Message Authentication Codes

CSS441: Security and Cryptography

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Message Authentication Requirements and Functions

Authentication using Symmetric Key Encryption

Authentication with Message Authentication Codes

Security of MACs

MAC Algorithms

Attacks on Communications across Network

1. Disclosure: encryption
2. Traffic analysis: encryption
3. Masquerade: message authentication
4. Content modification: message authentication
5. Sequence modification: message authentication
6. Timing modification: message authentication
7. Source repudiation: digital signatures
8. Destination repudiation: digital signatures

Authentication

- Receiver wants to verify:
  1. Contents of the message have not been modified (*data authentication*)
  2. Source of message is who they claim to be (*source authentication*)
- Different approaches available:
  - Symmetric Key Encryption
  - Message Authentication Codes (MACs)
  - Hash Functions
  - Public Key Encryption (i.e. Digital Signatures)

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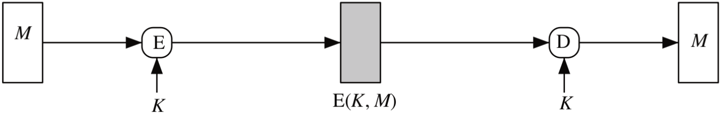
Symmetric Encryption for Authentication



Credit: Figure 12.1(a) in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

- Confidentiality: only B (and A) can recover plaintext
- Source Authentication: A is only other user with key; must have come from A
- Data Authentication: successfully decrypted; data has not been modified
- Assumption: decryptor can recognise correct plaintext

Recognising Correct Plaintext

Example 1

B receives ciphertext (supposedly from A, using shared secret key K):

`DPNFCTEJLYONCJAEZRCLASJTDQFY`

B decrypts with key K to obtain plaintext:

`SECURITYANDCRYPTOGRAPHYISFUN`

- Was the plaintext encrypted with key K (and hence sent by A)?
- Is the ciphertext received the same as the ciphertext sent by A?

Recognising Correct Plaintext

Example 2

B receives ciphertext (supposedly from A, using shared secret key K):

```
QEFPFPQEBTOLKDJBPPXDBPLOOVX
```

B decrypts with key K to obtain plaintext:

```
FTUEUEFTQIDAZSYQEEMSQEADDKM
```

- Was the plaintext encrypted with key K (and hence sent by A)?
- Is the ciphertext received the same as the ciphertext sent by A?

Recognising Correct Plaintext

Example 3

B receives ciphertext (supposedly from A, using shared secret key K):

0110100110101101010110111000010

B decrypts with key K to obtain plaintext:

0101110100001101001010100101110

- Was the plaintext encrypted with key K (and hence sent by A)?
- Is the ciphertext received the same as the ciphertext sent by A?

Recognising Correct Plaintext

Example 1

- Assume the message is English
- Plaintext had expected structure; assume the plaintext is correct
    - Sent by A and has not been modified

Example 2

- Assume the message is English
- Plaintext had no structure in expected language; assume plaintext is incorrect
    - Either not sent by A or modified

Example 3

- Binary data, e.g. image, compressed file
- Cannot know whether correct or incorrect

Recognising Correct Plaintext

- Valid plaintexts should be small subset of all possible messages
  - E.g. 26^n possible messages of length n; only small subset are valid English phrases
- Plaintext messages have structure
- BUT automatically detecting structure can be difficult
- Add structure to make it easier, e.g.
  - Error detecting code or Frame Check Sequence
  - Packet header

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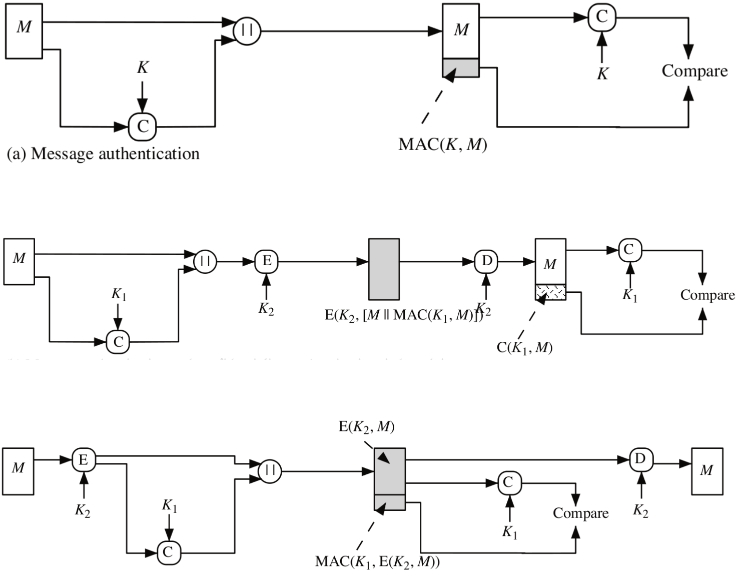
Authentication with Message Authentication Codes

- Append small, fixed-size block of data to message: cryptographic checksum or MAC

$$\mathrm{T} = \mathrm{MAC}(K, M)$$

  $M =$ input message
  $MAC =$ MAC function
  $K =$ shared secret key of k bits
  $T =$ message authentication code (or tag) of n bits
- MAC function also called *keyed hash function*
- MAC function similar to encryption, but does not need to be reversible
  - Easier to design stronger MAC functions than encryption functions

Example Uses of MAC



(a) Message authentication

Credit: Figure 12.4 in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

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Requirement of MACs

Objective of Attacker

- Assume MAC function is known, key K is not
- For valid MAC code for given message x

Requirement of MAC Function

Computation Resistance : given one or more text-MAC pairs $[x_i, MAC(K, x_i)]$, computationally infeasible to compute any text-MAC pair $[x, MAC(K, x)]$ for new input $x \neq x_i$

Security of MACs

Brute Force Attack on Key

- Attacker knows $[x_1, T_1]$ where $T_1 = MAC(K, x_1)$
- Key size of k bits: brute force on key, 2^k
- But . . . many tags match T_1
- For keys that produce tag T_1, try again with $[x_2, T_2]$
- Effort to find K is approximately 2^k

Brute Force Attack on MAC value

- For x_m, find T_m without knowing K
- Similar effort required as one-way/weak collision resistant property for hash functions
- For n bit MAC value length, effort is 2^n

Effort to break MAC: $\min(2^k, 2^n)$

Security of MACs

Cryptanalysis

- Many different MAC algorithms; attacks specific to algorithms
- MAC algorithms generally considered secure

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MACs Based on Block Ciphers

- Data Authentication Algorithm (DAA): based on DES; considered insecure
- Cipher-Based Message Authentication Code (CMAC): mode of operation used with Triple-DES and AES
- OMAC, PMAC, UMAC, VMAC, . . .

HMAC

- MAC function derived from cryptographic hash functions
  - MD5/SHA are fast in software (compared to block ciphers)
  - Libraries for hash functions widely available

  $$\mathrm{HMAC}(K, M) = \mathrm{H}((K \oplus \mathrm{opad})||\mathrm{H}((K \oplus ipad)||M))$$

  where ipad= 00110110 repeated, opad= 01011100 repeated
- Security of HMAC depends on security of hash function used