Authentication II

Cryptographic Hardware for Embedded Systems ECE 3170

Fall 2025

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Reading Assignment

- Please continue reading Chapter 3 of the course textbook by Schneier

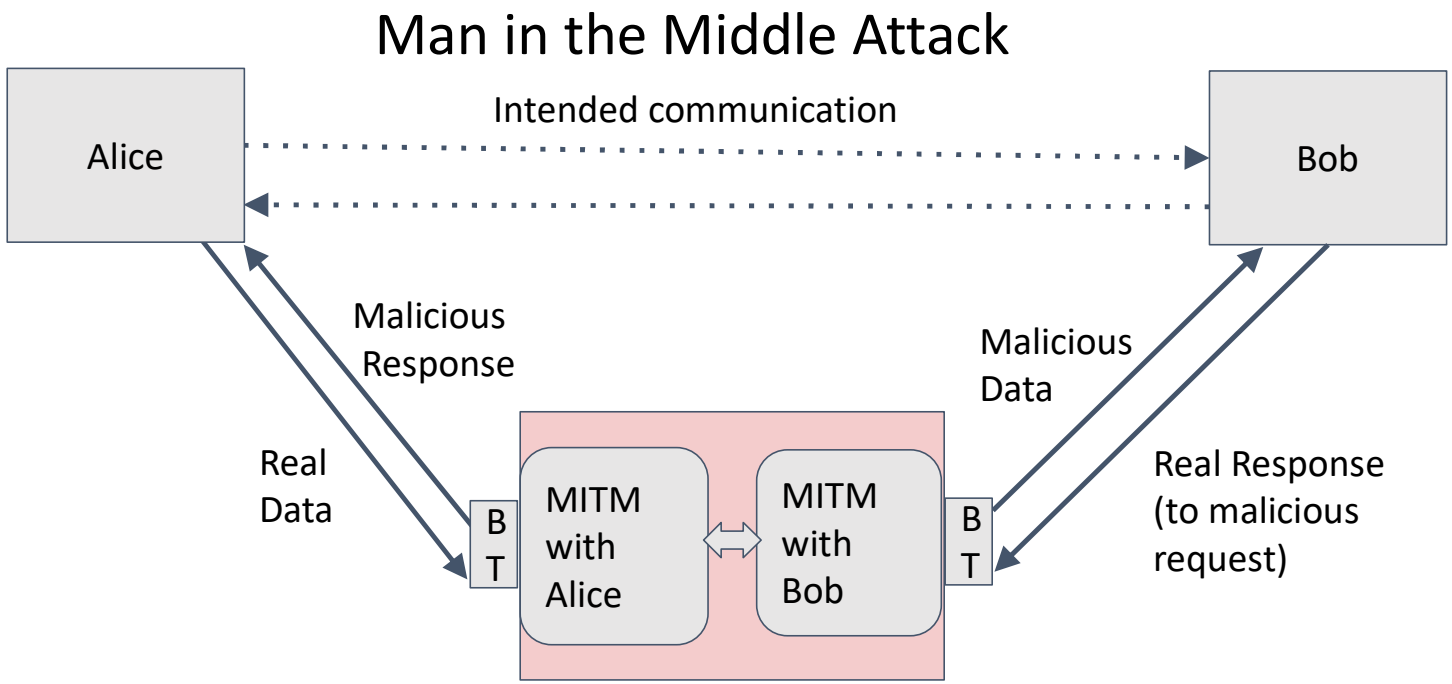
Characters in Use in This Lecture

- Alice is an honest participant in the protocols
- Bob is an honest participant in the protocols
- Mallory is a malicious active attacker
- Trent is a trusted arbiter

Interlock Protocol

- The interlock protocol aims to foil a Man-in-the-Middle attack
  1) Alice sends Bob her public key
  2) Bob sends Alice his public key
  3) Alice encrypts a message for Bob but only sends half of the message
  4) Bob encrypts a message for Alice but only sends half of the message
  5) Alice sends the rest of her message to Bob
  6) Bob puts together both halves of Alice's message and decrypts it; then he sends the rest of his message to Alice
  7) Alice puts together both halves of Bob's message and decrypts it

Threat Scenario



Ways to Require Both Halves For Decryption

- Send every other bit with each half
- Use an initialization vector (IV) which is not sent until the second half is sent
- The first “half” could be a hash of the message

What Exactly Does the Interlock Protocol Stop?

Key Exchange with Digital Signatures

- Trent signs Alice's key and Bob's key
  - $Dec_{Private\_Trent}(Public_{Alice})$
  - $Dec_{Private\_Trent}(Public_{Bob})$
- Note that even if Mallory later breaks into Trent's server and obtains Trent's private key $Private_{Trent}$, Mallory cannot obtain session keys exchanged between Alice and Bob
  - Why not?
- However, Mallory can now potentially carry out Man-in-the-Middle attacks for those who have yet to obtain public keys of others

Password Comparison Using a Hash

- A server need not store every user's password, only the hash
- Alice sends the server her password
- The server calculates the hash of the password
- The server compares the calculated hash value with a stored value of the hash
- If the server is compromised, Alice's password is not revealed

However…

- Most passwords are “weak”
- Dictionary attack
  - Rather than try all possible ASCII combinations, use a dictionary
  - E.g., try all words of eight letters or less, including proper names, and add random ASCII characters to make the length equal to eight
    - Can try also with the first letter capitalized or not

For Every Attack There is a Countermeasure

- Salt
  - Before applying the one-way function (i.e., the hash), use a random number
    - Append the random number to the end of the password
    - XOR the password with a random number of equal length
  - Store each password's random number (i.e., "salt") in a different location
    - E.g., in a separate filesystem with separate access privileges

Number used only Once (NONCE)

- Authentication with asymmetric cryptography
  - Server sends Alice a random number (a “nonce”) in plaintext
  - Alice encrypts the nonce with her private key and sends it back to the server along with her name
  - The server uses Alice’s public key to decrypt the message and verify that the nonce sent by Alice is correct
  - Now the server can proceed with the next steps, e.g., by sending Alice a session key (e.g., a 128-bit AES key) encrypted with Alice’s public key

Actually…

- The previous slide presented one-way authentication, e.g., Alice authenticated herself to the server
- What about communication pretending to be from the server but really from another entity?
- Two-way authentication
  - Server authenticates Alice
  - Alice authenticates the server
  - Then the next steps proceed…

Kerberos

- Alice sends Trent her identity and Bob's: *A*,*B*
- Trent generates key *K* and adds a timestamp *T* plus a lifetime *L*; he then encrypts two messages as follows and sends them to Alice
  - $E_A(T,L,K,B)$; $E_B(T,L,K,A)$
- Alice then uses *K* to send Bob her identity and timestamp, plus Trent's message
  - $E_K(A,T)$; $E_B(T,L,K,A)$
- Bob creates a message consisting of the timestamp plus one, encrypts it in *K*, and sends it to Alice
  - $E_K(T+1)$

Needham-Schroeder (1978)

- Alice to Trent: A, B, R_A
- Trent to Alice: $E_A(R_A,B,K,E_B(K,A))$
- Alice to Bob: $E_B(K,A)$
- Bob to Alice: $E_K(R_B)$
- Alice to Bob: $E_K(R_B\text{-}1)$

An Attack on Needham-Schroeder

- Mallory obtains an old session key K
- Mallory to Bob: $E_B(K,A)$
- Bob to Alice: $E_K(R_B)$
  - Mallory intercepts this message and decrypts it with K
- Mallory to Bob: $E_K(R_B\text{-}1)$

Lessons Learned

- Do not try to be too clever; do not remove important pieces
  - Names
  - Random numbers
  - Timestamps
- Focus on what has worked in the past and has not yet been broken; optimizing a protocol will often break it
- What is your communications need?
  - Client-server
  - Many to many
- Time synchronization can be a big issue
- Recovery