

Authentication and Hash Functions

CSS 322 – Security and Cryptography

Contents

- Authentication using Encryption
- Principles of MAC and Hash Functions
- Example MAC and Hash Functions

Types of Attacks

Encryption

- Disclosure: release message contents
- Traffic Analysis: discover pattern of communication
- Masquerade: create messages pretending to be from someone else
- Content modification: change messages along a path
- Sequence modification: re-order messages along a path
- Timing modification: delay or replay messages
- Source repudiation: denial of transmission by source
- Destination repudiation: denial of transmission by destination

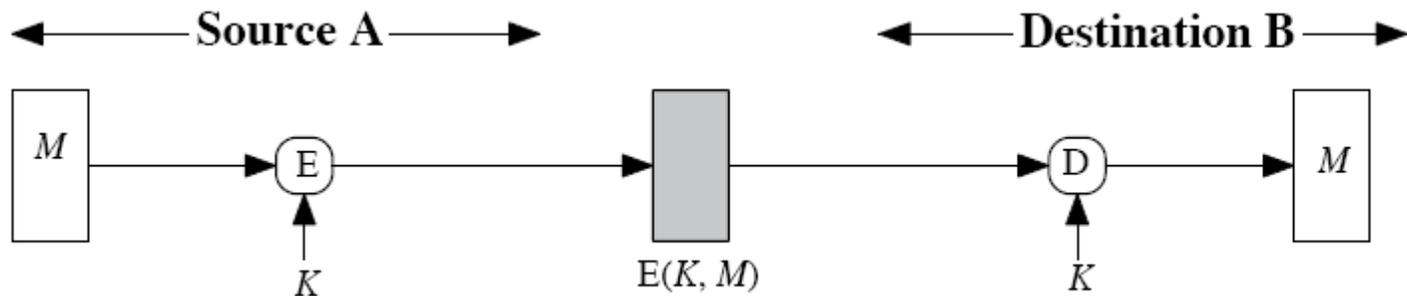
Authentication, Digital Signatures, ...

Authentication Functions

- Authentication consists of two parts:
 - Function that produces low level authenticator
 - Protocol that enables receiver to verify identity
- Three types of functions:
 - Message Encryption
 - Ciphertext of entire message serves as authenticator
 - Message Authentication Code (MAC)
 - A function of message and secret key produces a fixed length authenticator
 - Hash Function
 - A function maps message to fixed-length hash value that serves as authenticator

Symmetric Key Encryption for Authentication

- Symmetric key encryption provides:
 - Confidentiality
 - Authentication: message must have come from A because A is only person with secret key K



Symmetric Key Encryption for Authentication

- Assumes receiver can distinguish between legitimate and illegitimate ciphertext
 - When B decrypts ciphertext, must be able to determine that corresponding plaintext is legitimate
 - ... and should be automatic detection
 - With English language plaintext, this is possible
 - What about binary messages (images, compressed files)?
 - The plaintext needs some known structure
 - Of all possible patterns of plaintext, only a small subset should be legitimate

Example

- Using Caesar cipher ($K=1$), legitimate ciphertext:

nbsftfbupbutboeepftfbupbutboemjuumfmbnctfbujwz

- B decrypts to produce plaintext:

mareseatoatsanddoeseatoatsandlittlelambseativy

- If attacker generated illegitimate ciphertext randomly:

zuvrsoevgqxkzwigamdvnmhpmccxiuureosfbcebtqxsxq

- B would decrypt to:

ytuqrndufpwkyvhfzlcumlgolbbwhttqdnreabdasprwp

- B would know this is illegitimate ciphertext!

Example

- What if this is legitimate ciphertext:

```
01110101011101001100010101101
```

- B decrypts to produce plaintext:

```
11010010101110001010101001001
```

- If attacker generated illegitimate ciphertext randomly:

```
01010111010010110100011010010
```

- B would decrypt to:

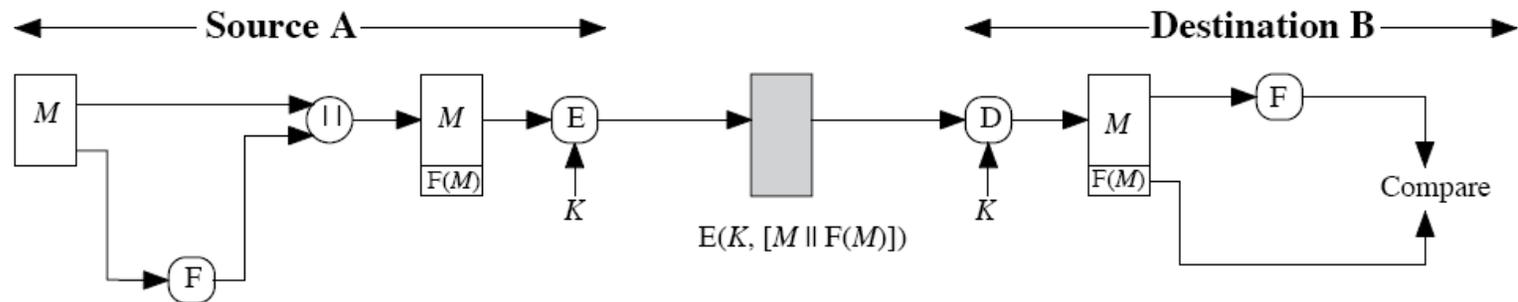
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01011011011101000101010001101
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- How does B know whether it is legitimate or not???

- Answer: need some expected structure in plaintext

Symmetric Key Encryption for Authentication

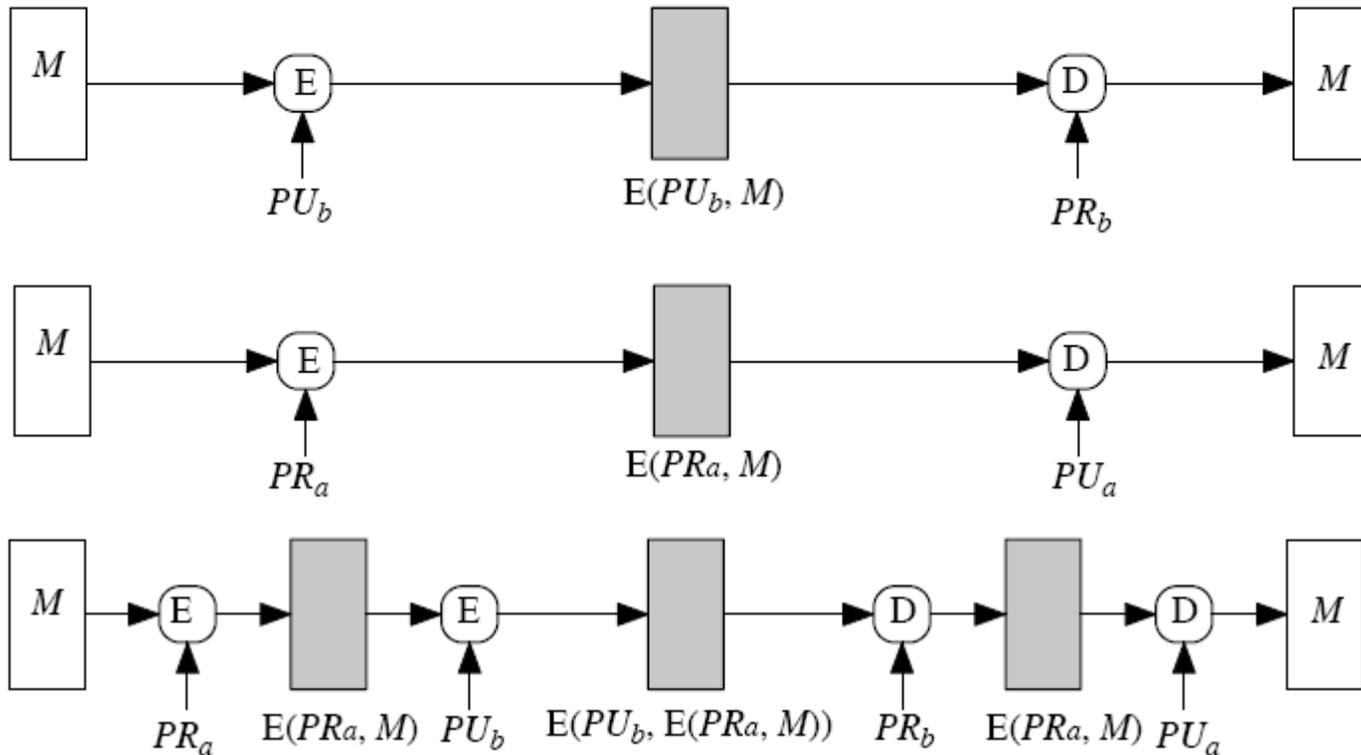
- Error checking codes (checksums) provide structure:
 - Append a checksum before encryption
 - At receiver, checksum must be correct



- Protocol headers provide structure:
 - For example, TCP contains a checksum and sequence numbers
 - If an attacker produces random ciphertext, the receiver B may detect that the TCP header is unstructured or contain incorrect fields

Public Key Encryption for Authentication

- Public key:
 - Encrypt with public key provides confidentiality
 - Encrypt with private key provides authentication
 - Same issues as using symmetric key for authentication

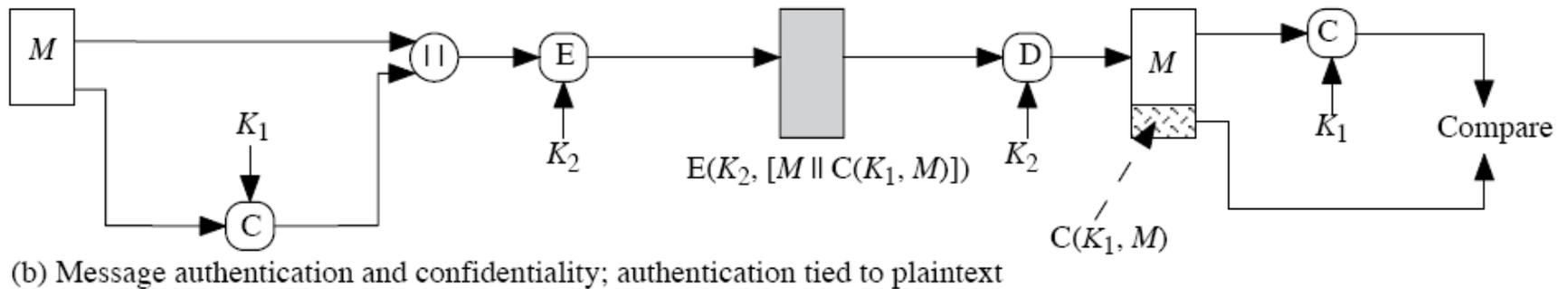
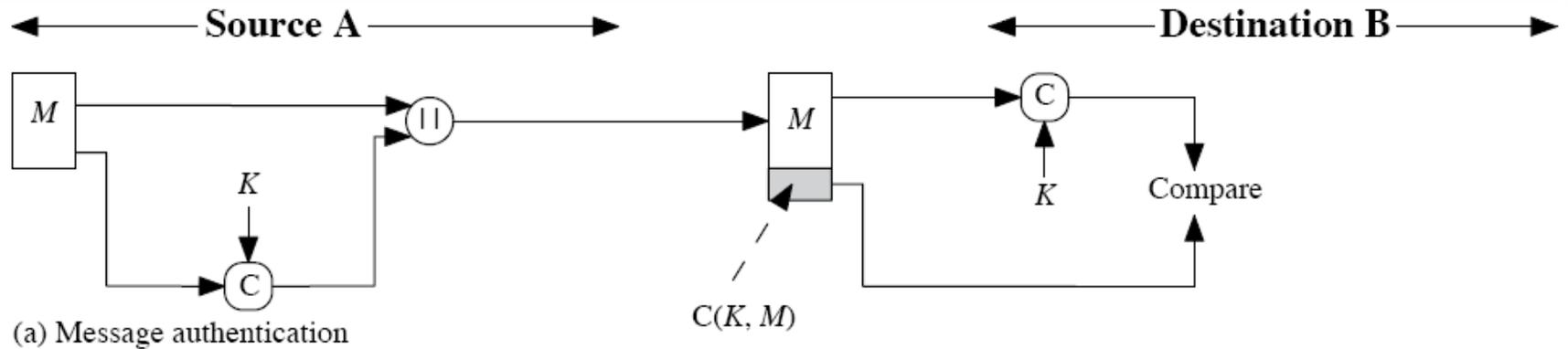


Message Authentication Codes

Message Authentication Code

- Known as MAC or cryptographic checksum
- Encrypt input message M and shared secret key K with MAC function C :
 - $MAC = C(K, M)$
- Transmit the message M and MAC to recipient
- If received MAC matches transmitted MAC:
 - Receiver knows message has not been altered (otherwise MAC's wouldn't match)
 - Receiver knows message is from sender A (as no-one else has K)
 - If message has sequence numbers (e.g. TCP), then receiver knows proper sequence has been maintained

Example Use of MAC

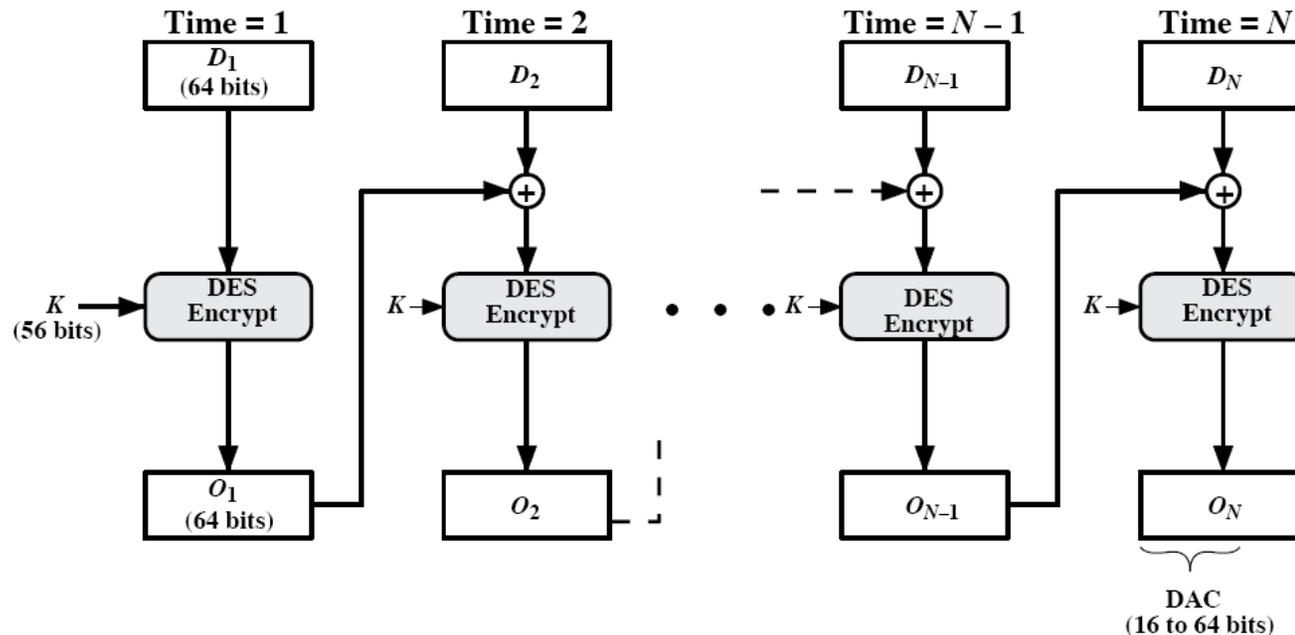


MAC and Encryption

- What is the difference?
 - MAC function is similar to encryption function, but can be made simpler
 - MAC does not need to be reversible (don't need decryption function)
 - The maths of MAC functions leads to MAC functions being stronger than encryption
- Why separate confidentiality and authentication?
 - Encryption is time consuming – some applications may not need encryption, but can do authentication to check sender
 - Example: SNMP for network management
 - Good to keep functionality separate – easier to design, implement and upgrade

Example: MAC based on DES

- Data Authentication Algorithm is based on DES
 - Was one of the most widely algorithms, but new faster and stronger algorithms in use
 - Use CBC and DES with initial value of 0



- Data Authentication Code (DAC) is O_N or left most bits of O_N

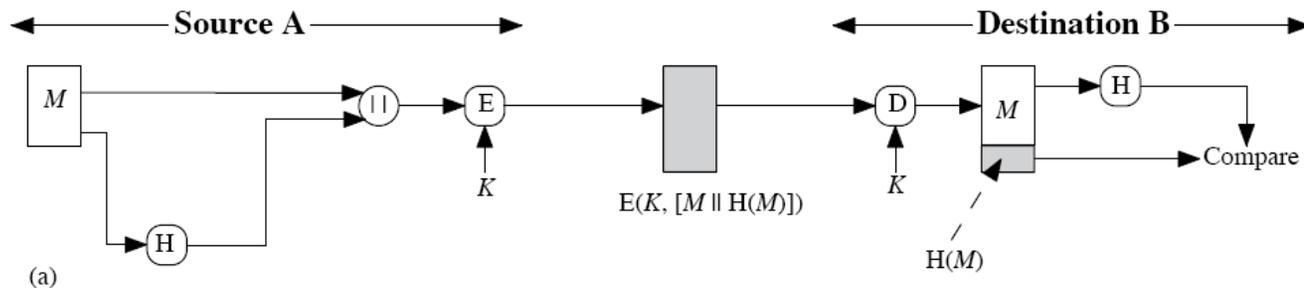
Hash Functions

Hash Function

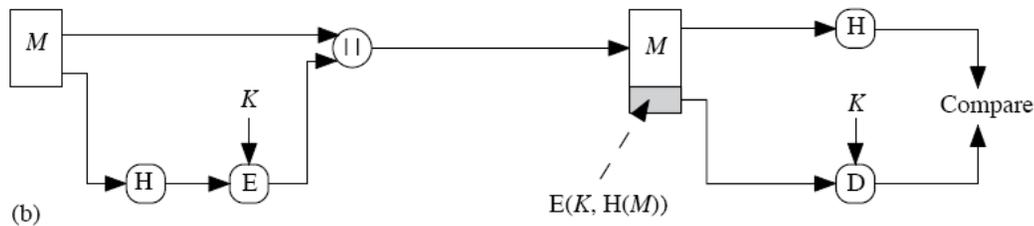
- Like a MAC, except do not need key:
 - Hash, $h = H(M)$
 - Output referred to as *hash value* or *message digest*
- Hash function has property that:
 - If you change any bits in the message, then the output hash value will be different

Using Hash Functions

- Message and hash using symmetric key encryption
 - Confidentiality and authentication

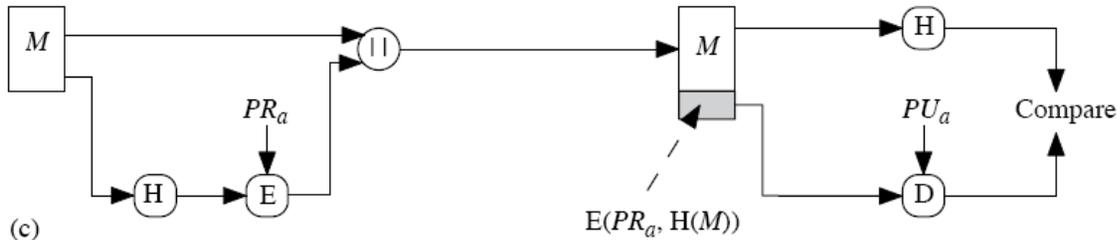


- Only hash encrypted with symmetric key
 - Authentication

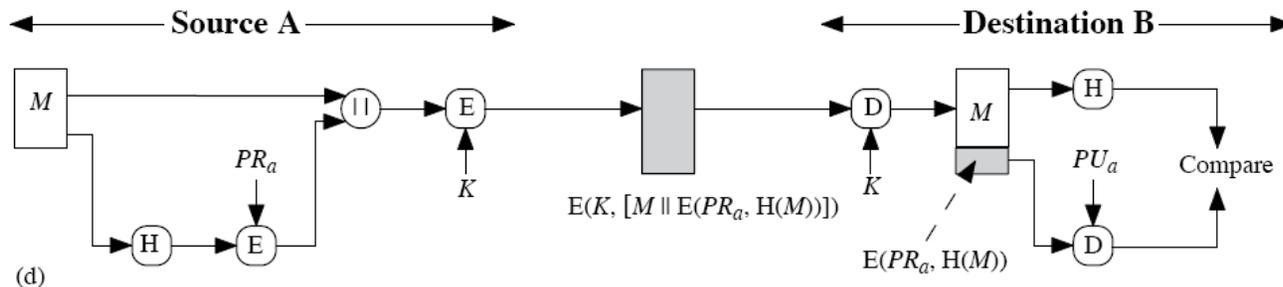


Using Hash Functions

- Only hash encrypted with sender's private key (using public key encryption)
 - Authentication and digital signature

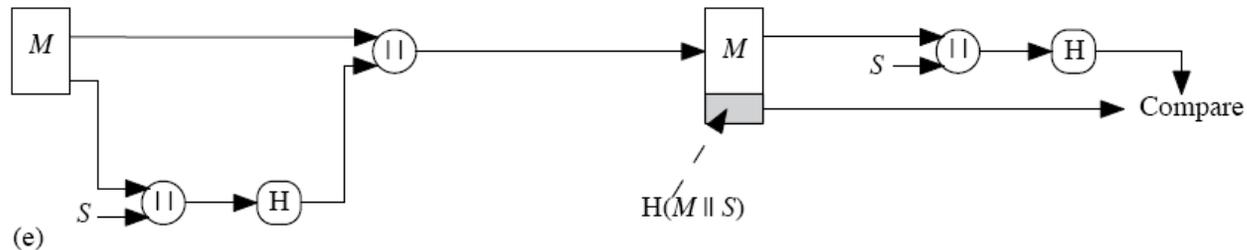


- Hash encrypted with sender's private key and message plus hash encrypted with symmetric shared key
 - Confidentiality, authentication and digital signature



Using Hash Functions

- Sender and receiver share secret value S ; Hash the message and S , and send with message
 - Authentication, does not need encryption



- Encrypting only the hash code (instead of message) makes computations easier
- The final approach (above) does not rely on encryption
 - Useful because encryption software is often slow, encryption hardware is expensive and encryption algorithms may be patented

Requirements of Hash Function

- Hash function acts as a “fingerprint” of a message
- Hash function, H , should have the properties:
 - H can be applied to input message of any size
 - H produces fixed length output
 - H is easy to compute for an input message
 - For a given h , hard (infeasible) to find x such that $H(x) = h$
 - *One way property*
 - For a given message x , hard (infeasible) to find another message y such that $H(x) = H(y)$
 - *Weak collision resistance*
 - Hard (infeasible) to find pair (x, y) such that $H(x) = H(y)$
 - *Strong collision resistance*
- (First 3 properties are for practical implementations)

Simple Hash Function

- Break input message into n -bit blocks
 - Process each n -bit block at a time
- Hash bit i is XOR of all i -th bits in message (m blocks)

$$C_i = b_{i1} \oplus b_{i2} \oplus b_{i3} \oplus \dots \oplus b_{im}$$

- Hash value is C

Security of MACs and Hash Functions

- Brute-force attack on Hash Functions with n-bit hash
 - One way property: 2^n
 - Weak collision resistance: 2^n
 - Strong collision resistance: $2^{n/2}$
 - Usually strong collision resistance is required
 - 128-bit hash can be broken in days; 160-bit is much more secure against brute force (but not other cryptanalysis!)
- Brute-force attack on MAC with n-bit MAC and k-bit key
 - Minimum of 2^n and 2^k
 - In practice, minimum of n, k is around 128 bits
- Cryptanalysis
 - Some efforts to use knowledge of algorithm, but attacks are quite hard and complex

MD5

- Developed by Ron Rivest in 1991
 - Improvements on previous Message Digest algorithms, MD1, ...
- Standardised by IETF in RFC1321
- Generates 128-bit hash
- Commonly used in Unix passwords and checksums on files
- No longer secure
 - Collisions can be found using the birthday attack
 - Tools and databases of MD5 hashes and corresponding message are publicly available

Secure Hash Algorithm

- Developed by NIST and published in 1993
 - Revised version is called SHA-1
 - Also published by IETF in RFC 3174
 - SHA-1 uses 160 bit message digest size (hash value)
 - NIST recommend replacing SHA-1 with SHA-256, SHA-384, SHA-512

	SHA-1	SHA-256	SHA-384	SHA-512
Message digest size	160	256	384	512
Message size	$< 2^{64}$	$< 2^{64}$	$< 2^{128}$	$< 2^{128}$
Block size	512	512	1024	1024
Word size	32	32	64	64
Number of steps	80	64	80	80
Security	80	128	192	256

HMAC

- Aim to use a Hash function for a MAC
 - Hash Functions do not use key as input
- Motivation of HMAC:
 - Make use of existing Hash Functions, which are faster in software than DES
- HMAC provides a “wrapper” service for Hash functions
 - Turns Hash Functions into MACs
 - HMAC algorithm is generic – can use different Hash Functions
 - HMAC can use MD5, SHA-1, Whirlpool, ... or any new hash functions