Practice Problem Set 2: Integrity (MACs & Signatures)

March 19, 2017

MAC security

The following is the security game for message authentication codes (MACs).

- The game master chooses a random k to the MAC.
- The adversary has access to a $MAC_k()$ oracle, that computes MACs on messages of the adversary's choice.
- The adversary has access to a $VER_k(,)$ oracle, that Verifies that a tag t is a valid MAC on a message m; both m and t can be chosen by the adversary.
- The adversary wins if outputs $m*, t*$ such that $m*$ has not been queried to the $MAC_k()$ oracle and $VER_k(m*, t*) = 1$.

We say the MAC is secure if no (polynomial time) adversary can win this game with probability better than about $\frac{1}{2^\ell}$, where ℓ is the length of the MAC tag.

Signature security

The following is the security game for digital signatures.

- The game master chooses a random asymmetric key (PK, SK) for the signature and gives PK to the adversary.
- The adversary has access to a $Sign_{SK}()$ oracle, that computes signatures on messages of the adversary's choice.
- The adversary wins if outputs $m*, \sigma*$ such that $m*$ has not been queried to the $Sign_{SK}()$ oracle and $VER_{PK}(m*, \sigma*) = 1$.

We say the digital signature is secure if no (polynomial time) adversary can win this game with non-negligible probability.

Questions.

Exercise 1. Show that

$$MD5(k||m)$$

is not a secure MAC. That is, present an attack that allows the adversary to win the MAC security game described above.

(Hint: Recall the length extension attack from Lab 1.)

Exercise 2. On Febuary 23, 2017, researchers announced that they found a collision in SHA1. The collision was two files f_1 and f_2 such that $SHA1(f_1) = SHA1(f_2)$. See `shattered.io`.

Consider PKCS #1 v1.5 RSA digital signatures. To sign a message m, the message is hashed and padded as shown below to obtain the padded value $p(m)$:

$$\texttt{00}\quad\texttt{01}\quad\underbrace{\texttt{FF}\cdots\texttt{FF}}_{k/8-38\text{ bytes wide}}\quad\texttt{00}\;\underbrace{\texttt{3021300906052B0E03021A05000414}}_{\text{ASN.1 ``magic'' bytes}}\quad\underbrace{\texttt{XX}\cdots\texttt{XX}}_{\text{SHA1}(m)\text{ (20-bytes)}}$$

Then, the signature is

$$p(m)^d \mod N$$

where N is the RSA modulus, d is the secret RSA decryption exponent, and e is the public encryption exponent. Thus, the public key is (e, N) and the secret key is (d, N).

Present an attack that proves that PKCS #1 v1.5 RSA is not a secure digital signatures when SHA1 is used as the hash function. You must use the two files f_1 and f_2 in your attack.

Exercise 3. Dr Snakeoil markets a new product that he claims protects the integrity of messages.

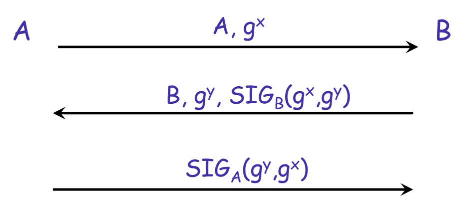
This product requires Alice and Bob to share a secret key 128-bit key k that they will use to authenticate every message they send.

Then, if Alice wants to send a message m to Bob, she breaks the message m up into blocks $m_1, m_2, ..., m_n$ and outputs the tag $t_1, t_2, ..., t_i, ..., t_n$ where each $t_i = HMAC_k(m_i)$.

Alice then sends $m_1, m_2, ..., m_n, t_1, t_2, ..., t_n$ to Bob.

1. Write down the verification algorithm for this scheme.
2. Prove that this scheme is not a secure MAC.

Exercise 4. (Key exchange). Consider the following diffie-helman key-exchange protocol. Recall that the shared key is $k = g^{xy}$, and that $SIG_A(m)$ is the (public-key) digital signature on message m signed by the secret key of A. Suppose that A, B and E all know each other's correct public keys.



After this protocol runs, Alice and Bob send each other messages encrypted and authenticated under the key k.

Suppose there is a man-in-the-middle adversary E that can intercept, add, drop, and the modify the traffic that A sends to B.

1. Suppose that Alice and Bob are running software that has the following implementation flaw: it forgets to validate digital signatures and just accepts any messages it receives as valid.

   Show how Eve E can launch an man-in-the-middle attack, where she can read any of the encrypted and authenticated messages that Alice sends Bob.

2. Now suppose E can launch an "identity misbinding attack" where she convinces B that he shares the key $k = g^{xy}$ with E, while convincing A that she shares $k = g^{xy}$ with B. Explain exactly how E does this. (What messages does she send, and to who?) [Note, with this attack, E doesnt know $k = g^{xy}$ but B considers anything sent by A as coming from E]

3. Give an example of a scenario where your identity misbinding attack might create problems.