Cryptography and Network Security

Third Edition

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Chapter 11 – Message Authentication and Hash Functions

At cats' green on the Sunday he took the message from the inside of the pillar and added Peter Moran's name to the two names already printed there in the "Brontosaur" code. The message now read: "Leviathan to Dragon: Martin Hillman, Trevor Allan, Peter Moran: observe and tail." What was the good of it John hardly knew. He felt better, he felt that at last he had made an attack on Peter Moran instead of waiting passively and effecting no retaliation. Besides, what was the use of being in possession of the key to the codes if he never took advantage of it?

***—Talking to Strange Men,* Ruth Rendell**

Message Authentication

- protecting message content (ie secrecy) by encrypting the message
- now consider
  - how to protect message integrity (ie protection from modification)
  - confirming the identity of the sender
- then three alternative functions used:
  - message encryption (the ciphertext itself is the authenticator)
  - message authentication code (MAC)
  - hash function

Security Attacks

- disclosure of message contents
- traffic analysis (discover the pattern)
- Masquerade (insert a msg from a fraudulent source)
- content modification
- sequence modification (insert, delete, reorder)
- timing modification (delay or replay)
- source repudiation (denial of a transmission)
- destination repudiation (denial of a receipt)

Message Encryption

- message encryption by itself also provides a measure of authentication
- if symmetric encryption is used then:
  - receiver know sender must have created it
  - since only sender and receiver now key used
  - know content cannot of been altered
  - if message has suitable structure, redundancy or a checksum to detect any changes

Message Encryption

- if public-key encryption is used:
  - encryption provides no confidence of sender
  - since anyone potentially knows public-key
  - however if
    - sender **signs** message using their private-key
    - then encrypts with recipients public key
    - have both secrecy and authentication
  - again need to recognize corrupted messages
  - but at cost of two public-key uses on message

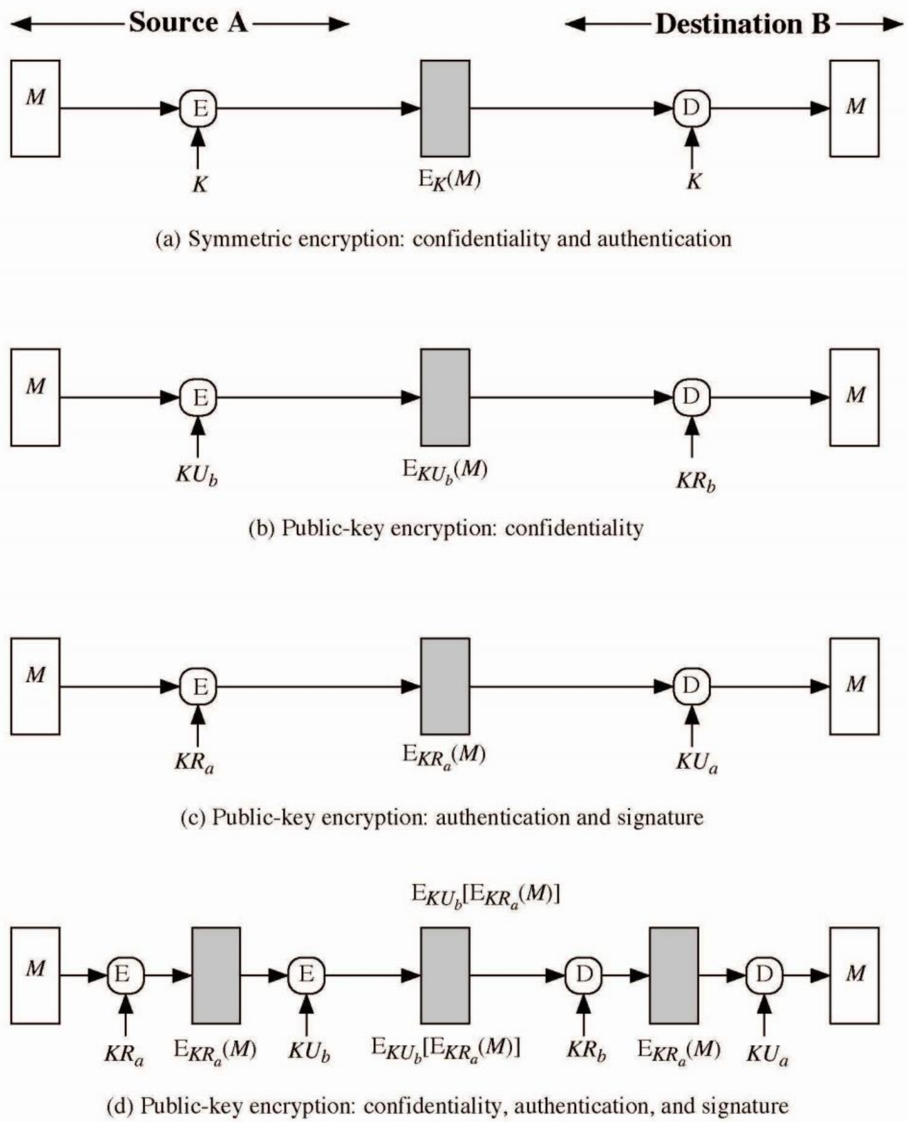
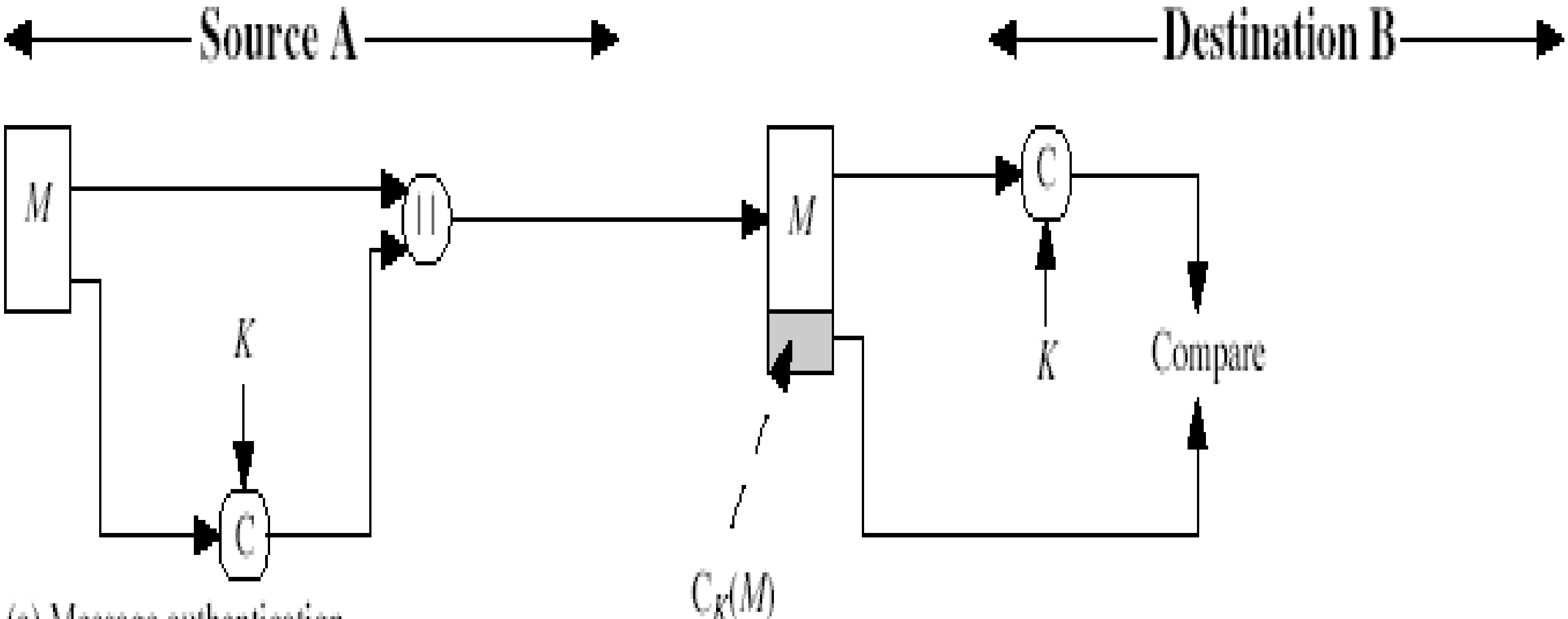


Figure 11.1 Basic Uses of Message Encryption

Message Authentication Code (MAC)

- generated by an MAC function C that creates a small fixed-sized block
  - depending on both message M and a shared secret key K, $MAC=C_K(M)$
  - MAC is appended to the message M
- receiver performs same computation on message and checks it matches the MAC
- provides assurance that message is unaltered and comes from sender

Message Authentication Code



(a) Message authentication

Message Authentication Codes

- can also use encryption for secrecy
  - generally use separate keys for each
  - can compute MAC either before or after encryption
  - is generally regarded as better done before
- why use a MAC?
  - MAC is much less expensive than en/decryption
  - sometimes only authentication is needed
  - One end with a heavy load, check MAC selectively

MAC Properties

- a MAC is a cryptographic checksum

  $MAC = C_K(M)$

  - condenses a variable-length message M
  - using a secret key K
  - to a fixed-sized authenticator
- is a many-to-one function
  - potentially many messages have same MAC
    - 100-bit M, and 20-bit MAC

Requirements for MACs

- taking into account the types of attacks
- need the MAC to satisfy the following:

1. knowing a message and MAC, is infeasible to find another message with same MAC
2. MACs should be uniformly distributed
3. MAC should depend equally on all bits of the message

Using Symmetric Ciphers for MACs

- can use any block cipher chaining mode and use final block as a MAC
- **Data Authentication Algorithm (DAA)** is a widely used MAC based on DES-CBC
  - using IV=0 and zero-pad of final block
  - encrypt message using DES in CBC mode
  - and send just the final block as the MAC
    - or the leftmost M bits ($16 \le M \le 64$) of final block
- but final MAC is now too small for security

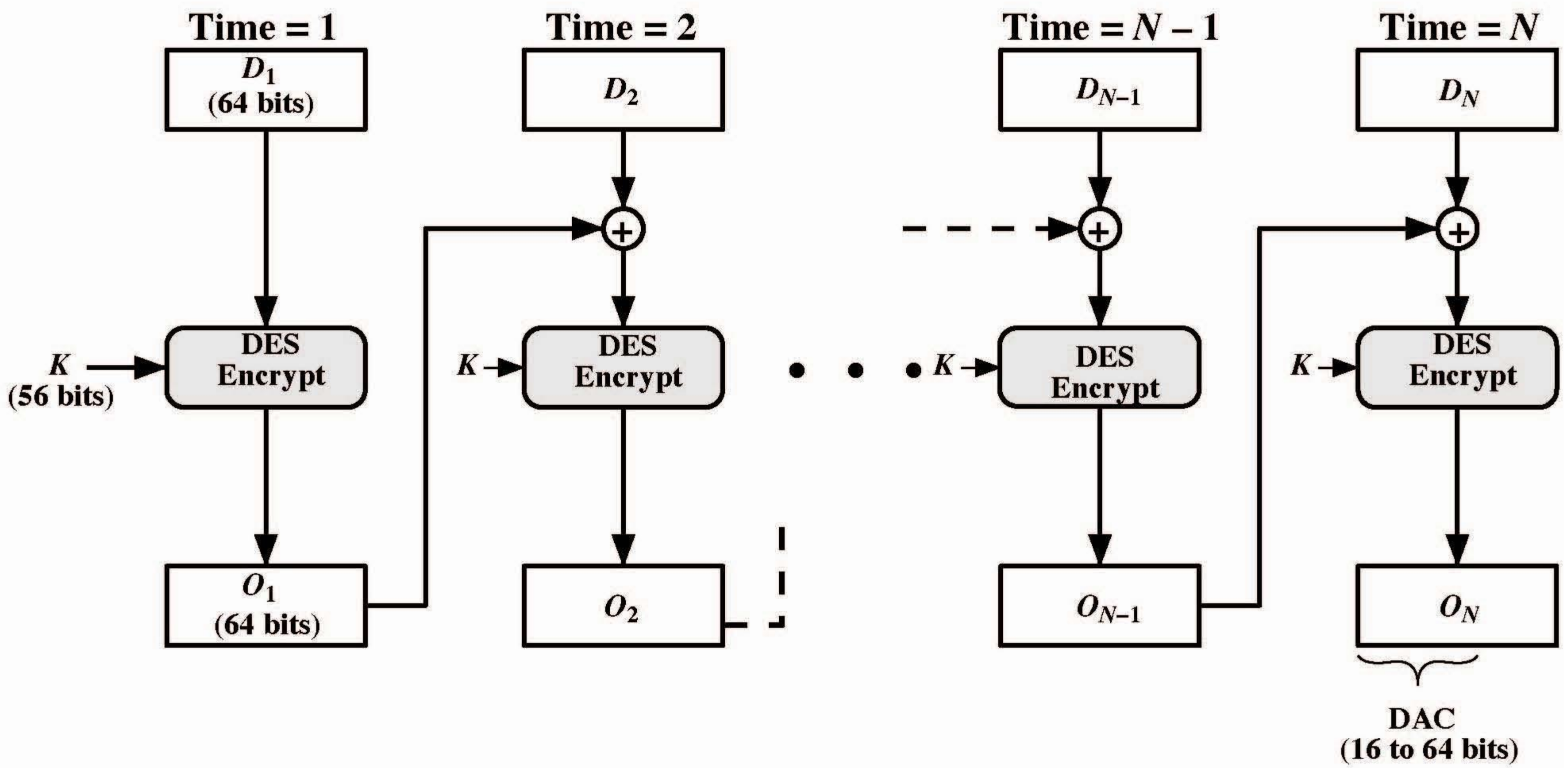
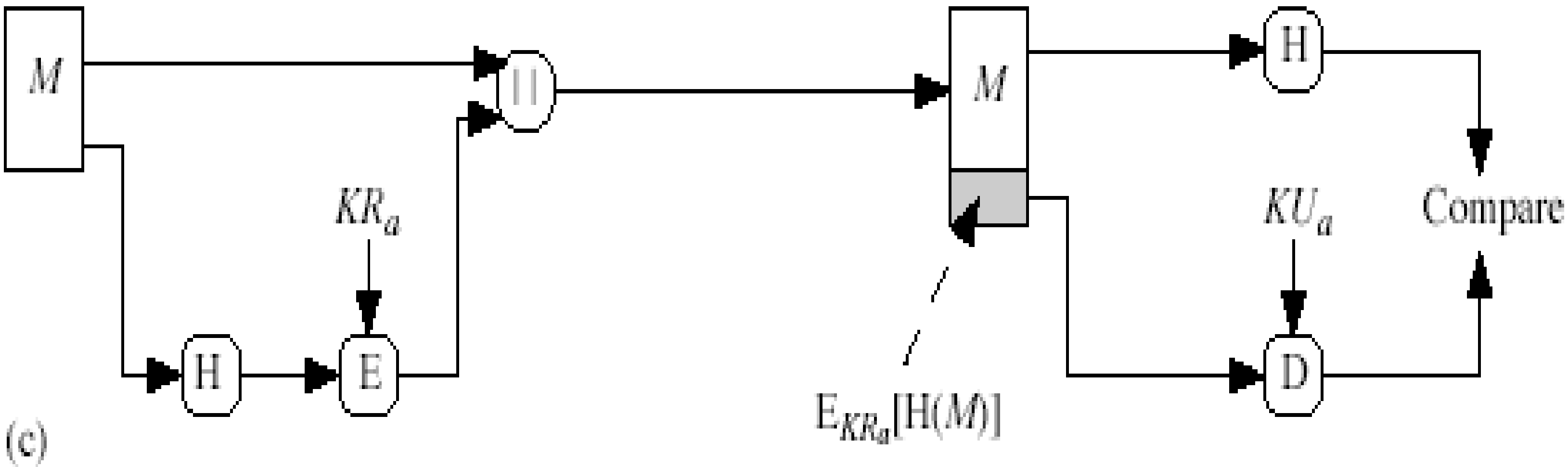


Figure 11.6 Data Authentication Algorithm (FIPS PUB 113)

Hash Functions

- condenses arbitrary message to fixed size
- usually assume that the hash function is public and not keyed
  - cf. MAC which is keyed
- used to detect changes to message
- can use in various ways with message
- most often to create a digital signature

Hash Functions & Digital Signatures



Hash Function Properties

- a Hash Function produces a fingerprint of some file/message/data

  `h = H(M)`

  – condenses a variable-length message M

  – to a fixed-sized fingerprint
- assumed to be public

Requirements for Hash Functions

1. can be applied to any sized message `M`
2. produces fixed-length output `h`
3. is easy to compute `h=H(M)` for any message `M`
4. given `h` is infeasible to find `x` s.t. `H(x)=h`
   - one-way property
5. given `x` is infeasible to find `y` s.t. `H(y)=H(x)`
   - weak collision resistance
6. is infeasible to find any `x,y` s.t. `H(y)=H(x)`
   - strong collision resistance

Simple Hash Functions

- are several proposals for simple functions
- based on XOR of message blocks
- not secure since can manipulate any message to produce a given hash
- need a stronger cryptographic function (next chapter)

	bit 1	bit 2	• • •	bit n
block 1	b_{11}	b_{21}		b_{n1}
block 2	b_{12}	b_{22}		b_{n2}
	⋮	⋮	⋮	⋮
block m	b_{1m}	b_{2m}		b_{nm}
hash code	C_1	C_2		C_n

Figure 11.7 Simple Hash Function Using Bitwise XOR

Birthday Attacks

- might think a 64-bit hash is secure
- but by **Birthday Paradox** is not
- **birthday attack** works thus:
  - opponent generates $2^{m/2}$ variations of a valid message all with essentially the same meaning
  - opponent also generates $2^{m/2}$ variations of a desired fraudulent message
  - two sets of messages are compared to find pair with same hash (probability > 0.5 by birthday paradox)
  - have user sign the valid message, then substitute the forgery which will have a valid signature
- conclusion is that need to use larger MACs

Dear Anthony,

{This letter is / I am writing} to introduce {you to / to you} {Mr. / --} Alfred {P. / --}
Barton, the {new / newly appointed} {chief / senior} jewellery buyer for {our / the}
Northern {European / Europe} {area / division} . He {will take / has taken} over {the / --}
responsibility for {all / the whole of} our interests in {watches and jewellery / jewellery and watches}
in the {area / region} . Please {afford / give} him {every / all the} help he {may need / needs}
to {seek out / find} the most {modern / up to date} lines for the {top / high} end of the
market. He is {empowered / authorized} to receive on our behalf {samples / specimens} of the
{latest / newest} {watch and jewellery / jewellery and watch} products, {up / subject} to a {limit / maximum}
of ten thousand dollars. He will {carry / hold} a signed copy of this {letter / document}
as proof of identity. An order with his signature, which is {appended / attached}
{authorizes / allows} you to charge the cost to this company at the {above / head office}
address. We {fully / --} expect that our {level / volume} of orders will increase in
the {following / next} year and {trust / hope} that the new appointment will {be / prove}
{advantageous / an advantage} to both our companies.

Figure 11.9 A Letter in 2^{37} Variations [DAVI89]

Block Ciphers as Hash Functions

- can use block ciphers as hash functions
  - using H_0=0 and zero-pad of final block
  - compute: $H_i = E_{M_i} [H_{i-1}]$
  - and use final block as the hash value
  - similar to CBC but without a key
- resulting hash is too small (64-bit)
  - due to direct birthday attack and variants

Hash Functions & MAC Security

- like block ciphers have:
- **brute-force** attacks exploiting
  - strong collision resistance hash have cost $2^{m/2}$
    - 128-bit hash looks vulnerable, 160-bits better
  - MACs with known message-MAC pairs
    - can either attack keyspace (cf key search) or MAC
      - Min(2^k, 2^n)
    - at least 128-bit MAC and 128-bit key is needed for security

Hash Functions & MAC Security

- **cryptanalytic attacks** exploit structure
  - like block ciphers want brute-force attacks to be the best alternative
- have a number of analytic attacks on iterated hash functions
  - $CV_i = f[CV_{i-1}, M_i]; H(M)=CV_N$
  - typically focus on collisions in function f
  - like block ciphers is often composed of rounds
  - attacks exploit properties of round functions

Summary

- have considered:
  - message authentication using
  - message encryption
  - MACs
  - hash functions
  - general approach & security