Announcements

• Optional HW5 due 3/13
• Midterm Upcoming on 3/15
  – Review sheet posted on course webpage
  – Solutions and Cheat Sheet posted soon on Canvas
Agenda

• Last time:
  – MACs (K/L 4.2, 4.3, 4.4)

• This time:
  – CCA security (K/L 3.7)
  – Authenticated Encryption (K/L 4.5)
  – Class Exercise on MACs
CCA Security

The CCA Indistinguishability Experiment $PrivK_{A,\Pi}^{cca}(n)$:
1. A key $k$ is generated by running $Gen(1^n)$.
2. The adversary $A$ is given input $1^n$ and oracle access to $Enc_k(\cdot)$ and $Dec_k(\cdot)$, and outputs a pair of messages $m_0, m_1$ of the same length.
3. A random bit $b \leftarrow \{0,1\}$ is chosen, and then a challenge ciphertext $c \leftarrow Enc_k(m_b)$ is computed and given to $A$.
4. The adversary $A$ continues to have oracle access to $Enc_k(\cdot)$ and $Dec_k(\cdot)$, but is not allowed to query the latter on the challenge ciphertext itself. Eventually, $A$ outputs a bit $b'$.
5. The output of the experiment is defined to be 1 if $b' = b$, and 0 otherwise.
CCA Security

A private-key encryption scheme \( \Pi = (Gen, Enc, Dec) \) has indistinguishable encryptions under a chosen-ciphertext attack if for all ppt adversaries \( A \) there exists a negligible function \( negl \) such that

\[
\Pr \left[ PrivK^{cca}_{A,\Pi}(n) = 1 \right] \leq \frac{1}{2} + negl(n),
\]

where the probability is taken over the random coins used by \( A \), as well as the random coins used in the experiment.
Authenticated Encryption

The unforgeable encryption experiment $\text{EncForge}_{A,\Pi}(n)$:

1. Run $\text{Gen}(1^n)$ to obtain key $k$.
2. The adversary $A$ is given input $1^n$ and access to an encryption oracle $\text{Enc}_k(\cdot)$. The adversary outputs a ciphertext $c$.
3. Let $m := \text{Dec}_k(c)$, and let $Q$ denote the set of all queries that $A$ asked its encryption oracle. The output of the experiment is 1 if and only if (1) $m \neq \bot$ and (2) $m \notin Q$. 
Authenticated Encryption

Definition: A private-key encryption scheme $\Pi$ is unforgeable if for all ppt adversaries $A$, there is a negligible function $neg$ such that:

$$\Pr[\text{EncForge}_{A,\Pi}(n) = 1] \leq neg(n).$$

Definition: A private-key encryption scheme is an authenticated encryption scheme if it is CCA-secure and unforgeable.
Generic Constructions
Encrypt-and-authenticate

Encryption and message authentication are computed independently in parallel.

\[ c \leftarrow Enc_{k_E}(m) \quad t \leftarrow Mac_{k_M}(m) \]

\[ \langle c, t \rangle \]

Is this secure? NO!
 Authenticate-then-encrypt

Here a MAC tag $t$ is first computed, and then the message and tag are encrypted together.

$$
t \leftarrow \text{Mac}_{k_M}(m) \quad c \leftarrow \text{Enc}_{k_E}(m || t)
$$

$c$ is sent

Is this secure? NO! Encryption scheme may not be CCA-secure.
Encrypt-then-authenticate

The message $m$ is first encrypted and then a MAC tag is computed over the result

$$c \leftarrow Enc_{k_E}(m) \quad t \leftarrow Mac_{k_M}(c)$$

$$\langle c, t \rangle$$

Is this secure? YES! As long as the MAC is strongly secure.