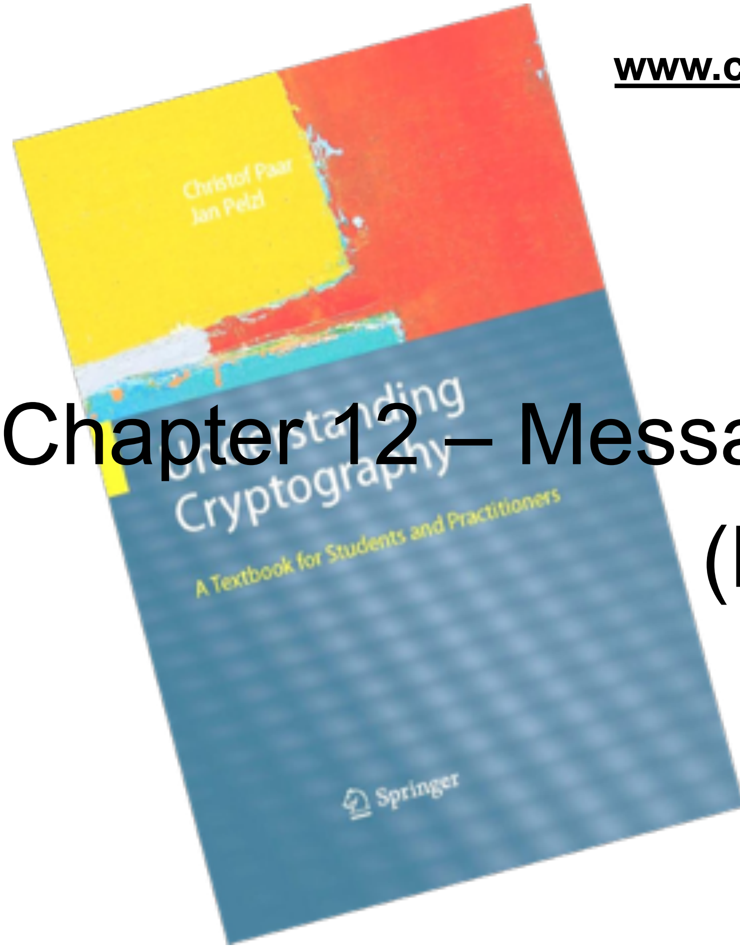
Understanding Cryptography

by Christof Paar and Jan Pelzl

www.crypto-textbook.com



Chapter 12 – Message Authentication Codes (MACs)

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These slides were prepared by Christof Paar and Jan Pelzl
And modified by Sam Bowne

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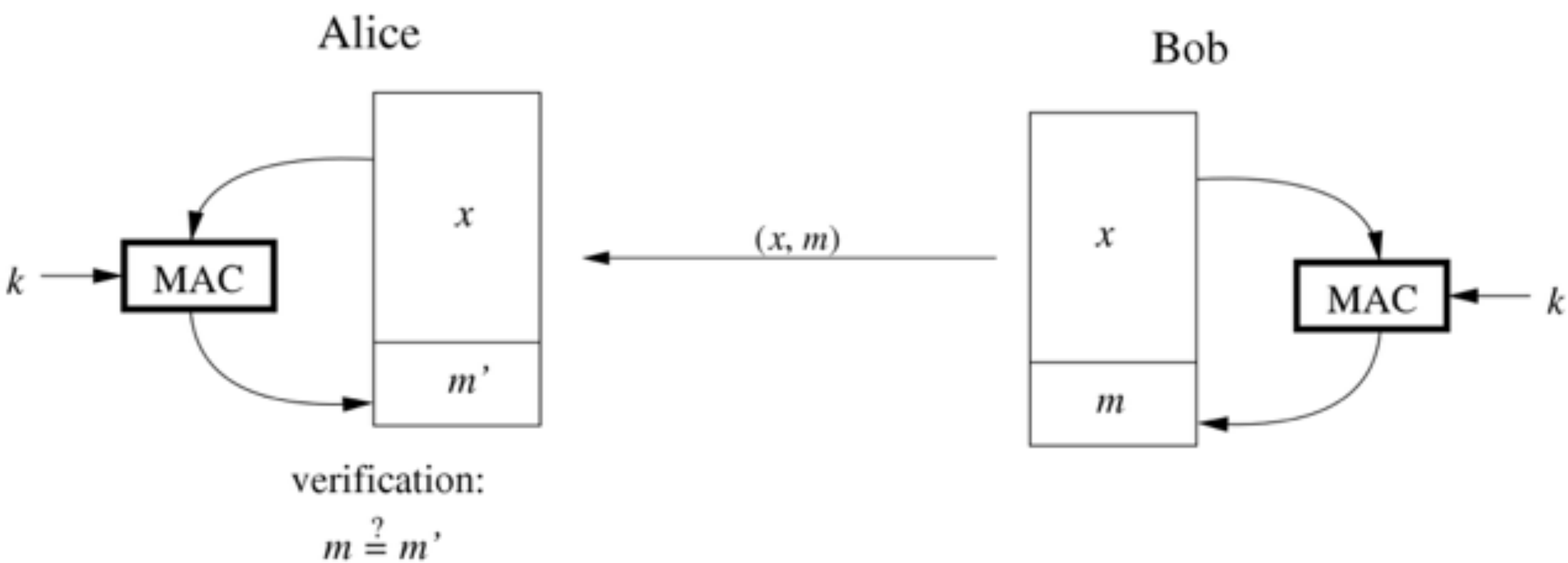
Contents of this Chapter

12.1

Principles of Message Authentication Codes

Principle of Message Authentication Codes

- Similar to digital signatures, MACs append an authentication tag to a message
- MACs use a symmetric key *k* for generation and verification
- Computation of a MAC: $m = MAC_k(x)$



Properties of Message Authentication Codes

1. **Cryptographic checksum**
   A MAC generates a cryptographically secure authentication tag for a given message.
2. **Symmetric**
   MACs are based on secret symmetric keys. The signing and verifying parties must share a secret key.
3. **Arbitrary message size**
   MACs accept messages of arbitrary length.
4. **Fixed output length**
   MACs generate fixed-size authentication tags.
5. **Message integrity**
   MACs provide message integrity: Any manipulations of a message during transit will be detected by the receiver.
6. **Message authentication**
   The receiving party is assured of the origin of the message.
7. **No nonrepudiation**
   Since MACs are based on symmetric principles, they do not provide nonrepudiation.

12.2

MACs from Hash Functions: HMAC

MACs from Hash Functions

- MAC is realized with cryptographic hash functions (e.g., SHA-1)
- HMAC is such a MAC built from hash functions
- Basic idea: Key is hashed together with the message
- Two possible constructions:
  - secret prefix MAC: $m = MAC_k(x) = h(k||x)$
  - secret suffix MAC: $m = MAC_k(x) = h(x||k)$

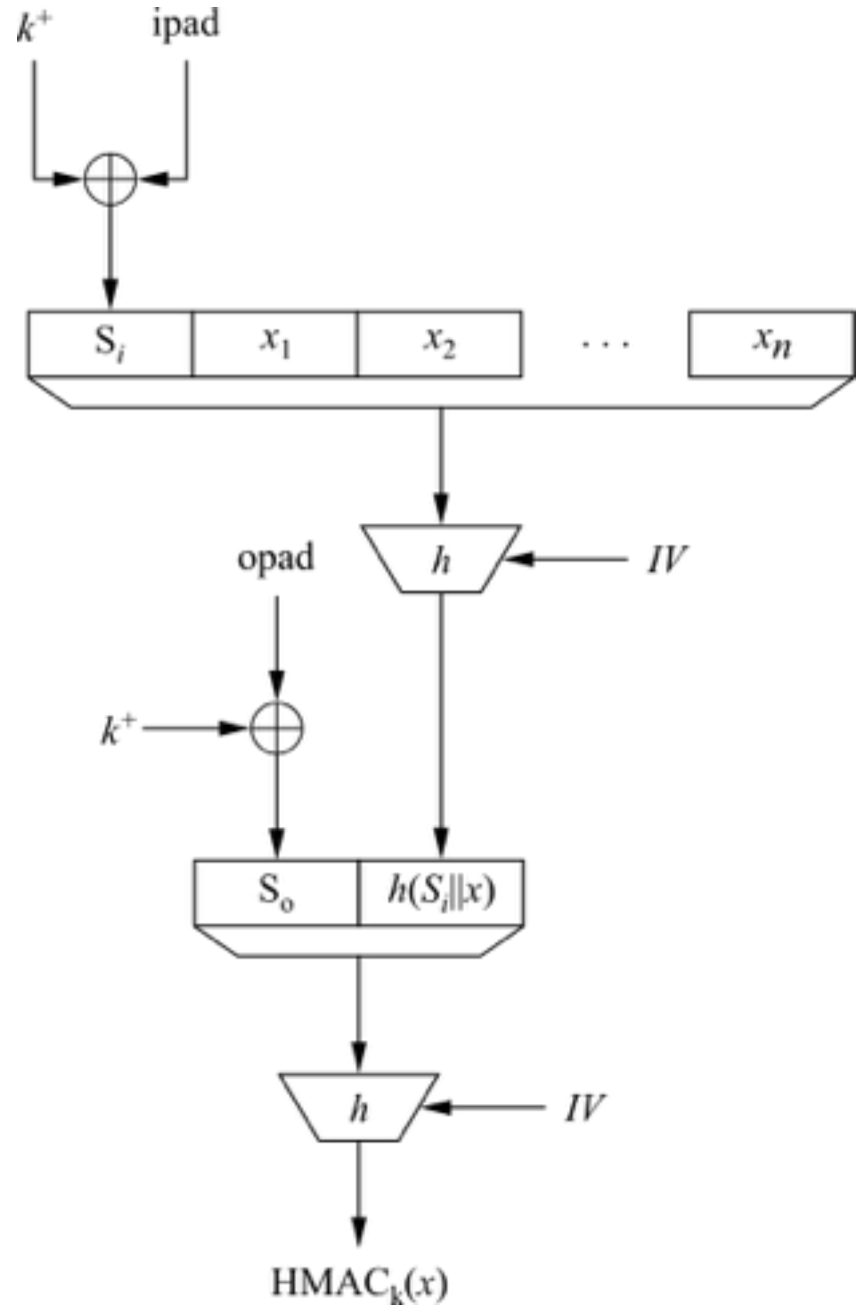
MACs from Hash Functions: Attacks

- Secret prefix MAC: Attack MAC for the message $x = (x1, x2, \ldots, xn, xn+1)$, *where* $xn+1$ is an arbitrary additional block, can be constructed from m *without knowing the* secret key
- Secret suffix MAC: find collision x and xO such that $h(x) = h(xO)$, then $m = h(x||k) = h(x_O||k)$
- Idea: Combine secret prefix and suffix: HMAC (cf. next slide)

HMAC

- Proposed by Mihir Bellare, Ran Canetti and Hugo Krawczyk in 1996
- Uses two hashes: **inner** & **outer**
    - k^+ is key *k* padded with zeroes to the block length of the hash function
    - expanded key k^+ is XORed with the inner pad
    - ipad = 00110110 *repeated*
    - opad = 01011100 *repeated*
- $HMAC_k(x)$ =

  $h[(k^+ \oplus \text{opad}) \,||\, h[(k^+ \oplus \text{ipad}) \,||\, x]]$



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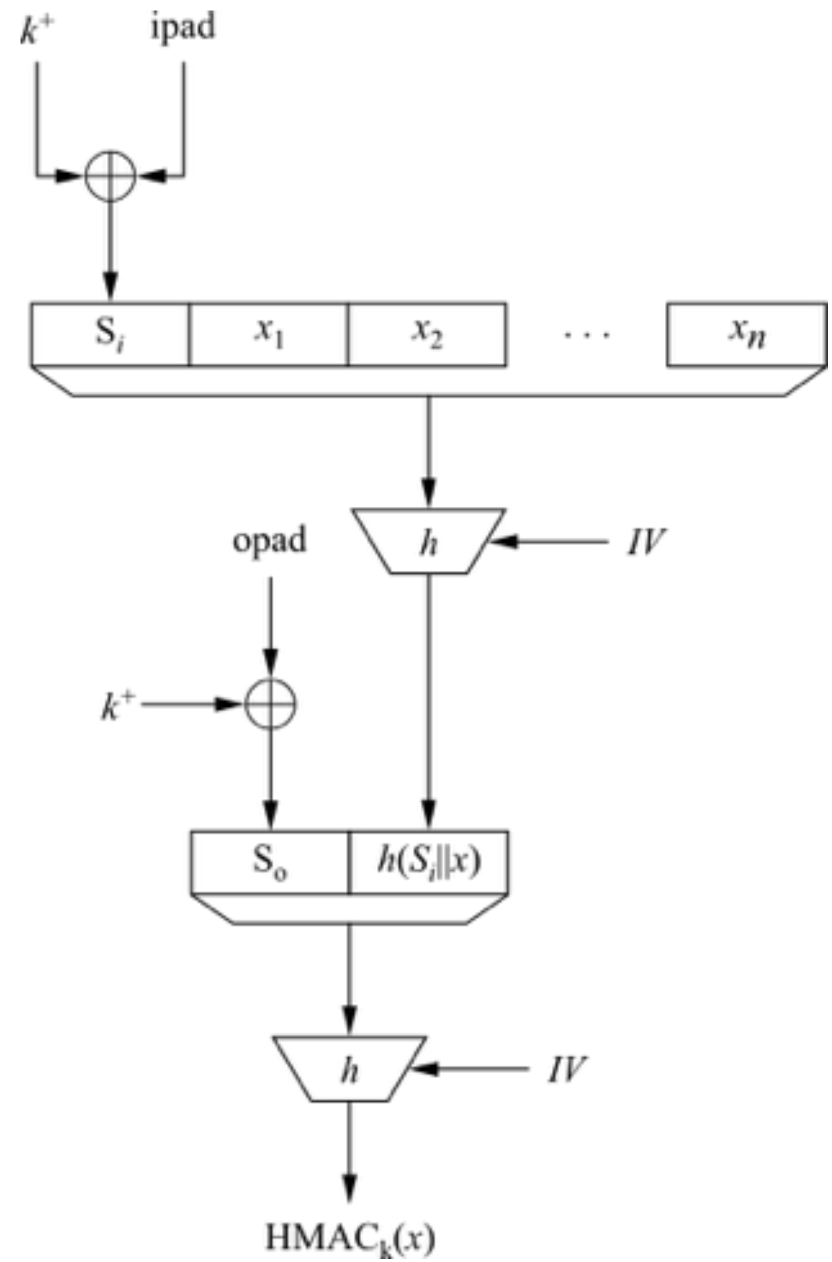
HMAC

- HMAC is provably secure
- The MAC can only be broken if a collision for the hash function can be found.



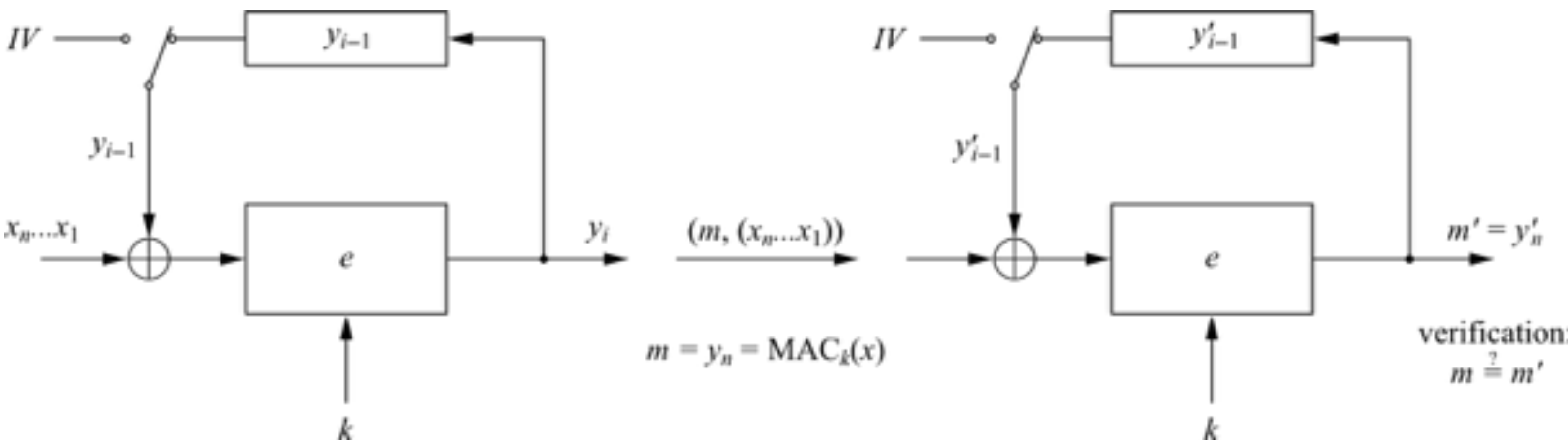
12.3

MACs from Block Ciphers: CBC-MAC

MACs from Block Ciphers

- MAC constructed from block ciphers (e.g. AES)
- Popular: Use AES in CBC mode

- CBC-MAC:



CBC-MAC

- MAC Generation
  - Divide the message x into blocks x_i
  - Compute first iteration $y_1 = e_k(x_1 \oplus IV)$
  - Compute $y_i = e_k(x_i \oplus y_{i-1})$ for the next blocks
  - Final block is the MAC value: $m = MAC_k(x) = y_n$

- MAC Verification
  - Repeat MAC computation (m')
  - Compare results: In case $m' = m$, the message is verified as correct
  - In case $m' \neq m$, the message and/or the MAC value m has been altered during transmission

12.4

Galois Counter Message Authentication Code: GMAC

CBC-MAC

- MAC Generation
  - Divide the message x into blocks x_i
  - Compute first iteration $y_1 = e_k(x_1 \oplus IV)$
  - Compute $y_i = e_k(x_i \oplus y_{i-1})$ for the next blocks
  - Final block is the MAC value: $m = MAC_k(x) = y_n$

- MAC Verification
  - Repeat MAC computation (m')
  - Compare results:In case $m' = m$, the message is verified as correct
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Lessons Learned

- MACs provide two security services, *message integrity and message authentication,* using symmetric techniques. MACs are widely used in protocols.
- Both of these services also provided by digital signatures, but MACs are much faster as they are based on symmetric algorithms.
- MACs do not provide nonrepudiation.
- In practice, MACs are either based on block ciphers or on hash functions.
- HMAC is a popular and very secure MAC, used in many practical protocols such as TLS.

Kahoot!