Lecture 16: Encrypting Long Messages
Objective

Earlier, we saw that the length of the secret-key in one-time pad has to be at least the length of the message being encrypted.

Our objective in this lecture is to use smaller secret-keys to encrypt longer messages (that is secure against computationally bounded adversaries).
Recall

- Suppose $f : \{0, 1\}^{2n} \rightarrow \{0, 1\}^{2n}$ is a one-way permutation (OWP).
- Then, we had see that the function $G : \{0, 1\}^n \times \{0, 1\}^n \rightarrow \{0, 1\}^{2n+1}$ defined by
  \[ G(r, x) = (r, f(x), \langle r, x \rangle) \]
  is a one-bit extension PRG.
- Let us represent $f^i(x)$ as a short-hand for $f(\cdots f(f(x))\cdots)$. $f^0(x)$ shall represent $x$.
- By iterating the construction, we observed that we can create a stream of pseudorandom bits by computing
  \[ b_i(r, x) = \langle r, f^i(x) \rangle \] (Note that, if we already have $f^i(x)$ stored, then we can efficiently compute $f^{i+1}(x)$ from it).
- So, the idea is to encrypt long messages where the $i$-th bit of the message is masked with the bit $b_i(r, x)$.
Without loss of generality, we assume that our objective is to encrypt a stream of bits \((m_0, m_1, \ldots)\).

Gen(): Return \(sk = (r, x) \leftarrow \{0, 1\}^{2n}\), where \(r, x \in \{0, 1\}^n\).

Alice and Bob, respectively, shall store their state variables: \(state_A\) and \(state_B\). Initially, we have \(state_A = state_B = x\).

\(Enc_{sk, state_A}(m_i): \ c_i = m_i \oplus \langle r, state_A \rangle\), and update \(state_A = f(state_A)\), where \(sk = (r, x)\).

\(Dec_{sk, state_B}(\tilde{c}_i) = \tilde{m}_i = \tilde{c}_i \oplus \langle r, state_B \rangle\), and update \(state_B = f(state_B)\), where \(sk = (r, x)\).

Note that the \(i\)-th bit is encrypted with \(b_i(r, x)\) and is also decrypted with \(b_i(r, x)\). So, the correctness holds. This correctness guarantee holds as long as the order of the encryptions and the decryptions remain identical.

Note that each bit \(b_i(r, x)\) is uniform and independent of all previous bits (for computationally bounded adversaries). So, the scheme is secure against all computationally bounded adversaries.