Disposition 4: Network Security Mechanisms

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Definition of AKE

An *authenticated key exchange protocol* is a protocol for two parties A, B. Each party starts the protocol with the intention of establishing a key with some other party. At the end, each party outputs either "accept" or "reject" as well as a key. The protocol is said to be secure if the three conditions hold.

Agreement

Agreement: Assume that A intends to talk to B and vice versa. Assume also that both parties accept A and outputs key K_A while B outputs key K_B, then $K_A = K_B$.

Secrecy and Authentication

Secrecy and Authentication: Assume A intends to talk to B, and accepts. Then it must be the case that B participated in the protocol and if B also accepts, he did indeed intend to talk to A. Furthermore, the adversary does not know the key K that A outputs. A symmetric condition holds for B.

Freshness

Freshness: if $A(B)$ follows the protocol and accepts, it is guaranteed that the key K that is output is a fresh key, i.e., it has been randomly chosen for this instance of the protocol, independently of anything else.

About AKE

These properties give us some desirable properties, such as the preventing the following attacks:

- Adversary cannot stop last message in the protocol for party A but not party B
- Freshness means adversary cannot trick you into using old key
- Worst thing adversary can do is attempt to block communication

The N-S protocol

1. A chooses nonce n_A and sends $E_{pk_B}(ID_A, n_A)$ to B.
2. B decrypts, checks ID_A, chooses nonce n_B and sends $E_{pk_A}(n_A, n_B)$ to A.
3. A decrypts and checks that the correct value of n_A appears in the result, and sends $E_{pk_B}(n_B)$ to B.
4. B decrypts and checks that the correct value of n_B appears in the result.
5. If the checks are executed are OK, each party computes the session key as some fixed function of n_A, n_B.

If some third-party E has a certified public key, they can mix two instances of the protocol and fool B.

1. A starts a session with E. A sends $E_{pk_E}(ID_A, n_A)$ to E
2. E decrypts this and starts session with B, pretending to be A. E sends $E_{pk_B}(ID_A, n_A) toB$
3. B decrypts and finds the right ID and sends $E_{pk_A}(n_A, n_B)$ to E
4. E is not able to decrypt, but forwards message $E_{pk_A}(n_A, n_B)$ to A
5. A will decrypt, and find an expected result, and will return $E_{pk_E}(n_B)$ to E
6. E can decrypt it, find n_B and can send $E_{pk_B}(n_B)$ to B
7. When B decrypts it, he can will accept because it's the right value of n_B.

SSL and TLS

SSL protocol for authenticated key exchange

- Uses digital signatures in addition to encryption, as opposed to Needham-Schroeder
- Basic idea: Party must sign a nonce chosen by the other
- Replaced by Transaction Layer Security (TLS), but still refered to as SSL due to minor differences
- SSL is secure against the Needham-Schroeder attack
- SSL sits between application and TCP/IP Transport Layers

SSL protocols

SSL is compromised of the followng protocols

- **Record Protocol**: Responsible for "raw" transmission of data. *cipher spec* determines what kinds of encryption algorithms to use
- **Handshake protocol**: The part of SSL that does the authenticated key exchange
- **Change cipher spec protocol**: Changes the cipher spec
- **Alert protocol**: Error messages

Handshake Protocol

The actual key-exchange protocol worksas follows. This is but one of the variations of the handshake protocol

- C sends a hello message containing nonce n_C
- S sends a nonce n_S and its certificate $Cert_S$ (containing public key pk_S of S)
- C verifies $Cert_S$ and chooses a so called pre master secret pms at random. C sends $E_{pk_S}(pms)$ to S, also C sends its certificate $Cert_C$ to S, plus its signature sig_C on the concat of n_C, n_S and $E_{pk_S}(pms)$
- S verifies $Cert_C$ and sig_C. If OK; it decrypts pms.
- S sends to C a "finished" message containing

Handshake Protocol

- S sends to C a "finished" message containing essentially a MAC all messages he has sent and received sent in this instance of the protocol, with *pms* the secret key.
- C verifies the MAC, and if OK returns its own finished message to S, also with a MAC on all messages sent and received up to this step (note that this now includes the finished message from S, so one cannot just repeat the previous message). S verifies the MAC when it is received.
- At this point both parties derive from n_S, n_C and *pms* a set of keys for secret-key authentication and encryption of the following data exchange.

It is important to point out that there are MAC's on all messages sent. This means that the attacker cannot modify messages sent. This doesn't prove that the interleaving attack doesn't work.

Why is it correct

Consider honest client C who wants to talk to S. C sends pms encrypted under pk_S. Only S will be able to decrypt this. Protocol never asks S for pms When C receives a message with a MAC that verifies using pms, he knows this MAC comes from S. The MAC can be verified w.r.t. all messages C has sent and received it must be the case that S has seen this same of messages on his side. An adversary that sits between C and S can have done nothing except forward all messages unchanged. Conversely, let us see things from the point of view of an honest S who wants to talk to C. He sees a signature from C on a ciphertext c and the nonces, and since he chose one of the nonces himself, he knows the signature and