Real-Time Communication Security: SSL/TLS

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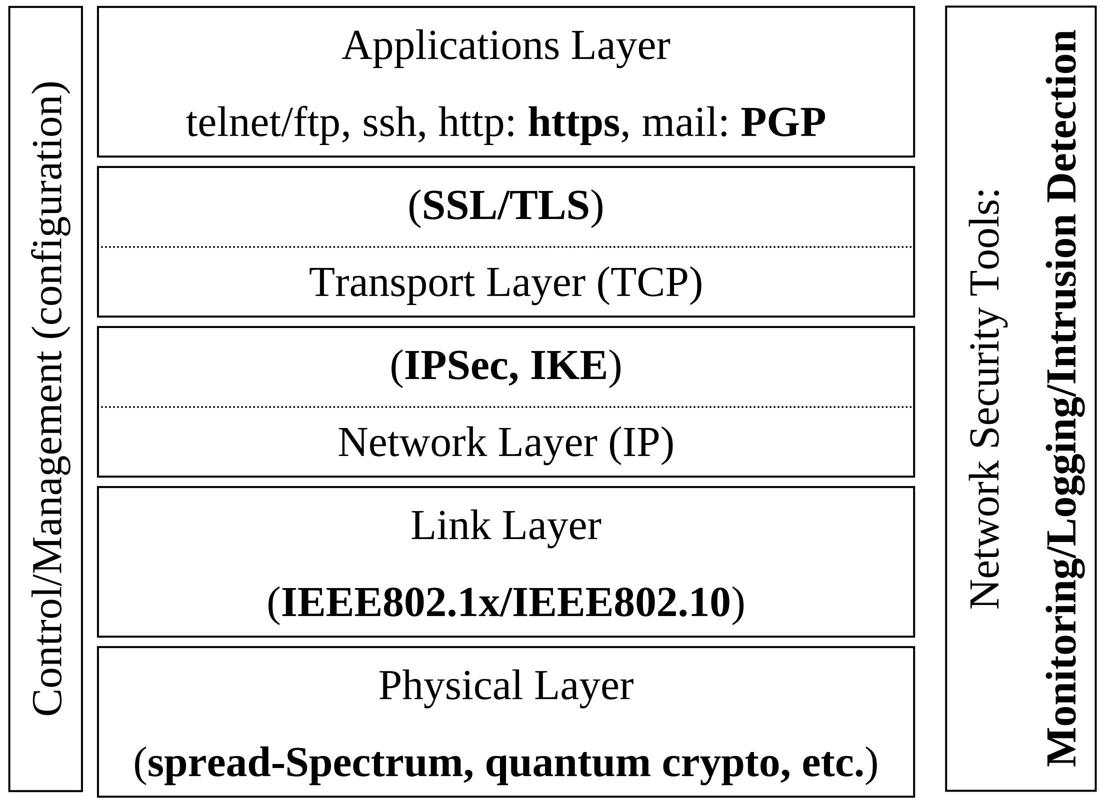
CSG254: Network Security

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

Securing Networks

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



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

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

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

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 of 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 from *K*

Computing the Keys

- S: pre-master secret (forget it after establishing K)
- $K = f(S, R_A, R_B)$
- 6 keys = $g_i(K, R_A, R_B)$
- 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

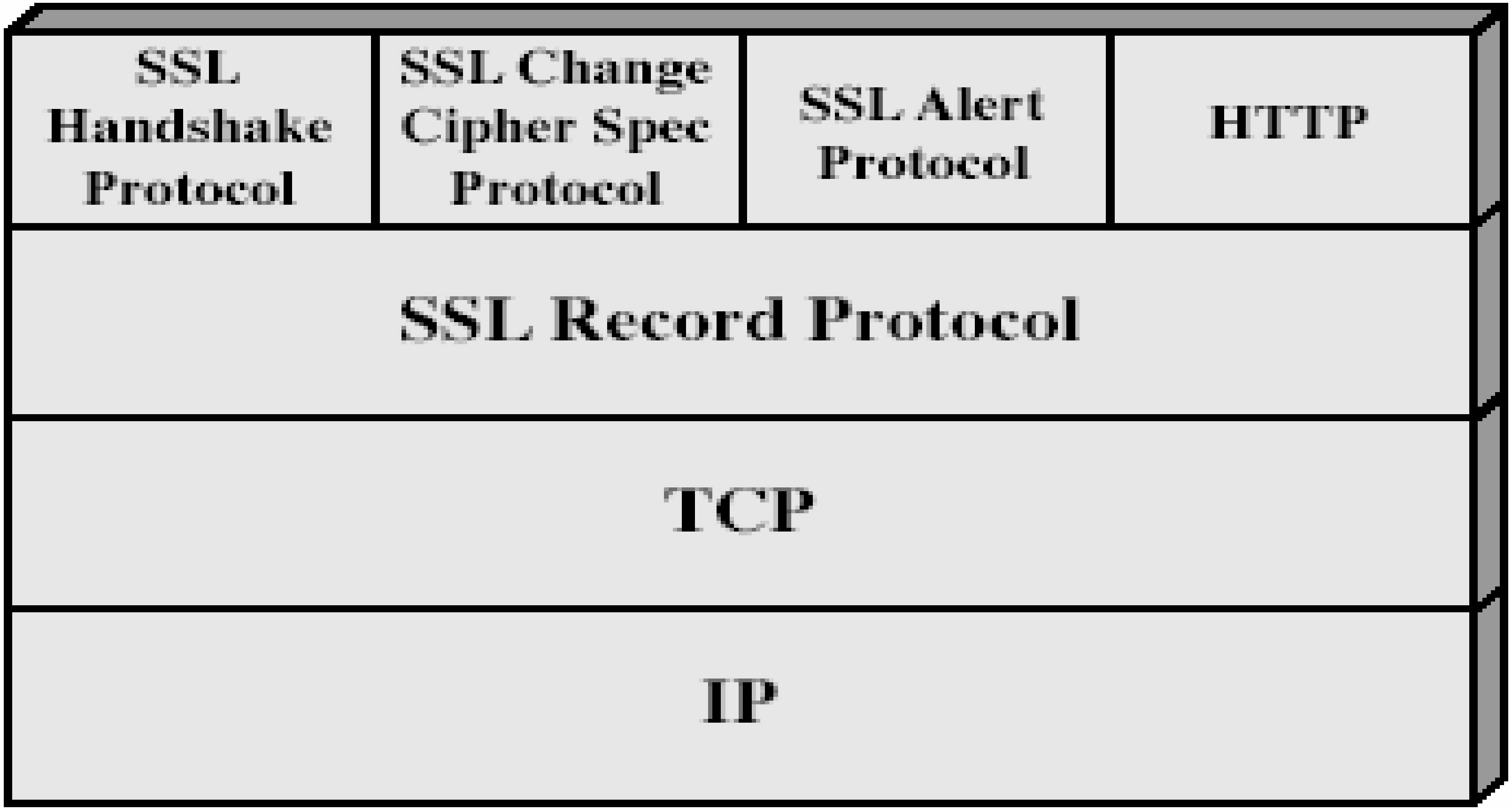
Negotiating Cipher Suites

- 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

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

SSL Stack


SSL Handshake Protocol
SSL Change Cipher Spec Protocol
SSL Alert Protocol
HTTP
SSL Record Protocol
TCP
IP

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

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

  $\Rightarrow$ all records following this will be protected with the ciphers agreed upon

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

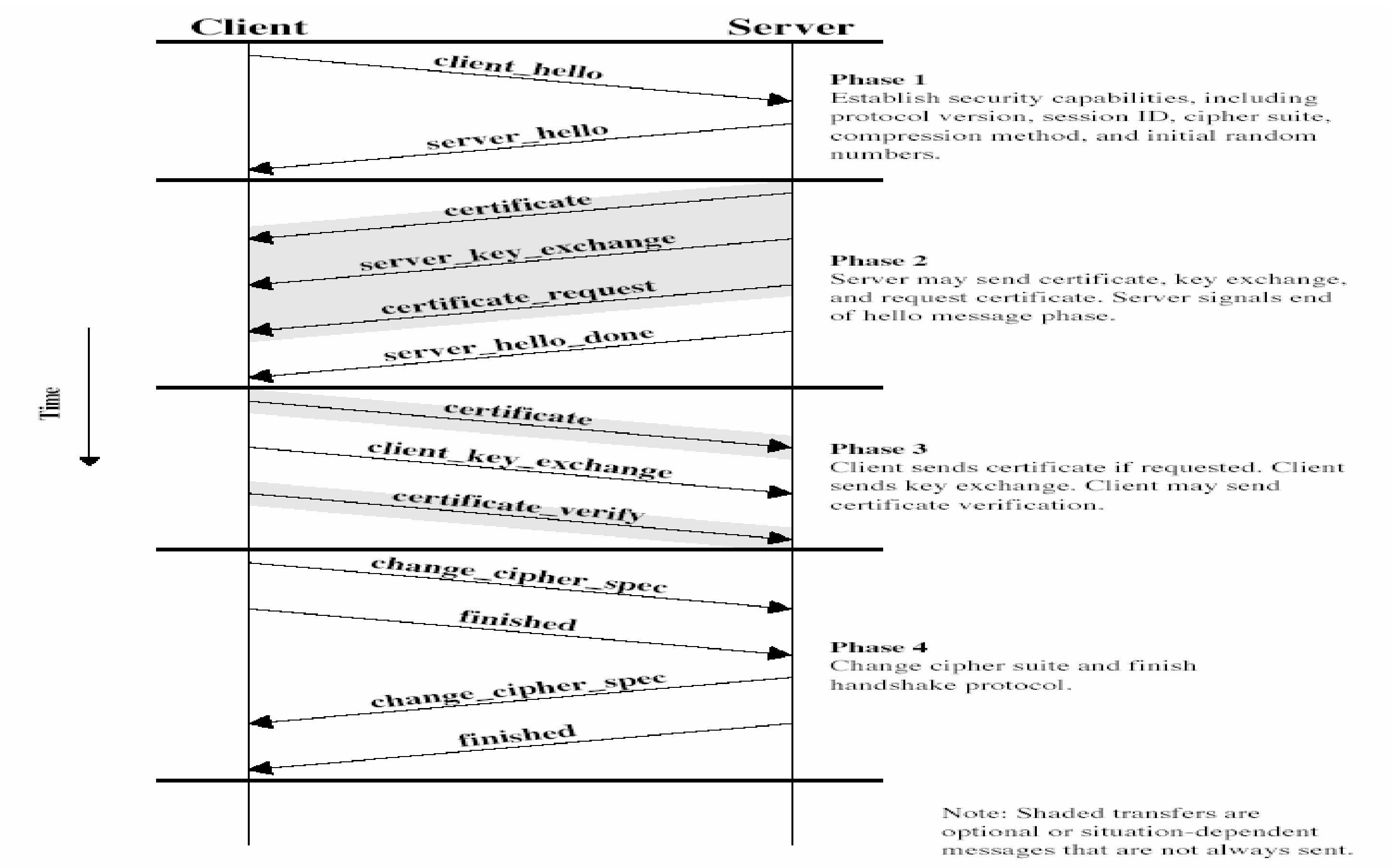
SSL Handshake Protocol

- 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

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]

SSL Handshake Protocol



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

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