Secure Socket Layer (SSL) and Transport Layer Security (TLS)

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Audio/Video recordings of this lecture are available at:

http://www.cse.wustl.edu/~jain/cse571-07/

Overview

- History and overview of SSL/TLS
- Products and Implementations
- Datagram Transport Layer Security (DTLS)
- Current TLS Issues and Extensions
- Secure Remote Password (SRP)

First part from the textbook. Remainder from Wikipedia and IETF

Key Features

- User level ⇒ Not operating system specific
- Uses TCP ⇒ Reliable transmission
  (No retransmissions at application layer)
- Features:
  - Crypto negotiation
  - Key Generation for encryption and Integrity
  - Authentication:
    - Servers use Certificates
    - Clients use password or certificates

SSL/TLS Applications

- HTTPS = HTTP over port 443
- FTPS = FTP over SSL
  (different from SFTP = FTP over SSH)
- NNTP over SSL
- OpenVPN

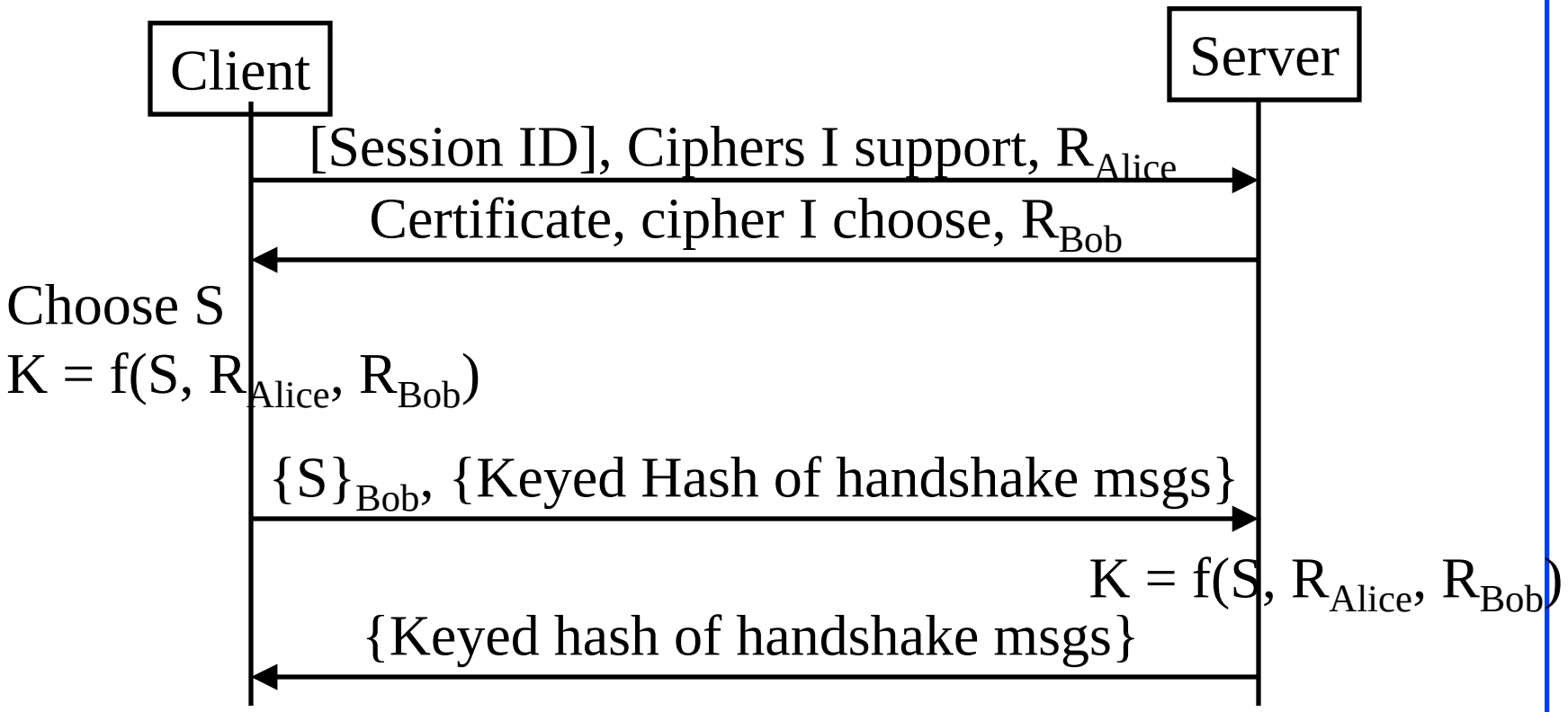
History

- Secure Socket Layer (SSL) V2 on Netscape Navigator 1.1 1995
- Private Communication Technology (PCT) by Microsoft fixed some bugs in SSL V2
- SSL v3 is most commonly deployed protocol
- Transport Layer Security (TLS) by IETF [RFC 2246 1999]
- TLS v1.1 [RFC 4346 2006]
- TLS v1.2 [draft-ietf-tls-rfc4346-bis-05.txt June 2007]

SSL v2 vs. v3

- **Downgrade Attack**: Crypto choices not protected in V2. Finished message in v3 contains digest of all previous messages
- **Truncation Attack**: V2 closes SSL on TCP connection close ⇒ Not protected. V3 added session finished message to close SSL session.

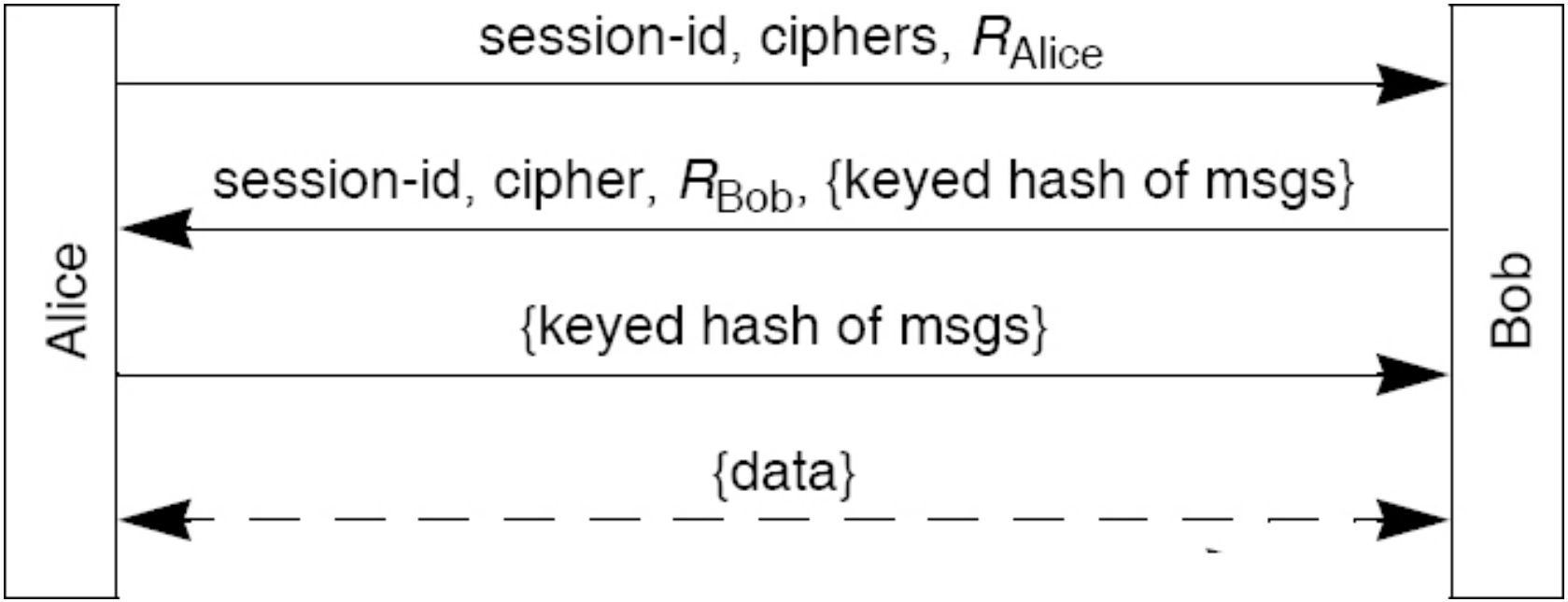
SSL/TLS Basic Protocol



- R's are 32B. First 4B = Unix time
- Secrets: Pre-master secret S, master secret K
- 6 Keys: Encryption, Integrity, IV (1 per direction)
- Authenticates server. Client authenticated by password.

Session Resumption

- Similar to Phase 2 of IKE
- Multiple session keys from master secret K
- HTTP 1.0 used many TCP connections
- Server stores session ID and master secret



Version

- 0.2 ⇒ SSL v2
- 3.0 ⇒ SSL v3
- 3.1 ⇒ TLS v1
- V3 clients send v2 client-hello with version 3.0
- V2 servers respond with v2 server-hello
- V3 servers respond with a v3 server-hello

Cipher Suites

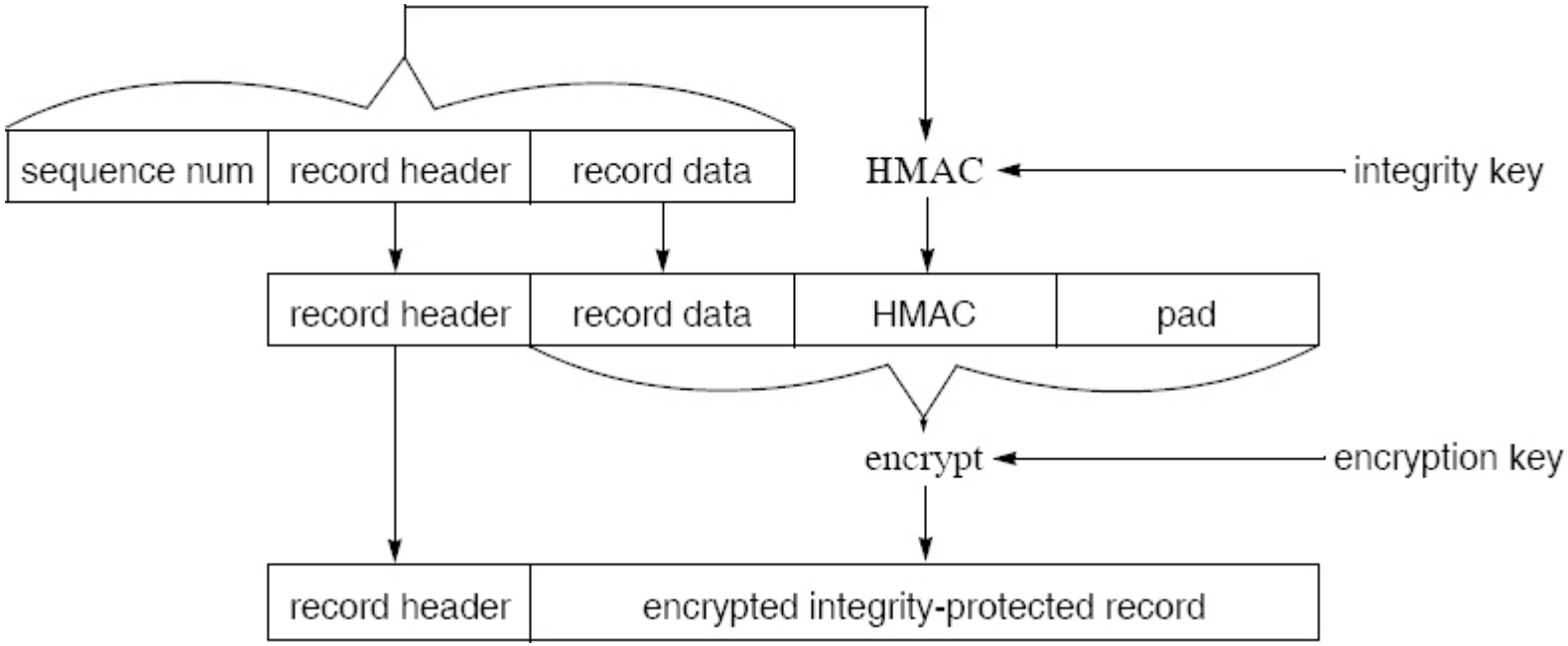
- V3 has a 2B field for cipher suite
- Standard numbers for 30 Cipher suites, e.g., SSL_RSA_EXPOERT_WITH _DES40_CBC_SHA
- Server decides one of the choices offered by Client
- **Crypto Algorithms**
  - Key exchange: RSA, Diffie-Hellman, DSA, SRP, PSK
  - Symmetric ciphers: RC4, Triple DES, AES or Camellia.
  - Hash function: HMAC-MD5 or HMAC-SHA

Export Issues

- Only 40 bits keys allowed.
- Servers can encrypt keys using 512b RSA keys.
- Normally RSA keys are 1024b. 512b Ephemeral key.
- Server Gated Cryptography/Step-Up:
  Financial transactions allowed to use longer keys.
- Server certificates signed by Verisign or Thawte contain SGC extension allowed.
- Initial handshake using 40b.
- Client would then send Change Cipher Spec message to renegotiate.

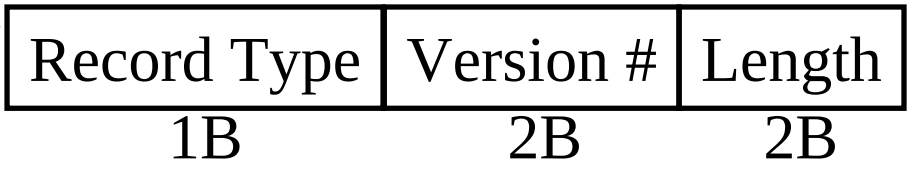
Encrypted Records

- Integrity is provided by HMAC using the integrity key
- Data prefixed by 64b sequence # but the sequence # not sent
- Block cipher $\Rightarrow$ 40B padding in SSLv3, 44B in TLS.
- Final block of each record is used as IV for the next



Encoding

- All exchanges are in records up to 2^{14}B or 2^{16}-1B.
- Standard allows multiple messages in one record or multiple records.
- Most implementations use one message per record.
- Four Record Types:
  - 20 = Change Cipher Spec
  - 21 = Alerts (1 = Warning, 2 = Fatal)
  - 22 = Handshake
  - 23 = Application Data
- Record header:



- Each message starts with a 1B message-type and 3B message length.

Handshake Messages

1 = Client Hello: Version, R_{Alice}, Session ID, Cipher Suites, Compressions

2 = Server Hello: Version, R_{Bob}, Session ID, Chosen Cipher, Chosen Compression

14 = Server Hello Done

16 = Client Key Exchange: Encrypted pre-master key

12 = Server Key Exchange: Modulus p, Exponent g, Signature (export only)

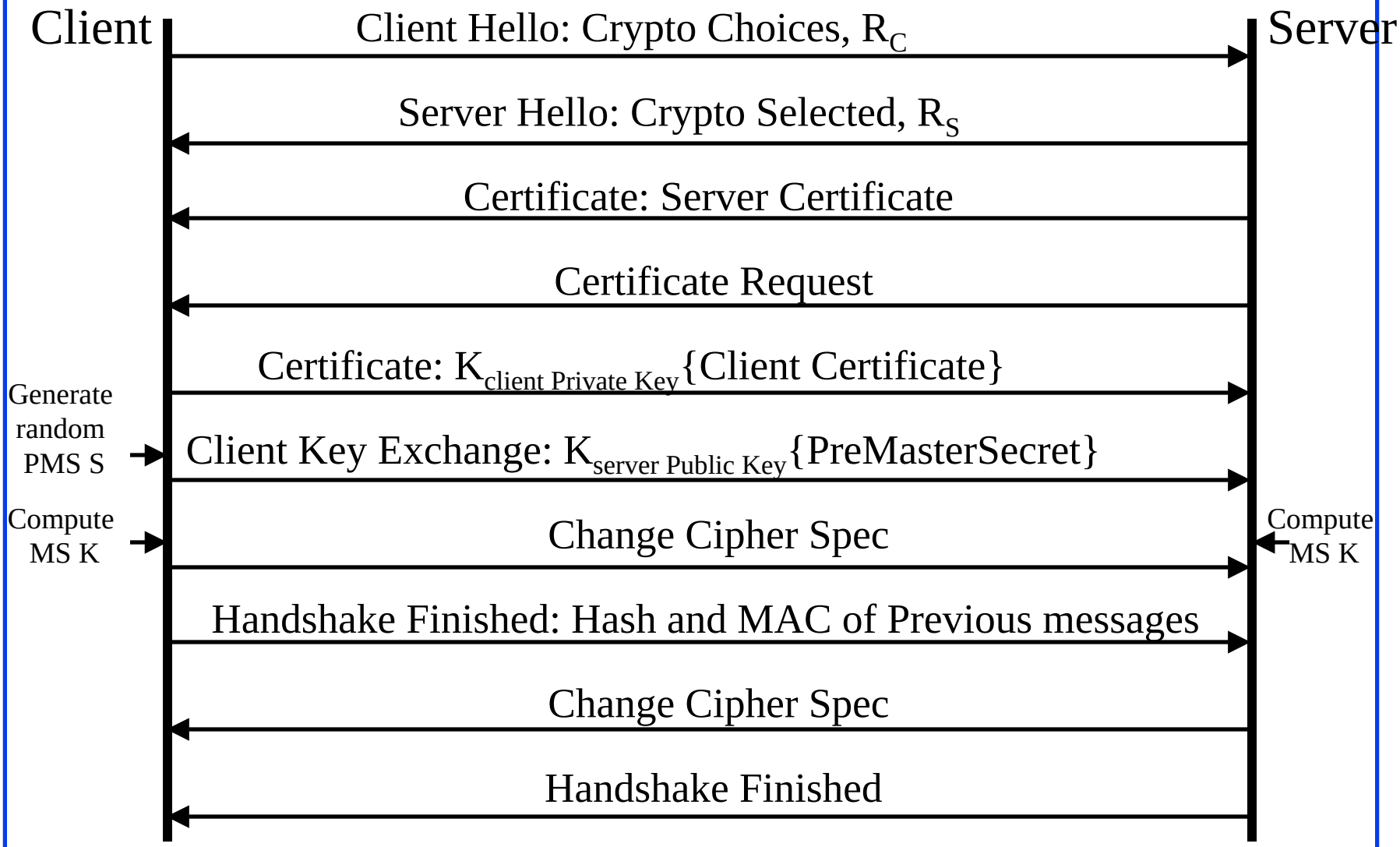
13 = Certificate Request: CA Names (requested by server)

11 = Certificate: sent by server

15 = Certificate Verify:signature of Hash of messages

20 = Handshake Finished: MD5 and SHA Digest of message halves

TLS Message Exchange



Alerts

0 Close notify (warning or fatal)

10 Unexpected message (fatal)

20 Bad record MAC (fatal)

21 Decryption failed (fatal, TLS only)

22 Record overflow (fatal, TLS only)

30 Decompression failure (fatal)

40 Handshake failure (fatal)

41 No certificate (SSL v3 only) (warning or fatal)

42 Bad certificate (warning or fatal)

43 Unsupported certificate (warning or fatal)

44 Certificate revoked (warning or fatal)

45 Certificate expired (warning or fatal)

Alerts (Cont)

46	Certificate unknown (warning or fatal)
47	Illegal parameter (fatal)
48	Unknown CA (fatal, TLS only)
49	Access denied (fatal, TLS only)
50	Decode error (fatal, TLS only)
51	Decrypt error (TLS only) (warning or fatal)
60	Export restriction (fatal, TLS only)
70	Protocol version (fatal, TLS only)
71	Insufficient security (fatal, TLS only)
80	Internal error (fatal, TLS only)
90	User cancelled (fatal, TLS only)
100	No renegotiation (warning, TLS only)

SSL Products and Implementations

- **Acceleration**:
  - Offload public key encryption/decryption
  - Sometimes all SSL message
  - H/W from F5, Cisco, Nortel, Juniper, Radware, ...
- **Software**:
  - OpenSSL: C library of SSL/TLS
  - GnuTLS: C Library under GNU Public license
  - Java Secure Socket Extension (JSSE)
  - Network Security Services (NSS): Open source security library includes SSL also

Datagram Transport Layer Security

- TLS runs on TCP
  - ⇒ Suitable for stream-oriented applications
  - ⇒ Not suitable for datagram applications
- DTLS uses UDP
- Need timeout, retransmission, fragmentation
- Some state is kept in the messages
- Explicit sequence number
- As close to TLS as possible
- RFC 4347, April 2006

TLS: Current Issues

- TLS V1.2
- Transport Layer Security (TLS) Extensions: Extension Definitions
- Using Secure Remote Password (SRP) protocol for TLS Authentication
- Using OpenPGP keys for TLS authentication
- TLS Elliptic Curve Cipher Suites with SHA-256/384 and AES Galois Counter Mode
- RSA based AES-GCM Cipher Suites for TLS

TSL V1.1

- RFC 4346, April 2006
- IV = Final Block of each record (in V1). Implicit IV to prevent CBC attacks
- Padding errors $\Rightarrow$ Bad Record MAC alert
  $\Rightarrow$ Prevents CBC attacks
- Sessions resumeable after premature TCP closes
- Informational notes on TLS attacks

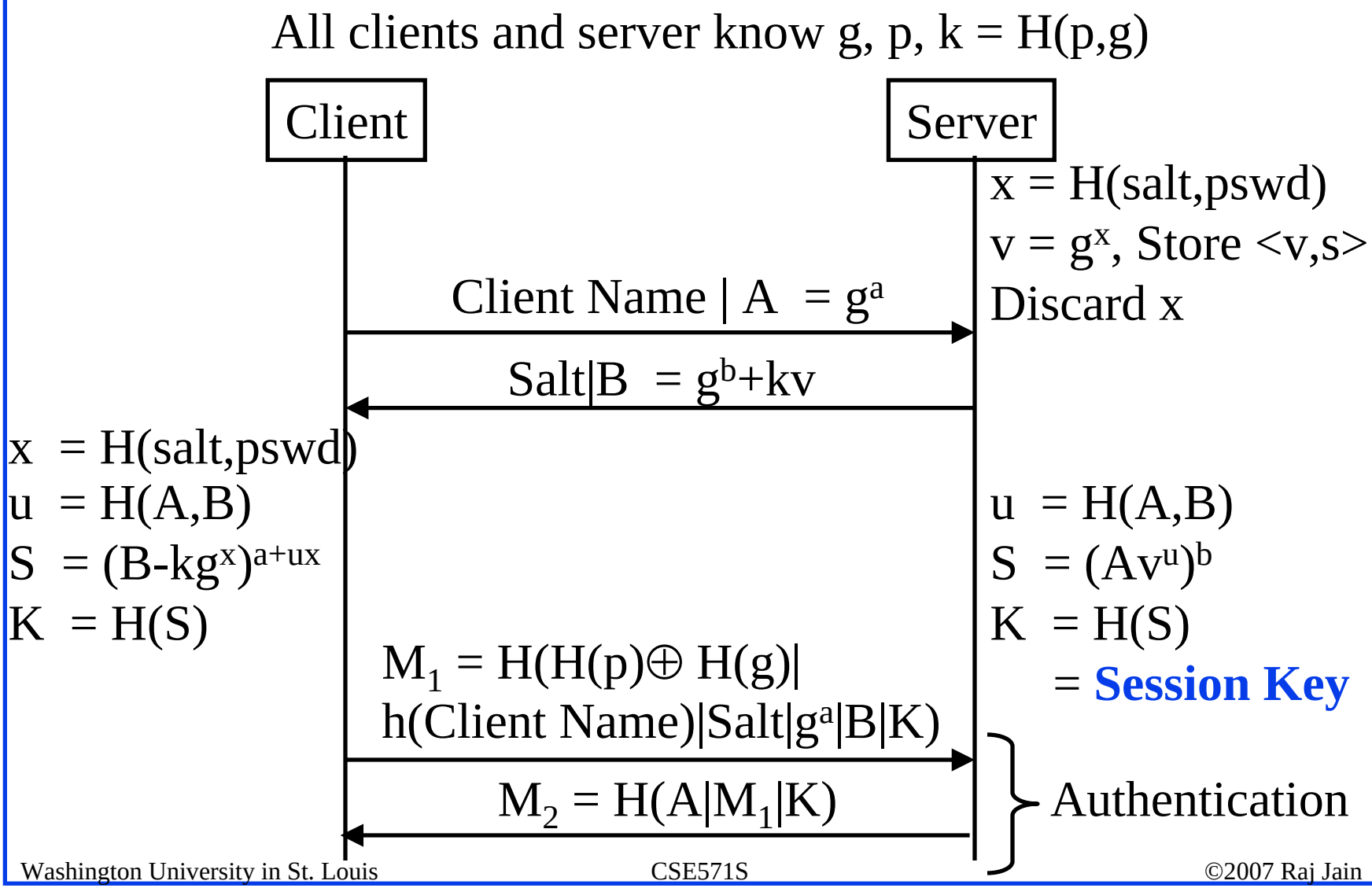
TLS V1.2

- draft-ietf-tls-rfc4346-bis-05.txt, Sep 2007
- Merged TLS extensions
- Replacement of MD5/SHA-1 combination
- Client specifies hash functions choices
- Server selects hash function
- Authenticated encryption with additional data modes
- Tighter checking of encrypted pre master secret version numbers
- Info on implementation pitfalls

TLS Extensions

- draft-ietf-tls-rfc4366-bis-00.txt, June 2007
- Server Name Indication: Clients can indicate the virtual server they are contacting
- Maximum Fragment Length Negotiation:
- Client Certificate URLs
- Trusted CA Indication: from clients
- Truncated HMAC: Save bandwidth
- Certificate Status Request: Send OCSP URL

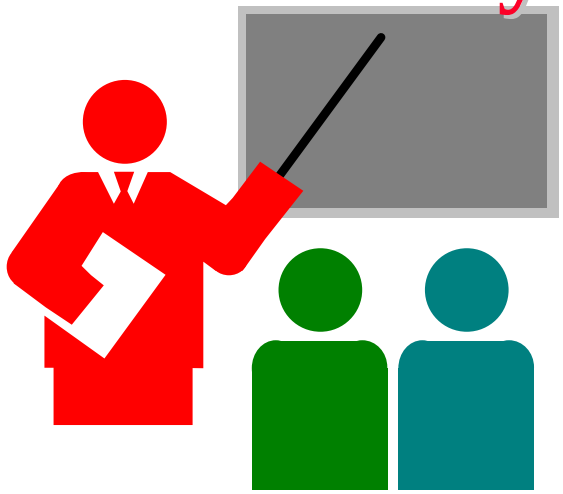
Secure Remote Password (SRP)



SRP

- Resistant to dictionary attacks
- Does not require trusted third party
- No client certificates
- Currently SRP V6 being standardized in IEEE 1363. V3 described in RFC 2945, Sept 2000.

Summary



- SSLv3 allows crypto negotiation, server authentication and key exchange. Uses PKI.
- TLS extensions allow using SRP and shared secrets
- DTLS = TLS over UDP $\Rightarrow$ Allows UDP applications
- Secure remote password (allows) authentication is stronger than simple password hashes

Homework 15

- Read chapter 19 of the textbook and Wikipedia
- Submit answer to the following exercise
- **Exercise 19.3**: What is the advantage, in the exportable SSLv3 case, of hashing the 40-bit secret with two non-secret values to produce a 128-bit key? How many keys would have to be tested to brute-force break a single session?