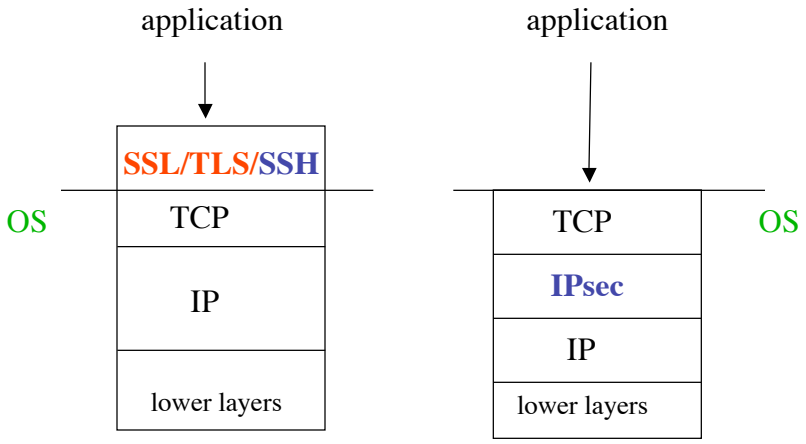
SSL/TLS

SSL/TLS as Real-Time Protocols

- A real-time protocol is one where parties negotiate interactively to authentication each other and establish a session key
- Examples: IPsec, SSL/TLS, SSH
  - Public key based
- SSL: Secure Socket Layer
- TLS: Transport Layer Security

Security at Layer 4 vs. 3



Assumption: TCP/IP are in the OS

SSL/TLS is on top of TCP

- SSL/TLS is in a user-level process
  - No requirement on OS changes
- Relies on TCP to ensure reliable delivery
  - Timing out issues or lost data will be retransmitted
- But relying on TCP introduces the rogue packet problem . . .

The Rogue Packet Problem

- A rogue packet with malicious data can be inserted into TCP stream
- TCP won't notice and forwards that to SSL
  - And will expect next packet in sequence
- SSL discard it
- Now the genuine packet comes
- TCP now discards the packet because the packet appears to be a duplicate :(

How about SSL/TLS Atop UDP?

- Well, it can solve the rogue packet problem
  - UDP does not care about the sequence numbers
- But SSL/TLS then needs to handle reliability issues

A Compromised Decision

- SSL/TLS is on top of TCP, not UDP
  - No worry about reliability issues
- But has to live with the rogue packet problem

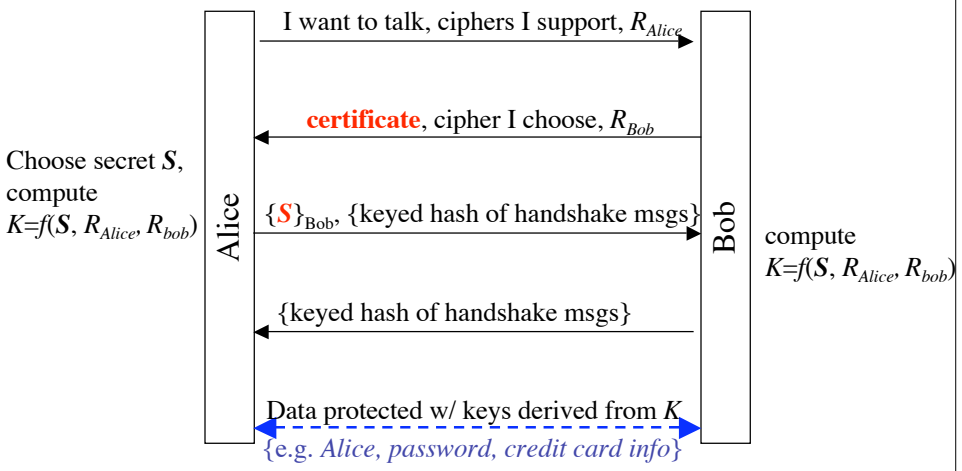
Quick History

- SSLv1: never deployed
- SSLv2: deployed in Netscape Navigator 1.1 in 1995
- Microsoft introduced PCT (Private Communication Tech) by improving SSLv2
- Netscape overhauled the protocol as SSLv3
- IETF introduced TLS to unify all of them
  - Seems just another incompatible protocol

SSL/TLS Processing Unit

- TCP stream is partitioned into records
- Each record has a header and crypto protection
- Four types of records:
  - User data
  - Handshake messages (we focus on this one)
  - Alerts
  - Change cipher spec
    - should be regarded as handshake

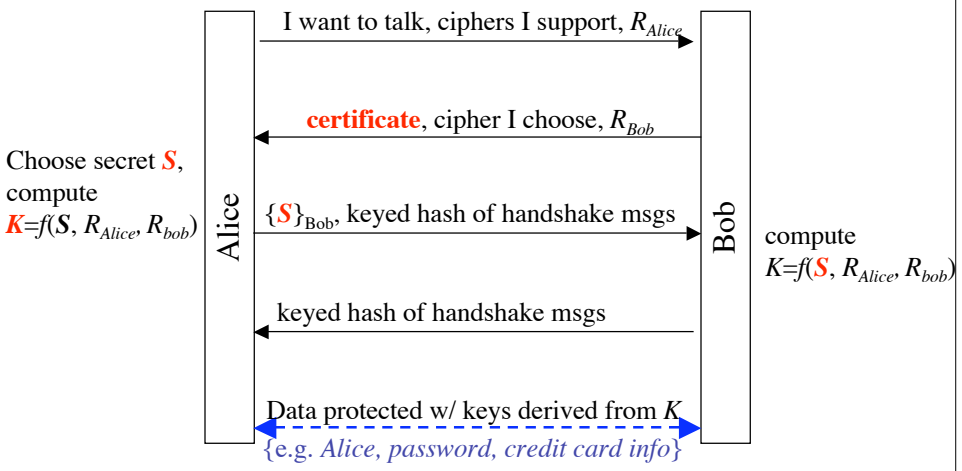
SSLv3/TLS Basic Protocol



Several Important Terms

- $\boldsymbol{R_{Alice}}$: a random number from Alice
- ***S***: pre-master secret
- ***K***: master secret
- $\{\}_{\text{Bob}}$ stands for message encrypted with Bob's public key
- {} stands for **protected** message using encryption and/or integrity protection through secret key algorithm

If a Keyed Hash Result in ***Plaintext***



How Bob Verifies the Key Hash

- Decrypt $\{\boldsymbol{S}\}_{\text{Bob}}$ using his private key
- Compute $\boldsymbol{K}=f(\boldsymbol{S}, R_{Alice}, R_{Bob})$
- Calculate *hash*($\boldsymbol{K}$, (m1, m2, "CLNT"))
  - HMAC algorithm
- Compares the result with the received one
- Verified if equal

- Q: must the keyed hash be protected?

How Alice Verifies the Key Hash

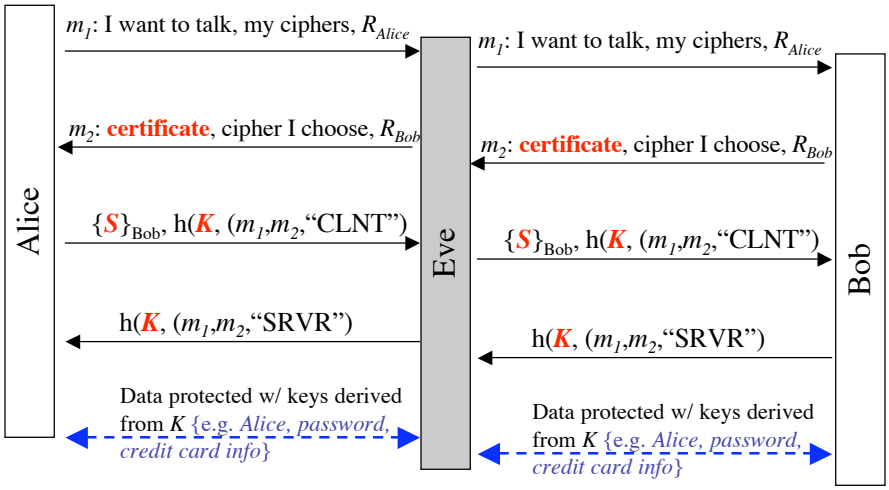
- Calculate *hash*($\boldsymbol{K}$, (m1, m2, "SRVR"))
  - HMAC algorithm
  - Recall Alice knows $\boldsymbol{K}$ already
  - The constant string make the hash different from what Bob receives
- Compares the result with the received one
- Verified if equal

- Q: must the keyed hash be protected?

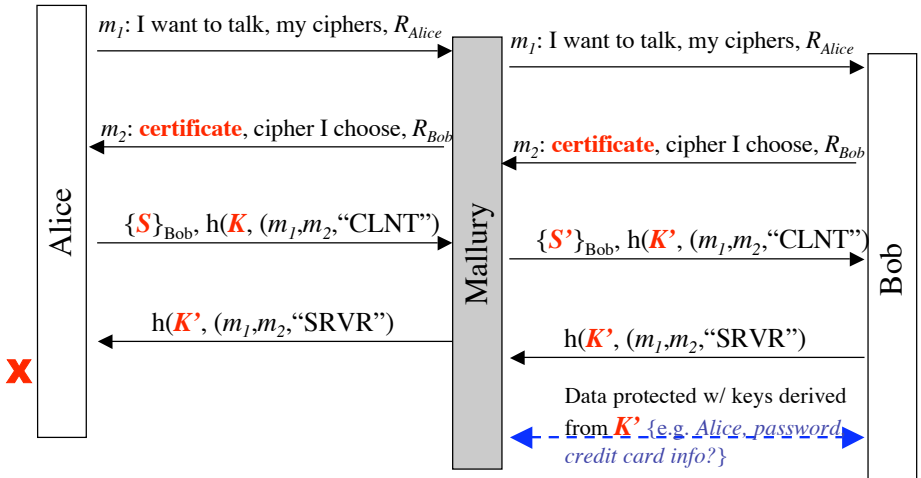
Questions

- Can Eve eavesdrop?
- Can Mallury manipulate the data stream?

When Eve is Eavesdropping



When Mallury is Manipulating



Questions

- When hashing, why add "CLNT" or "SRVR" ?
- What if not?

If Verified, What does Bob Prove?

- The following can be regarded as the same entity:
  - The one sending, or forwarding, message 1
  - the one computing the pre-master secret that Bob received
  - the one sending message 3
- But not necessarily Alice, even claimed so!
  - Could be Mallury!
  - But Alice won't be deceived

If Verified, What does Alice Prove?

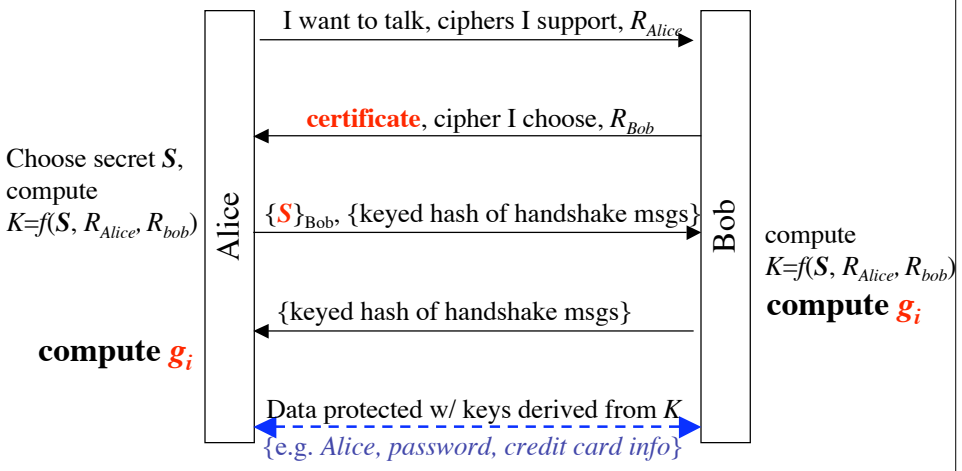
- The following are the same entity:
  - The one sending message 2
  - the one computing ***S*** and ***K*** on the other end, and
  - the one sending message 4
- And this entity is Bob!
  - Based on the certificate
- Also, this entity knows ***S*** and ***K***
  - ***S and K are decided by Alice***
- All handshake messages so far have NOT been tampered
  - Otherwise?

More Issues on SSL/TLS

- Six secrets to protect Alice-Bob communication
- Handling a long *session* with many *connections*
- What if Alice also has a certificate

Six Secrets

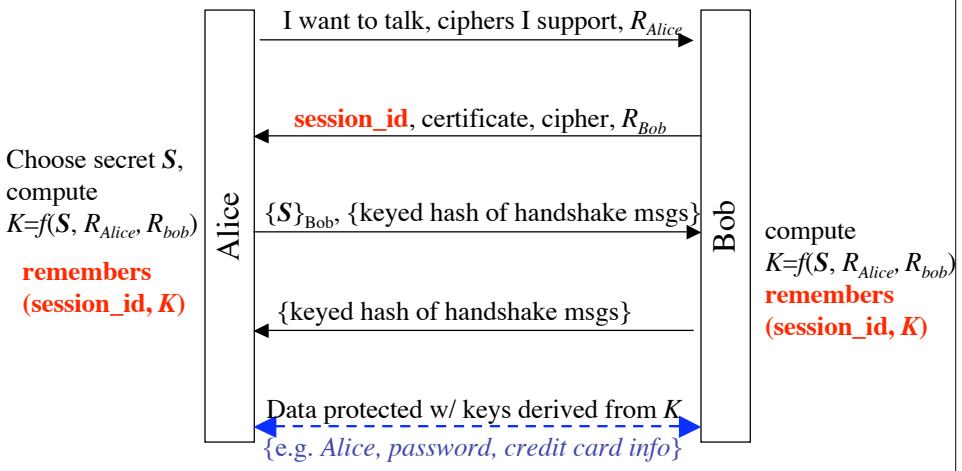
- In fact, it's not a single key ***K*** for a session
- Definition: write keys and read keys
  - Write keys: keys for transmission
  - Read keys: keys for reception
- Each direction needs three write keys
  - Integrity protection key
  - Encryption key
  - IV, if required by encryption algorithms
- And also three read keys
- Computed using $g_i(K, R_{Alice}, R_{Bob})$



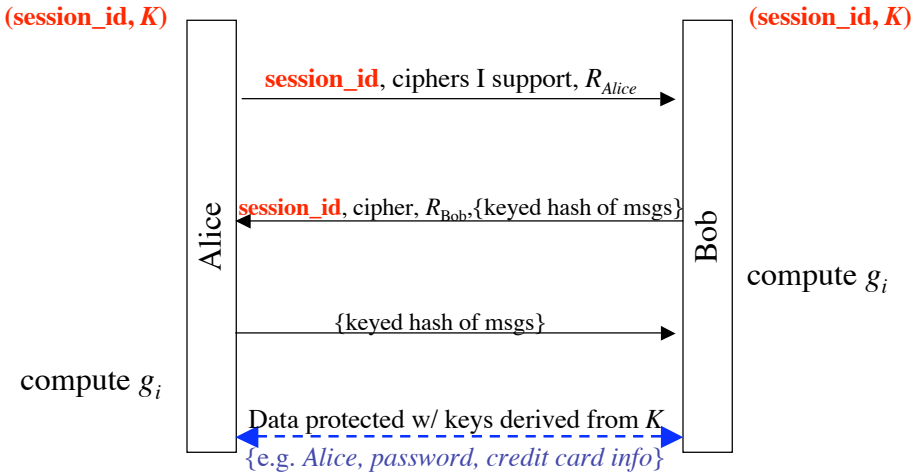
One Session w/ Multiple Connnections

- From a long SSL session, after one connection is set up, many other *connections* can further be derived
  - Alice (a browser) and Bob (a web site) can have many connections, for instance
- Simplify the SSL for later connections between Alice and Bob
  - They have gone through the pain anyway . . .

Session Initiation



Session Resumption



SSL/TLS is Asymmetrical

- Alice authenticated Bob
- But Bob does not authenticate Alice
  - Until Alice login to Bob
    - Kind of late
  - Could be Mallory handshaking with Bob
- SSL/TLS can be enhanced for mutual authentication
  - If the client has a certificate

Quiz 3

- How would the SSL/TLS protocol work if Alice also has a certificate?

Quiz 1: 410avg=4.5 510avg=9.1

Quiz 2: 410avg=3.5 510avg=8.1

Encoding SSL/TLS Protocol

- Read Textbook Page 490 - 497.