CS 556 – Computer Security
Fall 2012

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<th>Security Protocols</th>
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**Security Protocols**
Secure Sockets Layer Protocol

- Designed to establish a secure connection between a client and a server communicating over an insecure channel
- Attacker assumptions
  - Have substantial computational resources
  - Can capture, modify, delete, replay and otherwise tamper with messages
  - Cannot obtain secret information from sources outside the protocol
Placement in the IP Stack

SSL runs above TCP/IP and below high level application programs.
SSL Services

- Security parameter negotiation
- Peer entity authentication
- Data confidentiality
- Data authentication and integrity
- Compression / decompression
## SSL Architecture

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SSL Record Protocol

SSL Session and Connection

SSL Handshake Protocol

SSL Management and Administration

Secure Shell

Secure/Multipurpose Internet Mail Extensions (S/MIME)

SSL Record Protocol
Record Protocol Services

- Provides the secure tunnel for communication between client and server
- Five steps by sender to transmit packet
  - Fragmentation of message into packets
  - Compression of packets into smaller packets
  - Generating and appending Message Authentication Code to each packet
  - Encryption of packet (with MAC)
  - Add SSL record header and transmit
- Receiver perform the corresponding steps in reverse order
Record Protocol Overview

- Application Data
- Fragment
- Compress
- Add MAC
- Encrypt
- Add SSL Record Header
SSL Session and Connection

Secure Shell
Secure/Multipurpose Internet Mail Extensions (S/MIME)
SSL Session

- An association between a client and a server
- Generated by the SSL Handshake Protocol
- Define a set of cryptographic security parameter that can be shared among multiple connections
  - Used to avoid expensive negotiation of new security parameters for each connection
**Session State Elements**

**session identifier**  An arbitrary byte sequence chosen by the server to identify an active or resumable session

**peer certificate**  X.509v3 certificate of the peer. This element of the state may be null

**compression method**  The algorithm to compress the data prior to encryption
Session State Elements

cipher spec Specify the bulk encryption algorithm (such as null, DES etc.) and a MAC algorithm (such as MD5 or SHA). It also defines cryptographic attributes such as the hash size.

master secret 48-byte secret shared between the client and the server.

is resumable A flag indicating whether the session can be used to initiate new connections.
SSL Connection

- Connections are peer-to-peer relationships
- Are transient
- Every connection associated with one session
- Sessions can be reused across multiple secure connections
- Handshake protocol
  - establishes new session and connection together
  - may use existing session for new connection
server and client random  Byte sequences that are chosen by the server and client for each connection

server write MAC secret  The secret used in MAC operations on data written by the server

client write MAC secret  The secret used in MAC operations on data written by client

server write key  The bulk cipher key for data encrypted by the server and decrypted by the client
Connection State Elements

**client write key** The bulk cipher key for data encrypted by the client and decrypted by the server

**initialization vectors** When a block cipher in CBC mode is used, an initialization vector is maintained for each key. This field is first initialized by the SSL handshake protocol. Thereafter the final ciphertext block from each record is preserved for use with the following block

**sequence numbers** Each party maintains separate sequence numbers for transmitted and received messages for each connection. When a party sends or receives a change cipher spec message, the appropriate sequence number is set to zero
SSL HANDSHAKE PROTOCOL
## No Session Identifier, No Client Authentication

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<th>Message Type</th>
<th>Direction</th>
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<td>C → S</td>
<td>version, challenge-data, cipher-specs</td>
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<tr>
<td>Server-hello</td>
<td>S → C</td>
<td>connection-id, server-certificate, version, modified-cipher-specs</td>
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<tr>
<td>Client-master-key</td>
<td>C → S</td>
<td>cipher-kind, clear-master-key, {secret-master-key}server-public-key</td>
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<tr>
<td>Client-finish</td>
<td>C → S</td>
<td>{connection-id}client-write-key</td>
</tr>
<tr>
<td>Server-verify</td>
<td>S → C</td>
<td>{challenge-data}server-write-key</td>
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<tr>
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Client-hello Message Contents

- Version - highest SSL version that client can support
- Challenge data
  - 4 byte timestamp, 28 byte random value
  - It is used to authenticate the server at a later stage
- A list of ciphers and compression techniques that the client can support
Server-hello Message Contents

- Connection-id
- Server certificate
  - Used by the client to obtain the server’s public key and verify the identity of the server using some certification authority
- Version - version that server agrees to support
- Modified list of ciphers and compression that both the server and the client can support
Client-master-key Message Contents

- Final choice of the cipher (cipher-kind)
- Master-key in two parts
  - clear-master-key: if chosen cipher is export grade, then 88 bits of master key is sent in clear
  - secret-master-key: remaining 40 bits of key is sent encrypted with server’s public key
  - if full strength cipher key is chosen, then entire key is encrypted with server’s public key and clear-master-key field is empty
Read-write Keys from Master-Key

- The master-key is not used as it is for bulk encryption at the SSL record protocol level
  - master-key is used to calculate two sets of keys
    - client-write-key = server-read-key: client uses this key to encrypt data for the server
    - server-write-key = client-read-key: server uses this key to encrypt data for the client
  - some ciphers may require more than one actual key to encrypt or decrypt
    - e.g. Triple DES needs three keys each way
Client-finish Message Contents

- Connection-id originally sent by the server
  - Acts as a nonce value to prevent replay attacks
  - This is encrypted with the client-write-key
Server-verify Message Contents

- Challenge-data originally sent by the client
  - Encrypted using the server-write-key
  - Only the real server will have the private key necessary to decrypt the secret-master-key in the client-master-key message
- Thus the receipt and decryption of this message authenticates the server to the client
Server-finish Message Contents

- **Session-id**
  - Used in subsequent handshakes between the same client and same server to avoid having to go through all the cipher and master key negotiations again
  - Cached by each party after a connection is closed and only reused for subsequent connections provided they do not occur too far apart
  - Recommended that session-id have a 100s life in cache
## Session Identifier Used, No Client Authentication

### MESSAGE TYPE

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**Session Identifier Used, No Client Authentication**

- Challenge-data in client-hello message has the same use as in the initial case
- The server uses the session-id sent in client-hello message to look up the cipher kind and the master-key
- The cipher-specs is resend in client-hello in case the server has timed out the session-id by the time the client-hello message reaches it
  - In this case the server can continue as if it's a new session
Session Identifier Used, No Client Authentication

- If session-id was found in server’s cache
  - Server returns a connection-id and session-id-hit flag
  - Rest of the message exchange is the same as in the previous case except that no client-master-key message is exchanged

- If session-id was not found in server’s cache
  - This is a new session id – exchange messages as if no session identifier used
# No Session Identifier Used, Client Authentication

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<td>$S \rightarrow C$</td>
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Request-certificate Message Contents

- Authentication type
  - Specifies a message digest function and a form of public key encryption
- Certificate challenge data
  - Created by the server and is the data which the client uses to create a digital signature and return as response
Client-certificate Message Contents

- Certificate type
- Client certificate
  - Contains the client’s public key
- Response data
  - Certificate challenge data is hashed and then signed using the client’s private key
  - If response data properly decrypted with client’s public key in certificate then client is verified
### Session Identifier Used, Client Authentication

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### Session Identifier Used, Client Authentication

**Security Protocols**

**SSL Record Protocol**

**SSL Session and Connection**

**SSL Handshake Protocol**

**SSL Management and Administration**

**Secure Shell**

**Secure/Multipurpose Internet Mail Extensions (S/MIME)**

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Authentication and Key Exchange

- Three different authentication modes
  - Authentication of both parties
  - Server authenticated with an unauthenticated client
  - Total anonymity
Anonymous servers cannot authenticate clients

For any entity that is being authenticated, its certificate message must provide a valid certificate chain leading to an acceptable certificate authority

Each party is responsible for verifying that the other’s certificate is valid and has not expired or been revoked
Anonymous Sessions

- Provides protection only against passive eavesdropping
- Completely anonymous sessions are vulnerable to man-in-the-middle attacks
  ✦ Independent, tamper-proof channel is needed to verify that the finished messages were not replaced by an attacker
SSL Key Exchange Algorithms

- RSA
- Fixed Diffie-Hellman
- Ephemeral Diffie-Hellman
- Anonymous Diffie-Hellman
- Fortezza
SSL MANAGEMENT AND ADMINISTRATION
SSL Alert Protocol

- Alert messages convey a description of the alert and the severity of the message – namely warning, fatal, other
- Content type supported by the SSL Record layer
- Alert messages with a level of fatal result in the immediate termination of the connection. In this case, other connections corresponding to the session may continue, but the session identifier must be invalidated, preventing the failed session from being used to establish new connections.
**Closure Alerts**

**close_notify**  This message notifies the recipient that the sender will not send any more messages on this connection. The session becomes unresumable if any connection is terminated without the proper close_notify messages with level equal to warning.
Error Alerts

**unexpected_message**  An inappropriate message was received. This alert is always *fatal* and should never be observed in communication between proper implementations.

**bad_record_mac**  This alert is returned if a record is received with an incorrect MAC. This message is always *fatal*.

**decompression_failure**  The decompression function received improper input (e.g. data that would expand to excessive length). This message is always *fatal*.
Error Alerts

handshake_failure  Reception of this message indicates that the sender was unable to negotiate an acceptable set of security parameters given the options available. This is a fatal error.

np_certificate  This alert message may be sent in response to a certification request, if no appropriate certificate is available.

bad_certificate  A certificate was corrupt, contained signatures that did not verify correctly etc.

unsupported_certificate  A certificate was of an unsupported type.
Error Alerts

**certificate_revoked**  A certificate was revoked by its signer

**certificate_expired**  A certificate has expired or is not currently valid

**certificate_unknown**  Some other (unspecified) issue arose in processing of certificate rendering it unacceptable

**illegal_parameter**  A field in the handshake was out of range or inconsistent with other fields. This is always fatal
Applications and SSL

- Use dedicated port numbers for every application that uses SSL
- Negotiate use of SSL during normal TCP/IP connection establishment
- Use normal application port and negotiate security options as part of application protocol
SSH

- Still evolving
- Originally developed for secure remote login from client to server (host)
- Has potential to evolve into a general purpose transport layer security protocol
  - Alternate to SSL
SSH Protocol Features

- Secure terminal sessions utilizing secure encryption
- Full, secure replacement for FTP and Telnet as well as the UNIX r-series of commands – rlogin, rexec, rcp
- Multiple ciphers for encryption, including 3DES, Blowfish, and AES.
- Transparent and automatic tunneling of X11 connections and arbitrary TCP/IP-based applications, such as e-mail
- Automatic and secure authentication of both ends of connection
- Multiple channels that allow you to have multiple terminal windows and file transfers going through one secure and authenticated connection.
**SSH Architecture**

- **SSH-TRANS**
  - Transport layer protocol over TCP connection on port 22
  - Provides server authentication, confidentiality and integrity with optional compression

- **SSH-USERSAUTH**
  - Authenticates client side user to server

- **SSH-CONNECT**
  - Multiplexes encrypted connection into multiple logical channels
SSH Transport

- Each host must have a public key
  - May have more than one
  - Multiple hosts may share one public key

- Public keys of hosts are stored in a client database
  - Manually configured
  - Accept public keys from servers online
  - Use public key certificates
SSH Transport

Client

Connection request

Server

Connection response

Encrypted Session key

OK

Security Protocols

SSL Record Protocol

SSL Session and Connection

SSL Handshake Protocol

SSL Management and Administration

Secure Shell

Secure/Multipurpose Internet Mail Extensions (S/MIME)
SSH Transport

- **Connection request**
  - Protocol version number
  - Cryptographic algorithms that client can handle

- **Connection response**
  - Selects crypto algorithms (can be independent in both directions)
  - Public host key (long term)
  - Public server key (short term)

- **Encrypted session key**
  - 256 bit doubly encrypted with above public keys
SSH Authentication

- Client to server authentication alternatives
  - Password based
  - Skey based
  - Public-key based
  - Kerberos
  - Secure-id based
SECURE/MULTIPURPOSE INTERNET MAIL EXTENSIONS (S/MIME)
### S/MIME

- Standard for secure electronic messaging – endorsed by Lotus, Microsoft, Netscape and Qualcomm
- Based on IETF’s Cryptographic Message Syntax which is almost identical to PKCS #7
- Can be used for
  - Secure email
  - Secure EDI
  - Electronic commerce and online ordering services
  - Secure messaging for legal application and healthcare application
**S/MIME – Sending a Message**

- **Security Function**
  - Message
  - Sign
  - Encrypt
  - Attach Sender’s Certificate
  - Retrieve Recipient’s Certificate

- **S/MIME Message**
- **Mail**
To encrypt an outgoing message

✦ Obtain a valid certificate from each and every recipient in the address list (cannot be discussion group or mailing list) if not already there
✦ Update recipient’s certificate if necessary
S/MIME – Sending a Message

- To sign outgoing message
  - Must obtain a valid certificate for the sender if none existing
  - Update sender’s certificate if necessary
S/MIME – Receiving a Message

Security Function

S/MIME Message

Decrypt

Verify Signature

Validate Certificate

Message

Security Protocols

SSL Record Protocol

SSL Session and Connection

SSL Handshake Protocol

SSL Management and Administration

Secure Shell

Secure/Multipurpose Internet Mail Extensions (S/MIME)
S/MIME – How It Works

- To validate certificate
  - If new self-signed certificate, establish trust manually
  - If new CA-signed certificate, compare to stored CA-signed certificate
  - If old certificate, check against revocation lists