CS 465
Computer Security

MAC: Message Authentication Code

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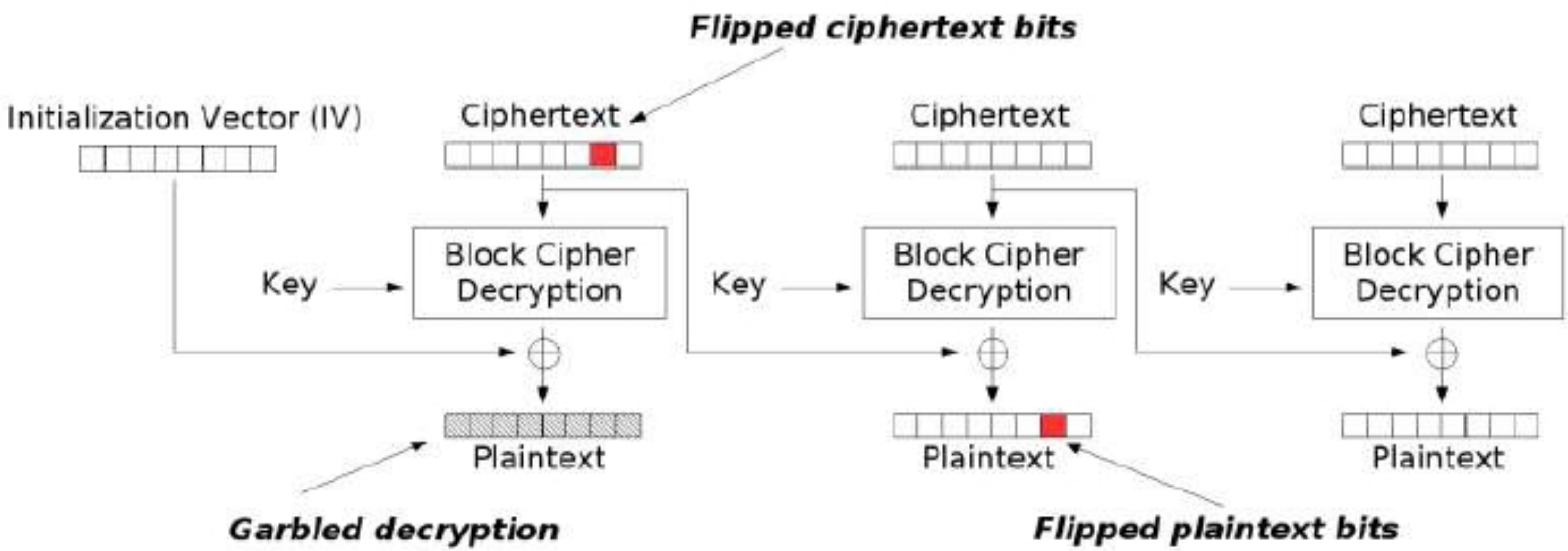
What Assurances are Provided by Symmetric Encryption?

Assume CTR or CBC mode

- Authentication?
- Confidentiality?
- Integrity?
- Non-repudiation?

Bit Flipping Attacks (Block Cipher)

Modification attacks on CBC



Modification attack on CBC

Bit Flipping Attacks (Stream Cipher)

- Plaintext:
  - ACCT_NO:123-45-6789 ADD:100
- Ciphertext:
  - 15b1206b7efa68b9 89 c87357507e3a27a138ca dc b2a1bb f8 eebee5

Goals of Message Authentication

- Assure that the message has not been altered

- Assure the source of the message is authentic

Message Authentication: Ciphertext vs. Plaintext

- Authentication of encrypted messages
  - Include an error-detection code in plaintext message
  - Attach a key-based error-detection code to an encrypted message
  - Attach a TAG – remember the newer AEAD modes
- Authentication of plaintext messages
  - Authentication without confidentiality
  - Attach a key-based error-detection code to plaintext message

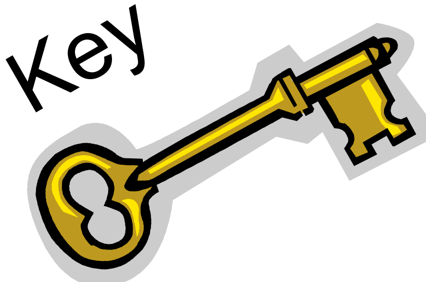
Message Authentication Code (MAC)

Dear BYU,

Thank you so much for an awesome computer security course.

Sincerely,
Emma

Key



MAC Algorithm

This message really is from me and hasn't been modified

Message Authentication Code (MAC)

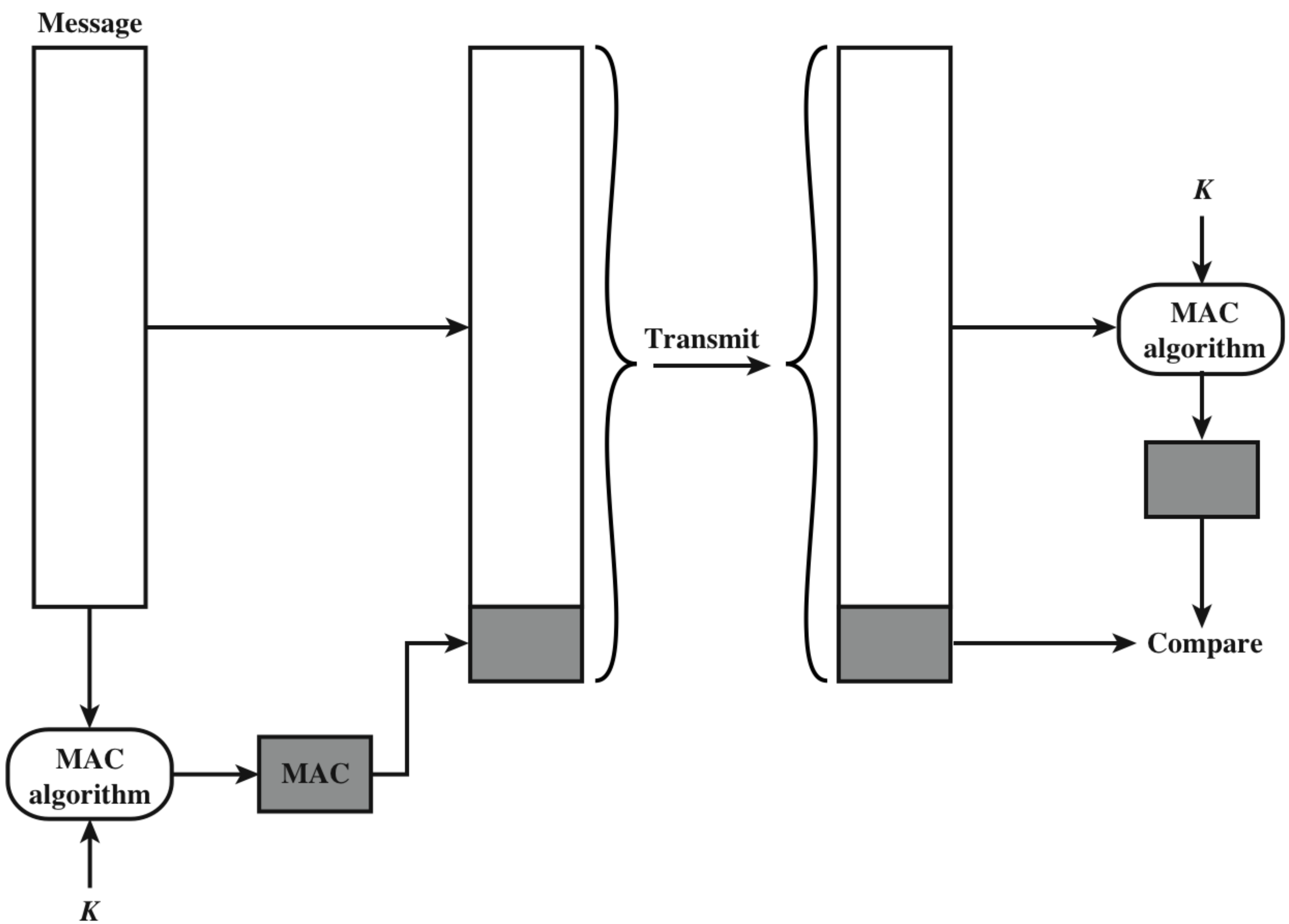


Figure 3.1 Message Authentication Using a Message Authentication Code (MAC)

Source: Network Security Essentials (Stallings)

Three Ways to Implement a MAC

1. CBC-MAC

- Use CBC mode and a block cipher — fixed length messages only
- OMAC — for variable length messages

Source: Network Security Essentials (Stallings)

OMAC1 (also called CMAC)

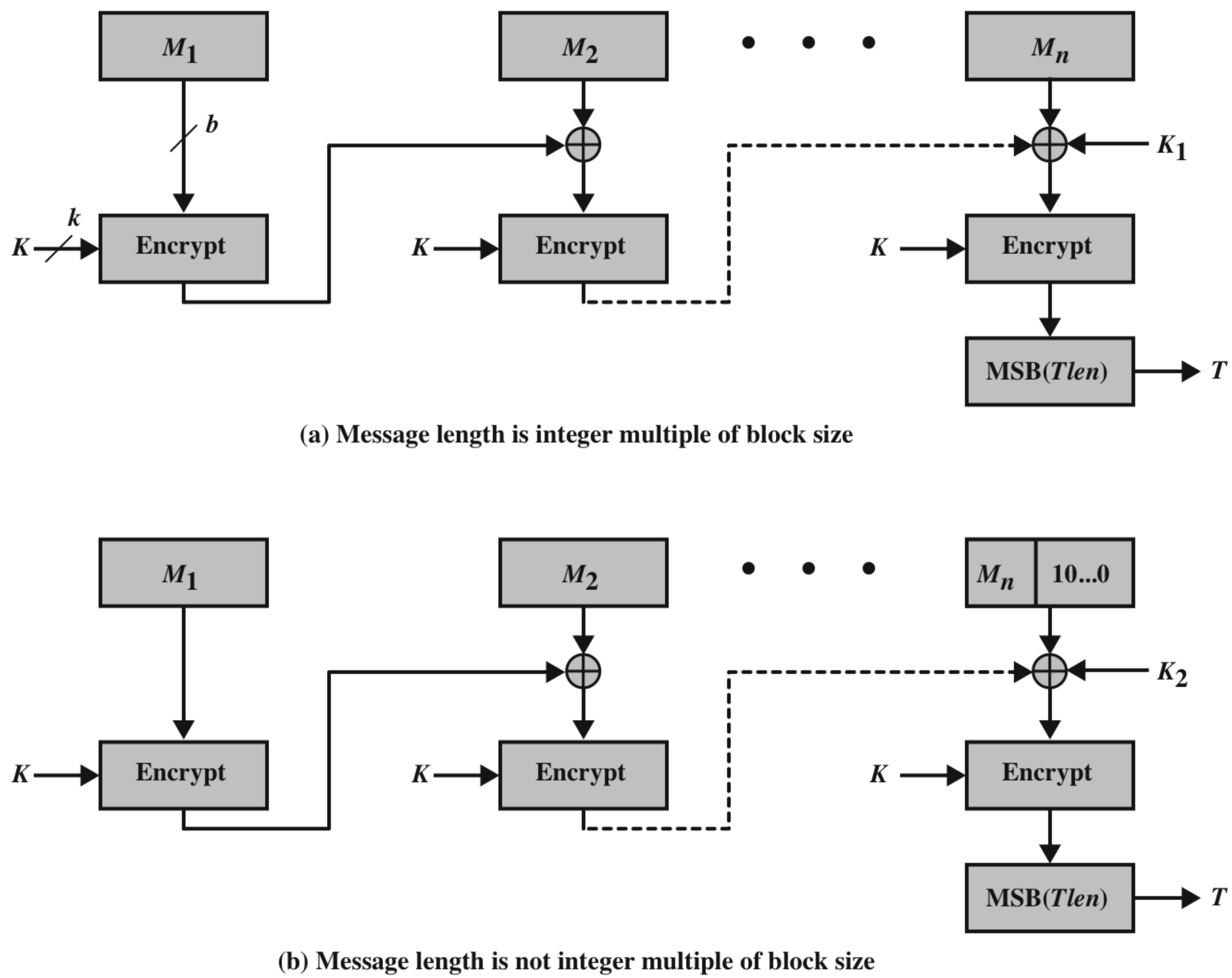
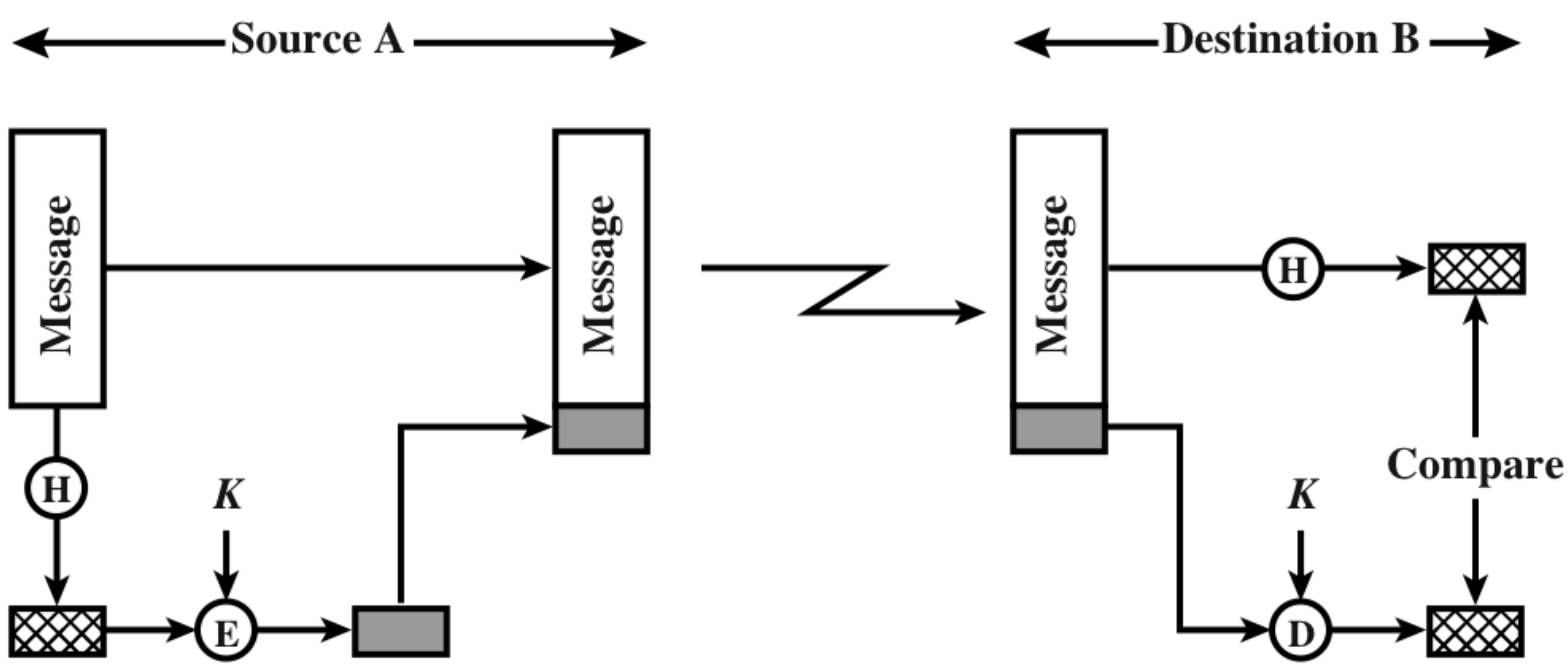


Figure 12.12 Cipher-Based Message Authentication Code (CMAC)

Three Ways to Implement a MAC

2. Hash the message and encrypt the digest

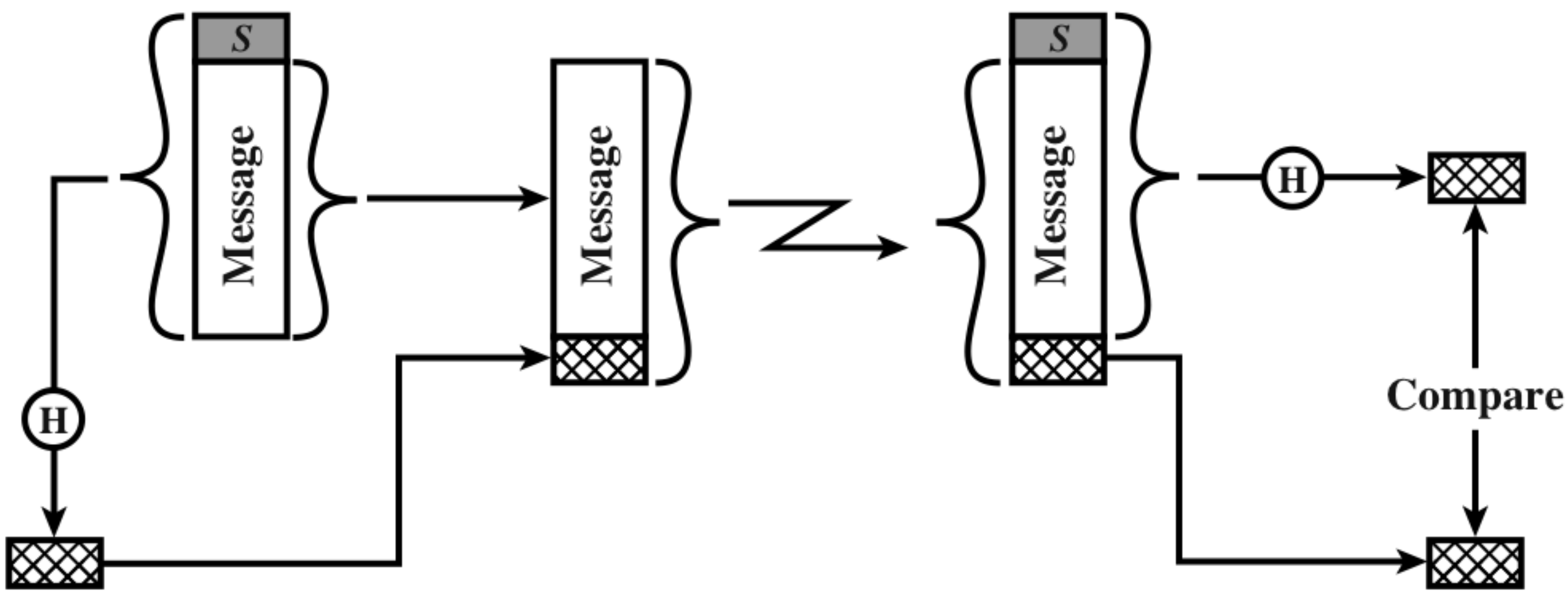


(a) Using conventional encryption

Source: Network Security Essentials (Stallings)

Three Ways to Implement a MAC

3. Hash the message along with a shared key



(c) Using secret value

Source: Network Security Essentials (Stallings)

Design Flaw!

- Cryptographers recommend against this kind of MAC using modern hash functions
- Vulnerable to a message extension attack

- Vulnerability comes from an interactive implementation technique knows as the Merkle-Damgård construction
- Hash functions that are vulnerable when used this way: MD5, SHA1, SHA2

HMAC

- Because of the message extension attack vulnerability, the government standard HMAC algorithm guards against this threat
  - FIPS 198
  - RFC 2104

$$\mathrm{HMAC}(K, m) = H\Big((K' \oplus opad) \| H\big((K' \oplus ipad) \| m\big)\Big)$$

- K' = H(K) if K is larger than the block size, otherwise K
- opad = 0x5c5c5c…5c5c, one-block-long constant
- ipad = 0x363636…3636, one-block-long constant
- IV is fixed, as with SHA-2 and other hash functions

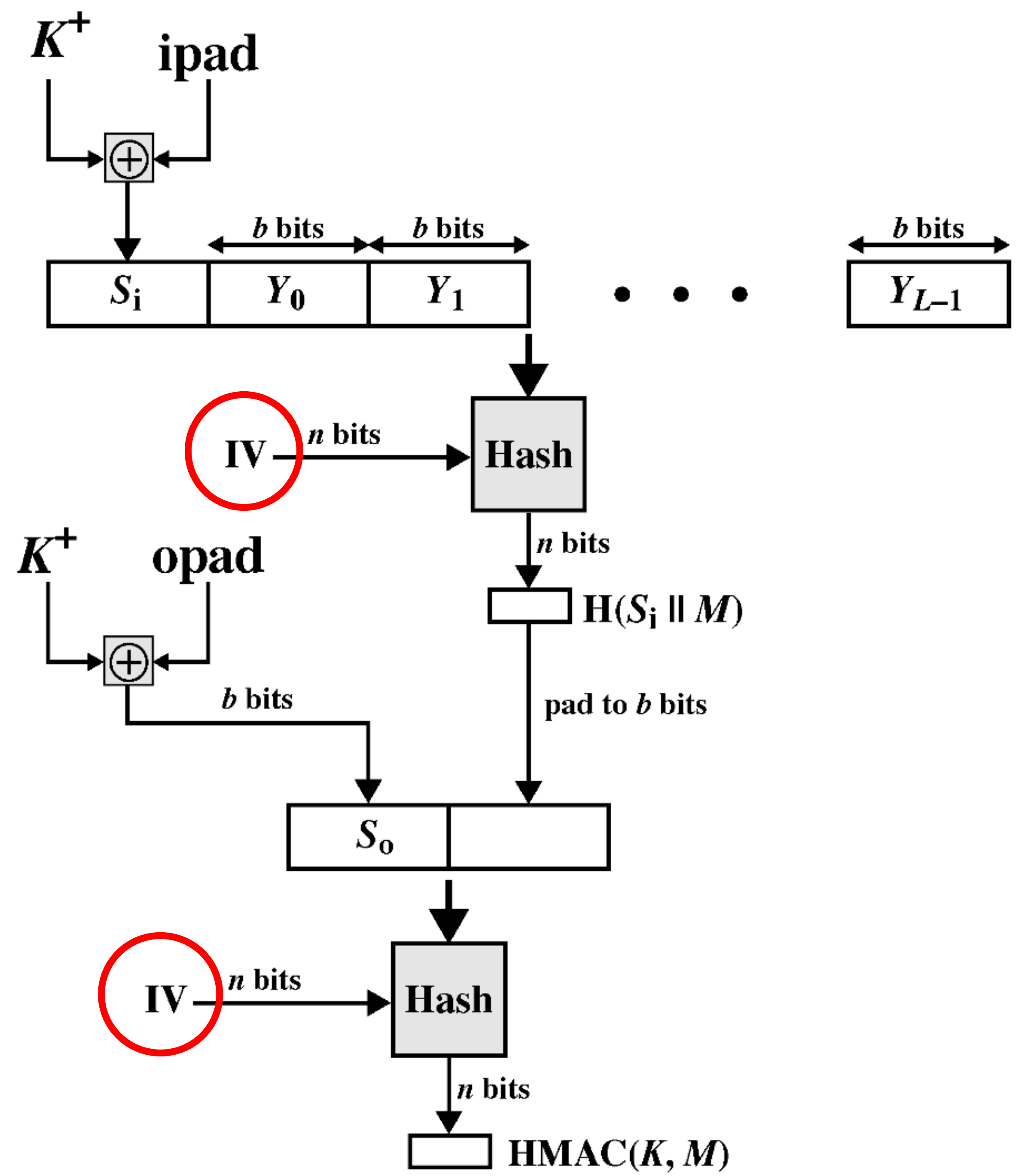


Figure 3.6 HMAC Structure

HMAC = Hashed MAC

- Wrong way: $H(secret||m)$
- Right way : $H((K' \oplus opad) || H((K' \oplus ipad) || m))$

Recommendation

- If you need just a MAC, use HMAC
- If you need encryption and a MAC, use AEAD
- See https://blog.cryptographyengineering.com/2013/02/15/why-i-hate-cbc-mac/

MAC ATTACK

Let's examine the message extension attack...

- Alice and Bob share a key K
- Alice sends message M1 to Bob such that Bob knows it came from Alice
  - Alice computes H(K || M1) = mac1
  - Alice sends M1 and mac1 to Bob
- Bob verifies the message
  - Bob computes H(K || M1) = mac2 and compares it to mac1. If they match, the message came from Alice.
  - Or did it????

Message Extension Attack

- Mallory can intercept a plaintext message and a mac.
- Mallory “extends” the message – adds new material to the end of the message
- She modifies the mac without knowing the key. She needs to know the length of the key.
- She replaces the message and mac with the extended message and new mac and forwards it along
- Bob receives the modified message and mac, and it passes his verification step. He believes is came from Alice!
- See Project 3, resources on that page

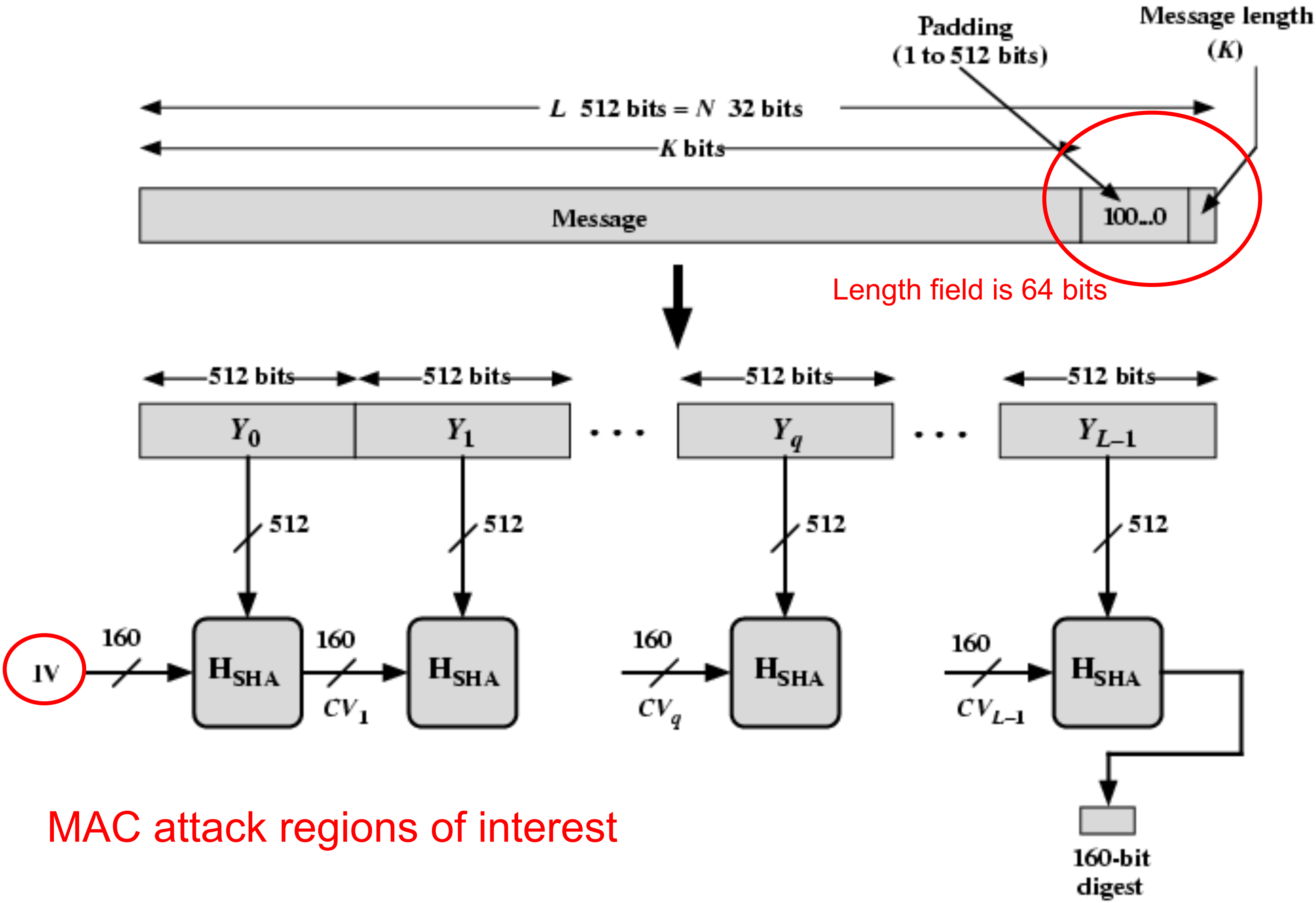


Figure 3.4 Message Digest Generation Using SHA-1

Message Extension Attack

- Extend the message by adding block Y_{L+1}
- If this block is now put through the H_{SHA} function, along with the output of the previous H_{SHA} calculation, what do you get?