Security protocols: TLS

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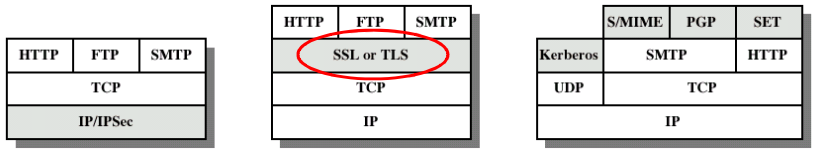
Location of security facilities in the TCP/IP stack



Network level transport/session level Application level

Secure Socket Layer (SSL)

- Protocollo per applicazioni client-server che garantisce la privacy delle comunicazioni su Internet (su rete IP)
- E' in grado di prevenire le intrusioni, le manomissioni e le falsificazioni dei messaggi
- Protocollo aperto e non proprietario proposto da Netscape Communication Corporation
- Utilizza TCP come protocollo di trasporto affidabile end-to-end
- Individuato da URL del tipo https://... (port 443)
- Supporta qualsiasi applicazione (HTTP, FTP, ...)
- Utilizza *server certificates*
- Supporta anche *client certificates* (optional)

Transport Layer Security (TLS)

- Transport Layer Security (TLS)
- IETF standard RFC 5246 TLSv1.2 (2008)
- TLS v1.0 == SSL v3.1
  - **SSL was maintained by Netscape**
  - **TLS is an IETF standard**
- minor differences
  - **in record format version number**
  - **uses HMAC for MAC**
  - **a pseudo-random function expands secrets**
  - **has additional alert codes**
  - **some changes in supported ciphers**
  - **changes in certificate negotiations**
  - **changes in use of padding**

TLS security goals

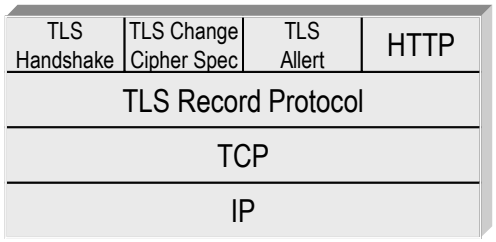
- Confidenzialità:
  Dopo un handshake iniziale viene definita una chiave segreta (scambiata cifrandola con la chiave pubblica del server)
  Per crittografare i dati è usata crittografia simmetrica (DES, RC4)
- Autenticazione:
  l'identità nelle connessioni può essere autenticata usando la crittografia asimmetrica o a chiave pubblica (RSA, DSS) (certificato X.509v3).
  - **É prevista la certificazione sia del server che del client (opzionale)**
- Integrità:
  il livello di trasporto include un check dell'integrità del messaggio basato su un apposito MAC (Message Authentication Code) che utilizza funzioni hash (SHA, MD5)

TLS phases

- Handshake
  - **Establish connection**
  - **Agree on encryption algorithm**
  - **Exchange key**
  - **Authentication**
    - Server only or both client and server
    - Authentication with certificates
- Securing messages
  - **Sending the actual enchrypted messages**
  - **Integrity checks with MACs**

TLS protocol stack

- Il protocollo è composto da due strati:
  - **a livello più basso c'è il protocollo TLS Record che è usato per l'incapsulamento dei vari protocolli di livello superiore**
  - **sul protocollo TLS Record si interfaccia il TLS Handshake Protocol che permette al server ed al client di autenticarsi a vicenda e di negoziare un algoritmo di crittografia e le relative chiavi**

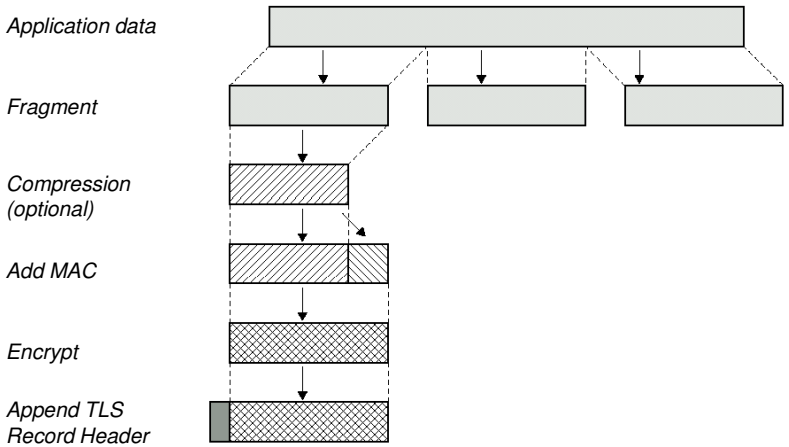


TLS Record Protocol

- Consente di incapsulare dati e informazioni di autenticazione
- I messaggi TLS sono accorpati in record lunghi fino a 32.767 byte
- Permette di garantire:
  - **confidentiality**
    - using symmetric encryption with a shared secret key defined by Handshake Protocol
    - IDEA, RC2-40, DES-40, DES, 3DES, Fortezza, RC4-40, RC4-128, AES
    - message is compressed before encryption
  - **message integrity**
    - using a MAC with shared secret key (by default it uses HMAC)
- Each message is appended with a MAC before it is encrypted
- The key for encryption, the key for the MAC and the Initialization Vector (if used) is extracted from the key exchange messages (Handshake Protocol)

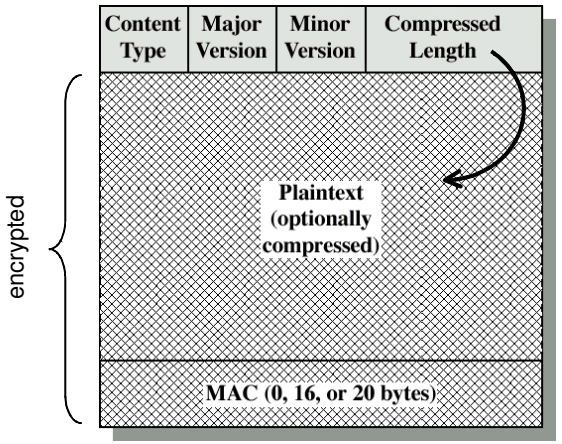
TLS Record Protocol

- TLS-RP operation:



TLS Record Protocol

- TLS-RP format



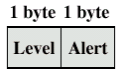
TLS Change Cipher Spec Protocol

- E' uno dei 3 possibili 3 sottoprotocolli di TLS incapsulati dentro TLS Record protocol
- Consiste in un messaggio di un solo byte (value=1)

- Trasforma il "pending state" appena negoziato in stato corrente
  - **permette di aggiornare la suite di cifratura da usarsi per i dati che seguono**

TLS Alert Protocol

- Permette di scambiare massaggi di "alert" tra gli estremi del TLS
- Usa un messaggio di 2 byte



- Specific alert
  - **fatal (first byte=2)**
    - unexpected message, bad record mac, decompression failure, handshake failure, illegal parameter
  - **warning (first byte=1)**
    - close notify, no certificate, bad certificate, unsupported certificate, certificate revoked, certificate expired, certificate unknown
- Viene compresso/criptato come ogni altro messaggio TLS

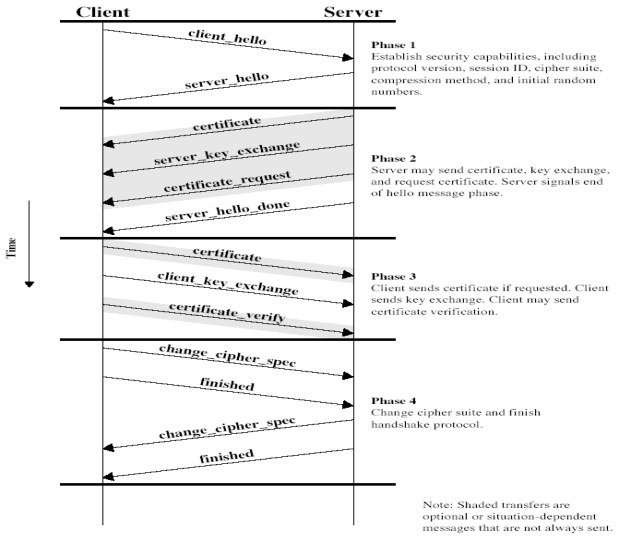
TLS Handshake Protocol

- Permette al TLS client e server di:
  - **autenticarsi tra loro**
  - **negoziare gli algoritmi di cifratura e di autenticazione (MAC) prima di incominciare a far transitare i dati**
  - **negoziare le chiavi di cifratura opportune**
- Utilizza i seguenti tipi di messaggi:
  - **Establish Security Capabilities**
  - **Server Authentication and Key Exchange**
  - **Client Authentication and Key Exchange**
  - **Finish**

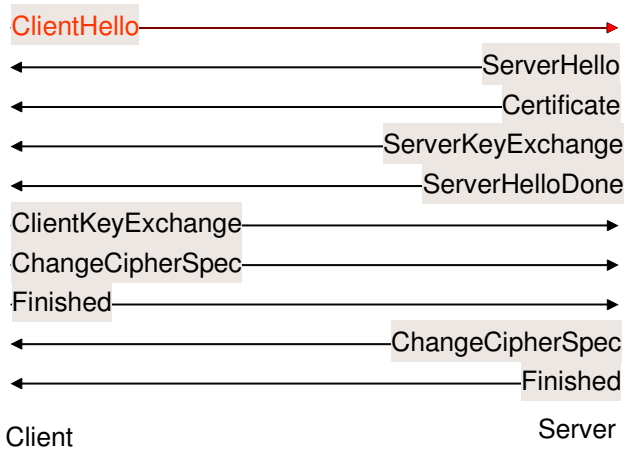
1 byte	3 bytes	≥ 0 bytes
Type	Length	Content

- Utilizza crittografia asimmetrica (e.g. RSA) per l'autenticazione delle parti
  - **è opzionale ma normalmente si applica almeno tra client (autenticatore) e server (autenticato)**

TLS Handshake Protocol



TLS Handshake Protocol (cont.)



TLS Handshake Protocol (cont.)

- ClientHello
  - **the communication by sending the ClientHello message**
  - **contains**
    - version number
    - optional session ID
      - used to resume a previous session
    - list of cipher suites supported
      - The cipher suite includes key exchange algorithm, symmetric algorithm (including chaining mode) and MAC algorithm

TLS Handshake Protocol (cont.)

- ServerHello
  - **sent in response to the ClientHello message**
  - **with this message, the server finally decides which cipher suite to use**
  - **contains**
    - version number
    - optional session ID (for resuming a previous session)
    - the cipher suite to be used, picked from the list of proposals given by the client
- Certificate
  - **contains the server certificate, including the chain leading up to the CA root certificate**
    - Optional according to the TLS specifications, but most (all?) implementations require a server certificate
    - If no certificate is sent, the ServerKeyExchange is required

TLS Handshake Protocol (cont.)

- ServerKeyExchange
  - **used for the key exchange**
    - Includes the server part of the key exchange
    - Exact meaning depends on the cipher suite chosen
      - For RSA, the server's public key is sent
      - For Diffie-Hellman, the modulus p, the generator g and $x = g^a$ is sent
    - Necessary if no public key is sent in the certificate
      - If the information in the certificate can be used for signing, the key information is signed
- ServerHelloDone
  - **marks the end of the server's part in the handshake**
    - It does not contain any other information

TLS Handshake Protocol (cont.)

- ClientKeyExchange
  - **contains the client part in the key agreement**
  - **the exact format depends on the exchange algorithm agreed on previously**
    - for Diffie-Hellman, the message contains $y = g^b$, the client's part in the agreement
      - from this the symmetric key is extracted
- ChangeCipherSpec
  - **indicates that from this point, communication is encrypted**
- Finished
  - **is encrypted**
  - **marks the end of the handshake**

TLS Handshake Protocol (cont.)

- ChangeCipherSpec and Finished
  - **play the same role as the client's message**
- After the handshake is complete, the client and the server start exchanging encrypted messages

Generating secretes

- Key exchange methods establish a “Pre Master Secret” (PMSK) between the client and server
- For all key exchange methods, the same algorithm is used to convert the PMSK into the “Master Secret” (MSK) [48B]
  - **the PMSK should be deleted from memory once the MSK has been computed**

MSK = PRF(PMSK, "master secret", ClientHello.random + ServerHello.random)

  - **with**

PRF(secret,label,seed) = PRF(S1||S2,label,seed) =

= P_MD5(S1,label+seed-i) ⊕ P_SHA-1(S2,label+seed-i)

  - **and**

seed-i = HMAC_hash(secret, seed-(i-1))

- note: S1 and S2 are the two halves of the MSK

Generating secretes (cont.)

- MSK is used to generates secrete material such as
  - **client write MAC secret,**
  - **a server write MAC secret,**
  - **a client write key,**
  - **a server write key,**
  - **a client write IV, and**
  - **a server write IV**
- The master secret is hashed into a sequence of secure bytes

key_block = PRF(MSK,"key expansion",server_random+client_random)

- assigned to the MAC secrets, keys, IVs...
- Final keys:

final_c_w_key = PRF(c_w_key, "client write key",c_rand+s_rand)

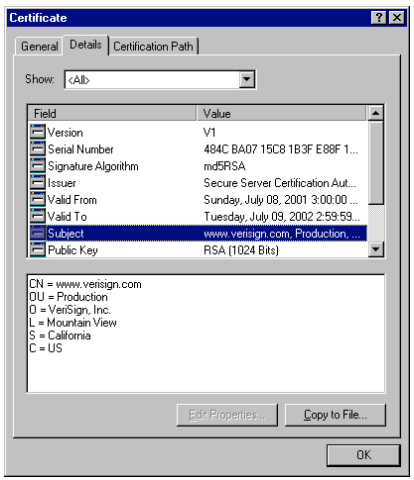
final_s_w_key = PRF(s_w_key,"server write key",c_rand+s_rand)

Verifying the certificate

- All certificates in TLS are in the X.509 format
- To verify that a certificate is valid, the verifier must
  - **Check that the CA signature is valid**
  - **Check that the owner of the certificate knows the private key**
  - **Check that the identifying information is what it should be**
- The protocol specifies how to perform the first two parts, but the last part is up to the implementation

Certificate contents

- This picture shows how Internet Explorer shows the contents of a certificate.
- Note that the CN field contains the host name of the server.



Web Browser Support

- Some Root/CA certificates pre-installed
  - **Firefox Opera and IE have different lists**
  - **CA's public key is used to verify the signatures on issued certificates**
  - **Browsers can accept unverifiable certificates or alert the user**
- Users can install additional certificates
  - **Additional Root/CA certificates**
    - Security vulnerability
  - **Client certificates**

Web Browser Support