Information Systems Security

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Chapter 12

Message Authentication

Message Authentication

- message authentication is concerned with:
  - protecting the integrity of a message
  - validating identity of originator
  - non-repudiation of origin (dispute resolution)
- Which attacks could be dealt with through message authentication?

Security Attacks

1. disclosure 2. traffic analysis	Dealt with through message confidentiality
3. masquerade 4. content modification 5. sequence modification 6. timing modification	Dealt with through message authentication
7. source repudiation	Digital signatures
8. destination repudiation	

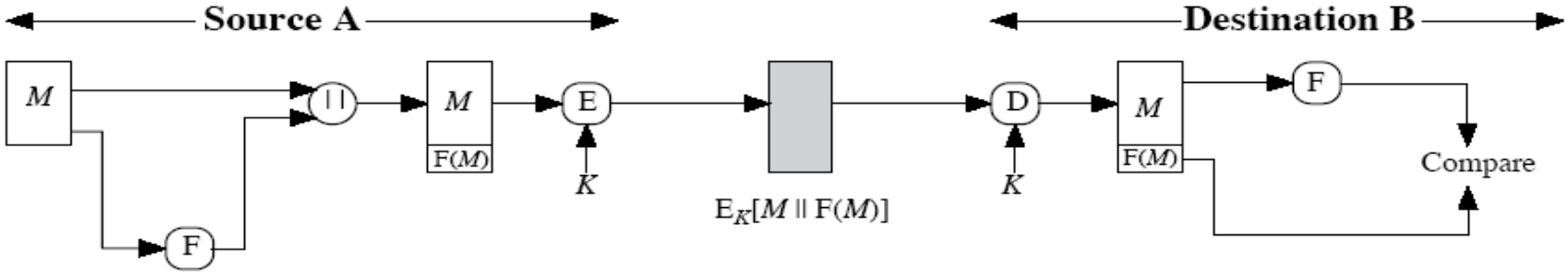
Authentication Functions

- Two levels
  - Use a *function* to produce an authenticator
  - Use the function as a primitive in a higher-level authentication protocol
    - Enable receiver to verify authenticity of a message
- Three alternative functions
  - Message encryption
    - Ciphertext of entire message serves as authenticator
  - Message authentication code (MAC)
    - A public function and a secret key produce a fixed-length value serving as the authenticator
  - Hash function
    - A public function that maps a message of any length into a fixed-length hash value, which serves at the authenticator

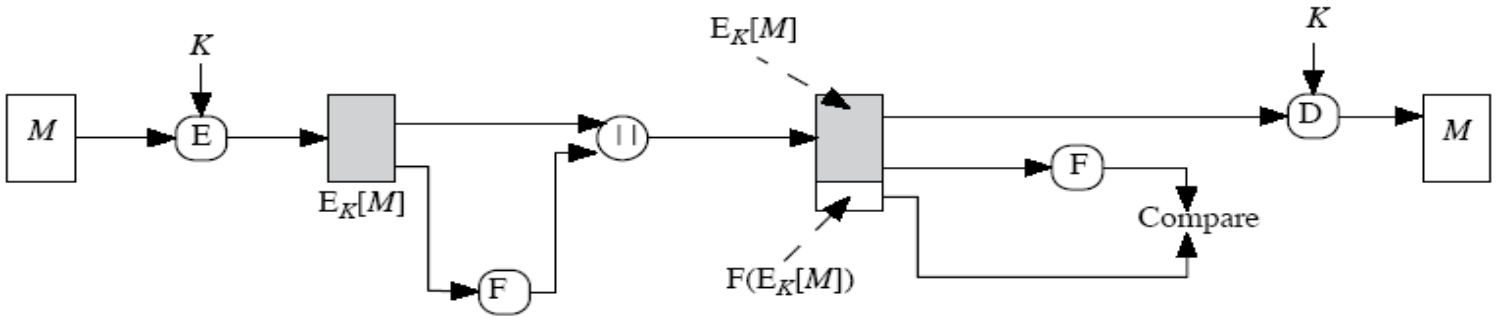
Message Encryption 1/3

- 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 have been altered
  - if message has suitable structure, redundancy or a checksum to detect any changes

Message Encryption 2/3



(a) Internal error control



(b) External error control

Figure 11.2 Internal and External Error Control

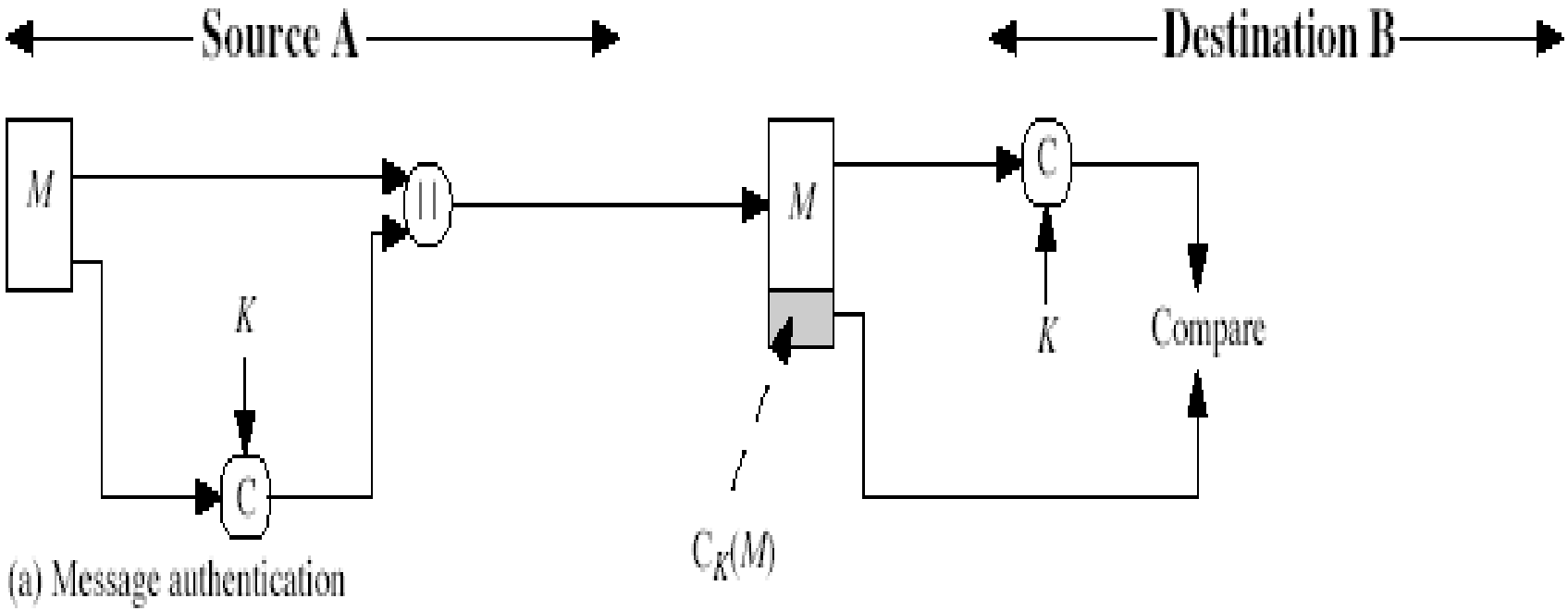
Message Encryption 3/3

- 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
- Please see Table 11.1

Message Authentication Code (MAC)

- generated by an algorithm that creates a small fixed-sized block
  - depending on both message and some key
  - like encryption *though need not be reversible*
- appended to message as a **signature**
- receiver performs same computation on message and checks it matches the MAC
- provides assurance that message is unaltered and comes from sender
  - If message includes a sequence number → receiver assured of proper sequence

MAC Use for Authentication

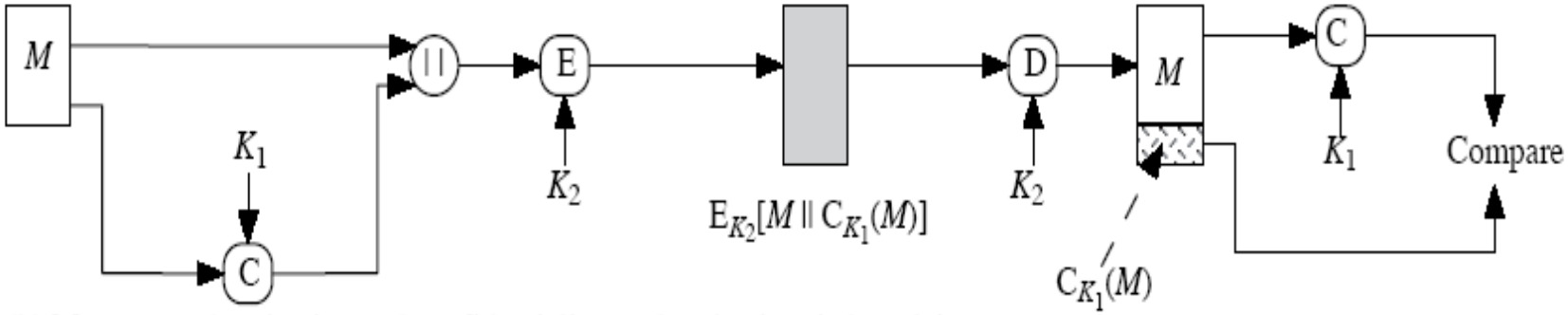


(a) Message authentication

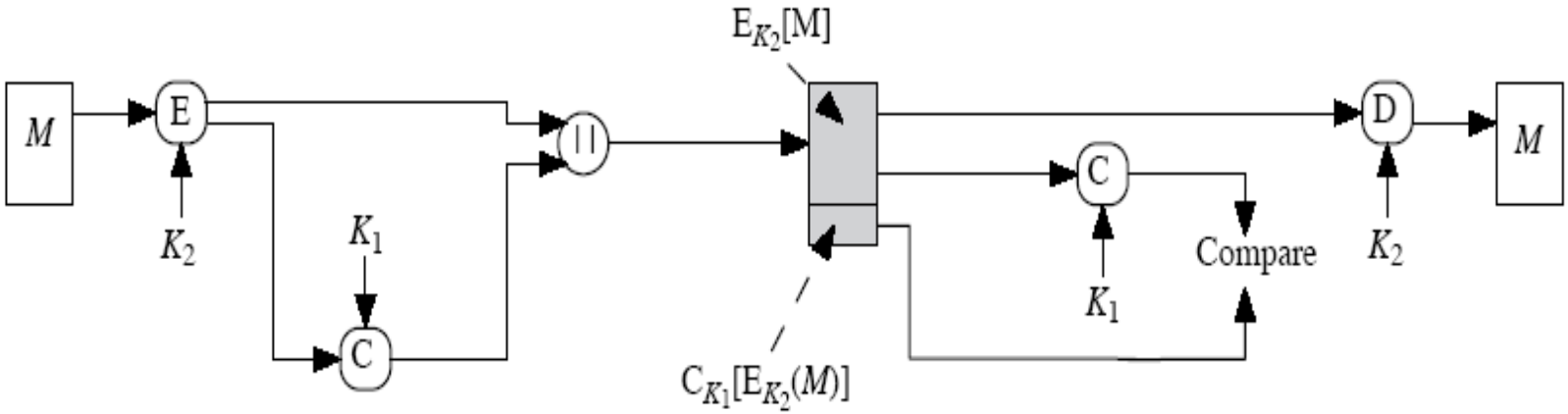
MAC use for Confidentiality 1/2

- as shown the MAC provides authentication
- 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?
  - sometimes only authentication is needed
  - sometimes need authentication to persist longer than the encryption (e.g. archival use)
- note that a MAC is not a digital signature

MAC use for Confidentiality 2/2



(b) Message authentication and confidentiality; authentication tied to plaintext



(c) Message authentication and confidentiality; authentication tied to ciphertext

Figure 11.4 Basic Uses of Message Authentication Code (MAC)

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
  - but finding these needs to be very difficult
    - Assume 100-bit messages, and a 10-bit MAC
    - On average, each MAC is generated by a total of 2^{90} messages

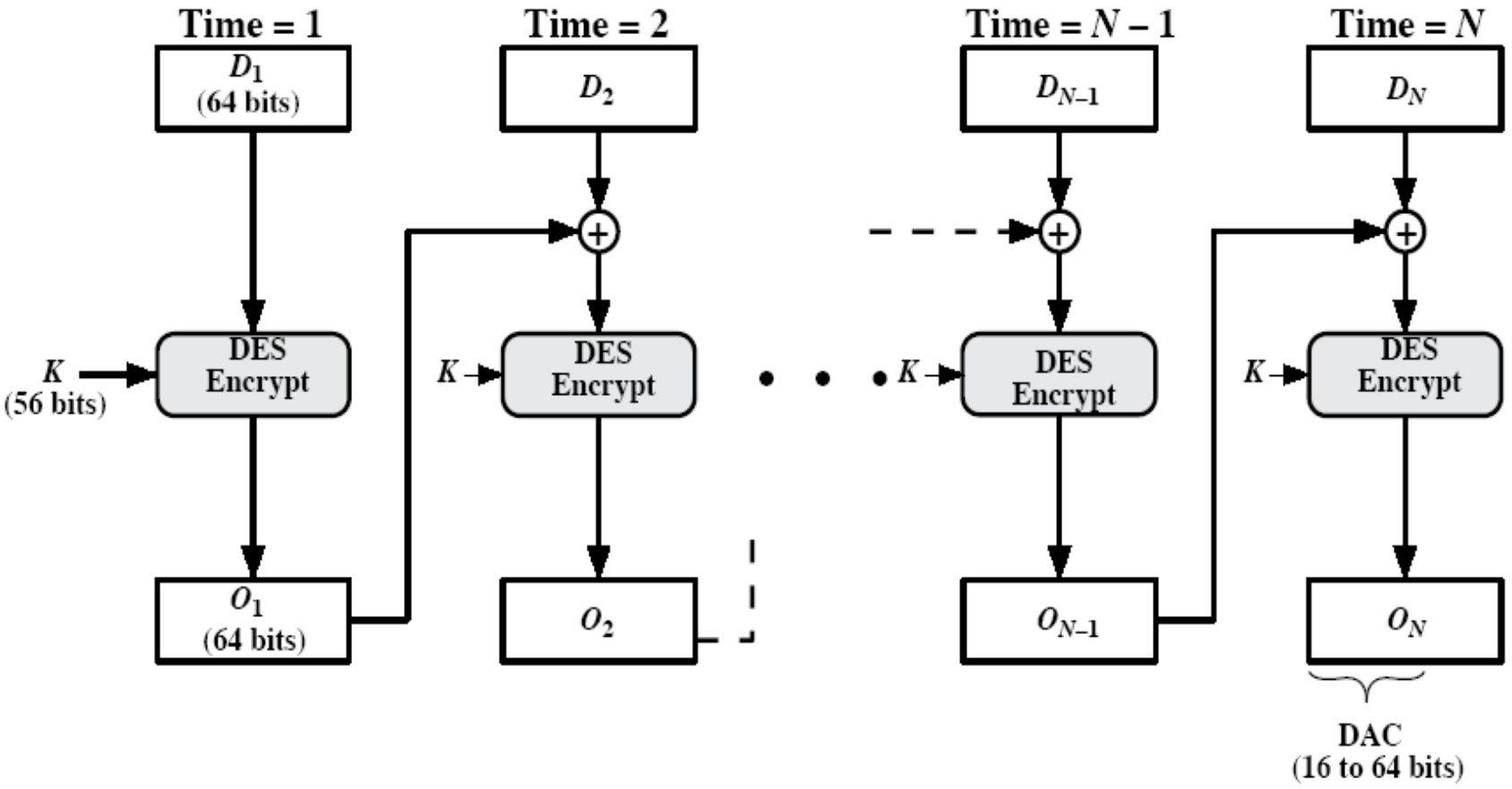
Requirements for MACs

- 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 1/2

- 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 ($16 \leq M \leq 64$) of final block
- but final MAC is now too small for security

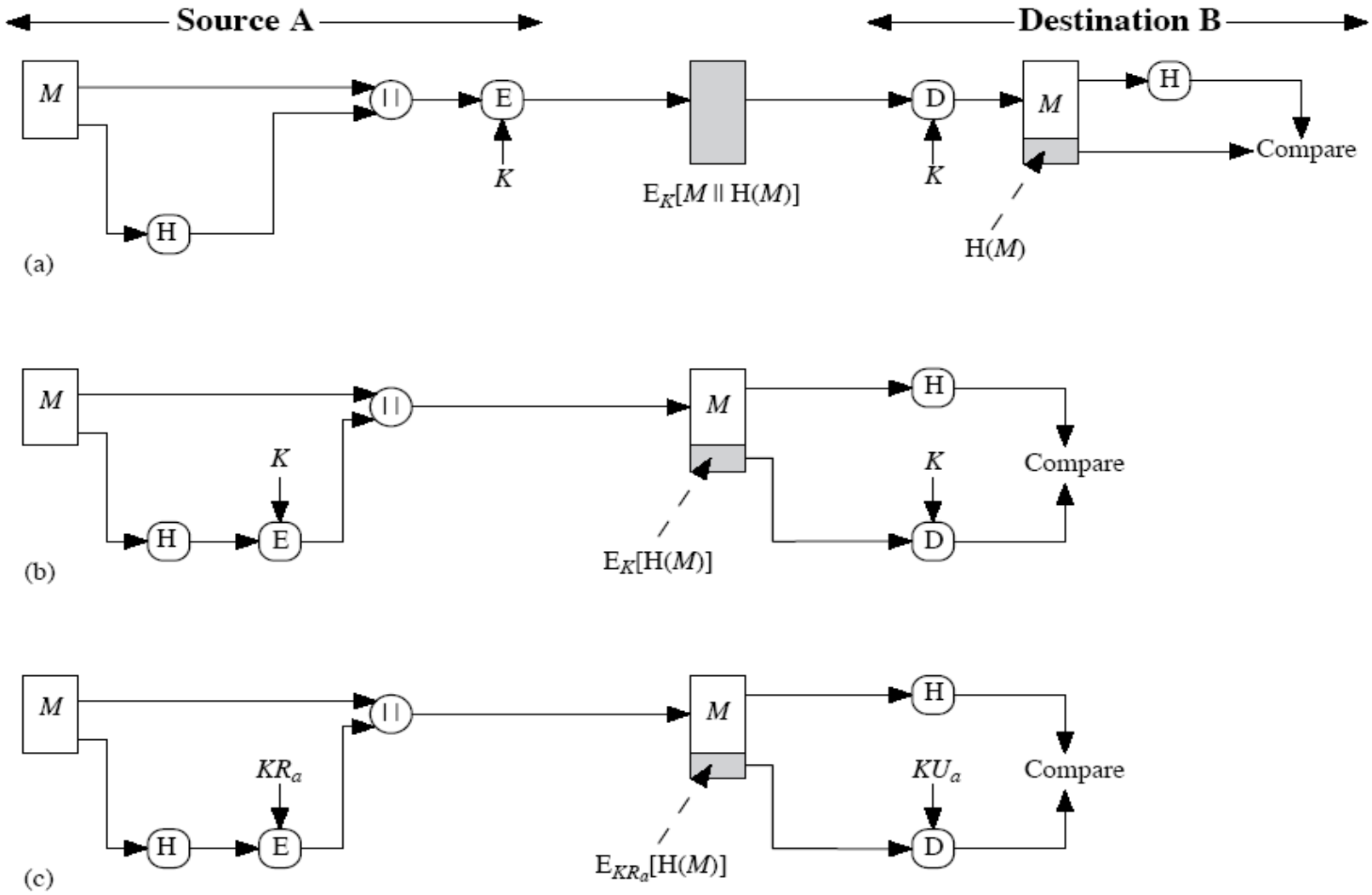
Using Symmetric Ciphers for MACs 2/2



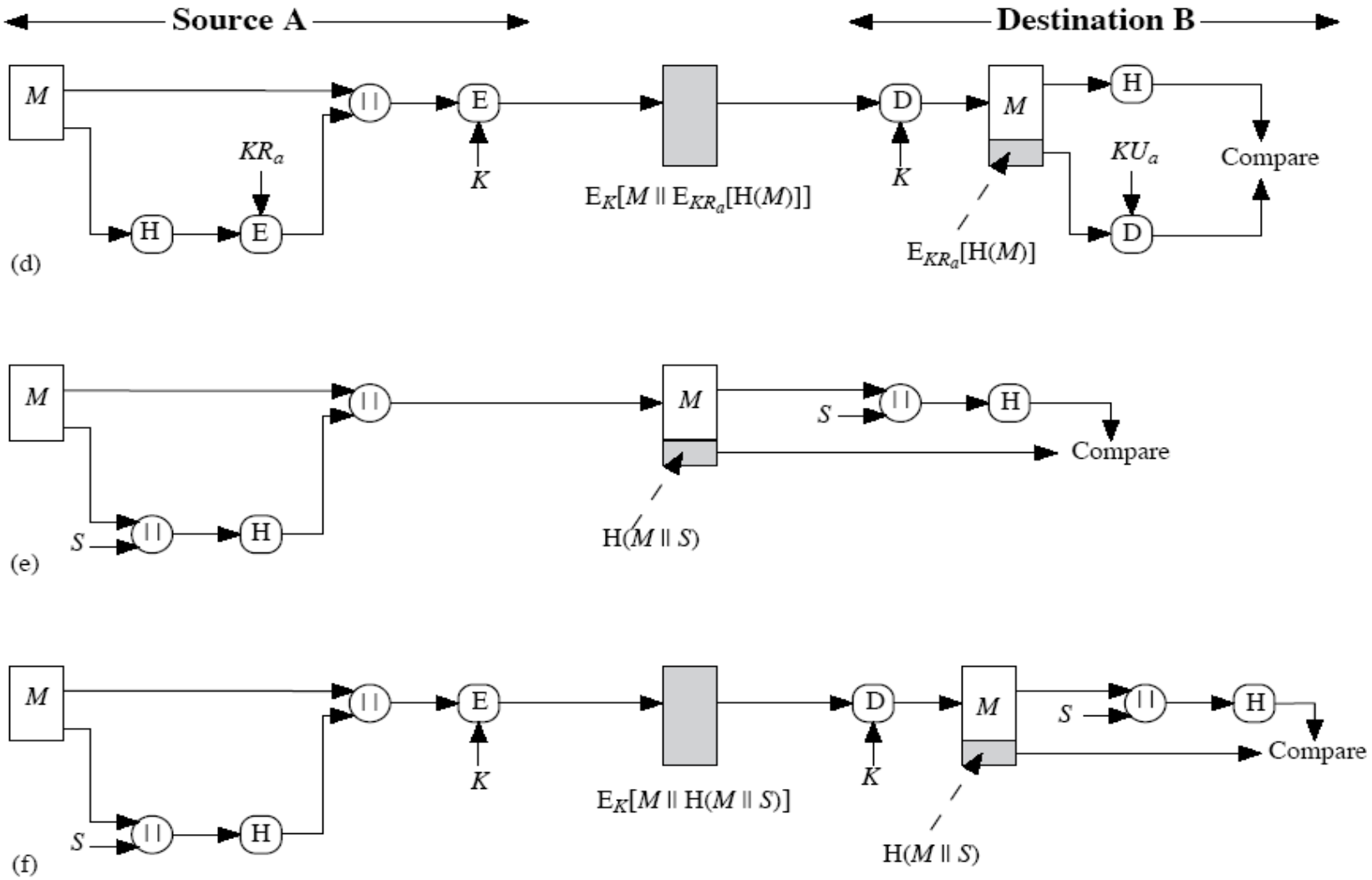
Hash Functions

- condenses arbitrary message to fixed size
  - H(M) = message digest = hash value
- usually assume that the hash function is public and not keyed
- hash used to detect changes to message
- can use in various ways with message
- most often to create a digital signature

Basic Uses of Hash Functions 1/2



Basic Uses of Hash Functions 2/2



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

- Several proposals for simple functions
- based on XOR of message blocks
- not secure since can manipulate any message and either not change hash or change hash also
  - Given a message, produce a new message that yields the hash code
  - Prepare the desired alternate message and then append an *n*-bit block to force the new message + block to yield desired hash code
- need a stronger cryptographic function
- Need to use a substantial number of bits a hash size

Block Ciphers as Hash Functions

- can use block ciphers as hash functions
  - using H_0=initial value 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)

Hash Functions & MAC Security

- like block ciphers have:
- **brute-force** attacks exploiting
  - strong collision resistance hash
    - proposal for h/w MD5 cracker
    - 128-bit hash looks vulnerable, 160-bits better
  - MACs with known message-MAC pairs (x_i,$C_k(x_i)$)
    - can either attack key-space (key search) or MAC
    - at least 128-bit MAC 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_0=IV; CV_i = f[CV_{i-1}, M_i]; H(M)=CV_N
  - typically focus on collisions in function f (compression function)
  - like block ciphers is often composed of rounds
  - attacks exploit properties of round functions