Cryptography

Hash Function

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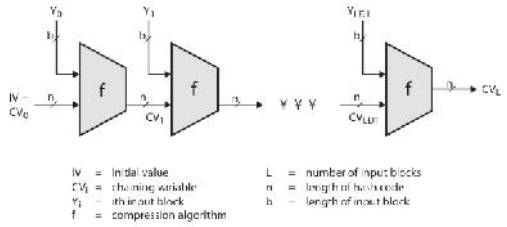
Hash and MAC Algorithms

- Hash Functions
  - condense arbitrary size message to fixed size
  - by processing message in blocks
  - through some compression function
  - either custom or block cipher based
- Message Authentication Code (MAC)
  - fixed sized authenticator for some message
  - to provide authentication for message
  - by using block cipher mode or hash function

Hash Algorithm Structure



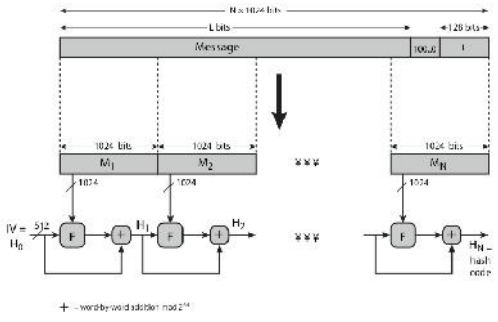
Secure Hash Algorithm

- SHA originally designed by NIST & NSA in 1993
- was revised in 1995 as SHA-1
- US standard for use with DSA signature scheme
  - standard is FIPS 180-1 1995, also Internet RFC3174
  - nb. the algorithm is SHA, the standard is SHS
- based on design of MD4 with key differences
- produces 160-bit hash values
- recent 2005 results on security of SHA-1 have raised concerns on its use in future applications

Revised Secure Hash Standard

- NIST issued revision FIPS 180-2 in 2002
- adds 3 additional versions of SHA
  - SHA-256, SHA-384, SHA-512
- designed for compatibility with increased security provided by the AES cipher
- structure & detail is similar to SHA-1
- hence analysis should be similar
- but security levels are rather higher

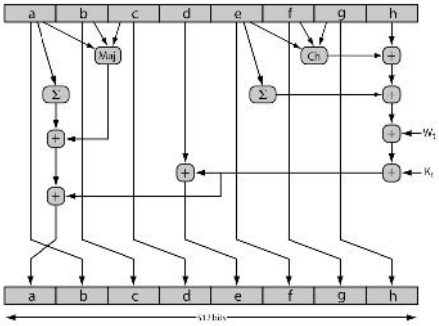
SHA-512 Overview



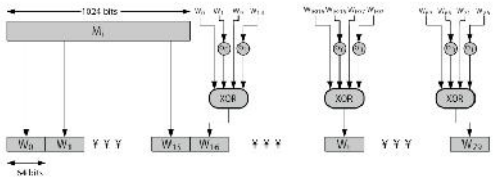
SHA-512 Compression Function

- heart of the algorithm
- processing message in 1024-bit blocks
- consists of 80 rounds
  - updating a 512-bit buffer
  - using a 64-bit value Wt derived from the current message block
  - and a round constant based on cube root of first 80 prime numbers

SHA-512 Round Function



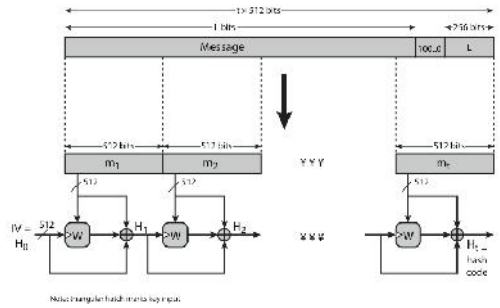
SHA-512 Round Function



Whirlpool

- now examine the Whirlpool hash function
- endorsed by European NESSIE project
- uses modified AES internals as compression function
- addressing concerns on use of block ciphers seen previously
- with performance comparable to dedicated algorithms like SHA

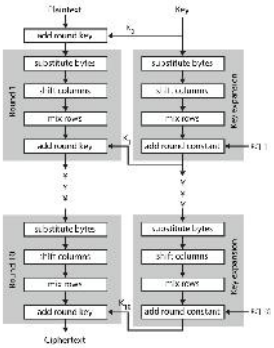
Whirlpool Overview



Whirlpool Block Cipher W

- designed specifically for hash function use
- with security and efficiency of AES
- but with 512-bit block size and hence hash
- similar structure & functions as AES but
  - input is mapped row wise
  - has 10 rounds
  - a different primitive polynomial for GF(2^8)
  - uses different S-box design & values

Whirlpool Block Cipher W



Whirlpool Performance & Security

- Whirlpool is a very new proposal
- hence little experience with use
- but many AES findings should apply
- does seem to need more h/w than SHA, but with better resulting performance

Keyed Hash Functions as MACs

- want a MAC based on a hash function
  - because hash functions are generally faster
  - code for crypto hash functions widely available
- hash includes a key along with message
- original proposal:

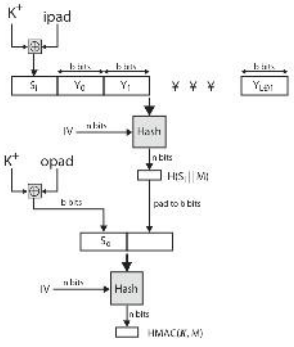
  `KeyedHash = Hash(Key|Message)`
  - some weaknesses were found with this
- eventually led to development of HMAC

HMAC

- specified as Internet standard RFC2104
- uses hash function on the message:

  $HMAC_K$ = `Hash[(K+ XOR opad) || Hash[(K+ XOR ipad)||M)]]`
- where K^+ is the key padded out to size
- and opad, ipad are specified padding constants
- overhead is just 3 more hash calculations than the message needs alone
- any hash function can be used
  - eg. MD5, SHA-1, RIPEMD-160, Whirlpool

HMAC Overview



HMAC Security

- proved security of HMAC relates to that of the underlying hash algorithm
- attacking HMAC requires either:
  - brute force attack on key used
  - birthday attack (but since keyed would need to observe a very large number of messages)
- choose hash function used based on speed verses security constraints

CMAC

- previously saw the DAA (CBC-MAC)
- widely used in govt & industry
- but has message size limitation
- can overcome using 2 keys & padding
- thus forming the Cipher-based Message Authentication Code (CMAC)
- adopted by NIST SP800-38B

CMAC Overview

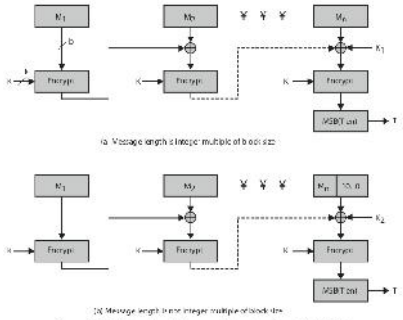


Figure 12.12 Cipher-Based Message Authentication Code (CMAC)