



Securing Wireless Networks

PGP Secure Socket Layer (SSL) and TLS

Never Stand Still

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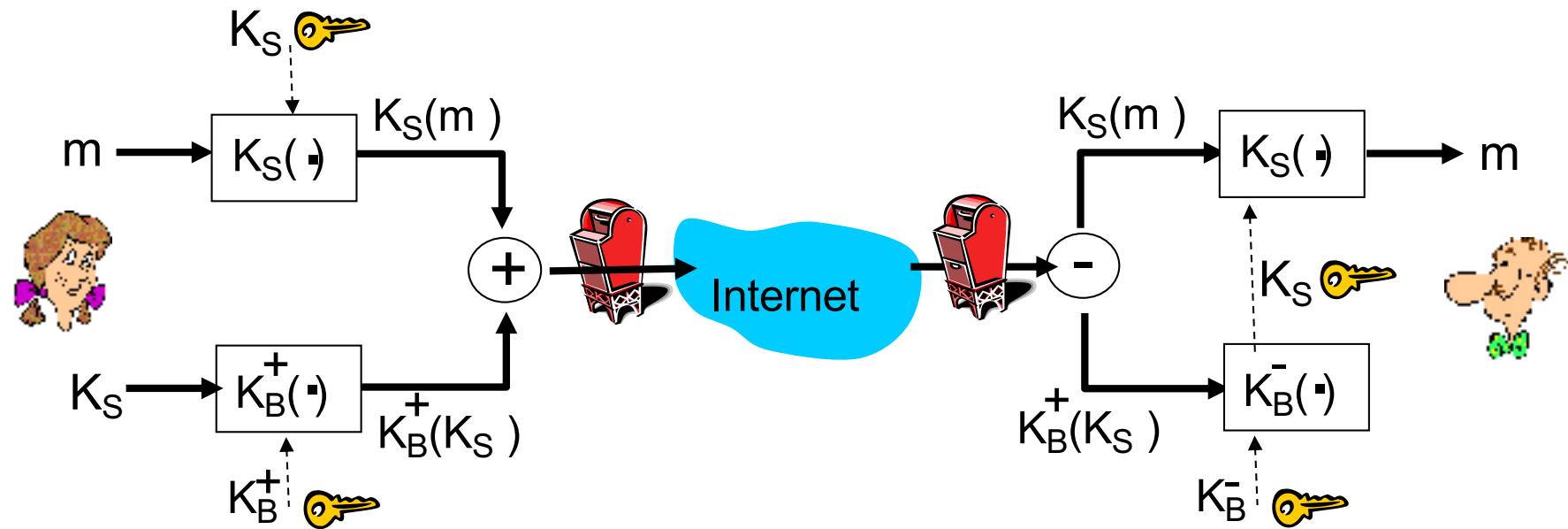
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Security at Internet Protocol Layers

- Security can be implemented at various layers
- Application Layer Security
 - A quick glimpse at secure email (PGP)
- Secure Socket Layer (SSL) / Transport Layer Security (TLS)
 - this week
- Network Layer Security
 - IPSec next week
- Link Layer Security
 - WLAN covered earlier, more on Enterprise later

Secure e-mail: Alice

- ❖ Alice wants to send confidential e-mail, m , to Bob.

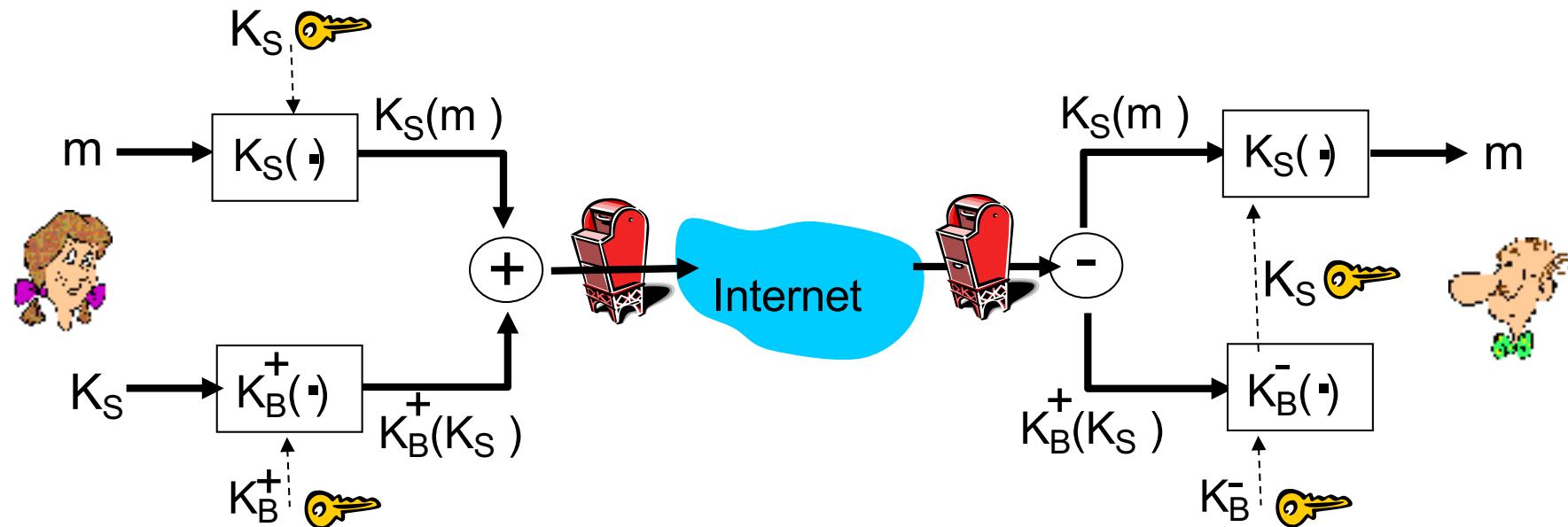


Alice:

- ❖ generates random *symmetric* private key, K_S
- ❖ encrypts message with K_S (for efficiency)
- ❖ also encrypts K_S with Bob's public key
- ❖ sends both $K_S(m)$ and $K_B(K_S)$ to Bob

Secure e-mail: Bob

- ❖ Alice wants to send confidential e-mail, m , to Bob.

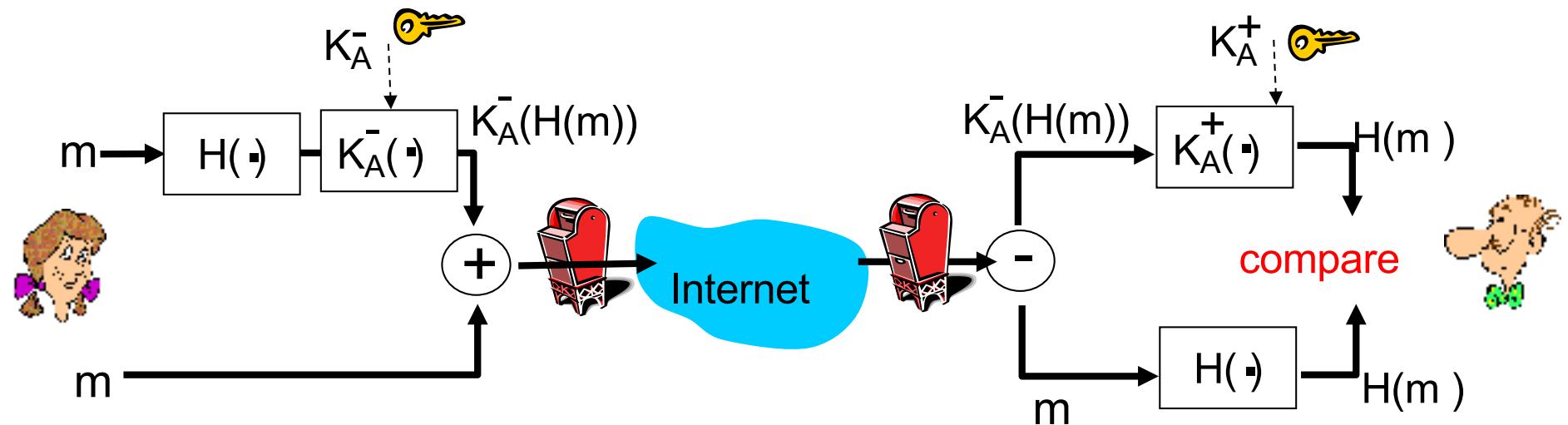


Bob:

- ❖ uses his private key to decrypt and recover K_S
- ❖ uses K_S to decrypt $K_S(m)$ to recover m

Secure e-mail (continued)

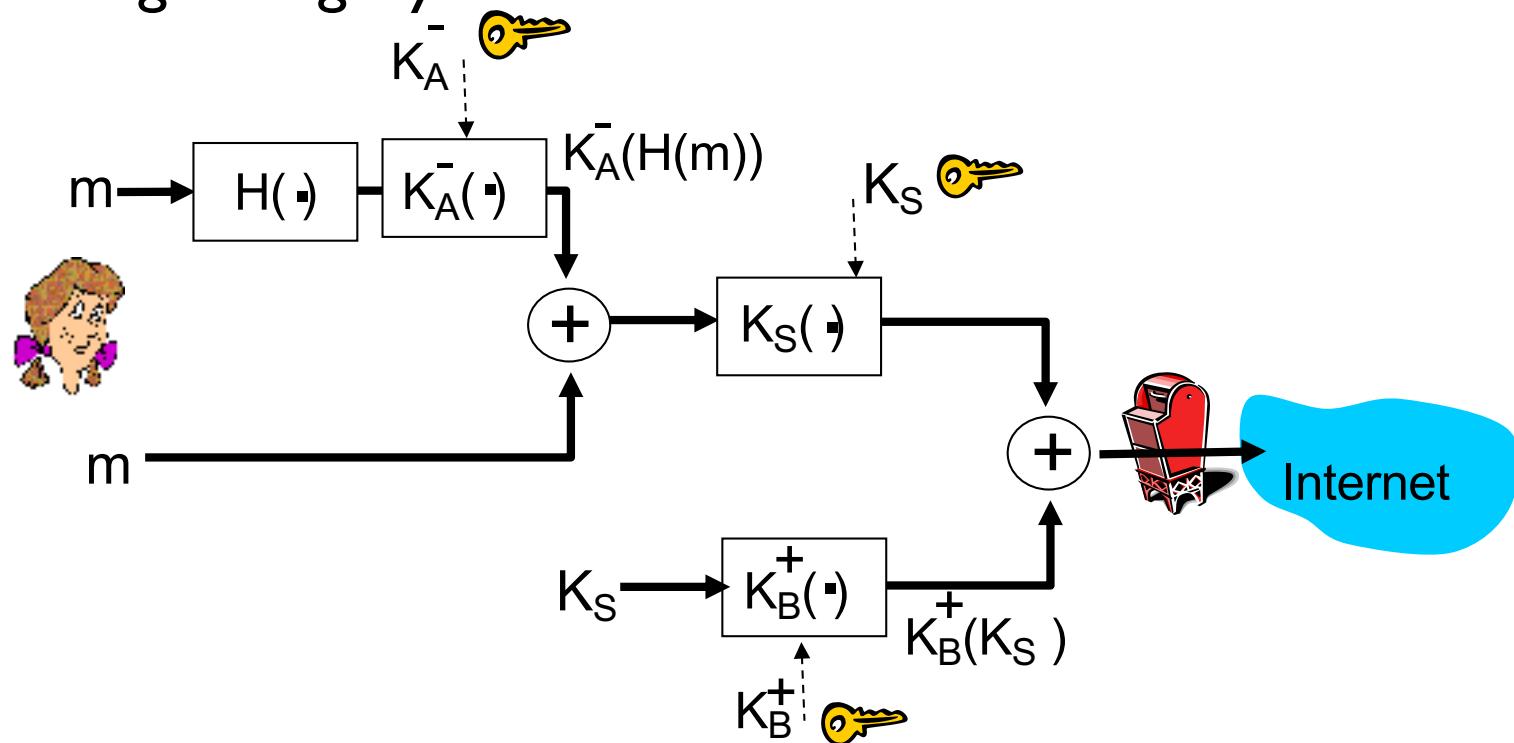
- ❖ Alice wants to provide sender authentication message integrity



- ❖ Alice digitally signs message
- ❖ sends both message (in the clear) and digital signature

Secure e-mail (continued)

- ❖ Alice wants to provide secrecy, sender authentication, message integrity.



Alice uses three keys: her private key, Bob's public key, newly created symmetric key (Exercise: see how Bob's side works)

DNS Attacks

- Domain Name Service: translation between a host name and the corresponding IP address, maintained by a hierarchy of name servers.
- DoS Attack: A number of Denial of Service (DOS) attacks in recent years
- MiTM: attacker can impersonate a DNS server
 - return a bogus address , divert traffic to a malicious server, allows into collect user passwords or other credentials.
- Cache poisoning attack aka DNS spoofing:
 - attackers to plant bogus addresses, thus diverting a user request to malicious servers.

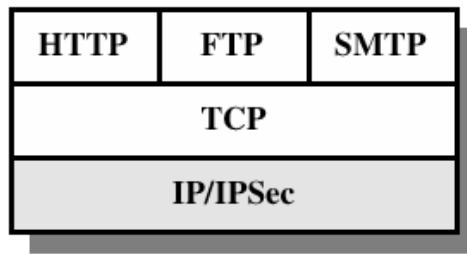
DNS Security

- IETF DNS Security Extensions (DNSSEC)
- Approach similar to PGP
 - response signed by the private key of a DNS server.
 - a requester can verify using the corresponding public key.
 - a digital signature also provides the integrity of the response data, Confidentiality not an issue for DNS records
- Recent study : only 1% of domains use the DNSSEC
- Very few registrars support DNSSEC .
- Mechanism for communicating DNSSEC information has several security vulnerabilities.
- DDoS defence is not part of DNSSEC
 - Intrusion Detection/Prevention System for DOS (later week)

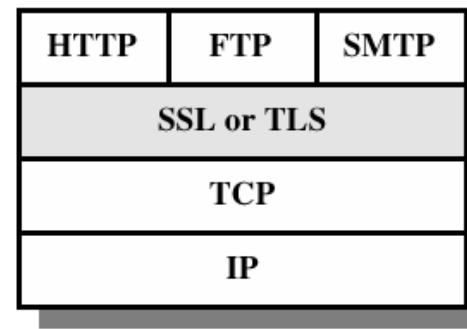
SSL: Secure Sockets Layer

- widely deployed security protocol
 - supported by almost all browsers, web servers
 - https
 - billions \$/year over SSL
- mechanisms: [Woo 1994], implementation: Netscape
- variation -TLS: transport layer security, RFC 2246
- provides
 - *Confidentiality, integrity, authentication*
- original goals:
 - Web e-commerce transactions
 - encryption (especially credit-card numbers)
 - Web-server authentication
 - optional client authentication
 - minimum hassle in doing business with new merchant
- available to all TCP applications
 - secure socket interface

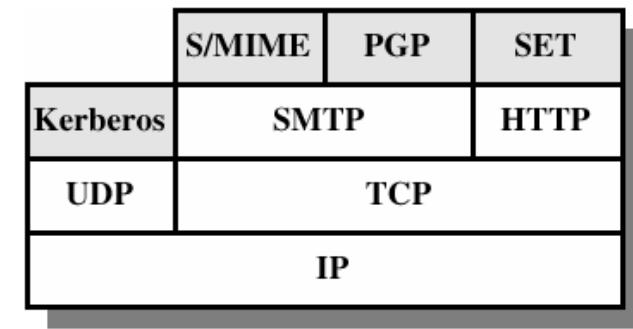
SSL in TCP/IP protocol stack



(a) Network Level

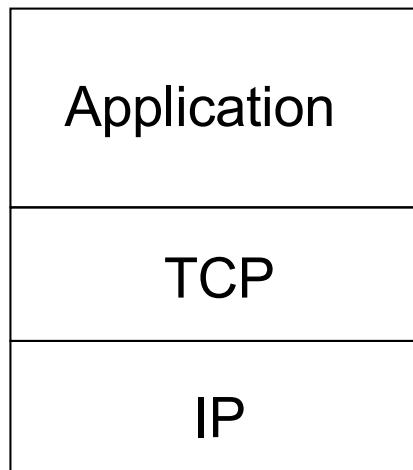


(b) Transport Level

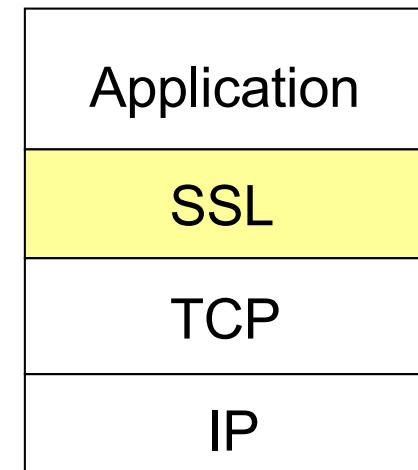


(c) Application Level

SSL and TCP/IP



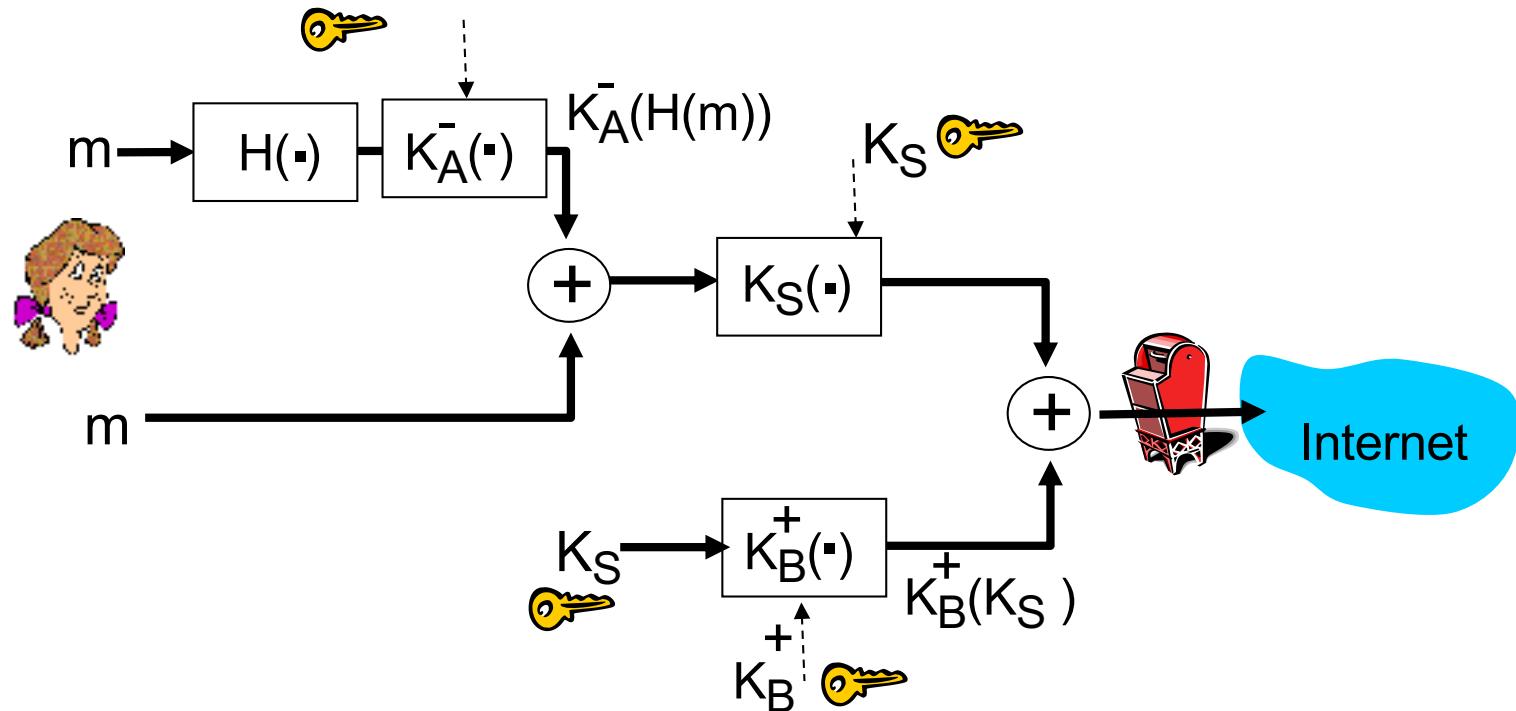
normal application



application with SSL

- ❖ SSL provides application programming interface (API) to applications
- ❖ C and Java SSL libraries/classes readily available

Could do something like PGP

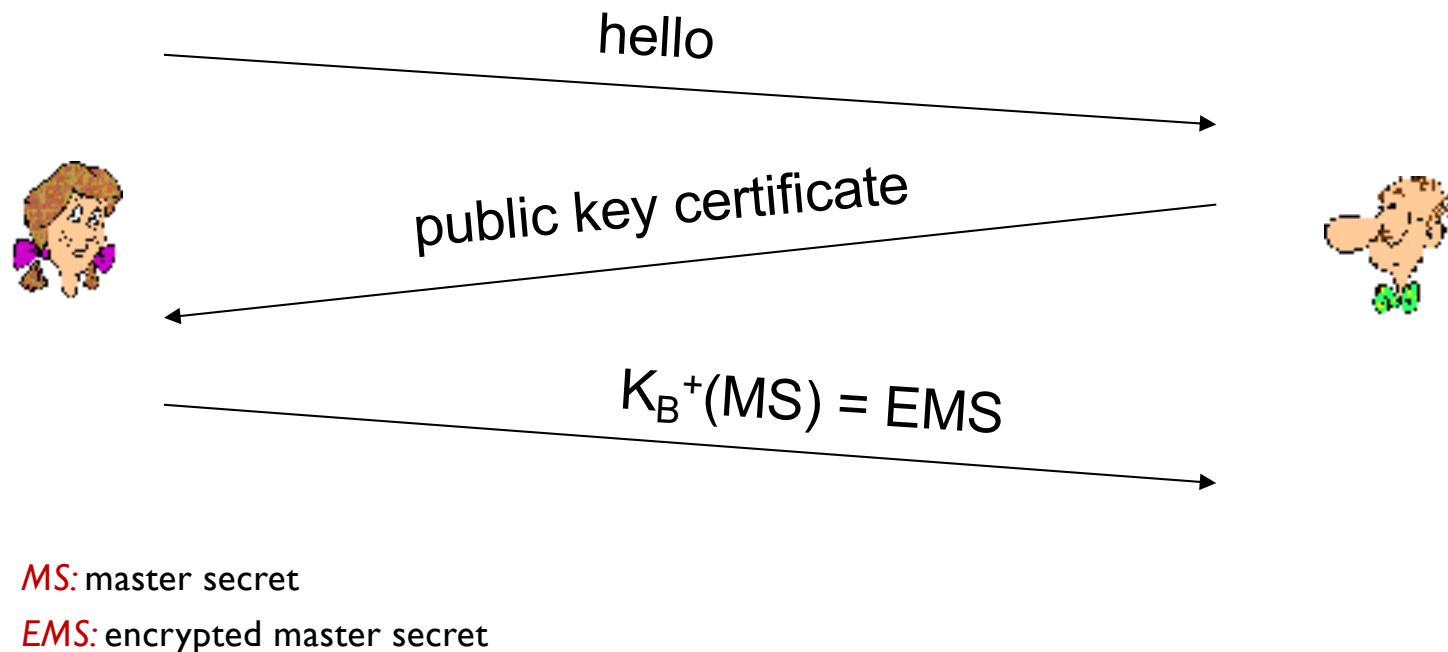


- ❖ but want to send byte streams & interactive data
- ❖ want set of secret keys for entire connection
- ❖ want certificate exchange as part of protocol: handshake phase

Toy SSL: a simple secure channel

- *handshake*: Alice and Bob use their certificates, private keys to authenticate each other and exchange shared secret
- *key derivation*: Alice and Bob use shared secret to derive set of keys
- *data transfer*: data to be transferred is broken up into series of records
- *connection closure*: special messages to securely close connection

Toy: a simple handshake



Toy: key derivation

- considered bad to use same key for more than one cryptographic operation
 - use different keys for message authentication code (MAC) and encryption
- four keys:
 - K_c = encryption key for data sent from client to server
 - M_c = MAC key for data sent from client to server
 - K_s = encryption key for data sent from server to client
 - M_s = MAC key for data sent from server to client
- keys derived from key derivation function (KDF)
symmetric key
 - takes master secret and (possibly) some additional random data and creates the keys

Toy: data records

- why not encrypt data in constant stream as we write it to TCP?
 - where would we put the MAC? If at end of TCP connection, no message integrity until all data processed.
 - e.g., with instant messaging, how can we do integrity check over all bytes sent before displaying? 通过把record break切成小段的方式来确保data integrity
- instead, break stream in series of records
 - each record carries a MAC
 - receiver can act on each record as it arrives
- issue: in record, receiver needs to distinguish MAC from data
 - want to use variable-length records



Toy: sequence numbers

- ❖ **problem:** attacker can capture and replay record or re-order records
- ❖ **solution:** put sequence number into MAC:
 - $\text{MAC} = \text{MAC}(M_x, \text{sequence} \parallel \text{data})$
 - *note: no sequence number field*
- ❖ **problem:** attacker could replay all records in future
- ❖ **solution:** use nonce

Toy: control information

- **problem:** truncation attack:
 - attacker forges TCP connection close segment
 - one or both sides thinks there is less data than there actually is.
- **solution:** record types, with one type for closure
 - type 0 for data; type 1 for closure
- $\text{MAC} = \text{MAC}(M_x, \text{sequence} \parallel \text{type} \parallel \text{data})$



SSL Architecture

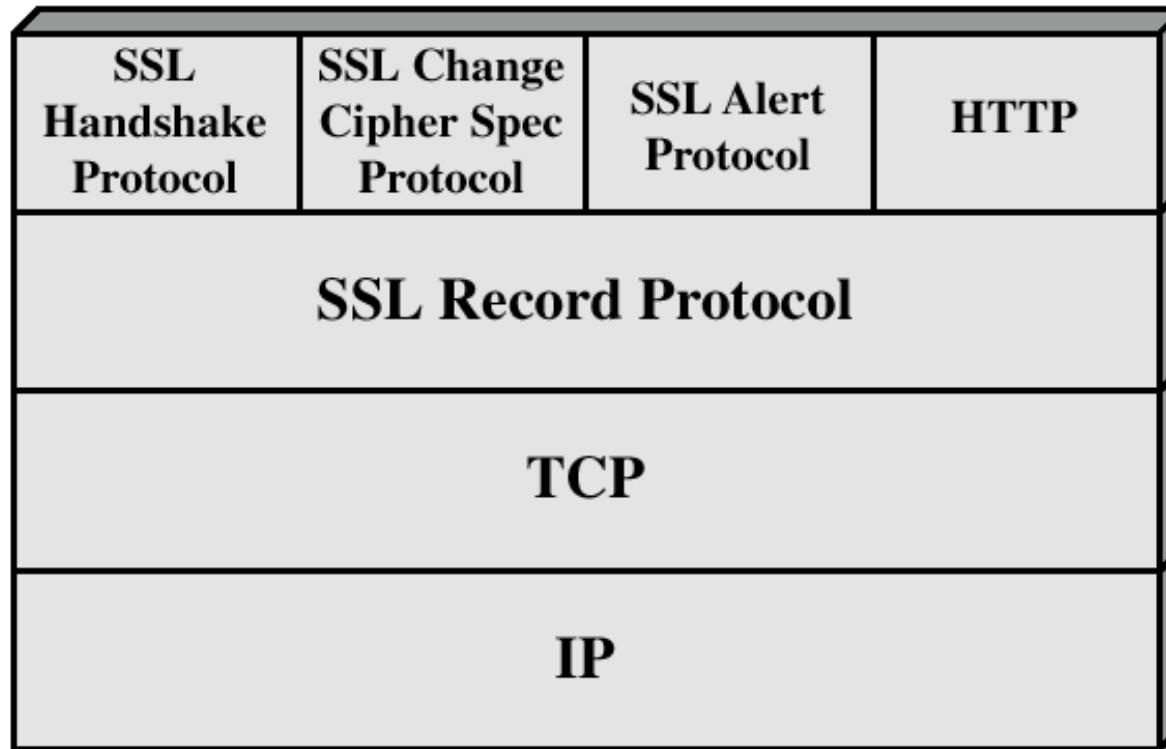


Figure 7.2 SSL Protocol Stack

Real SSL: handshake (1)

Purpose

1. server authentication
2. negotiation: agree on crypto algorithms
3. establish keys
4. client authentication (optional)

Real SSL: handshake (2)

1. client sends list of algorithms it supports, along with client nonce
2. server chooses algorithms from list; sends back: choice + certificate + server nonce
3. client verifies certificate, extracts server's public key, generates pre_master_secret, encrypts with server's public key, sends to server
4. client and server independently compute encryption and MAC keys from pre_master_secret and nonces
5. client sends a MAC of all the handshake messages
6. server sends a MAC of all the handshake messages

Real SSL: handshaking (3)

Why last two messages with MAC exchanged?

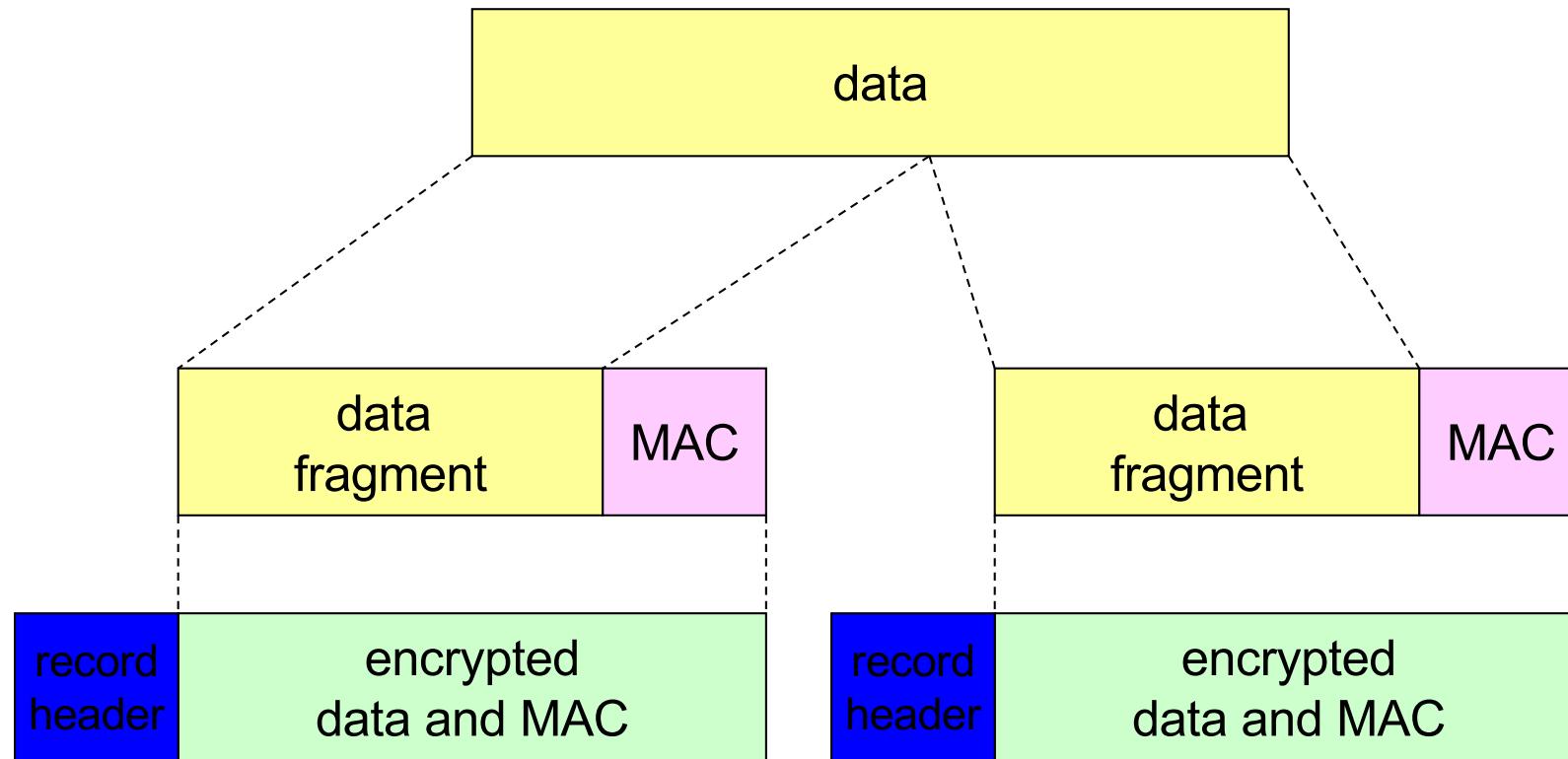
- client typically offers range of algorithms, some strong, some weak
- man-in-the middle could delete stronger algorithms from list
- last 2 steps prevent this
 - last two messages are encrypted

Real SSL: handshaking (4)

Why two random nonces?

- suppose Trudy sniffs all messages between Alice & Bob
- next day, Trudy sets up TCP connection with Bob, sends exact same sequence of records
 - Bob (Amazon) thinks Alice made two separate orders for the same thing
 - solution: Bob sends different random nonce for each connection. This causes encryption keys to be different on the two days
 - Trudy's messages will fail Bob's integrity check

SSL record protocol

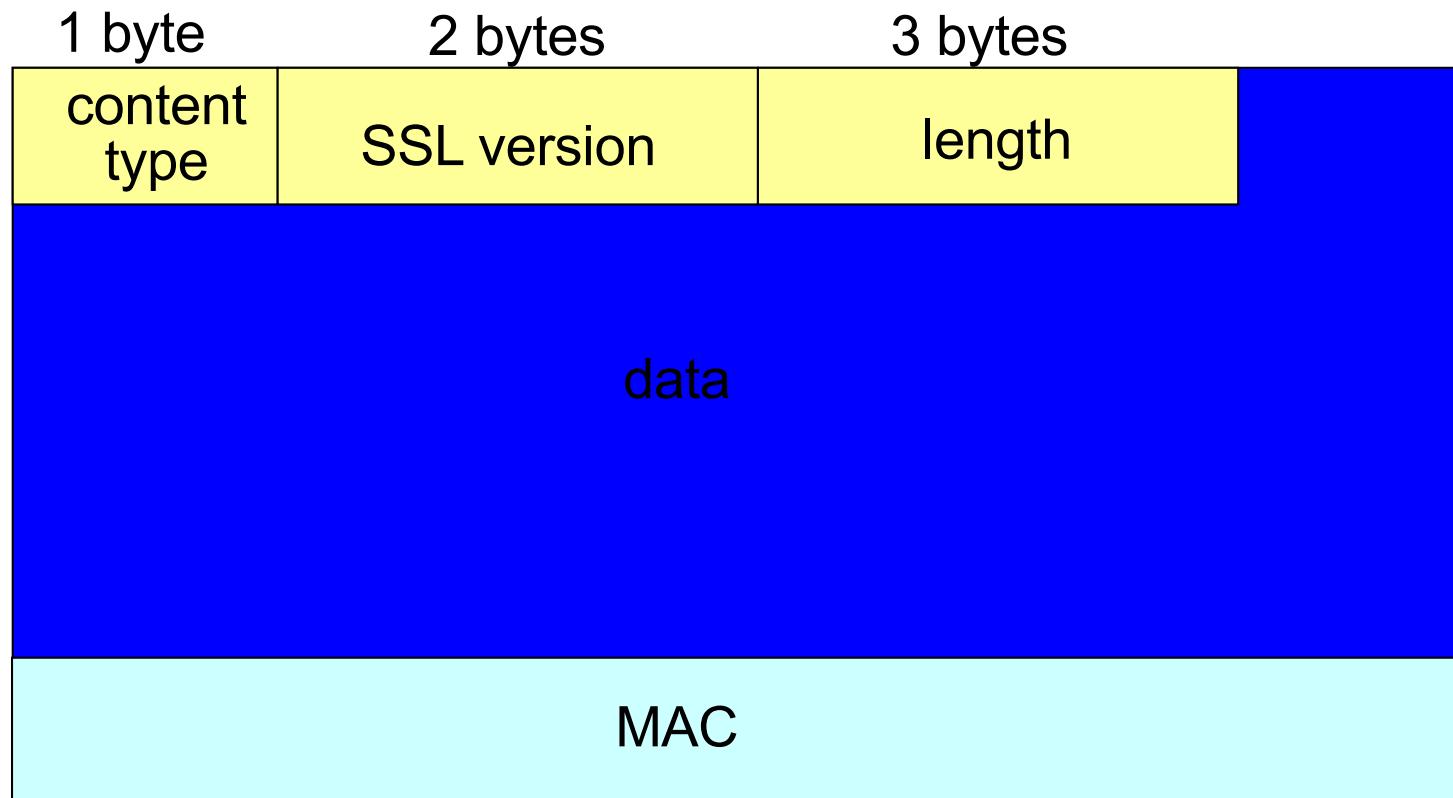


record header: content type; version; length

MAC: includes sequence number, MAC key M_x

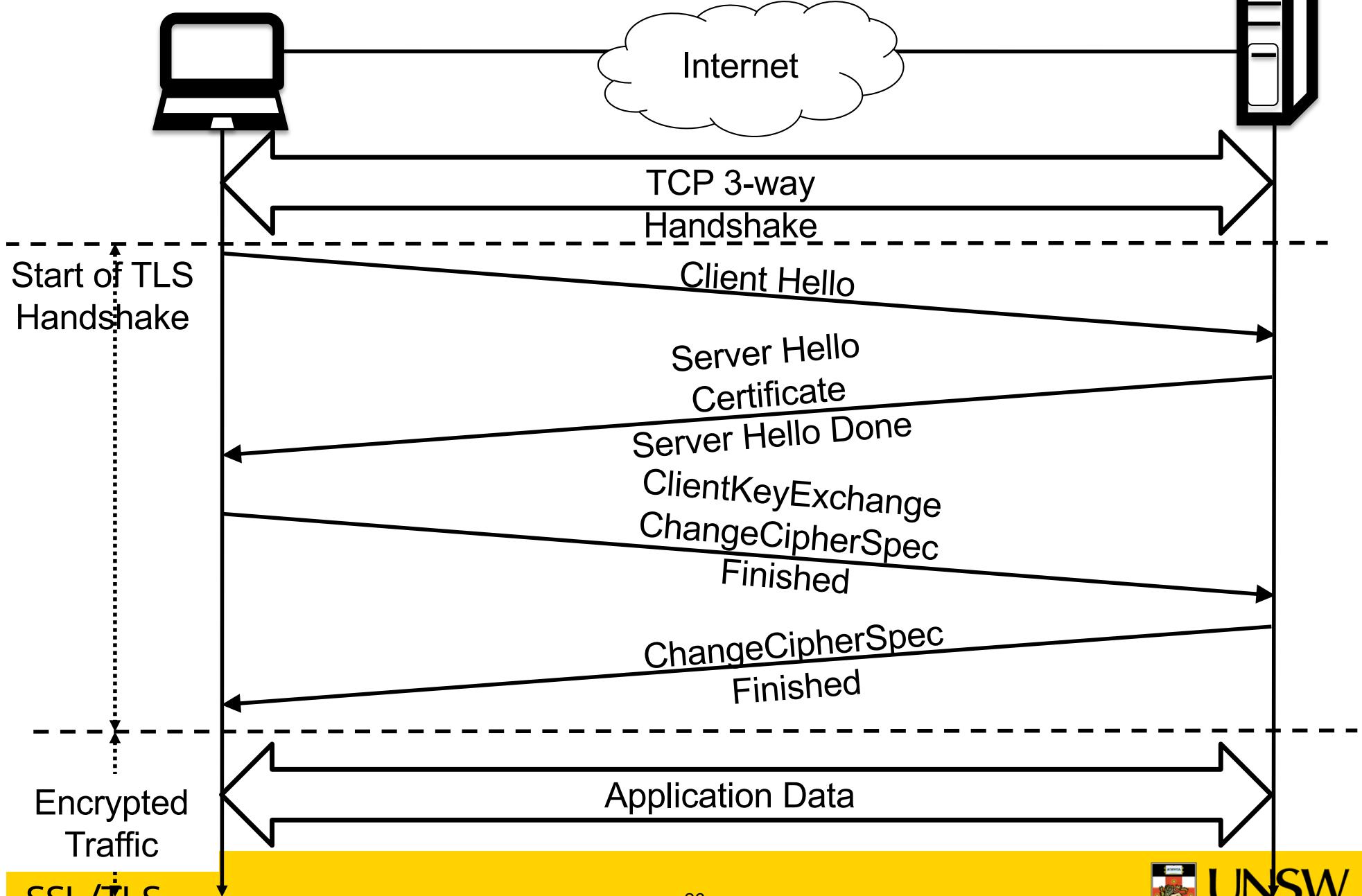
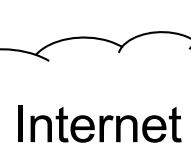
fragment: each SSL fragment 2^{14} bytes (~ 16 Kbytes)

SSL record format



data and MAC encrypted (symmetric algorithm)

Bob (Sender)



Handshake

- First Bob and Alice exchange the three-way TCP SYN, SYNACK and ACK messages.
- Bob then sends a ClientHello message to Alice along with the cipher suites (ciphers and thehash functions it supports) and a nonce, a large, random number, chosen specifically for this run of the protocol.
- Alice responds with a ServerHello message along with her choice from the cipher suites (e.g.,AES for confidentiality, RSA for the public key, SHA2 for the Message Authentication Code (MAC)), a certificate containing her public key and a nonce. Additionally, she could also request the client's certificate and parameters for other TLS extensions.

Handshake (Contd)

有两种方法一种是RSA 用certificate里面alice的public key去加密,另一种用diffie-hellman算法来生成key

- Bob checks validity of the certificate and is assured that it belongs to Alice. He initiates the ClientKeyExchange message. This can use a range of key exchange methods, e.g., RSA or the Diffie-Hellman (and variants) to establish a symmetric key for the ensuing session.
 - For example, when using RSA, Bob could generate a 48-bit Pre-master secret (PMS) and encrypt it with Alice's public key obtained using the steps as described above and send it to Alice.
- Bob sends a ClientCipherSpec and a Finished Message suggesting that the key generation and authentication are complete.
- Alice also has the shared key at this point. She responds with a ChangeCipherSpec and a Finished Message back to Bob.
- Bob decrypts the message with the negotiated symmetric key and performs a message integrity check

Key derivation

用三组伪随机数联成的随机数可以近似称为real随机数然后通过一个generator的计算得到sessionkey

- client nonce, server nonce, and pre-master secret input into pseudo random-number generator.
 - produces master secret
- master secret and new nonces input into another random-number generator: “key block”
- key block sliced and diced:
 - client MAC key
 - server MAC key
 - client encryption key
 - server encryption key
 - client initialization vector (IV)
 - server initialization vector (IV)

Transport Layer Security

- The same record format as the SSL record format.
- Defined in RFC 2246.
- Similar to SSLv3.
- Differences in the:
 - version number
 - message authentication code
 - pseudorandom function
 - alert codes
 - cipher suites
 - client certificate types
 - certificate_verify and finished message
 - cryptographic computations
 - padding

Acknowledgements

- Computer Networking A top-Down Approach: Jim Kurose and Keith Ross, Chapter 8, (foils provided by Authors)
 - Reference section 8.5
- Network Security Essentials: Stallings, 6, Foils provided by Henric Johnson, Blekinge Institute of Technology, Sweden
 - Reference Section 6.2 for SSL
 - Optional read Section 6.3 for TLS
- See Cybok NETWORK SECURITYKNOWLEDGE AREA for references and research papers.