Lecture 22: Message Authentication Codes from PRF
In the previous lecture we defined MACs and their security, and constructed them using pseudorandom functions.

In today’s lecture we shall construction MACs using pseudo-random functions.
MAC using Pseudorandom Functions I

Scheme.

- **Secret-key Generation.** Sample $sk$ uniformly at random from $\{0, 1\}^{n/100}$ and provide $sk$ to both the sender and the verifier.

- **Tagging a message** $m \in \{0, 1\}^n$. The sender computes tag $\tau = g_{sk}(m)$ (evaluate using the GGM construction, where we consider functions $\{0, 1\}^n \to \{0, 1\}^{n/100}$ and id in $\{0, 1\}^{n/100}$).

- **Verifying a message-tag pair** $(\tilde{m}, \tilde{\tau})$. Check whether $\tilde{\tau}$ is same as $g_{sk}(\tilde{m})$ or not.
Security

- An adversary cannot forge if it sees $t$ message-tag pairs, where $t = \text{poly}(n)$ and the adversary is computationally bounded. If there exists an adversary who can forge a signature in this case, then we can distinguish the random functions from pseudo-random functions. Because, in the former case, forgeability was not possible for any adversary. However, in the latter case, forgeability is being made possible by this adversary.
The scheme mentioned above is secure ONLY for messages in $\{0, 1\}^n$ and NOT $\{0, 1\}^*$.

What does it mean?

- The set $\{0, 1\}^n$ represents $n$-bit messages, and $\{0, 1\}^*$ represents arbitrary-length messages. This scheme is secure only when an adversary sees message-tag pairs for messages $m_1, m_2, \ldots, m_t$ such that all of them have identical length $n$. Moreover, the adversary has to forge by producing $(m', \tau')$ pair such that the length of the message $m'$ is exactly $n$.

- The scheme is not secure if the adversary can produce a message of a different length. The attack is explained in the next slide.
Adversarial strategy to forge a message-tag pair of different length.

- Suppose the adversary has seen a message-tag pair \((m, \tau)\) such that \(\tau = F_{sk}(m)\)
- The adversary creates \(m' = m0\) (i.e., the message \(m\) concatenated at the end with 0). The adversary computes \(\tau'\) as the first half of \(G(\tau)\).
- Verify that \(F_{sk}(m') = \tau'\)
- In fact, the adversary can successfully tag any \(m'\) such that \(m\) is the prefix of \(m'\)
The sender and the verifier should establish one secret-key \( sk \) for EACH length of the message that they want to sign. For example

- They establish a secret-key \( sk \in \{0, 1\}^k \) for 1024-bit messages and use \( F_{sk}(m) \) as the tag for 1024-bit messages \( m \).
- If they want to tag 2048-bit messages, then they establish a new secret-key \( sk' \in \{0, 1\}^k \) and use \( F_{sk'}(m) \) as the tag for 2048-bit messages \( m \).
- The verifier should only check the validity of the tags corresponding to 2048-bit messages using the secret-key associated with message-length 2048 (in our case, it is the secret-key \( sk' \)).
Suppose we want to construct a MAC so that if $t$-parties among a set of $n$-parties decide to endorse a message $m$, then they can add a tag that the verifier can verify. How to construct such a scheme?