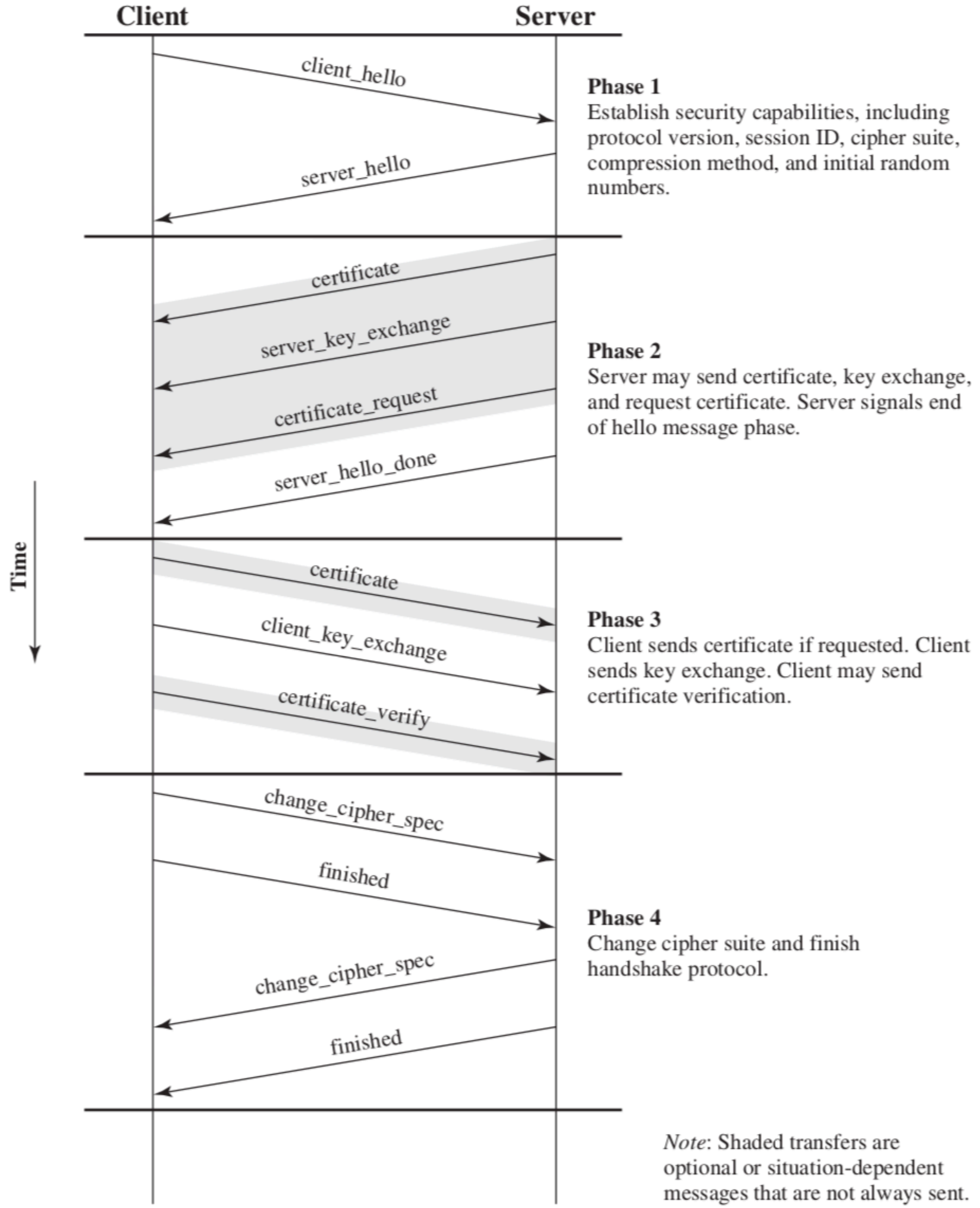
# Protocol Versions: TLS and SSL Protocols

**SSL and TLS protocols**

| Protocol | Published | Status | |
|---|---|---|---|
| **SSL 1.0** | Unpublished | Unpublished | |
| **SSL 2.0** | 1995 | Deprecated in 2011 (RFC 6176) | |
| **SSL 3.0** | 1996 | Deprecated in 2015 (RFC 7568) | |
| **TLS 1.0** | 1999 | Deprecation planned in 2020[11] | Def. RFC 2246, Jan/99 |
| **TLS 1.1** | 2006 | Deprecation planned in 2020[11] | Def. RFC 4346, Apr/06 |
| **TLS 1.2** | 2008 | | Def. RFC 5246, Aug/08 |
| **TLS 1.3** | 2018 | | Def. RFC 8446, Aug/18 |

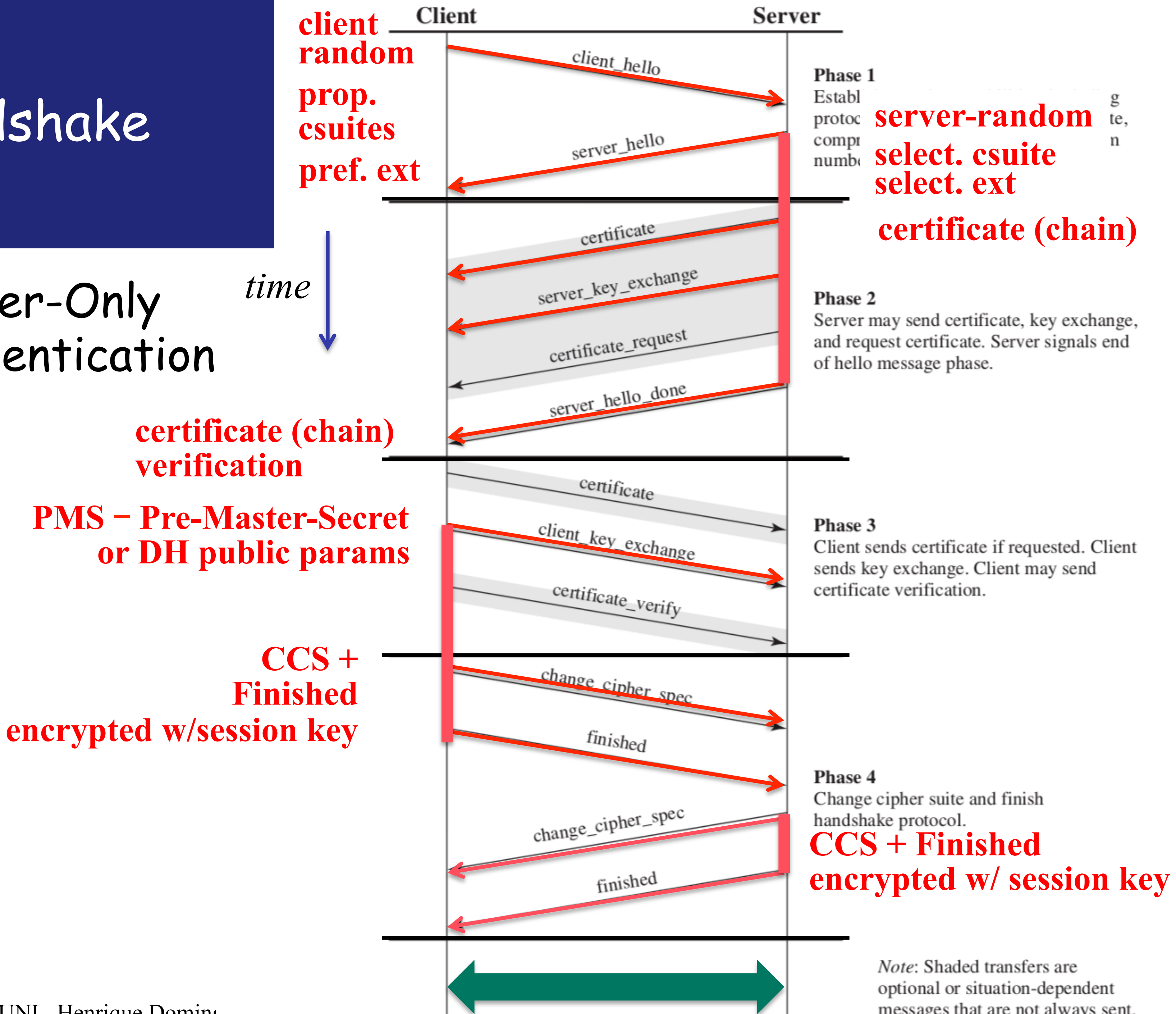
# TLS Handshake Flow

## Generic Flow



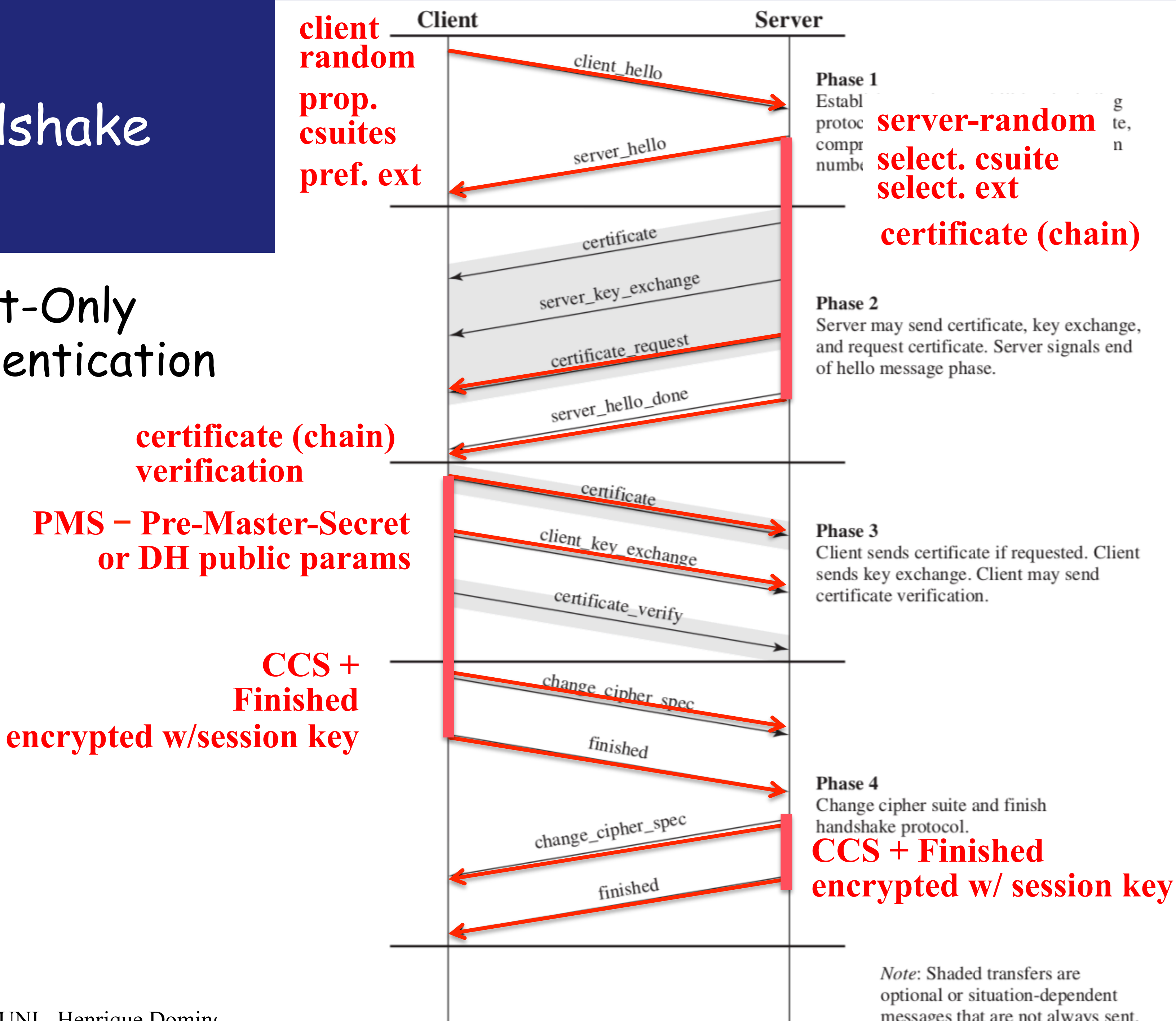
# TLS Handshake Flow

Server-Only Authentication



# TLS Handshake Flow

Client-Only Authentication



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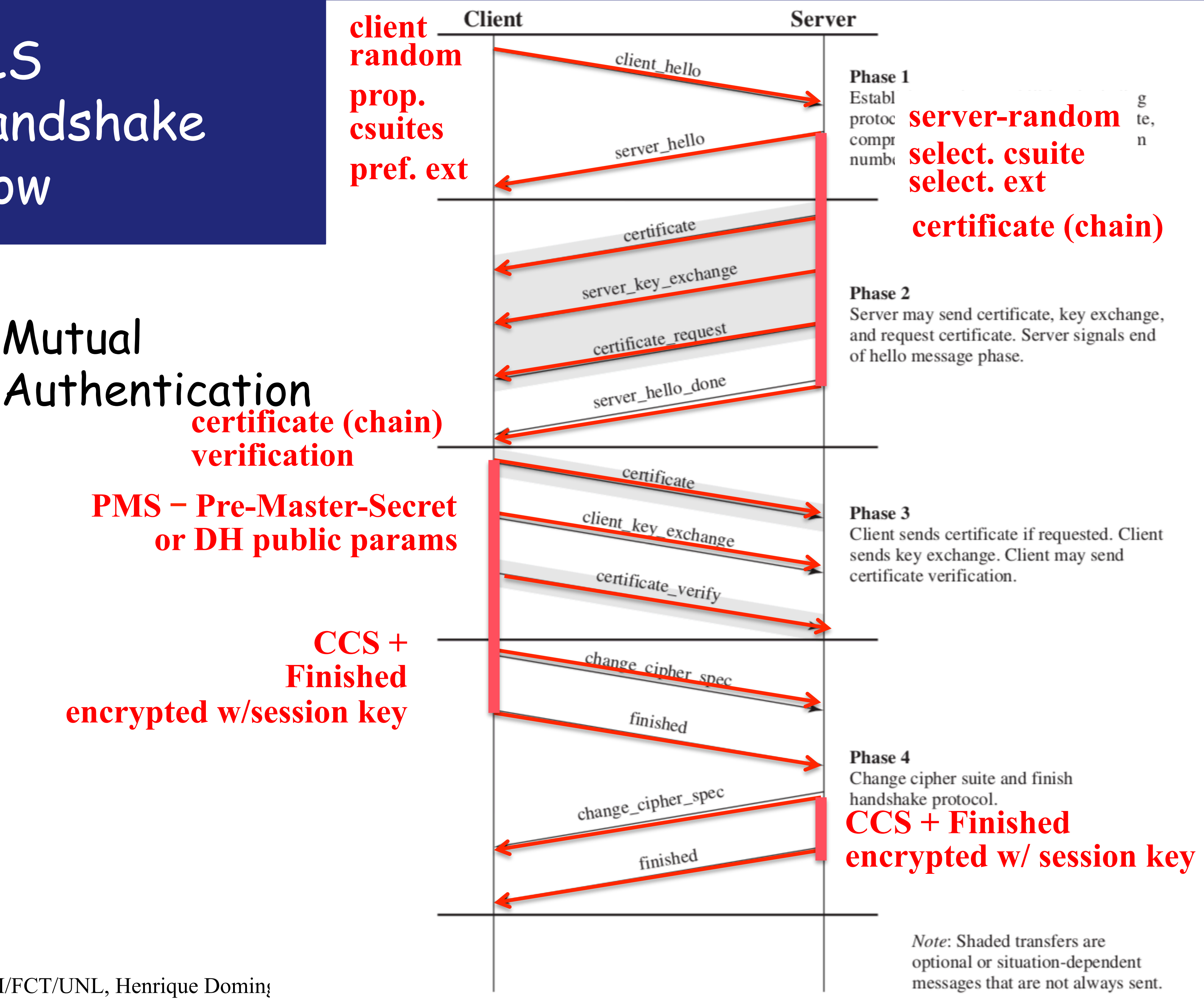


# Hands-On TLS Analysis

Hands-On TLS Sessions
Security Inspection and Traffic Analysis

(see also the practical context in Labs: Lab 6)

# TLS Analysis: openssl tool and JRE instrumentation

## openssl tool (example):

```
$ openssl s_client -connect www.gmail.com:443
```

Security enforcement (ex., TLS protocol version, Client-enabled/proposed Ciphersuites)

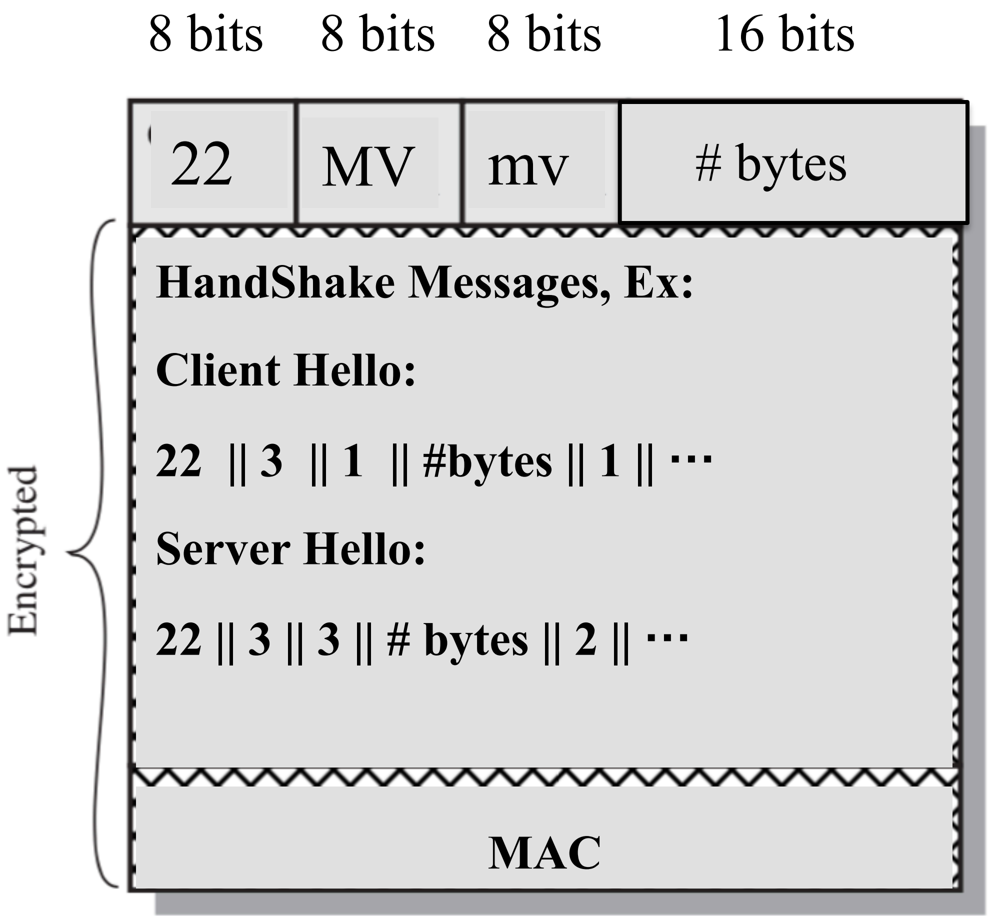
```
$ openssl ciphers
$ openssl s_client -connect www.gmail.com:443 -tls1_3 -cipher
TLS_AES_256_GCM_SHA384
… etc
```

JRE / TLS Runtime Instrumentation

```
$ java -Djavax.net.debug=all    ...
```

See also examples in LAB 6

# Ex: Handshake / RLP Message Format

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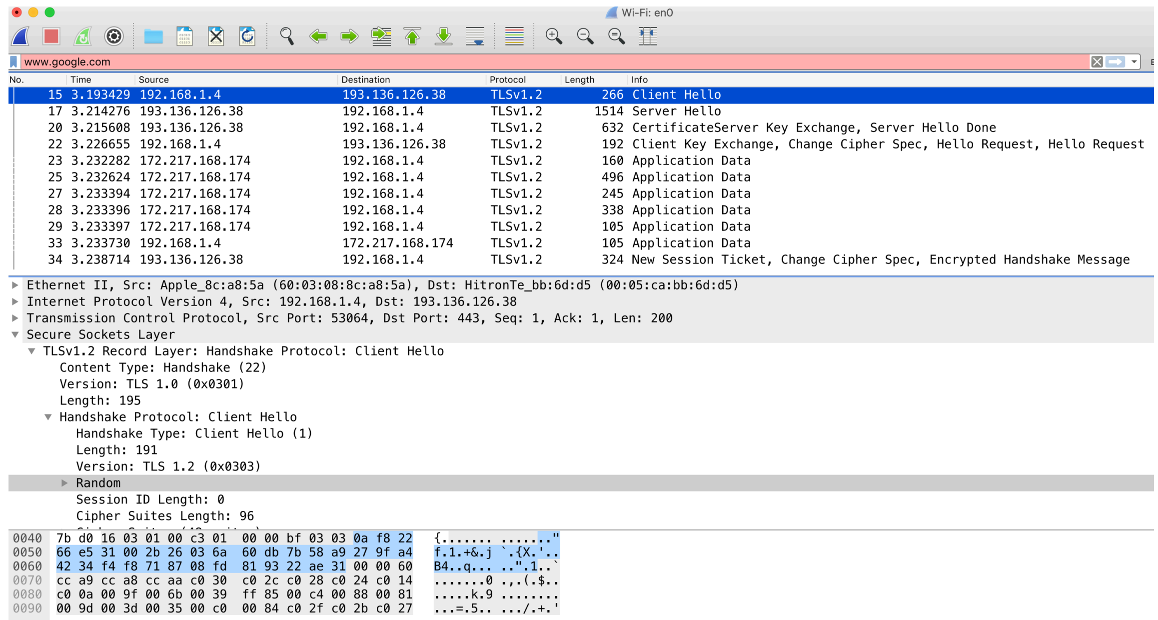
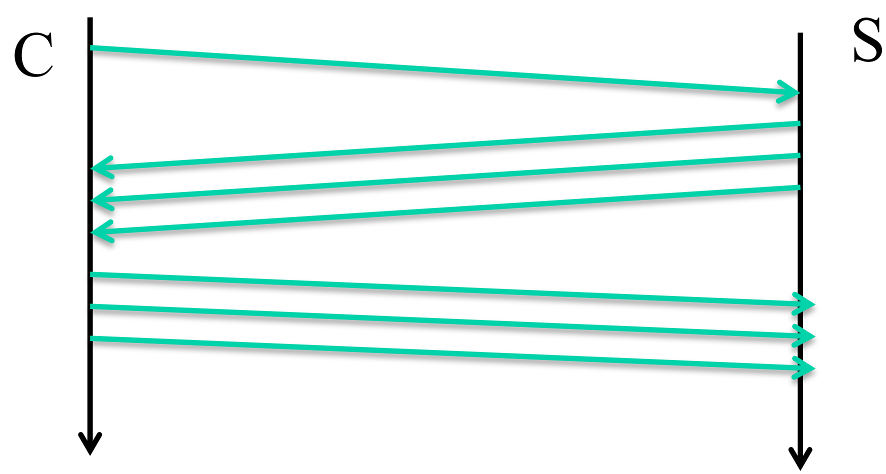
# TLS Traffic Flow Analysis: Wireshark
## (can use a TLS client: browser or openssl tool and TLS server)

**Suggestion:**
Analyze the TLS Traffic Flow in a Real TLS Trace: Ex: TLS 1.0, TLS 1.2, TLS 1.3 using the openssl and wireshark tools




**SEE LAB 6**
**Will do this in LAB 6**

# TLS Traffic Flow Analysis: openssl + ssldump

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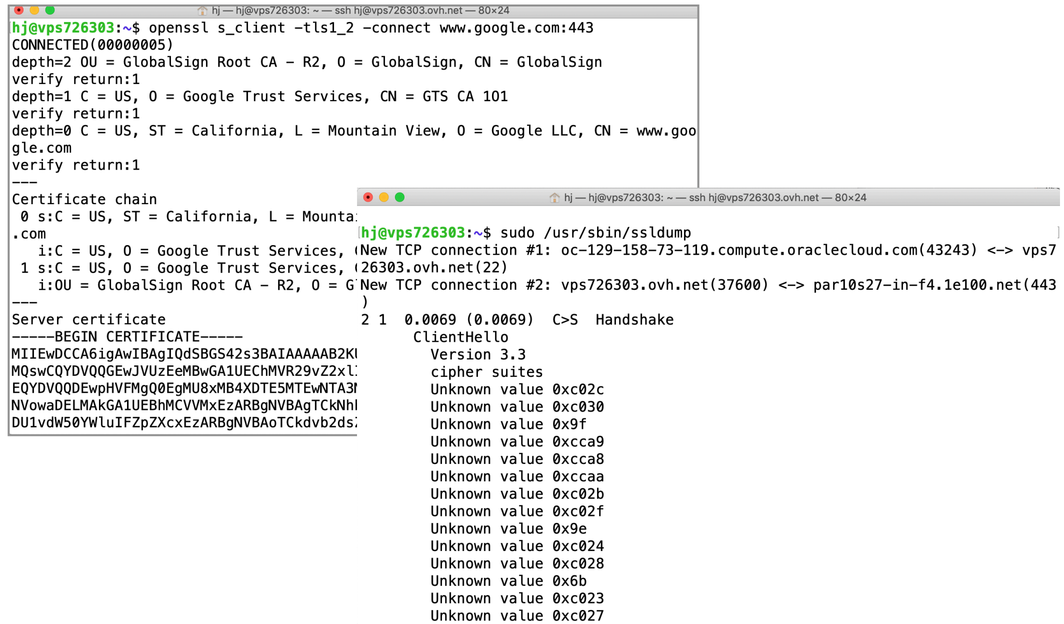
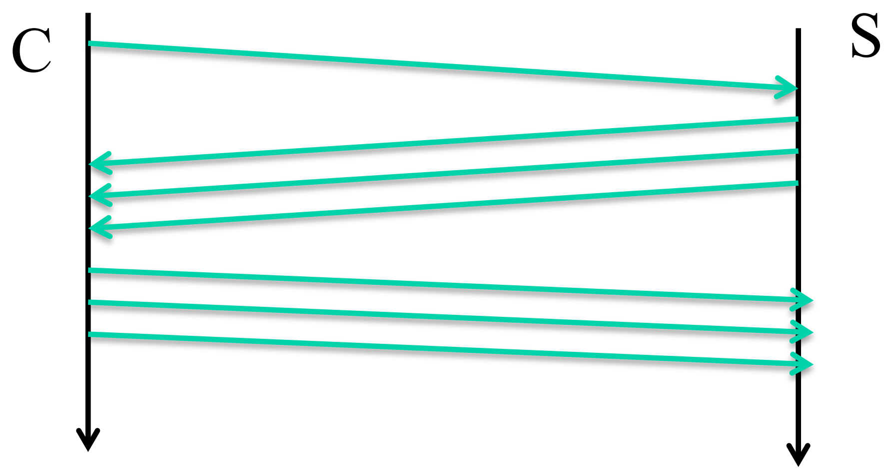
SEE LAB 6
Will do this in LAB 6



# TLS Traffic Flow Analysis:
## Security Analysis w/ your Browser Development Tools

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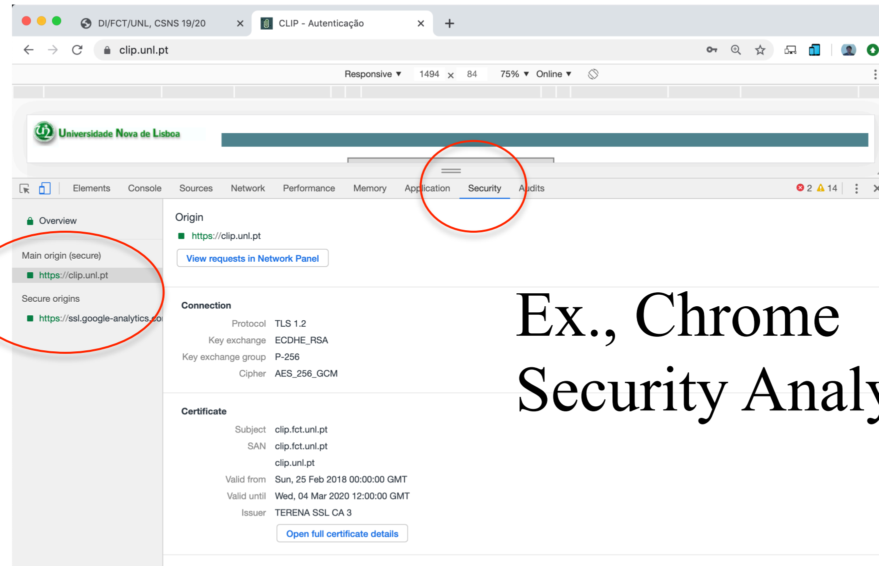
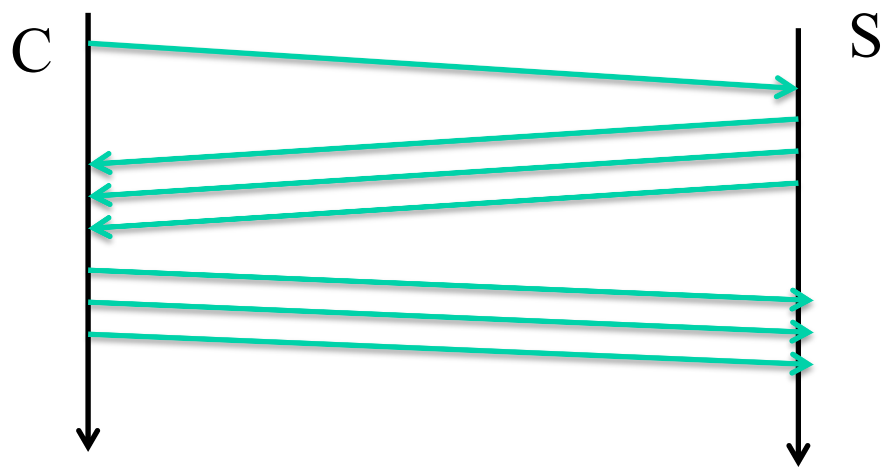



Ex., Chrome Security Analysis

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# TLS Traffic Flow Analysis

## Other interesting tools: mobile inspection

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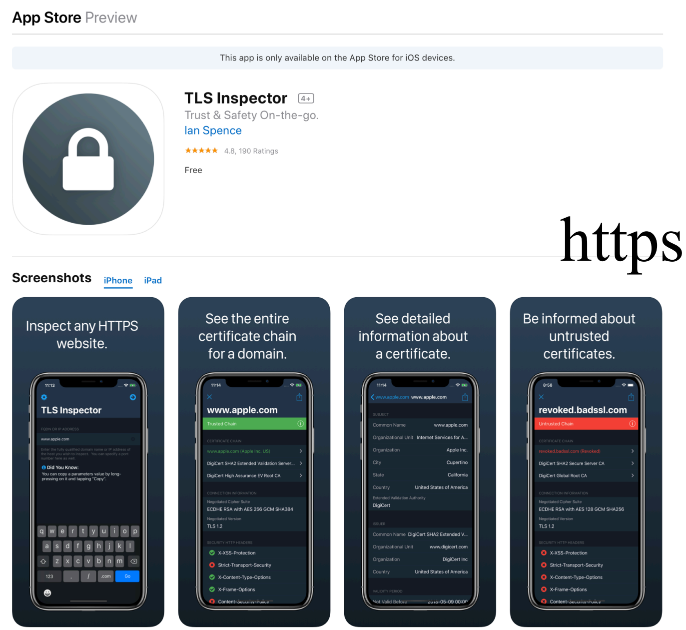


https://tlsinspector.com

AppStore TLSInspector

https://github.com/google/nogotofail
https://source.android.com/security

GoogleStore nogotofail

# Handshake Types for Key & SA Establishment

- RSA: RSA Signatures + RSA encryption envelopes
- ECDSA: EC DSA Signatures + ECC Envelopes
- EDH: Ephemeral authenticated Diffie Hellman Agreement, w/ RSA or DSA Signatures
- EC-EDH or EC-DHE: Ephemeral authenticated Diffie Hellman Agreement, w/ EC-DSA Signatures

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Very specific use

- SRP: Secure Remote Password Protocol
- PSK: Pre-Shared Keys

- FDH (Fixed Diffie Hellman): Fixed authenticated Diffie Hellman Agreement, w/ Certificates of DH-Public Numbers
- EC-FDH or EC-DH: Fixed authenticated Diffie Hellman Agreement, w/ EC-DSA Signatures

---

Must not be used for security

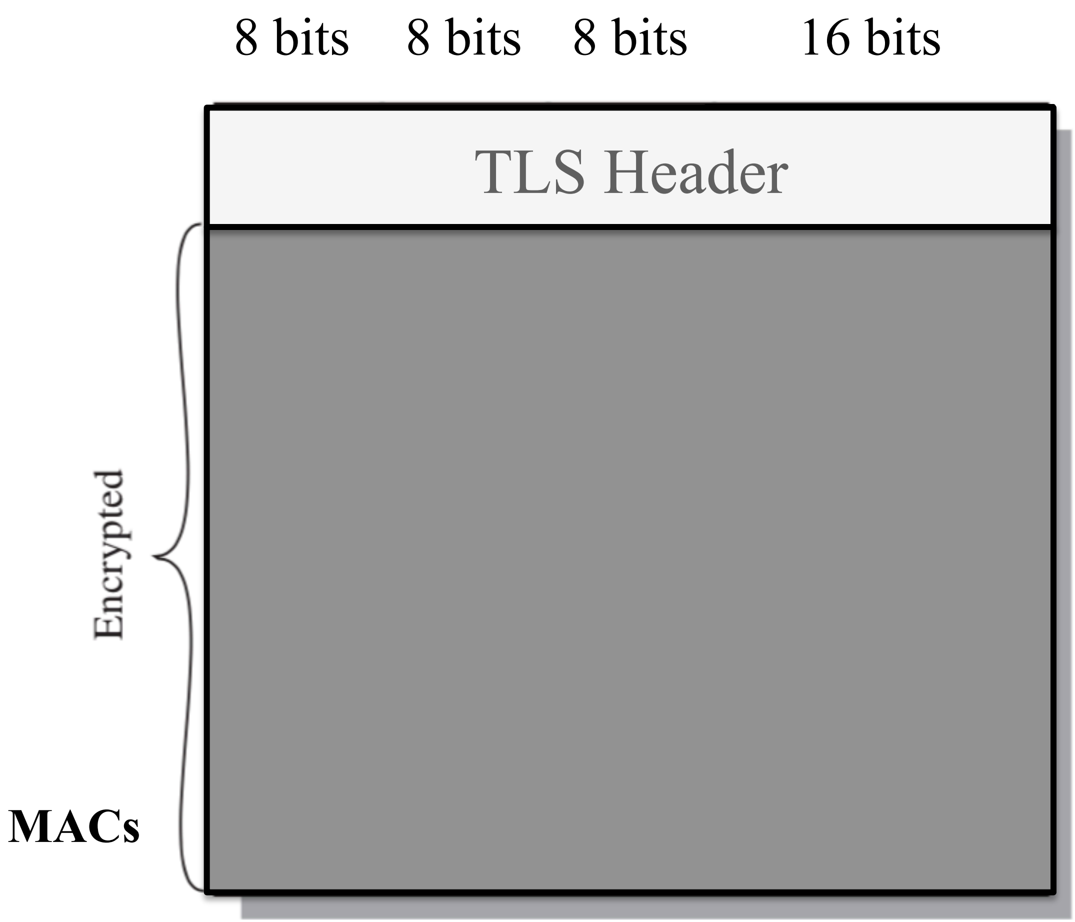
- No Authentication
- ADH (Anonymous Diffie Hellman)
- Fortezza

# Standardized Ciphersuites: Support vs. Enabling
# Ex., see openssl ciphers or TLS client proposed ciphersuites

- Combinations of the cryptographic methods for the handshake negotiation, usually represented in the following way (example):

TLS_ECDHE_ECDSA_WITH_CHACHA20_POLY1305_SHA256 (0xcc14)
TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384 (0xc02c)
TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256 (0xc02b)
TLS_ECDHE_ECDSA_WITH_AES_256_CBC_SHA384 (0xc024)
TLS_ECDHE_ECDSA_WITH_AES_128_CBC_SHA256 (0xc023)
TLS_ECDHE_ECDSA_WITH_CHACHA20_POLY1305_SHA256 (0xcc14)
TLS_ECDHE_RSA_WITH_CHACHA20_POLY1305_SHA256 (0xcc13)
TLS_DHE_RSA_WITH_CHACHA20_POLY1305_SHA256 (0xcc15)
TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384 (0xc030)
TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256 (0xc02f)
TLS_DHE_RSA_WITH_AES_256_GCM_SHA384 (0x9f)
TLS_DHE_RSA_WITH_AES_128_GCM_SHA256 (0x9e)
TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384 (0xc02c)
TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256 (0xc02b)
… etc

# RLP Message Format




**Content types**

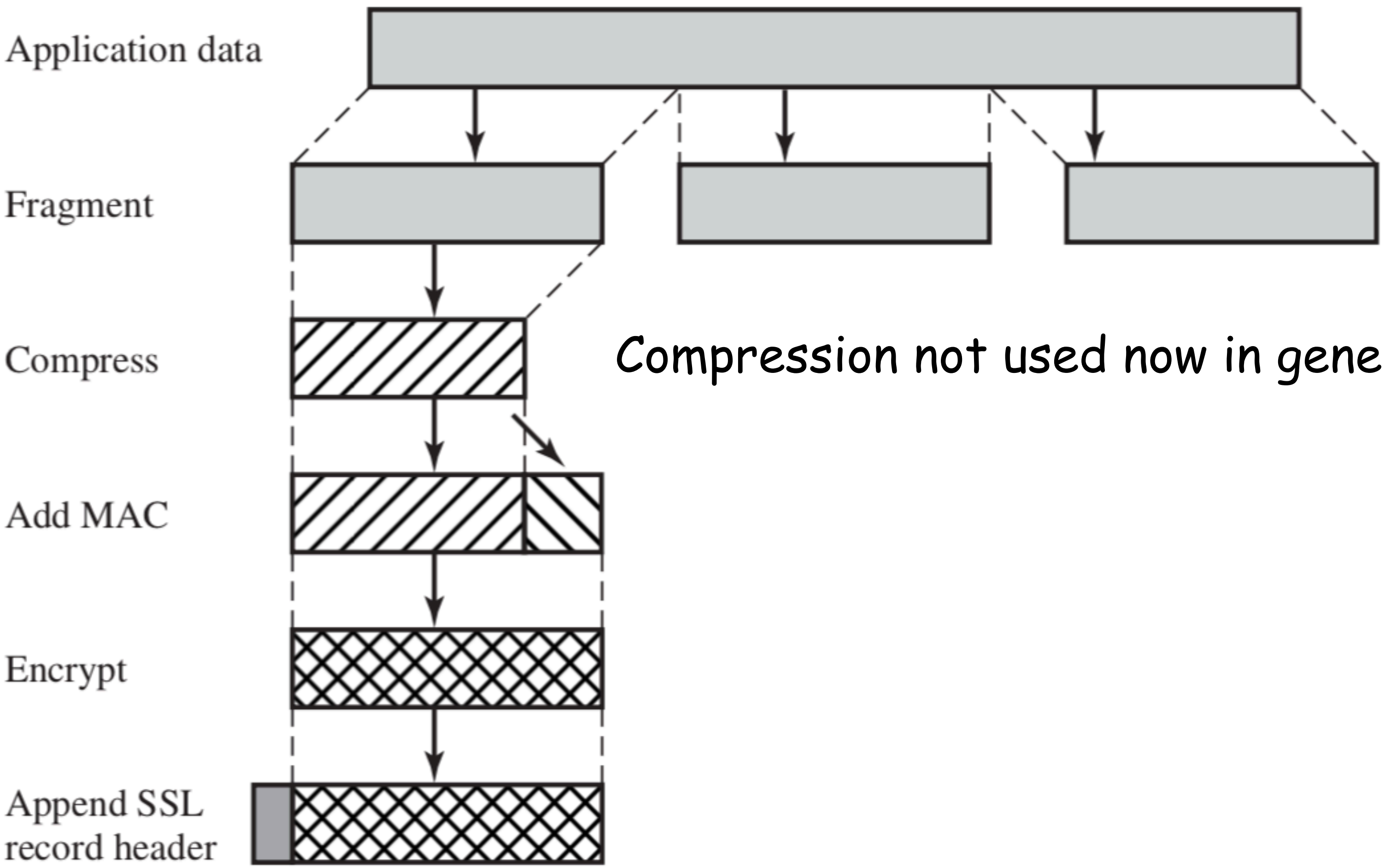
| Hex | Dec | Type |
|---|---|---|
| 0x14 | 20 | ChangeCipherSpec |
| 0x15 | 21 | Alert |
| 0x16 | 22 | Handshake |
| 0x17 | 23 | Application |
| 0x18 | 24 | Heartbeat |

**Versions**

| Major version | Minor version | Version type |
|---|---|---|
| 3 | 0 | SSL 3.0 |
| 3 | 1 | TLS 1.0 |
| 3 | 2 | TLS 1.1 |
| 3 | 3 | TLS 1.2 |
| 3 | 4 | TLS 1.3 |

# TLS: TLP - Record Layer Protocol

## Message Processing in Endpoints




Compression not used now in general

# Even more easy (Java) app. level programming … (hands-on: Lab 6)

Transparent support for base URL operations
(URL/HTTP or URL/HTTPS): URL Class and URL Connections

Analysis with:

- openssl tool: TLS Session establishment inspection and observation of established ciphersuites
- wireshark: TLS protocol analysis

JSSE Programming Client/Server w/ detailed parameterization of TLS endpoints

JSSE-Based Rest Code

See Materials in Lab6 Class

Also for protection/parameterization of TLS-enabled endpoints and communications in the TP2 (Work Assignment #2) requirements

# Java JSSE Programming (Lab, hands-on)

- See Lab 6 (Hands-On Exercises)
  - Debugging / TLS Traffic Analysis
    - Use of openssl, wireshark and browser/browser-dev. tools
  - Programming with JSSE (Demos/Exercises)
    - Fine-tuned TLS parameterizations and TLS session context control
    - Unilateral vs. Mutual authentication
    - TLS debug in java with -Djavax.net.debug=all

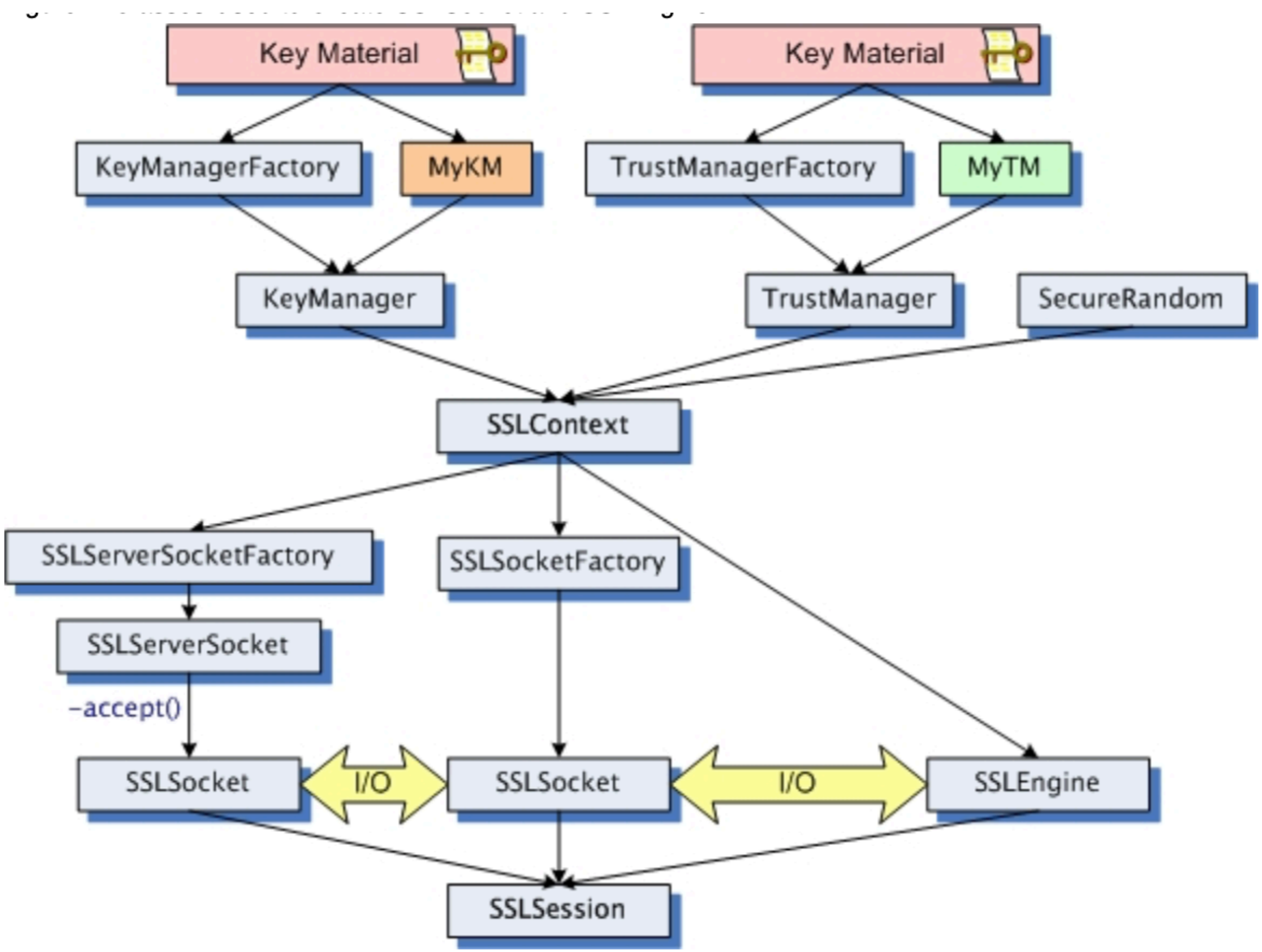
# JSSE Programming: Base Server Skeleton

```
import java.io.*;
import javax.net.ssl.*;
. . .
int port = availablePortNumber;
SSLServerSocket s;
try {
SSLServerSocketFactory sslSrvFact =
(SSLServerSocketFactory)SSLServerSocketFactory.getDefault();
s = (SSLServerSocket)sslSrvFact.createServerSocket(port);
SSLSocket c = (SSLSocket)s.accept();
OutputStream out = c.getOutputStream();
InputStream in = c.getInputStream();
// Send and Recv messages
} catch (IOException e) {     }
```

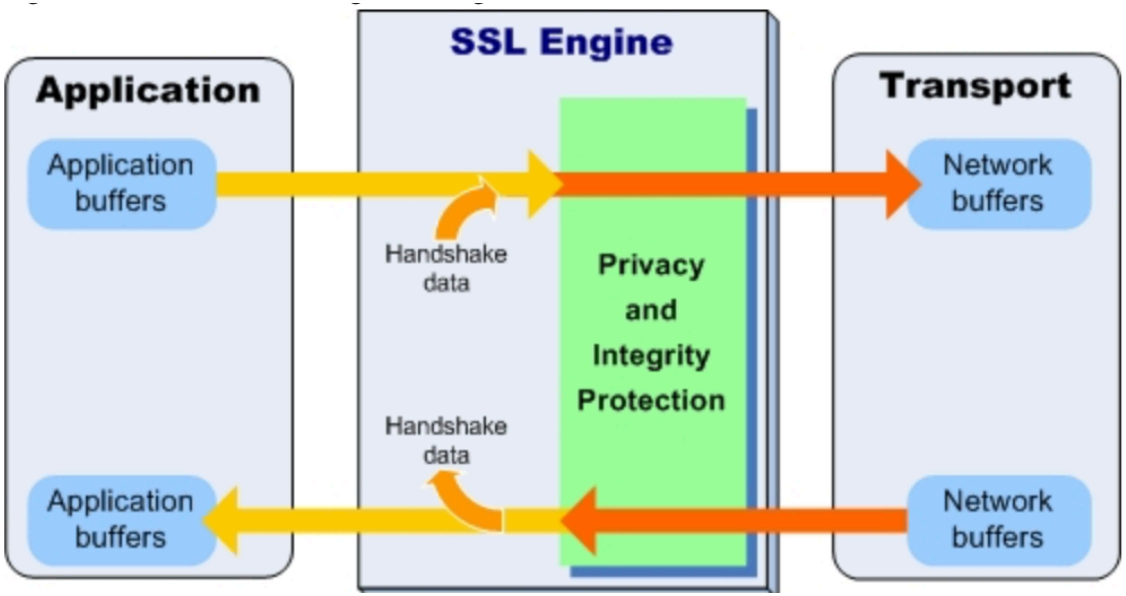
# JSSE Programming; Base Client Skeleton

```
import java.io.*;
import javax.net.ssl.*;
. . .
int port = availablePortNumber;
String host = "hostname";
try {
  SSLSocketFactory sslFact =
     (SSLSocketFactory)SSLSocketFactory.getDefault();
  SSLSocket s = (SSLSocket)sslFact.createSocket(host, port);
  OutputStream out = s.getOutputStream();
  InputStream in = s.getInputStream();
  // Send / Recv messages from the server
}  catch (IOException e) {     }
```

# JSSE Classes and Interfaces



# Dataflows protected by JSSE TLS Engine




App-Level Session-Level Transport-Level

**Engine (runtime) states (TLS session-level management):**

- ***Creation***: Ready to be configured
- **Initial handshaking**: Perform authentication and negotiate communication parameters
- ***Application data***: Ready for application exchange
- **Re-handshaking**: Renegotiate communications parameters/ authentication; handshaking data may be mixed with application data
- ***Closure***: Ready to shut down the connection

# TLS in Work Assignement #2 variants

Requires a fine-grain approach for the security parameterization of TLS endpoints (establishment of client/server TLS sessions)

- Control of enabled and established ciphersuites
- Mutual authentication (not only unilateral authentication)
- Security control of the TLS handshake protocol (including X509v3 certification chains, certificate types and certificate validation/verification procedures) and possible exceptions that must be managed

Possible use of TLS (and above controls) in different type of programming support:

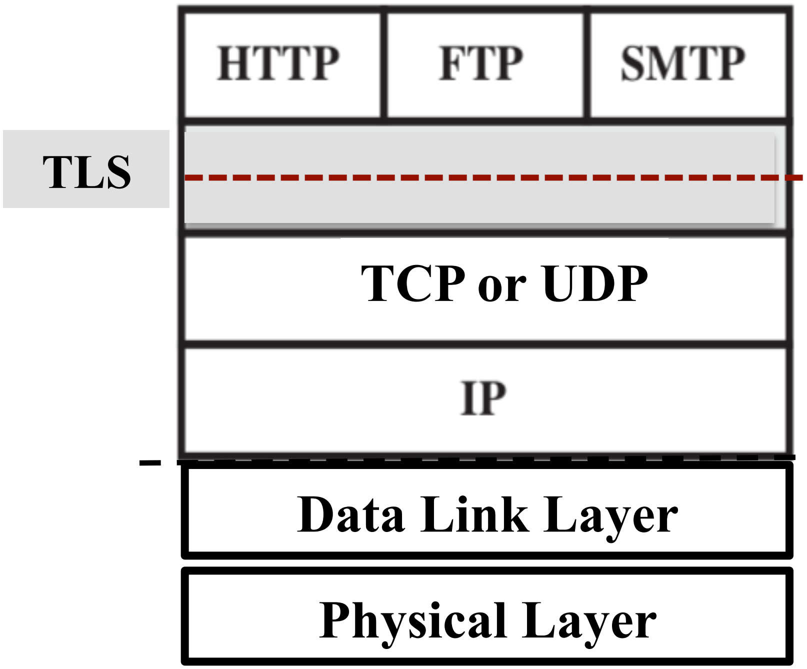
- Java JSSE Sockets
- Rest/TLS
- Use of TLS enabled support on Web Development Frameworks (ex., SPRING, … others)

# Outline

- WEB security issues
  - Web traffic security threats: the role of SSL and TLS
  - TCP/IP Stack and TLS
  - Security properties and services addressed by TLS
  - TLS operation and TLS based programming
- TLS: Session-Security vs. Transport Security Layers
  - TLS architecture and protocol stack
  - TLS protocol versions
  - TLS configurability and flexibility issues
  - TLS Ciphersuites
  - Analysis of TLS Sub-Protocols: RLP, CSP, AP, HP and HB
- TLS vs. HTTPS
- TLS Practical Security: Weak Ciphersuites and Security Tradeoffs
- Web Security and Threats beyond TLS

# TLS: Secure Session vs. Secure Transport

## Transport-Level Security Service Levels




Session Security Layer

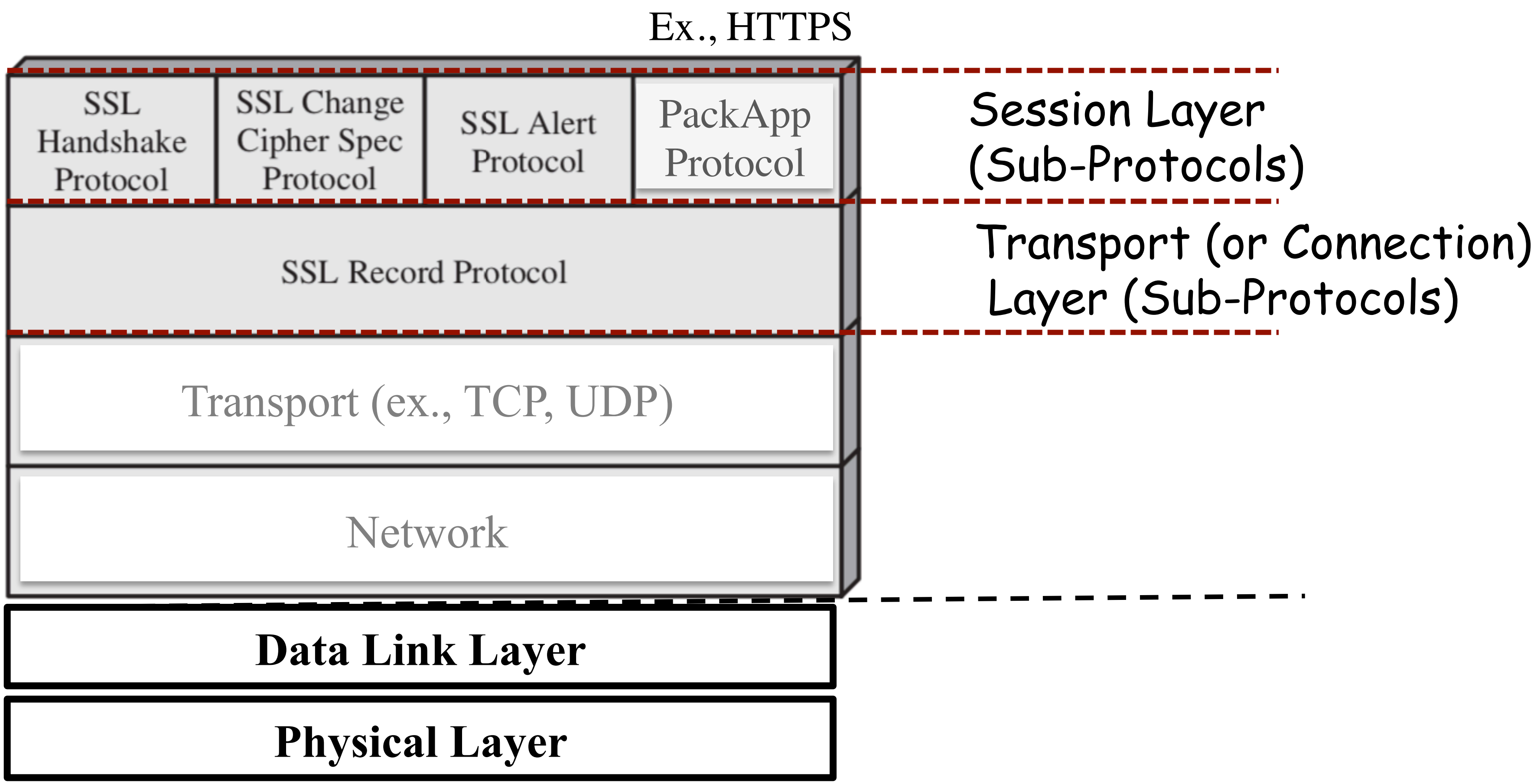
Transport (or Connection) Security Layer

(IPv5, v6 ··· or 6LoWPan)

Net. Access Channels
Data Link Tec:
Ex., IEEE 802.11, 802.3,...
802.1 to 802.15.x
https://en.wikipedia.org/wiki/IEEE_802

# TLS: Secure Session vs. Secure Transport

## Transport-Level Security Service Levels and related protocols in the TLS Stack



# TLS: Secure Session vs. Secure Transport

## TLS Security Association Parameters: Established and Setup from the Handshake Protocol

| | |
|---|---|
| Security state established and maintained from a set of session-level security association parameters | Session Layer (Sub-Protocols) |
| Transport state established and maintained from a set of transport-level security association parameters | Transport (or Connection) Layer (Sub-Protocols) |

Transport (ex., TCP, UDP)

Network (IP)

...

# TLS: Transport Security Control Parameters

A transport or connection state is defined by a set of parameters, (transport or connection security association parameters) exchanged and initially established in the context of the Handshake protocol

- **Server and client random values.**
- **Server write MAC secrets** (Server MAC Key)
- **Client write MAC secret** (Client Mac Key)
- **Server write key** (Server Encryption Key)
- **Client write key** (Client Encryption Key)
- **Initialization vectors**: established from an initial IV
- **Sequence numbers**: From 0 to $2^{64}$ -1

# TLS: Session Security Control Parameters

A session state is defined by a set of security association parameters, exchanged and initially established in the context of the Handshake protocol

**Session identifier:** An arbitrary byte sequence proposed bi the client but chosen by the server to identify an active or resumable session state.

**Peer certificate:** An X509.v3 certificate of the peer. This element of the state may be null, depending on different authentication modes

In general: a certification chain, validated during the handshake

**Compression method:** algorithm to compress data prior to encryption.

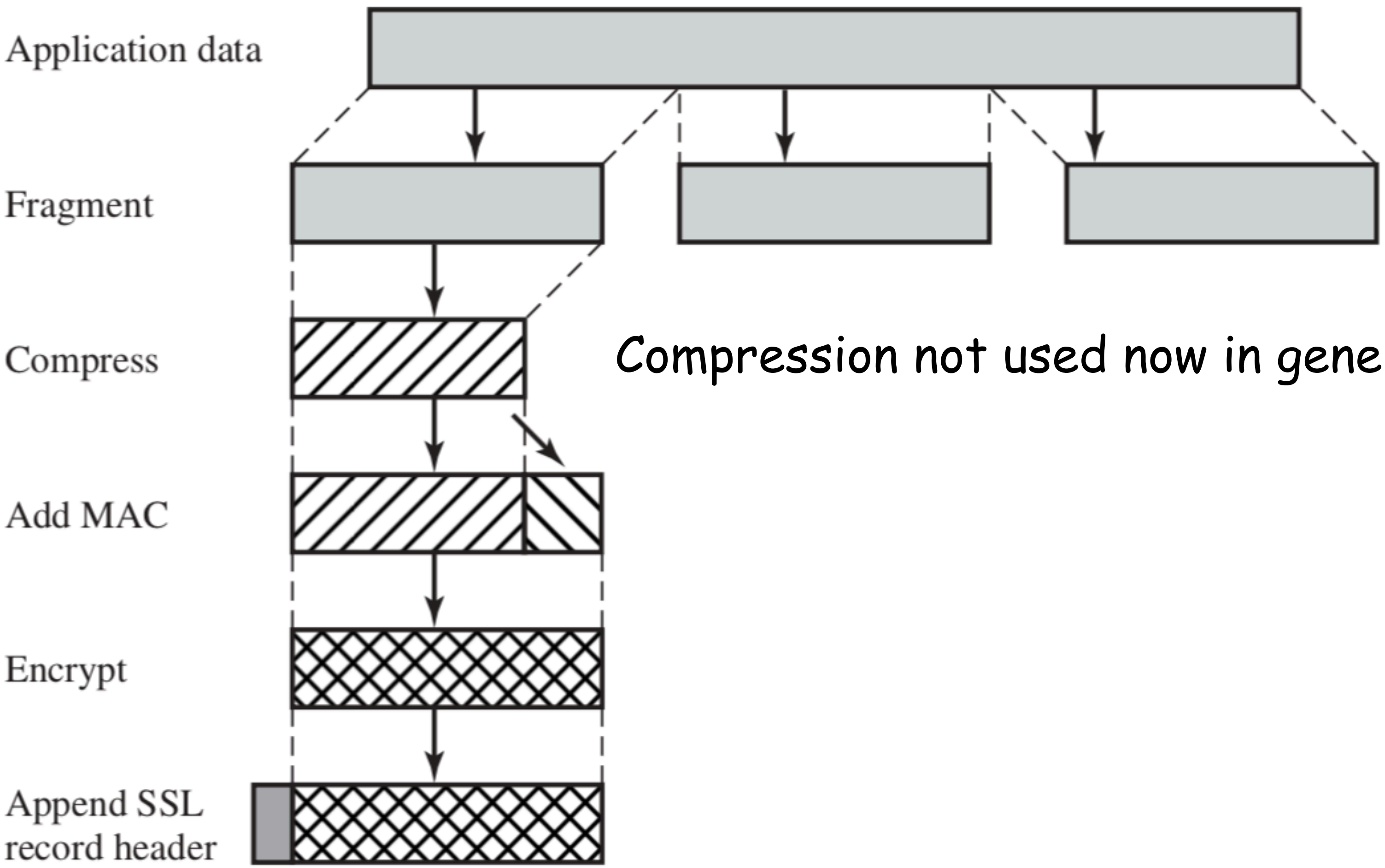
**Cipher spec:** Specifies the bulk data encryption algorithm (such as null, AES, etc.) and a hash algorithm (such as MD5 or SHA-1) used for MAC calculation. It also defines cryptographic attributes such as the hash_size.

**Master secret:** 48-byte secret shared between the client and server.

**Is_resumable:** A flag indicating whether the session can be used to initiate new connections

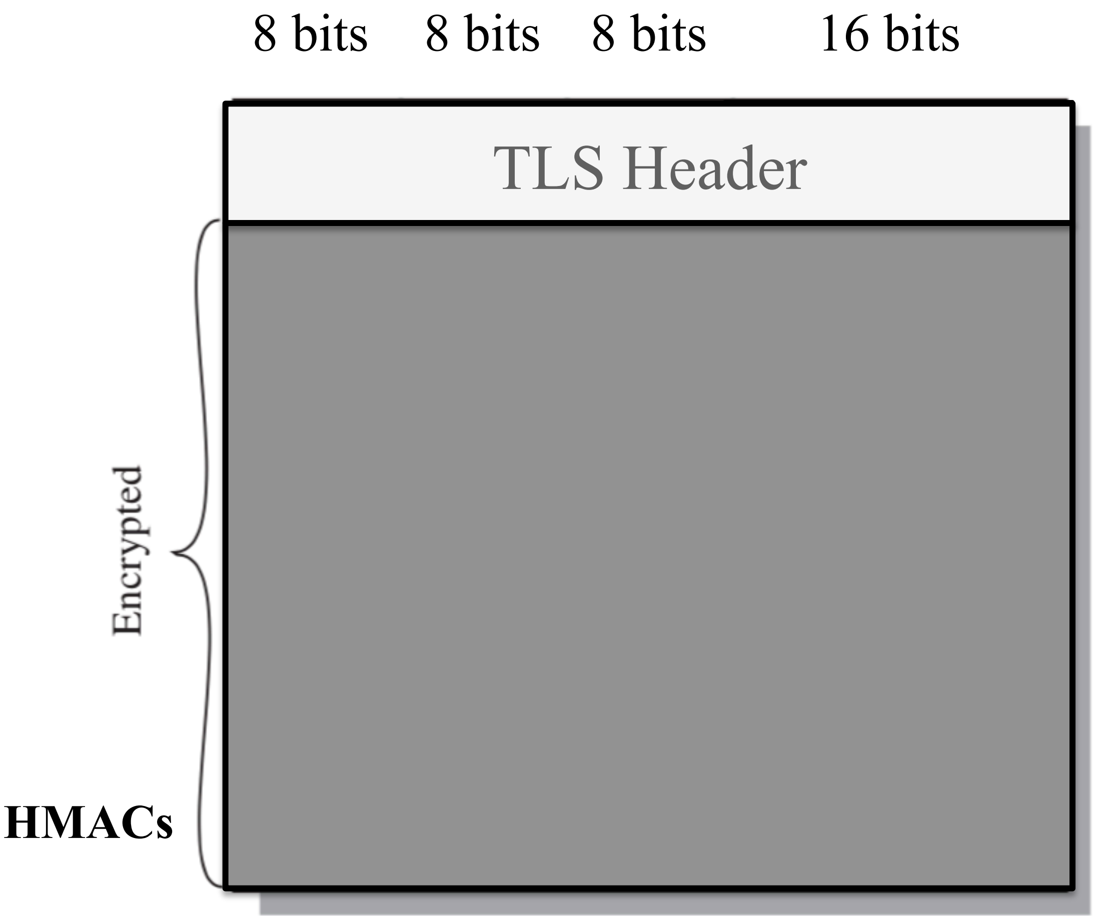
# TLS: TLP - Record Layer Protocol

## RLP Processing in Endpoints




Compression not used now in general

# RLP Message Format




HMAC-MD5
HMAC-SHA-1

Also: HMAC-SHA256
HMAC-SHA384
and AEAD

**Content types**

| Hex | Dec | Type |
|---|---|---|
| 0x14 | 20 | ChangeCipherSpec |
| 0x15 | 21 | Alert |
| 0x16 | 22 | Handshake |
| 0x17 | 23 | Application |
| 0x18 | 24 | Heartbeat |

**Versions**

| Major version | Minor version | Version type |
|---|---|---|
| 3 | 0 | SSL 3.0 |
| 3 | 1 | TLS 1.0 |
| 3 | 2 | TLS 1.1 |
| 3 | 3 | TLS 1.2 |
| 3 | 4 | TLS 1.3 |

# TLS AP: Alert Protocol


(b) Alert Protocol

(d) Other Upper-Layer Protocol (e.g., HTTP)

Standardized Alert Control Messages and Encodings (see bibliography) are categorized in different levels: warning or fatal

Fatal alerts: close the session and remove all the security association parameters.

# TLS Handshake - Handshake Message Types

| Message Type | Parameters |
|---|---|
| hello_request | null |
| client_hello | version, random, session id, cipher suite, compression method |
| server_hello | version, random, session id, cipher suite, compression method |
| certificate | chain of X.509v3 certificates |
| server_key_exchange | parameters, signature |
| certificate_request | type, authorities |
| server_done | null |
| certificate_verify | signature |
| client_key_exchange | parameters, signature |
| finished | hash value |

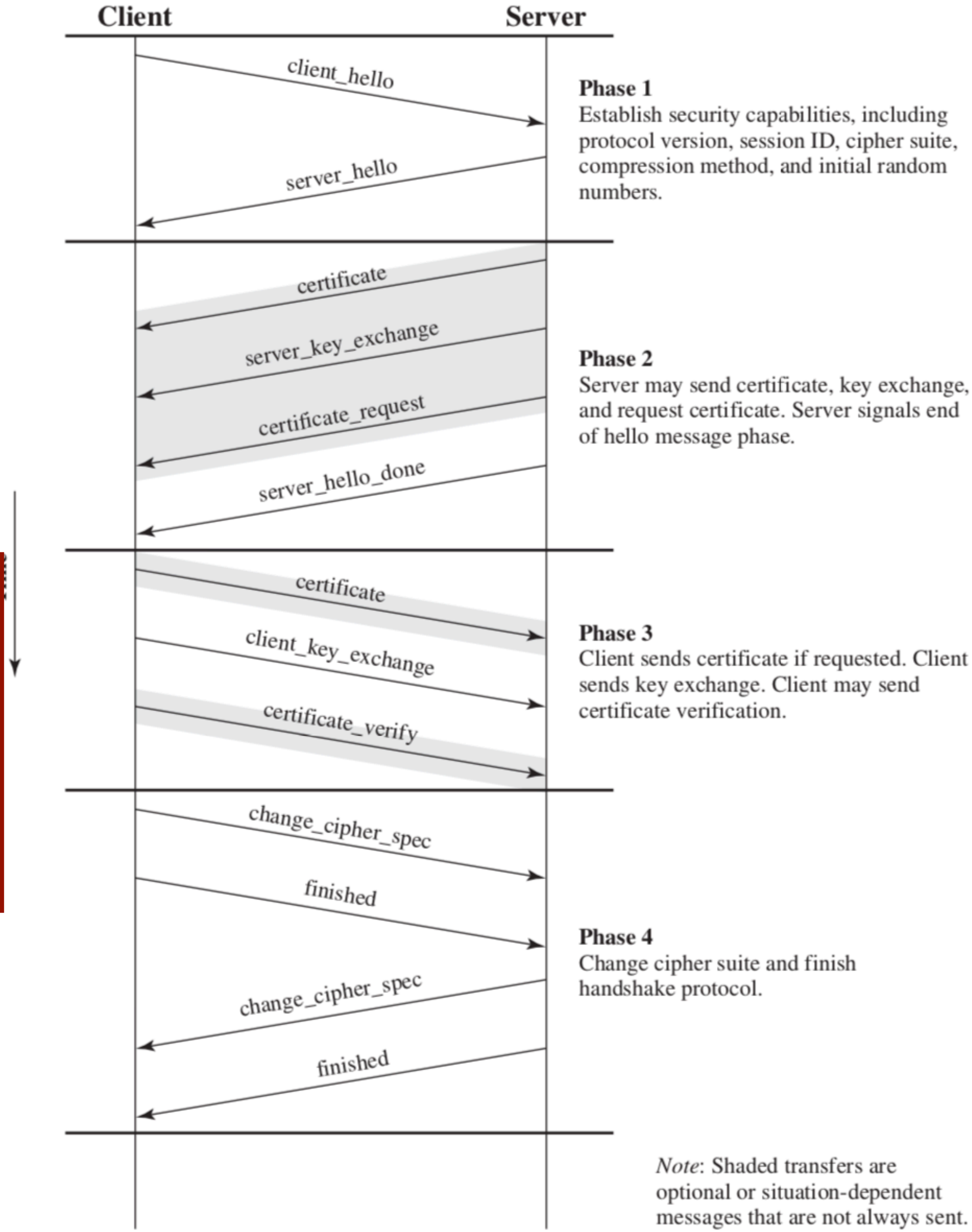
# TLS Handshake Phases

- Four Phases:
  - Phase 1:
    - Establishment of Security Capabilities: Negotiation and Parameterization Phase
  - Phase 2:
    - Server Authentication and Key-Exchange (establishment of security parameters authenticated from the server side)
  - Phase 3:
    - Client Authentication and Key-Exchange (establishment of security parameters authenticated from the server side)
  - Phase 4: Finish Phase
    - Phase for establishment and setup of all the security association parameters
    - Includes the CCSP message exchanges

# TLS Handshake:

# Handshake Flow

The Better for
Your detailed study:
Use wireshark (or
ssldump) and inspect
TLS traffic to learn !



# TLS in more detail …

Details on TLS: Flexibility, Security and Detailed End-Point Parameterizations for Handshake and TLS Session-Establishment

# TLS Key Exchanges in the Handshake

- Key-Exchange Methods in the Handshake
  - RSA Based (TLS_RSA)
  - FDH or Fixed Diffie-Hellman (TLS_DH, TLS_ECDH)
  - EDH or Ephemeral Diffie-Hellman (TLS_DHE, TÇS_ECDHE)
  - ADH or Anonymous Diffie-Hellman (TLS_DH_ANON, TLS_DHE_ANON)

  - TLS_PSK and TLS_SRP
  - Fortezza (not used now is TLS)

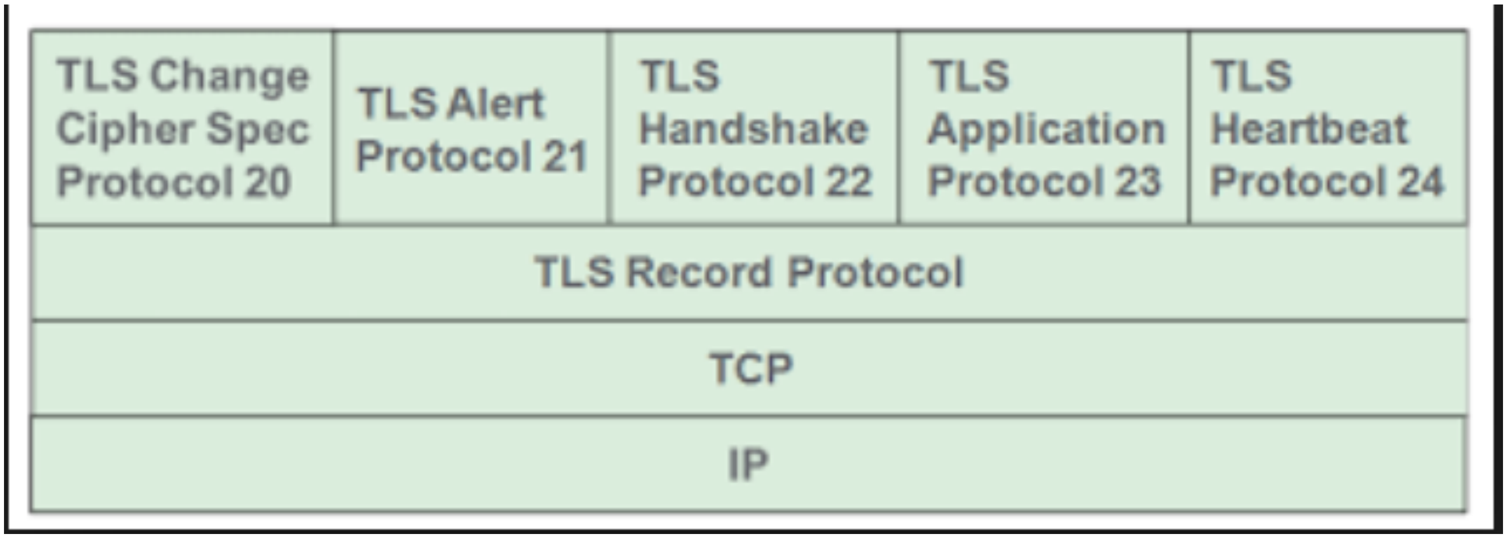
- Flexibility and Authentication Modes for Key-Exchanges:
  - Server Only (Unilateral Server Authentication)
  - Client Only (Unilateral Client Authentication)
  - Mutual Authentication (Client and Server)
  - No Authentication (Anonymous)

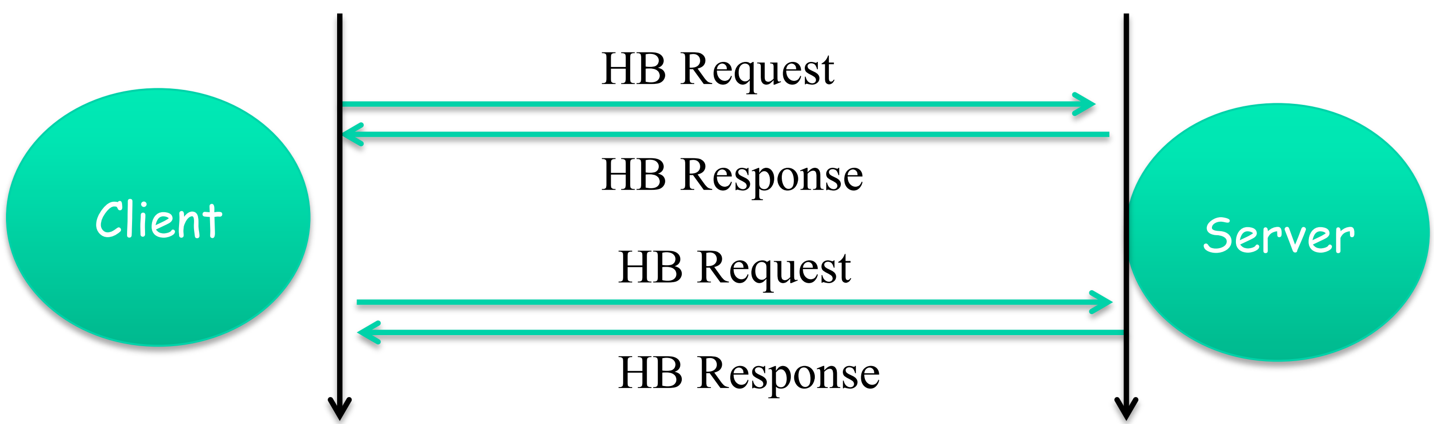
**Key exchange/agreement and authentication**

| Algorithm | SSL 2.0 | SSL 3.0 | TLS 1.0 | TLS 1.1 | TLS 1.2 | TLS 1.3 | Status |
|---|---|---|---|---|---|---|---|
| RSA | Yes | Yes | Yes | Yes | Yes | No | Defined for TLS 1.2 in RFCs |
| DH-RSA | No | Yes | Yes | Yes | Yes | No | |
| DHE-RSA (forward secrecy) | No | Yes | Yes | Yes | Yes | Yes | |
| ECDH-RSA | No | No | Yes | Yes | Yes | No | |
| ECDHE-RSA (forward secrecy) | No | No | Yes | Yes | Yes | Yes | |
| DH-DSS | No | Yes | Yes | Yes | Yes | No | |
| DHE-DSS (forward secrecy) | No | Yes | Yes | Yes | Yes | No[45] | |
| ECDH-ECDSA | No | No | Yes | Yes | Yes | No | |
| ECDHE-ECDSA (forward secrecy) | No | No | Yes | Yes | Yes | Yes | |
| PSK | No | No | Yes | Yes | Yes | | |
| PSK-RSA | No | No | Yes | Yes | Yes | | |
| DHE-PSK (forward secrecy) | No | No | Yes | Yes | Yes | | |
| ECDHE-PSK (forward secrecy) | No | No | Yes | Yes | Yes | | |
| SRP | No | No | Yes | Yes | Yes | | |
| SRP-DSS | No | No | Yes | Yes | Yes | | |
| SRP-RSA | No | No | Yes | Yes | Yes | | |
| Kerberos | No | No | Yes | Yes | Yes | | |
| DH-ANON (insecure) | No | Yes | Yes | Yes | Yes | | |
| ECDH-ANON (insecure) | No | No | Yes | Yes | Yes | | |
| GOST R 34.10-94 / 34.10-2001[46] | No | No | Yes | Yes | Yes | | Proposed in RFC drafts |

# TLS - HB (Heartbeat Protocol Extension)

Introduced in 2012, RFC 6520 (as a keep-alive control to maintain the connection state)



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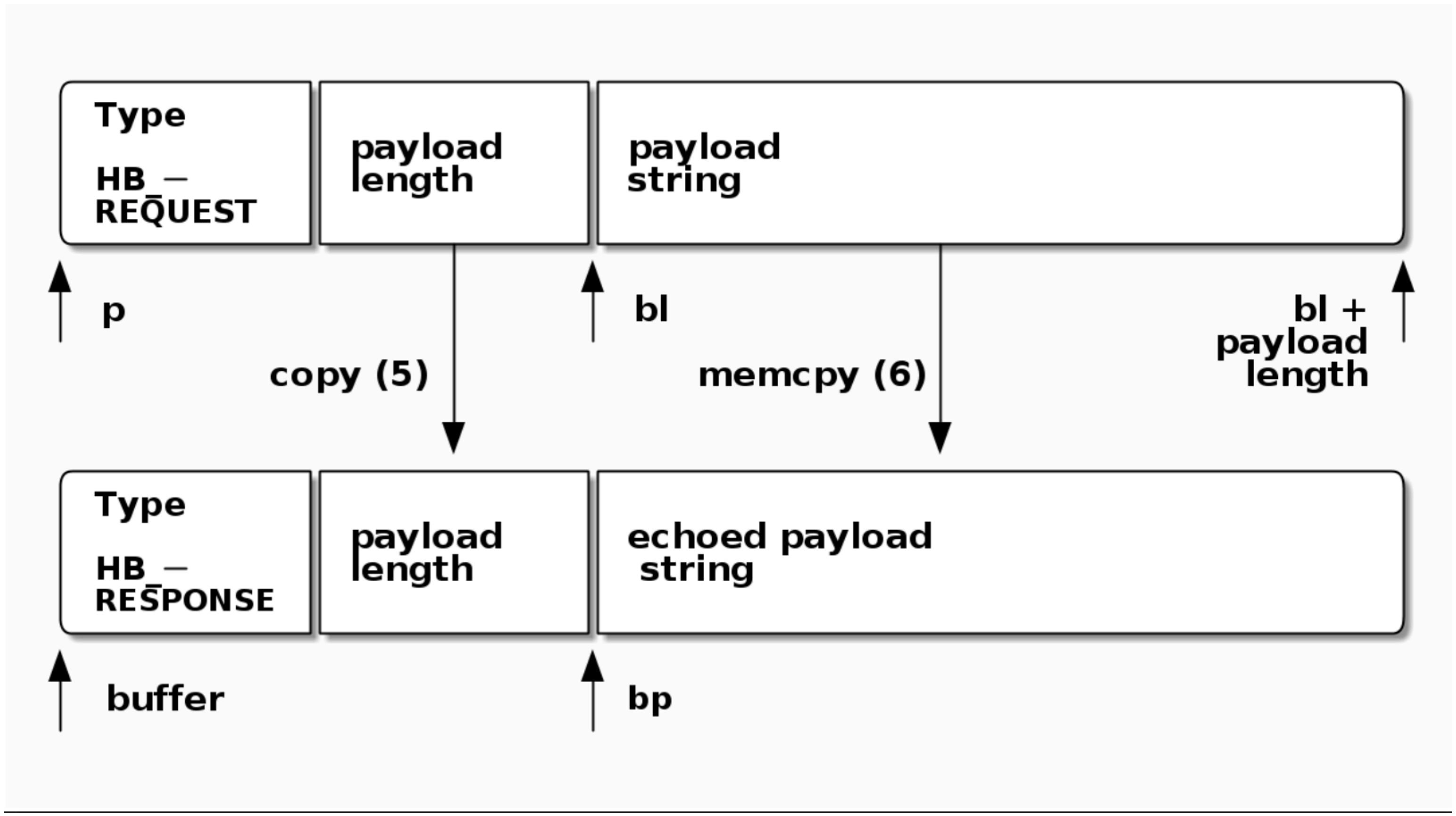

# Outline

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# HTTPS Connection Initiation

Connection Initiation:

- HTTPS Client maps on TLS Client endpoint
- TLS starts with the handshake
  - Implicitly after a TCP connection is established
  - When the TLS handshake has finished, the client may then initiate the first HTTP request.
  - All HTTP data is to be sent as TLS application data. Normal HTTP behavior, including retained connections, should be followed.

# HTTPS Connection Closure

## Connection Closure:

- An HTTP client or server can indicate the closing of a connection by including the following line in an HTTP record:

  Connection: close.

- This indicates that the connection will be closed after this record is delivered, terminating the TLS "Session" Control State

- The closure of an HTTPS connection requires that TLS close the connection with the peer TLS entity on the remote side, which will involve also closing the underlying TCP connection.
  - Double handshake FIN/ACK FIN in TCP connnection Closures

- Client sends a TLS alert protocol (**close_notify alert)**. Then, TLS implementations must initiate an exchange of closure alerts before closing a connection.

# HTTPS Connection Closure w/ Incomplete Closes

- A TLS implementation may, after sending a closure alert, close the connection without waiting for the peer to send its closure alert, generating an "incomplete close".
  - Note that an implementation that does this may choose to reuse the session.
  - This should only be done if the application knows (typically through detecting HTTP message boundaries) that it has received all the message data that it cares about.

For more information (hands-on):

See HTTPS debug with wireshark and browser/https (web) server interaction

# HTTPS Connection Closure without close_notify

HTTP clients must cope with a situation in which the underlying TCP connection is terminated without a prior close_notify alert and without a Connection: close indicator.

- Such a situation could be due to a programming error on the server or a communication error that causes the TCP connection to drop.

The unannounced TCP closure could be also evidence of some sort of attack.

- So the HTTPS client should issue some sort of security warning(typically awareness control and logging such situations) when this occurs.

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# Web insecurity vs. TLS Cryptosuites

## TLS Cryptographic Suites:

Negotiation options (handshake), flexibility, complexity (design vs. implementation)

vs. Security vs. Insecurity

One relevant issue for Web Security concerns:

See (ex.):

OWASP (Open Web Application Security Project) Foundation

> Top Ten Vulnerability Rank (2010, 2013, 2017)

https://www.owasp.org/index.php/Category:OWASP_Top_Ten_Project

https://www.owasp.org/images/7/72/OWASP_Top_10-2017_%28en%29.pdf.pdf

# OWASP: Ten Most Critical Web App Security Risks: 2017

1. Injection
2. Broken Authentication
3. Sensitive Data Exposure

   Weak-Ciphers, No PBS/PFS provisioning, unsecure PWD-encryption/hashing w/ impact on TLS misconfigurations
4. XML External Entities (XXE)
5. Broken Access Control
6. Security Misconfiguration
7. Cross-Site Scripting (XSS)
8. Insecure Deserialization
9. Using Components with Known Vulnerabilities
10. Insufficient Logging & Monitoring

# TLS and SSL Versions (Installation Base)

After Apr/2016, latest versions of major browsers adopt TLS V1.1, 1.2, 1.3
… but many vulnerabilities are induced by old browsers and old versions of OSes and many implementations (libraries or App packaged implementations)

TLS v1.3 is recent: in Safari 12.0, Opera v60, Firefox v66, Google Chrome v73
See here: https://en.wikipedia.org/wiki/Transport_Layer_Security

| Protocol version | Website support[59] | Security[59][60] |
|---|---|---|
| SSL 2.0 | 1.9% | Insecure |
| SSL 3.0 | 7.8% | Insecure[61] |
| TLS 1.0 | 68.8% | Depends on cipher[n 1] and client mitigations[n 2] |
| TLS 1.1 | 77.9% | Depends on cipher[n 1] and client mitigations[n 2] |
| TLS 1.2 | 95.0% | Depends on cipher[n 1] and client mitigations[n 2] |
| TLS 1.3 | 13.6% | Secure |

Client and Server Endpoints must agree In the protocol version

# Ciphersuites and related parameterizations

- The established *ciphersuites* (standardized cryptography) are defined in different versions of SSL and TLS
  - Dynamically negotiable in different TLS and SSL versions and Handshake Sub-protocols, between clients (ex., browsers) and servers (ex., HTTPS servers):
    - Clients: propose supported ciphersuites (typically in a set) and Keysizes
    - Servers: accept the ciphersuite (from the client set)
    - Relevant issue: possible bad default settings

- Standardization of different client or server certificate types, digital signatures supported: correct verification in implementations and operational trust assumptions are very important issues !

- Padding processing and insufficient mitigation of DoS/DDoS is another security standardization issue (remember the base RLP message format and design implications)

# TLS Authentication and Key-Exhange Methods

**Key exchange/agreement and authentication**

| Algorithm | SSL 2.0 | SSL 3.0 | TLS 1.0 | TLS 1.1 | TLS 1.2 | TLS 1.3 | Status |
|---|---|---|---|---|---|---|---|
| RSA | Yes | Yes | Yes | Yes | Yes | No | Defined for TLS 1.2 in RFCs |
| DH-RSA | No | Yes | Yes | Yes | Yes | No | |
| DHE-RSA (forward secrecy) | No | Yes | Yes | Yes | Yes | Yes | |
| ECDH-RSA | No | No | Yes | Yes | Yes | No | |
| ECDHE-RSA (forward secrecy) | No | No | Yes | Yes | Yes | Yes | |
| DH-DSS | No | Yes | Yes | Yes | Yes | No | |
| DHE-DSS (forward secrecy) | No | Yes | Yes | Yes | Yes | No[45] | |
| ECDH-ECDSA | No | No | Yes | Yes | Yes | No | |
| ECDHE-ECDSA (forward secrecy) | No | No | Yes | Yes | Yes | Yes | |
| PSK | No | No | Yes | Yes | Yes | | |
| PSK-RSA | No | No | Yes | Yes | Yes | | |
| DHE-PSK (forward secrecy) | No | No | Yes | Yes | Yes | | |
| ECDHE-PSK (forward secrecy) | No | No | Yes | Yes | Yes | | |
| SRP | No | No | Yes | Yes | Yes | | |
| SRP-DSS | No | No | Yes | Yes | Yes | | |
| SRP-RSA | No | No | Yes | Yes | Yes | | |
| Kerberos | No | No | Yes | Yes | Yes | | |
| DH-ANON (insecure) | No | Yes | Yes | Yes | Yes | | |
| ECDH-ANON (insecure) | No | No | Yes | Yes | Yes | | |
| GOST R 34.10-94 / 34.10-2001[46] | No | No | Yes | Yes | Yes | | Proposed in RFC drafts |

Cipher security against publicly known feasible attacks

| Cipher | | | Protocol version | | | | | | Status |
|---|---|---|---|---|---|---|---|---|---|
| Type | Algorithm | Nominal strength (bits) | SSL 2.0 | SSL 3.0 [n 1][n 2][n 3][n 4] | TLS 1.0 [n 1][n 3] | TLS 1.1 [n 1] | TLS 1.2 [n 1] | TLS 1.3 | |
| Block cipher with mode of operation | AES GCM[47][n 5] | 256, 128 | N/A | N/A | N/A | N/A | Secure | Secure | Defined for TLS 1.2 in RFCs |
| | AES CCM[48][n 5] | | N/A | N/A | N/A | N/A | Secure | Secure | |
| | AES CBC[n 6] | | N/A | N/A | Depends on mitigations | Depends on mitigations | Depends on mitigations | N/A | |
| | Camellia GCM[49][n 5] | 256, 128 | N/A | N/A | N/A | N/A | Secure | N/A | |
| | Camellia CBC[50][n 6] | | N/A | N/A | Depends on mitigations | Depends on mitigations | Depends on mitigations | N/A | |
| | ARIA GCM[51][n 5] | 256, 128 | N/A | N/A | N/A | N/A | Secure | N/A | |
| | ARIA CBC[51][n 6] | | N/A | N/A | Depends on mitigations | Depends on mitigations | Depends on mitigations | N/A | |
| | SEED CBC[52][n 6] | 128 | N/A | N/A | Depends on mitigations | Depends on mitigations | Depends on mitigations | N/A | |
| | 3DES EDE CBC[n 6][n 7] | 112[n 8] | Insecure | Insecure | Insecure | Insecure | Insecure | N/A | |
| | GOST 28147-89 CNT[46][n 7] | 256 | N/A | N/A | Insecure | Insecure | Insecure | N/A | Defined in RFC 4357 |
| | IDEA CBC[n 6][n 7][n 9] | 128 | Insecure | Insecure | Insecure | Insecure | N/A | N/A | Removed from TLS 1.2 |
| | DES CBC[n 6][n 7][n 9] | 56 | Insecure | Insecure | Insecure | Insecure | N/A | N/A | |
| | | 40[n 10] | Insecure | Insecure | Insecure | N/A | N/A | N/A | Forbidden in TLS 1.1 and later |
| | RC2 CBC[n 6][n 7] | 40[n 10] | Insecure | Insecure | Insecure | N/A | N/A | N/A | |
| Stream cipher | ChaCha20-Poly1305[57][n 5] | 256 | N/A | N/A | N/A | N/A | Secure | Secure | Defined for TLS 1.2 in RFCs |
| | RC4[n 11] | 128 | Insecure | Insecure | Insecure | Insecure | Insecure | N/A | Prohibited in all versions of TLS by RFC 7465 |
| | | 40[n 10] | Insecure | Insecure | Insecure | N/A | N/A | N/A | |
| None | Null[n 12] | – | N/A | Insecure | Insecure | Insecure | Insecure | N/A | Defined for TLS 1.2 in RFCs |

# HMACs

HMACs standardized by RFC 2104

**Data integrity**

| Algorithm | SSL 2.0 | SSL 3.0 | TLS 1.0 | TLS 1.1 | TLS 1.2 | TLS 1.3 | Status |
|---|---|---|---|---|---|---|---|
| HMAC-MD5 | Yes | Yes | Yes | Yes | Yes | No | Defined for TLS 1.2 in RFCs |
| HMAC-SHA1 | No | Yes | Yes | Yes | Yes | No | |
| HMAC-SHA256/384 | No | No | No | No | Yes | No | |
| AEAD | No | No | No | No | Yes | Yes | |
| GOST 28147-89 IMIT[46] | No | No | Yes | Yes | Yes | | Proposed in RFC drafts |
| GOST R 34.11-94[46] | No | No | Yes | Yes | Yes | | |

# Standardized Functions in TLS endpoints

- Cryptographic computations are different in different SSL and TLS versions

- Key and MAC Generation for Cryptogrphic Computations MACs: TLS v1.2 (RFC 5246)

- Other critical cryptographic computations:
  - PRE-MASTER Secrets
  - MASTER SECRET CREATION : 48 bytes (384 bits)
  - KEY-BLOCK generation by PRF Pseudorandom Function based on HMACs from previous random seeds and shared secrets along the handshake exchanged parameters

See the bibliography

# Ciphersuites and related parameterizations

- Important security measures (default baseline):
  - Avoidance of SSL versions and TLS 1.0
  - Avoidance of considered "Weak Cryptosuites"
  - Appropriate key sizes (RSA, DSA keys >= 2048 bits) for the proper protection of secure envelopes for the establishment of session or MAC keys and security transport and session association parameters
  - The problem of "possibly unsecure ECCs" (on going problem)
  - Only Ephemeral Diffie Hellman Agreements with parameterizations for public and private numbers >= 2048 bits
    - Trade-off for Efficiency: fixed shared initialization parameters (primitive root and prime number for the modular operations)
  - Problem: scale, installation base vs. "relaxed" TLS server configurations

See the bibliography and also

- LABs (hands-on study and verifications in tracing Handshake Protocol)
- Security auditing on possible weak ciphersuites and vulnerabilities

# SSL/TLS Attacks

SSL/TLS Attacks and Impact

- Design implications
- Implementation implications

# TLS and SSL Attacks vs. Countermeasures

The history of SSL (versions 1., 2., 3) and TLS (versions 1.1 and 1.2) attacks and related countermeasures (as many other protocols) that the "perfect secure protocol" and "the perfect implementation strategy for security vs. flexibility vs. usability tradeoffs" have not been achieved.

Constant back-and-forth between threats and counter-measures has been a constant struggle ….

New complexities and tradeoffs =>
New threats and threat models =>
New adversarial conditions =>
New counter-measures (patching ?) =>
Evolution/Revision of standardization =>
Evolution/Revision of Implementations

# Some references on Web App. Security Risks and TLS Vulnerabilities

- Ref. OWASP (Open Web Application Security Project)
- https://www.owasp.org
- https://www.owasp.org/index.php/Category:OWASP_Top_Ten_Project
- https://cheatsheetseries.owasp.org/cheatsheets/Transport_Layer_Protection_Cheat_Sheet.html

- Example of some interesting available and free-tools for TLS security auditing tests
  - https://testssl.sh
    - https://github.com/drwetter/testssl.sh
  - https://www.ssllabs.com/ssltest/
  - https://www.immuniweb.com/ssl/

# TLS Security Auditing

- Typical roadmap for TLS endpoint auditing:
  - Testing Validity of Certificates / Certification Chains
  - Testing TLS protocol enabled versions
  - Testing considered weak ciphersuites
  - Testing robustness for perfect secrecy
  - Testing ciphersuites ordering of acceptance for the enabled TLS protocol versions
  - Testing for keysizes (or avoidance of considered weak keys)
  - Testing enforcements for required Extended Verifiable Certificates
  - Testing critical and other required attributes as security requirements for certificates
  - Testing available CRL and OCSP endpoints
  - Testing App Level Protocols encapsulated on TLS enabled sessisons
  - Testing for auditable vulnerabilities
  - Testing specifically ciphersuites, used crypto algorithms and key sizes (according to expected requirements)
  - Testing security  compliance face to different client – environments and systems

# TLS Security Auditing (Vulnerabilities): A possible / typical verification roadmap

- **CCS** (CVE-2014-0224)
- **Ticketbleed** (CVE-2016-9244)
- **ROBOT**
- **Secure Renegotiation (RFC 5746)**
- **Secure Client-Initiated Renegotiation**
- **CRIME, TLS** (CVE-2012-4929)
- **BREACH** (CVE-2013-3587)
- **POODLE, SSL** (CVE-2014-3566)
- **TLS_FALLBACK_SCSV** (RFC 7507) Downgrade attack prevention
- **SWEET32** (CVE-2016-2183, CVE-2016-6329**)**
- **FREAK** (CVE-2015-0204) **DROWN** (CVE-2016-0800, CVE-2016-0703)
- **LOGJAM** (CVE-2015-4000), no DH EXPORT ciphers
- **BEAST** (CVE-2011-3389)
- **LUCKY13** (CVE-2013-0169)
- **RC4** (CVE-2013-2566, CVE-2015-2808)
- **HACKERSCHOICE**

# TLS and SSL Attacks

**Attacks involving PKI and X509 Certificates' Management and Validation**

**Attacks against the Handshake Protocol**

**Attacks on the record layer protocol**

- **BEAST** (Browser-Exploit Against SSL/TLS): Crypto Attack (Chosen-Plaintext Crypto. Attack)
- **CRIME** Attack (Compression Ratio Info-Leak Cookies): Session Hijacking on TLS protected cookies and compression/decompression processing, can break the authentication of TLS sessions
- Attacks on PKIs and Certification-Chain validations in many libraries, overtime:
  - OpenSSL, GnuTLS, JSSE, ApacjeHttpCLient, Weberknetch, cURL, PHP, Python, and other Applications with integrated Packaged TLS processing
- **HackersChoice Attack**: DoS against the Handshake Proecessing Computations for usual Server-Only Authentication Modes currently used

**Heatbleed Attack:**

Endpoint from client side TLS negotiation of Heartbeat messages

Attack against TLS SW implementations (Bad TLS Heartbeat implementation) causing access to "memory mapped" security association parameters

https://en.wikipedia.org/wiki/Heartbleed

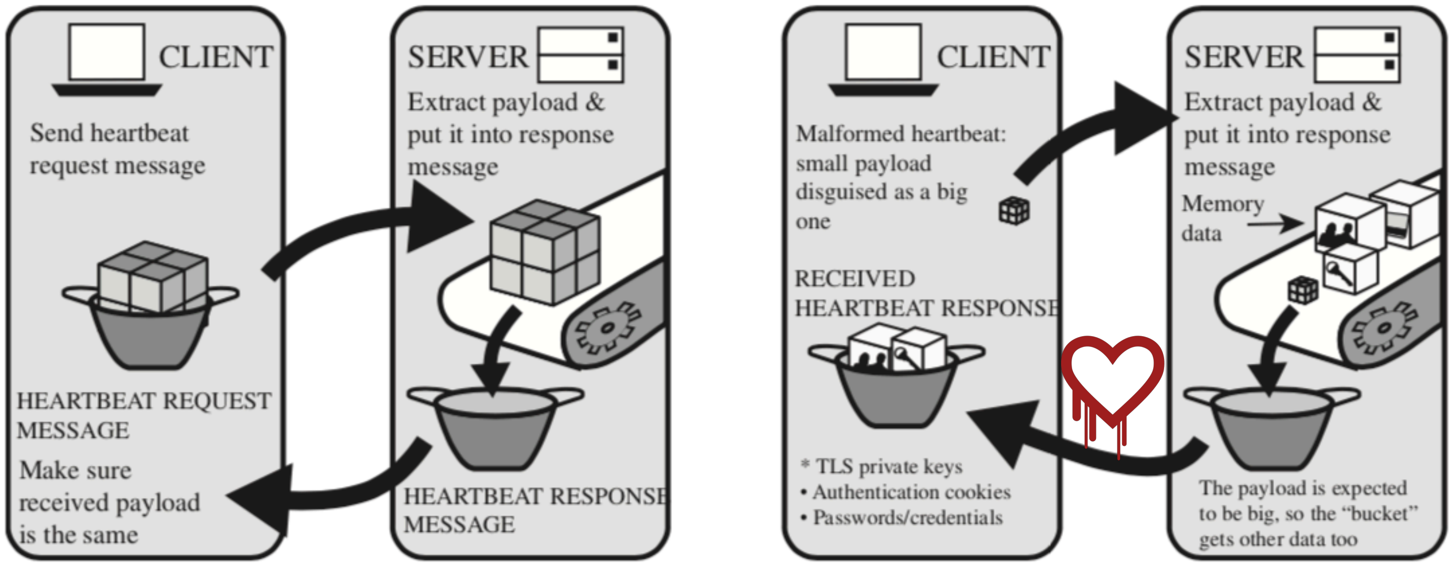
**POODLE** (Padding Oracle On Downgraded Legacy Encryption)

Man in the Middle Attack: exploit which takes advantage of Internet and security software clients' fallback to "weak-ciphersuites' negotitated and accepted by the HTTPS server endpoint

https://en.wikipedia.org/wiki/POODLE

# Heartbeat Protocol vs. Heartbleed Attack

Heartbleed -The Open SSL Heartbeat Exploit" Copyright © 2014 BAE Systems Applied Intelligence




(a) How TLS Heartbeat Protocol works

(b) How TLS Heartbleed exploit works

Attacker sends a message indicating maximum payload length (64 KB) but only includes minimum payload (16 bytes).

Almost 64 KB of the buffer is not overwritten and whatever happened to be in memory at the time will be sent to the requestor:
Repeated attacks can result in the exposure of significant amounts of memory on the vulnerable system: private keys, user identification information, authentication data, passwords, or other sensitive data

# TLS vulnerabilities and impact

| Attacks | Security | | | | |
|---|---|---|---|---|---|
| | Insecure | | Depends | Secure | Other |
| **Renegotiation attack** | 1.2% (−0.1%) support insecure renegotiation | | 0.4% (±0.0%) support both | 96.2% (+0.1%) support secure renegotiation | 2.2% (±0.0%) no support |
| **RC4 attacks** | <0.1% (±0.0%) support only RC4 suites | 6.0% (−0.3%) support RC4 suites used with modern browsers | 28.5% (−0.7%) support some RC4 suites | 65.5% (+1.0%) no support | N/A |
| **CRIME attack** | 2.4% (−0.1%) vulnerable | | N/A | N/A | N/A |
| **Heartbleed** | 0.1% (±0.0%) vulnerable | | N/A | N/A | N/A |
| **ChangeCipherSpec injection attack** | 0.8% (±0.0%) vulnerable and exploitable | | 4.7% (−0.2%) vulnerable, not exploitable | 92.6% (+0.4%) not vulnerable | 1.9% (+0.1%) unknown |
| **POODLE attack against TLS** (Original POODLE against SSL 3.0 is not included) | 2.1% (−0.1%) vulnerable and exploitable | | N/A | 97.1% (+0.2%) not vulnerable | 0.8% (−0.1%) unknown |
| **Protocol downgrade** | 23.2% (−0.4%) TLS_FALLBACK_SCSV not supported | | N/A | 67.6% (+0.7%) TLS_FALLBACK_SCSV supported | 9.1% (−0.4%) unknown |

# Current relevance of TLS 1.3

TLS 1.3, IETF Defined in 2014
(Today coexisting w/ TLS 1.2 …)

TLS 1.3 removes:

- Compression
- Not Authenticated Modes and Handshake Exchanges
- Considered Weak Chiphers
- Static RSA and DH Key Exchange Methods
- 32 bit timestamps as part of Random parameters in Client/Server Hello Handshake Messages
- Renegotiation of secrets from previous established parameters
- Heartbeat Protocol
- Change Cipher Spec Protocol
- RC4
- Use of MD5, SHA-1 and SHA-224

# Current relevance of TLS 1.3

TLS 1.3, IETF Defined in 2014
(Today coexisting w/ TLS 1.2)

TLS 1.3 includes (for improving the tradeoff security and efficiency):

- DH and EC-DH for Key Exchanges (no RSA Key Exchange)
- Simplification of "one-shot" Handshake rounds (one round trip time handshake), by reordering/piggybacking (or pipelining) the handshake sequence
- Client side must send authenticated parameters, before the negotiation of cipher suites when client-authentication or mutual-aiuthentication is adopted

# A Bibliography on TLS security research

- The most dangerous code in the world: validating SSL certificates in non-browser software, M. Georgiev, S. Iyengar, S. Jana, R. Anubhai, D. Boneh and V. Shmatikov, ACM CCS 2012
- Forward Secrecy and TLS Renegotiation: F. Giesen et al., On the Security of TLS Renegotiation, ACM CCS 2013

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- T. Jager et al., On the Security of TLS v1.3 and QUIC against Weaknesses in PKCS#1 .5 Encryption, ACM CCS 2015

- The 9 Lives of Bleichenbacher's CAT: New Cache Attacks on TLS Implementations , Eyal Ronen, Robert Gillham, Daniel Genkin, Adi Shamir, David Wong, and Yuval Yarom, Dec 2018

See also:

- https://www.nccgroup.trust/uk/about-us/newsroom-and-events/blogs/2019/february/downgrade-attack-on-tls-1.3-and-vulnerabilities-in-major-tls-libraries/ , Nov 2018

- Selfie: reflections on TLS 1.3 with PSK, Nir Drucker and Shay Gueron , https://eprint.iacr.org/2019/347.pdf,

# A Recent Research Bibliog. … (TLS Vulnerabilities and Proposed Solutions)

## ACM CCS 2018

- Pseudo Constant Time Implementations of TLS Are Only Pseudo Secure
  *Eyal Ronen (Weizmann Institute of Science), Kenny Paterson (Royal Holloway, University of London), Adi Shamir (Weizmann Institute of Science)*
- Partially specified channels: The TLS 1.3 record layer without elision
  *Christopher Patton (University of Florida), Thomas Shrimpton (University of Florida)*
- The Multi-user Security of GCM, Revisited: Tight Bounds for Nonce Randomization
  *Viet Tung Hoang (Florida State University), Stefano Tessaro (University of California Santa Barbara), Aishwarya Thiruvengadam (University of California Santa Barbara)*

## Usenix Sec. Symp. 2018:

- Return Of Bleichenbacher's Oracle Threat (ROBOT), H. Bock et al.,

## IEEE Sympo. On Security and Privacy 2018

- A Formal Treatment of Accountable Proxying over TLS, Karthikeyan Bhargavan at al.

## IEEE Synp. On Sec and Privacy 2019:

- The 9 Lives of Bleichenbacher's CAT: New Cache Attacks on TLS Implementations, E. Ronen et al.

## NDSS 2018:

- Removing Secrets from Android's TLS. Jaeho Lee *(Rice University)* and Dan S. Wallach *(Rice University)*.
- TLS-N: Non-repudiation over TLS Enablign Ubiquitous Content Signing. Hubert Ritzdorf *(ETH Zurich)*, Karl Wust *(ETH Zurich)*, Arthur Gervais *(Imperial College London)*, Guillaume Felley *(ETH Zurich)*, and Srdjan Capkun *(ETH Zurich)*.

## NDSS 2019:

- The use of TLS in Censorship Circumvention. Sergey Frolov, Eric Wustrow

# TLS in current practice …

- TLS v1.2 and v 1.3 is the base of current baseline security

- A strict control on considered secure ciphersuites, and parameterizations must be addressed as baseline countermeasures against the more prevalent attacks:

Hands-on (Ref. Example):
https://www.ssllabs.com/ssltest/
https://www.ssllabs.com/ssltest/viewMyClient.html
https://www.ssllabs.com/projects/index.html

See also: https://www.howsmyssl.com
Hands-on with TLS checking Tools: https://testssl.sh

# Outline

- WEB security issues
  - Web traffic security threats: the role of SSL and TLS
  - TCP/IP Stack and TLS
  - Security properties and services addressed by TLS
  - TLS operation and TLS based programming
- TLS: Session-Security vs. Transport Security Layers
  - TLS architecture and protocol stack
  - TLS protocol versions
  - TLS configurability and flexibility issues
  - TLS Ciphersuites
  - Analysis of TLS Sub-Protocols: RLP, CSP, AP, HP and HB
- TLS vs. HTTPS
- TLS Practical Security: Weak Ciphersuites and Security Tradeoffs
- Web Security and Threats beyond TLS

# Threats beyond TLS

- Remember: TLS is designed to protect transport-based communication channels (UDP or TCP)

- TLS and HTTPS don't means WEB Security: it is just one of the security elements for WEB Security
  - See: OWASP Web Security Attacks and Top-Ten Vulnerabilities
  - OWASP: See https://www.owasp.org/index.php/Main_Page

- Relates with communication security properties, not considering intrusions on endpoints

- The required secure processing in implementing the TLS endpoints (transport and session states and sensitive security association parameters and correct and trusted TLS state-machine execution control ) is out of scope of TLS protocols' security standardization effort

# Threats beyond TLS

- SW and Application Level Security
  - Can use TLS but with Application-Level Vulnerabilities
  - Bad or unmatched use of TLS Parameterizations
- PKI SW based vulnerabilities
- Related Attacks: Attacks against Time Synchronization Protocols
- Unsecure management of X509 certificates and incorrect verification and validation of x509 (namely X509v3 extension attributes) in the TLS handshake of Certification chains: Recurrent vulnerabilities in many TLS libraries
  - This included deficient management of the "trusted root assumption" in acceptance or pre-installed X509 certificates (including CA certificates)
  - Incorrect operation and management of X509 certificates' life-cycles – include lack of proper control for CRLs and management of OCSP endpoints
- DoS or DDoS
  - No effective protection on TLS…. It Can be aggravated w/ TLS

# Web / SW Security auditing and assessment tools

- Suggestions for the interested students:
  - OWASP Flagship Projects / Tools and Code Projects
    - https://www.owasp.org/index.php/Main_Page
    - https://www.owasp.org/index.php/
  - OWASP Mobile Security Testing Guide
    - https://www.owasp.org/index.php/OWASP_Mobile_Security_Testing_Guide

# Slides Revision and Suggested Readings and Study

## Readings (for frequency test):

W. Stallings, Network Security Essentials – Applications and Standards

- Ed.. 2017 Chap 6 Transport Layer Security, 6.1-6.4, pp. 187-208
- Ed. 2011 Chap 5 Transport Layer Security, 5.1-5.4, pp. 139-162

Practical Study:
TLS and HTTPS Traffic Analysis with different tools (see the slides and "hands-on" traffic analysis in Labs)

- Particularly: Handshake, RLP exchanges and TLS flow depending on the Handshake negotiation and parameterizations
- See also the "fine-grain" parameterization when programing with TLS (ex., Java JSSE Lab Exercises)

# Revision: Complementary Readings

See the other references on the slides and bibliog. references in the textbook