

INTRODUCTION TO COMPUTATIONAL LOGIC
HOMEWORK 5
DUE DATE: DECEMBER 20, 2017

In this homework, we will build a NuSMV model to reconstruct the man-in-the-middle attack to the Needham-Schroeder authentication protocol. Consider a simplified public-key Needham-Schroeder protocol:

- (1) $A \rightarrow B: \{N_a, A\}_{K_b}$
- (2) $B \rightarrow A: \{N_a, N_b\}_{K_a}$
- (3) $A \rightarrow B: \{N_b\}_{K_b}$

where N_a, N_b are the nonces of A, B , and K_a, K_b are the public keys of A, B respectively. Messages encrypted by a party's public key can only be decrypted by the party. At Step (1), A initiates the protocol by sending a nonce and its identity (encrypted by B 's public key) to B . Using its private key, B deciphers the message and gets A 's identity. At Step (2), B sends A 's and its nonces (encrypted by A 's public key) back to A . Using its private key, A decodes the message and checks its nonce is returned. At Step (3), A returns B 's nonce (encrypted by B 's public key) back to B .

Here is the man-in-the-middle attack to the simplified protocol:

- (1A) $A \rightarrow E: \{N_a, A\}_{K_e}$ (A wants to talk to E)
- (1B) $E \rightarrow B: \{N_a, A\}_{K_b}$ (E wants to convince B that it is A)
- (2B) $B \rightarrow E: \{N_a, N_b\}_{K_a}$ (B returns nonces encrypted by K_a)
- (2A) $E \rightarrow A: \{N_a, N_b\}_{K_a}$ (E forwards the encrypted message to A)
- (3A) $A \rightarrow E: \{N_b\}_{K_e}$ (A confirms it is talking to E)
- (3B) $E \rightarrow B: \{N_b\}_{K_b}$ (E returns B 's nonce back)

The NuSMV source code (<http://www.iis.sinica.edu.tw/~bywang/courses/comp-logic/hw3-1.smv>) contains a model for the Needham-Schroeder protocol.

When the attack was found, a fix was proposed to prevent the attack:

- (1) $A \rightarrow B: \{N_a, A\}_{K_b}$
- (2) $B \rightarrow A: \{N_a, N_b, B\}_{K_a}$
- (3) $A \rightarrow B: \{N_b\}_{K_b}$

In Step (2) of the Needham-Schroeder-Lowe protocol, B sends its identity along with the nonces back to A .

For this homework, please turn in two NuSMV files.

- (1) Please write an LTL formula and a NuSMV module `eve` to model the attacker and witness the man-in-the-middle attack.
- (2) Please add the fix to your NuSMV source code and check if the fix prevents the attack.