Real-Time Communication Security: SSL/TLS

Guevara Noubir
noubir@ccs.neu.edu
CSG254: Network Security

1

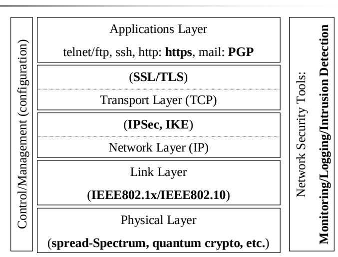
Some Issues with Real-time Communication

- Session key establishment
- Perfect Forward Secrecy
  - Diffie-Hellman based PFS
  - Escrow-foilage:
    - If keys are escrowed Diffie-Hellman protects against passive attacks
    - Signature keys are usually not escrowed
- Preventing Denial of Service
  - SYN attack on TCP: use stateless cookies = hash(IP addr, secret)
  - Puzzles: e.g., what 27-bit number has an MD = x?
  - These techniques do not fully protect against DDOS launched through viruses
- Hiding endpoint identity:
  - DH + authentication allows anonymous connection or detects man-in-the-middle
- Live partner reassurance:
  - Modify DH to include a nonce in the computation of the session key
- Optimization using parallel computation, session resumption, deniability

2

Securing Networks

- Where to put the security in a protocol stack?
- Practical considerations:
  - End to end security
  - No modification to OS/network stack



3

SSL vs. IPsec

- SSL:
  - Avoids modifying "TCP stack" and requires minimum changes to the application
  - Mostly used to authenticate servers
- IPsec
  - Transparent to the application and requires modification of the network stack
  - Authenticates network nodes and establishes a secure channel between nodes
  - Application still needs to authenticate the users

4

General Description of SSL/TLS

- Terminology:
  - SSL: Secure Socket Layer
  - TLS: Transport Layer Security
- Concept: secure connections on top of TCP
  - OS independent
  - TCP instead of UDP
    - Cons: Rogue packet problem
    - Pro: SSL/TLS doesn't have to deal with packet retransmission
- History:
  - SSLv2 proposed and deployed in Netscape 1.1 (1995)
  - PCT (Private Communications Technology) by Microsoft
  - SSLv3: most commonly used (1995)
  - TLS proposed by the IETF based on SSLv3 but not compatible (1996)
    - Uses patent free DH and DSS instead of RSA which patent didn't expire yet

5

SSL Architecture

- **SSL session**
  - An association between client & server
  - Created by the Handshake Protocol
  - Defines a set of cryptographic parameters
  - May be shared by multiple SSL connections
- **SSL connection**
  - A transient, peer-to-peer, communications link
  - Associated with 1 SSL session

6

SSL/TLS Basic Protocol

- SSL/TLS partitions TCP byte stream into records:
  - A record has: header, cryptographic protection => provides a reliable encrypted, and integrity protected stream of octet
  - Record types:
    - User data
    - Handshake messages
    - Alerts: error messages or notification of connection closure
    - Change cipher spec
- Basic Protocol:
  - *A* -> *B*: I want to talk, ciphers I support, R_A
  - *B* -> *A*: certificates, cipher I choose, R_B
  - *A* -> *B*: $\{S\}_B$, {keyed hash of handshake msgs}
  - *B* -> *A*: {keyed hash of handshake msgs}
  - *A* <-> *B*: data encrypted and integrity checked with keys derived from *K*
  - Keyed hashes use $K = f(S, R_A, R_B)$

SSL/TLS Basic Protocol (Cont'd)

- How do you make sure that keyed hash in message 3 is different from *B*'s response?
  - Include a constant *CLNT/client finished* (in SSL/TLS) for *A* and *SRVR/server finished* for *B*
- Keyed hash is sent encrypted and integrity protected for no real reason
- Keys: derived by hashing *K* and R_A and R_B
  - 3 keys in each direction: encryption, integrity and IV
  - Write keys (to send: encrypt, integrity protect)
  - Read keys (to receive: decrypt, integrity check)

What's still missing?

- SSL/TLS allowed to authenticate the server
- How would the server authenticate the user?
  - SSL/TLS allows clients to authenticate using certificates:
    - *B* requests a certificate in message 2
    - *A* sends: certificate, signature on a hash of the handshake messages

Session Resumption

- Many secure connections can be derived from the session
  - Cheap: how?
- Session initiation: modify message 2
  - *B* -> *A*: session_id, certificate, cipher, R_B
- *A* and *B* remember: (session_id, master key)
- To resume a session: *A* presents the session_id in message 1
  - *A* -> *B*: session_id, ciphers I support, R_A
  - *B* -> *A*: session_id, cipher I choose, R_B, {keyed hash of handshake msgs}
  - *A* -> *B*: {keyed hash of handshake msgs}
  - *A* <-> *B*: data encrypted and integrity checked with keys derived

Computing the Keys

- *S*: pre-master secret (forget it after establishing *K*)
- $K = f(S, R_A, R_B)$
- 6 keys = $g(K, R_A, R_B)$
- *Rs*: 32 bytes (usually the first 4 bytes are Unix time)

PKI in SSL

- Client comes configured with a list of "trusted organizations": CA
- What happens when the server sends its certificate?
- When the server whishes to authenticate the client:
  - Server sends a list of CA it trusts and types of keys it can handle
- In SSLv3 and TLS a chain of certificates can be sent

Negotiating Cipher Suites

- A cipher suite is a complete package:
  - (encryption algorithm, key length, integrity checksum algorithm, etc.)
- Cipher suites are predefined:
  - Each assigned a unique value (contrast with IKE)
  - SSLv2: 3 bytes, SSLv3: 2 bytes => upto 65000 combinations
    - 30 defined,
    - 256 reserved for private use: FFxx (risk of non-interoperability)
- Selection decision:
  - In v3 A proposes, B chooses
  - In v2 A proposes, B returns acceptable choices, and A chooses
- Suite names examples:
  - SSL_RSA_EXPORT_WITH_DES40_CBC_SHA
  - SSL2_RC4_128_WITH_MD5

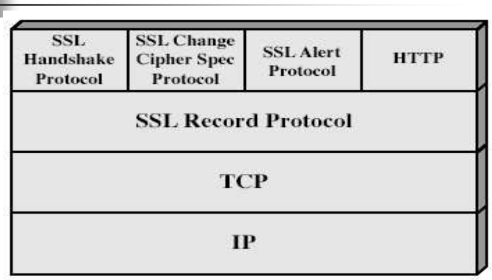
13

Attacks fixed in v3

- Downgrade attack:
  - In SSLv2 there is no integrity protection for the initial handshake
  - Active attacker can remove strong crypto algorithm from proposed cipher suite by *A =>* forcing *A* and *B* to agree on a weak cipher
  - Fixed by adding a *finished* message containing a hash of previous messages
- Truncation attack:
  - Without the *finished* message an attacker can send a TCP FIN message and close the connection without communicating nodes detecting it

14

SSL Stack



15

SSL Record Protocol

- SSL Record Protocol defines these two services for SSL connections:
  - **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
    - CBC mode (except for RC4)
    - Message is compressed before encryption
  - **Message integrity**
    - Using a MAC with shared secret key
    - Based on HMAC and MD5 or SHA (with a padding difference due to a typo in an early draft of HMAC RFC2104)
- Records sent after *ChangeCipherSpec* record are cryptographically protected
- Record header:
  - [record type, version number, length]
    - ChangeCipherSpec = 20, Alert = 21, Handshake = 22, Application_data = 23

16

SSL Change Cipher Spec Protocol

- One of 3 SSL-specific protocols which use the SSL Record Protocol
- Single message
  - Causes pending state to become current

  ⇒ all records following this will be protected with the ciphers agreed upon

17

SSL Alert Protocol

- Conveys SSL-related alerts to peer entity
- Severity
  - warning or fatal
- Specific alerts
  - Unexpected message, bad record mac, decompression failure, handshake failure, illegal parameter
  - Close notify, no certificate, bad certificate, unsupported certificate, certificate revoked, certificate expired, certificate unknown
- Compressed & encrypted

18

SSL Handshake Protocol

- Allows server & client to:
  - Authenticate each other
  - Negotiate encryption & MAC algorithms
  - Negotiate cryptographic keys to be used
- Comprises a series of messages in phases
  - Establish Security Capabilities
  - Server Authentication and Key Exchange
  - Client Authentication and Key Exchange
  - Finish

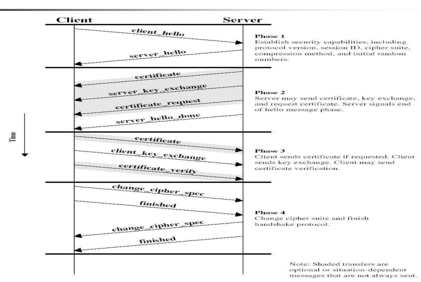
19

Handshake Messages

- ***ClientHello*** **message:**
  - [type=1, length, version number, R_A, length of session_id, session_id, length of cipher suite list, sequence of cipher suites, list of compression methods]
- ***ServerHello***: [type=2, length, version number, R_B, length of session_id, session_id, chosen cipher, chosen compression method]
- ***Certificate***: [type=11, length, length of first certificate, first certificate, …]
- ***ServerKeyExchange***: (for export: ephemeral public key)
  - [type=12, length, length of modulus, modulus, length of exponent, exponent]
- ***CertificateRequest***: [type=13, length, length of key type list, list of types of keys, length of CA name list, length of first CA name, 1stCA name, …]
- ***ServerHelloDone***: [type=14, length=0]
- ***ClientKeyExchange***: [type=16, length, encrypted pre-master secret]
- ***CertificateVerify***:[type=15, length, length of signature, signature]
- ***HandshakeFinished***:[type=20, length=36 (SSL) or 12 (TLS), digest]

20

SSL Handshake Protocol



21

Exportability Issues

- Exportable suites in SSLv2:
  - 40 secret bits out of 128 in symmetric keys
  - 512-bits RSA keys
- Exportability in SSLv3:
  - Integrity keys computed the same way
  - Encryption keys: 40 bits secret
  - IV non-secret
  - When a domestic server (e.g., 1024-bit RSA key) communicates with an external client the server creates an ephemeral key of 512-bits and signs it with it's 1024-bit key

22

TLS (Transport Layer Security)

- IETF standard RFC 2246 similar to SSLv3
- Minor differences
  - Record format version number
  - HMAC for MAC
  - Pseudo-random function to expand the secrets
  - Additional alert codes
  - Changes in supported ciphers
  - Changes in certificate negotiations
  - Changes in use of padding

23