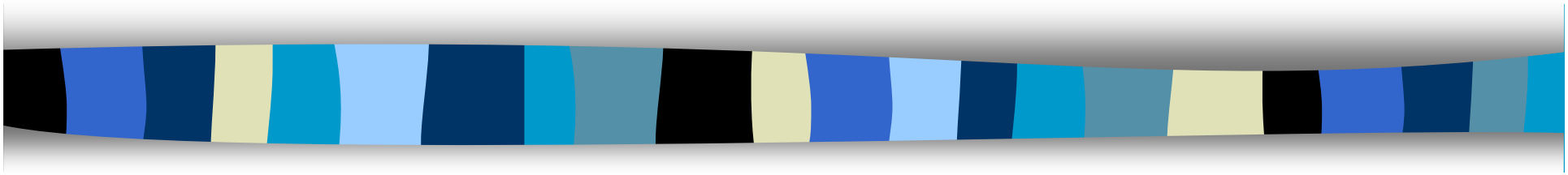
Computer Security
CS 426
Lecture 6



Cryptography: Message Authentication Code

Announcements

- Homework 1 handled out on Sept 1, due on Sept 10
- Will have first quiz on Sept 8

Limitation of Using Hash Functions for Authentication

- Require an authentic channel to transmit the hash of a message
  - anyone can compute the hash value of a message, as the hash function is public
  - not always possible
- How to address this?
  - use more than one hash functions
  - use a key to select which one to use

Hash Family

- A hash family is a four-tuple (X, Y, K, H), where
  - X is a set of possible messages
  - Y is a finite set of possible message digests
  - K is the keyspace
  - For each $K \in \mathcal{K}$, there is a hash function $h_K \in H$. Each $h_K: X \rightarrow Y$
- Alternatively, one can think of H as a function $K \times X \rightarrow Y$

Message Authentication Code

- A MAC scheme is a hash family, used for message authentication
- MAC = $C_K(M)$
- The sender and the receiver share K
- The sender sends (M, $C_k(M)$)
- The receiver receives (X,Y) and verifies that $C_K(X)=Y$, if so, then accepts the message as from the sender
- To be secure, an adversary shouldn't be able to come up with (X',Y) such that $C_K(X)=Y$.

Example of Insecure Hash Families

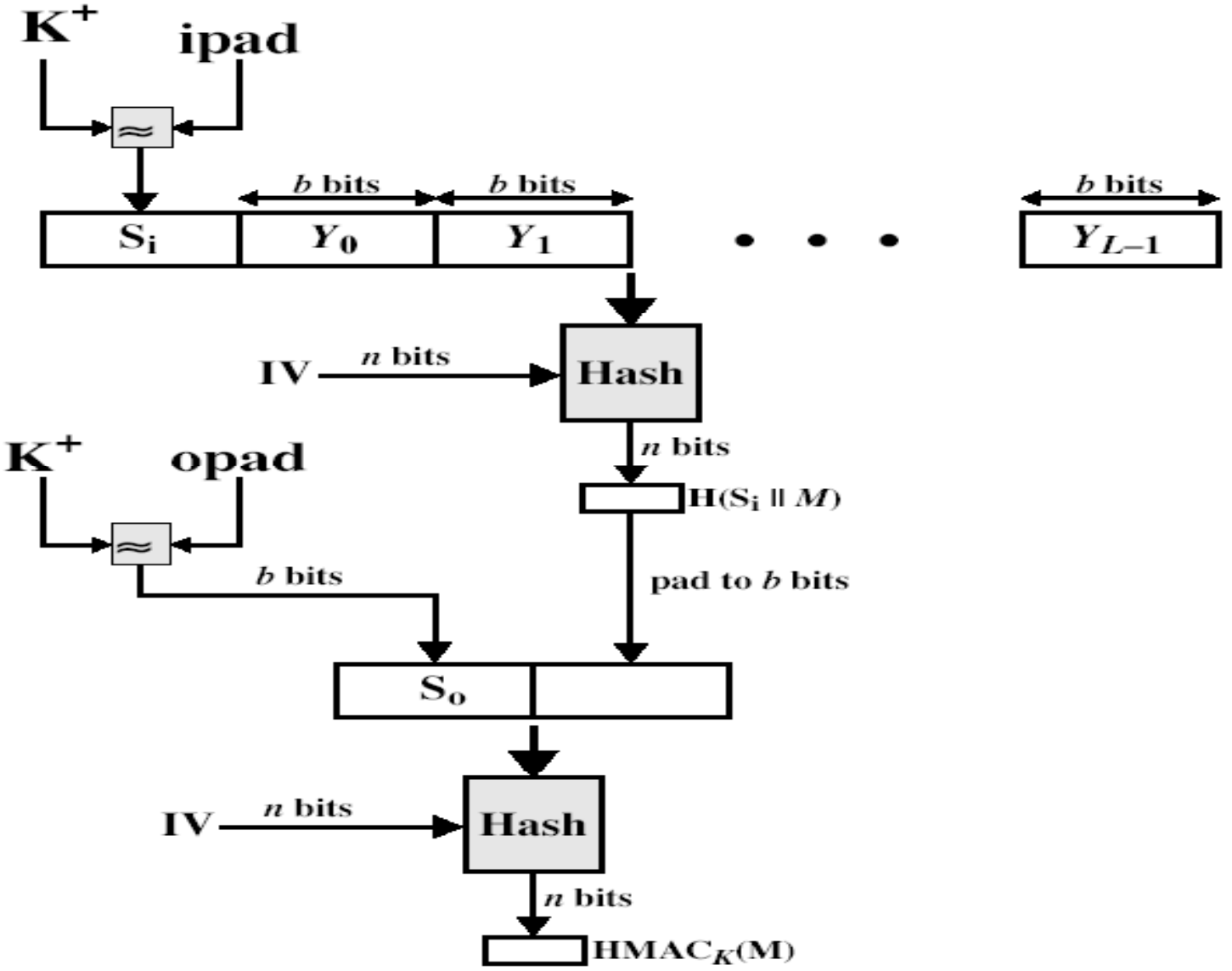
- Let h be a one-way hash function
- H(K,M) = h(K || M), where || denote concatenation
  - Insecure as MAC
  - Given M and a=h(K || M), can compute M'=M||… and a', such that h(K||M') = a'
- H(K,M) = h(M || M),
  - Also insecure as MAC

HMAC: Constructing MAC from Cryptographic Hash Functions

$$HMAC_K[M] = Hash[(K^+ \oplus opad) \,||\, Hash[(K^+ \oplus ipad)||M)]]$$

- K^+ is the key padded (with 0) to B bytes, the input block size of the hash function
- ipad = the byte 0x36 repeated B times
- opad = the byte 0x5C repeated B times.

HMAC Overview



HMAC Security

- If used with a secure hash functions (e.g., SHA-256) and according to the specification (key size, and use correct output), no known practical attacks against HMAC

Encryption and Authentication

- Three ways for encryption and authentication
  - Authenticate-then-encrypt (AtE), used in SSL
    - a = MAC(x), C=E(x,a), transmit C
  - Encrypt-then-authenticate (EtA), used in IPSec
    - C=E(x), a=MAC(C), transmit (C,a)
  - Encrypt-and-authenticate (E&A), used in SSH
    - C=E(x), a=MAC(x), transmit (C,a)
- Which way provides secure communications when embedded in a protocol that runs in a real adversarial network setting?

Encryption Alone May Be Insufficient for Privacy

- If an adversary can manipulate a ciphertext such that the observable behavior (such as success or failure of decryption) differs depending on the content of plaintext, then information about plaintext can be leaked
- To defend against these, should authenticate ciphertext, and only decrypt after making sure ciphertext has not changed
- Encrypt-then-authenticate (EtA) is secure
  - C=E(x), a=MAC(C), transmit (C,a)

Encryption Alone May Be Insufficient for Privacy: An Artificial Example

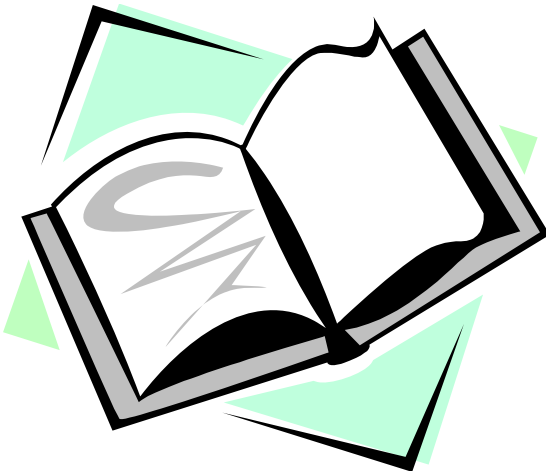
- Given a secure stream cipher (or even one-time pad) E, Consider encryption E*
  - E*[x] = E[encode[x]]
    - encode[x] replaces 0 with 00, and 1 with either 01 or 10.
  - How to decrypt?
  - E*[x] is secure
- Using E* may not provide confidentiality in some usage
  - Consider the case an adversary flips the first two bits of E*[x]
  - When the bits are 01 or 10, flipping results in no change after decrypt
  - When the bits are 00, flipping result in decryption failure
  - Learning whether decryption succeeds reveal first bit

AtE and E&A are insecure

- Authenticate-then-encrypt (AtE) is not always secure
  - a = MAC(x), C=E(x,a), transmit C
  - As first step is decryption, its success or failure may leak information.
  - AtE, however, can be secure for some encryption schemes, such as CBC or OTP (or stream ciphers)
- Encrypt-and-authenticate (E&A) is not secure
  - C=E(x), a=MAC(x), transmit (C,a)
  - MAC has no guarantee for confidentiality

Readings for This Lecture

- Wikipedia
  - Message Authentication Code
- Optional reading
  - Hugo Krawzyck.: The Order of Encryption and Authentication for Protecting Communications”



Coming Attractions …

- Operating System Security Basics