Computer Networks Advanced Course

Secure Sockets Part 2 – Cipher Suites

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Part 2 – Cipher Suites

- Hashing
- Data Integrity
- Encryption
  - Asymmetric
  - Symmetric
- Authentication

Hashing

- “One directional” function
  - Easy to calculate the hashed result from the source
  - Very difficult to calculate source from hashed results
  - Example: sum of digits
    123459 -> 24

Hashing

- "Good" hash characteristics:
  - Fixed length result
  - Small change in source, yields big change in result
  - No two sources yield same result

“Improved” Hash

- Improved hash:
  - Source X 1234
  - Square the result
  - Pick digits in indexes 4-9
  - Square the result
  - Pick digits in indexes 4-8
- How many sources may be (at most) before the results repeat?

Source	Result
99	57569
100	83553
101	64178

Common Hash Algorithms

- MD5 – 128 bits, declared unsafe in 2008
- SHA1 – 160 bits, declared unsafe in 2017
- SHA2 – 256, 384, 512 bits

- Exercise:
  - Create two text files. First file should store "hello cool cyber class". Second file should store the same, plus a dot in the end. Use Powershell to find their MD5 and SHA256

Get-FileHash filename –algorithm MD5/SHA256

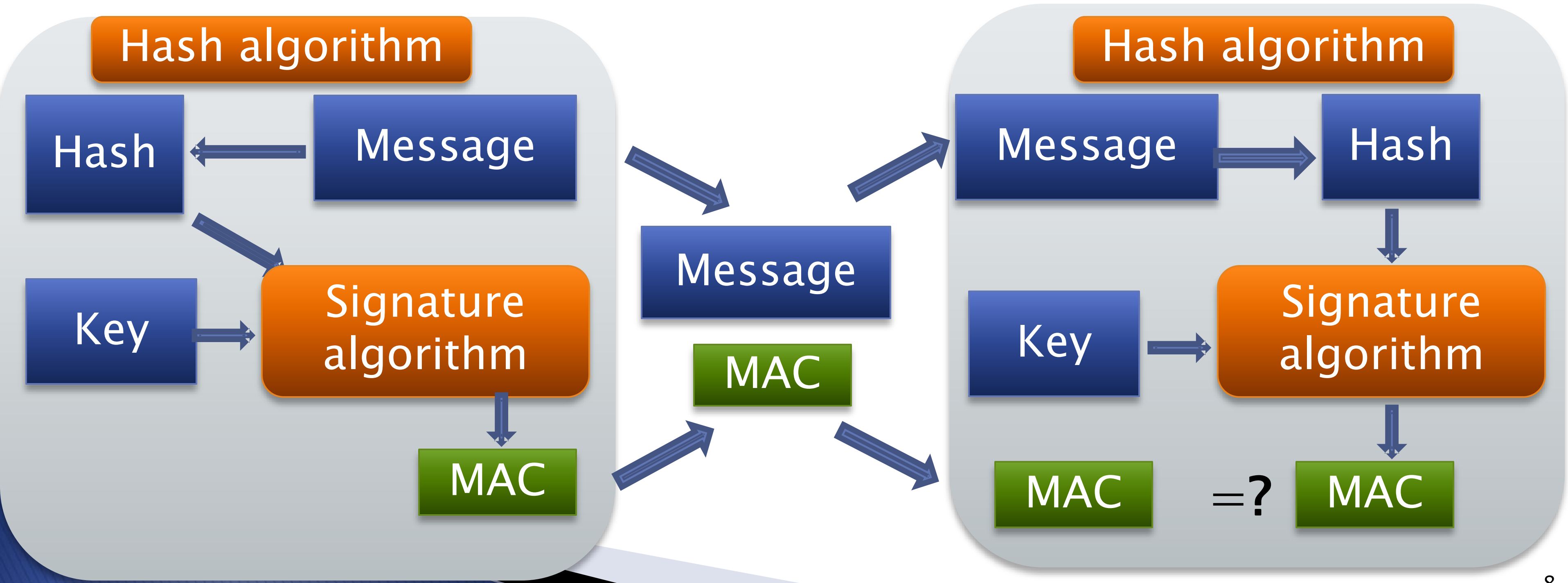
  - Do the same in python

MD5 hash using encode()

```
import hashlib

# initializing string
str1hash = "Hello cool cyber class"
str2hash = "Hello cool cyber class."

# encoding string using encode() and then sending to md5()
result = hashlib.md5(str1hash.encode())
result2 =  hashlib.md5(str2hash.encode())
print(result)
print(result2)

# printing the equivalent hexadecimal value.
print("The hexadecimal equivalent of hash is : ", result.hexdigest())
print("The hexadecimal equivalent of hash is : ", result2.hexdigest())
```

Data Integrity

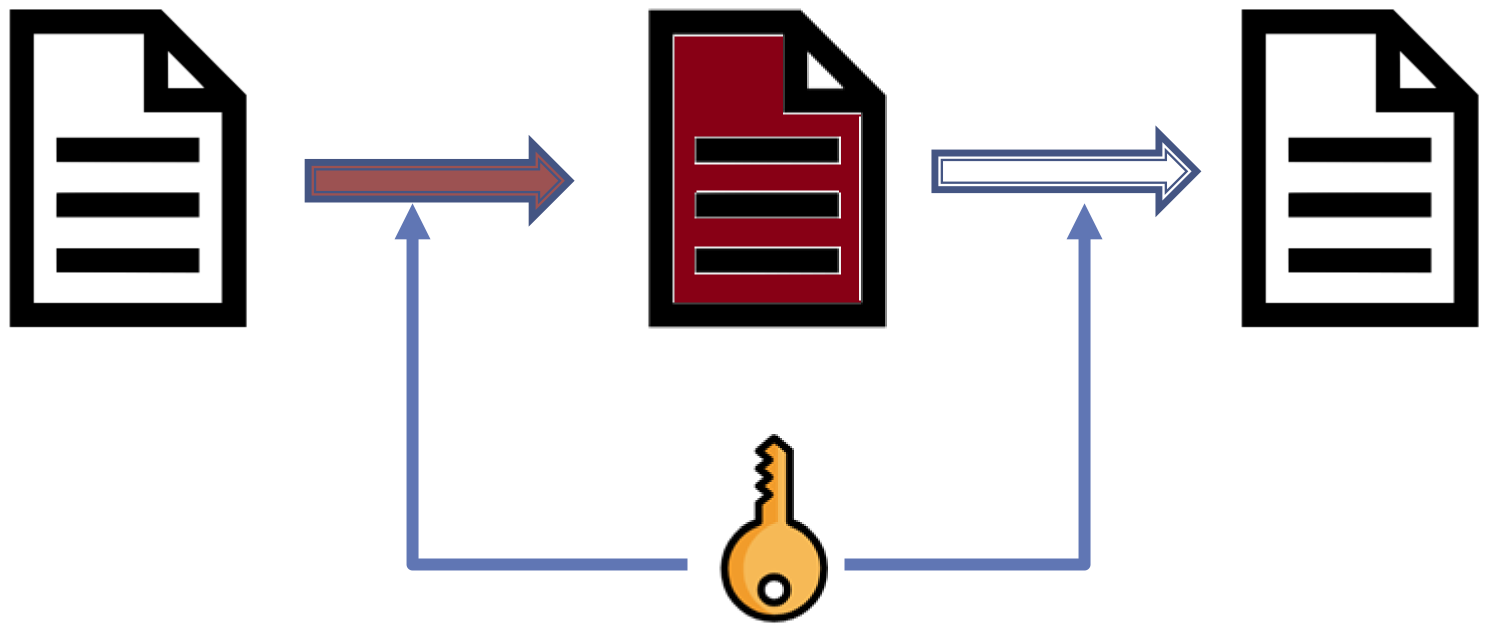
- Method to ensure data was not changed
- Message Authentication Code (MAC)
- The key is shared only by sender and recipient
- Recipient compares hash to calculated hash



Key Based Encryption

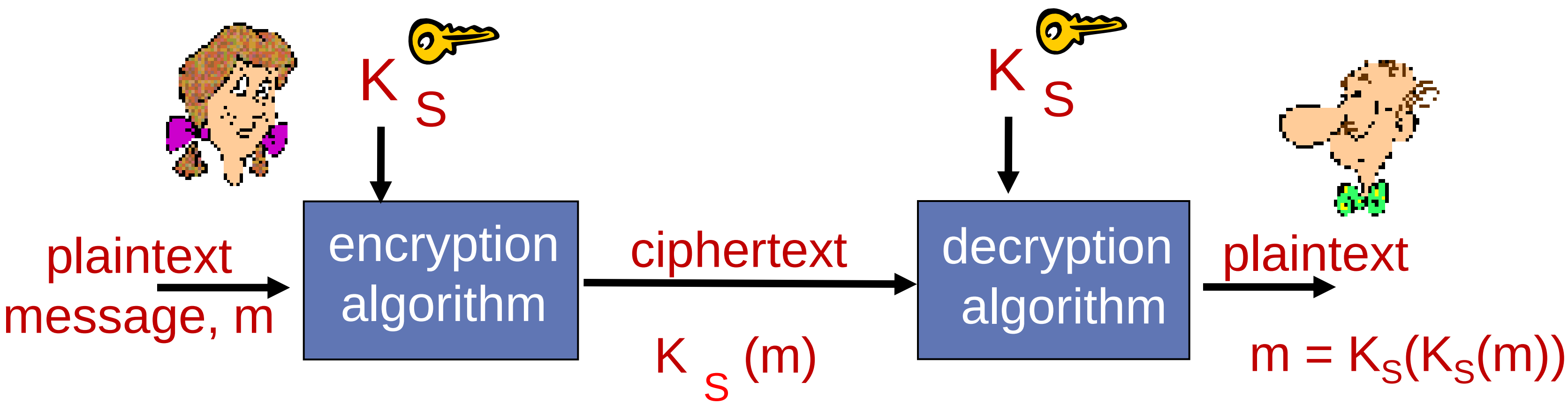
- Public algorithm
- Secret key
- Encryption types:
  - Symmetric
  - Asymmetric

Symmetric Encryption



- Same key used for encryption / decryption
  - Shift cypher
  - XOR function

Symmetric key cryptography



symmetric key crypto: Bob and Alice share same (symmetric) key: K_S

Q: how do Bob and Alice agree on key value?

XOR Encryption – Example

Data: 1001 0011

Key: 0101 0100

1001 0011 xor
0101 0100

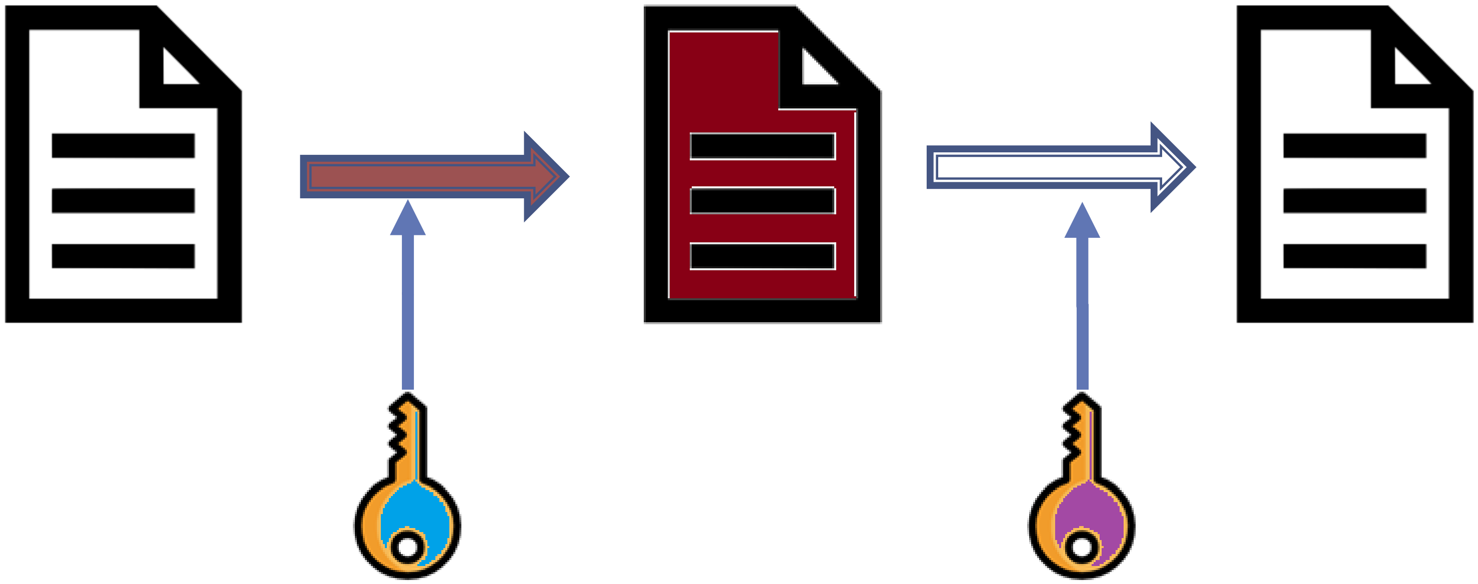
1100 0111 – encrypted

1100 0111 xor
0101 0100

1001 0011

- The key is required to decrypt

Asymmetric Encryption



- Different keys are used to encrypt / decrypt
  - Keys come in pairs
  - Only the complementary key can decrypt
  - Order of keys does not matter

RSA – Asymmetric Cipher

- Rivest, Shamir, Adleman (1977)
- Used for exchanging <u>symmetric</u> keys
  - Idea: public key, private key
- Other usages:
  - Integrity– digital signatures
  - Encryption (slow, but can be used)

RSA

- Pick two prime numbers – P, Q
- Calculate PxQ
- Calculate Totient φ T=(P−1)x(Q−1)
  - totient (plural totients) (mathematics) The number of positive integers not greater than a specified integer that are relatively prime to it.
- Pick public key E
  - Prime
  - Smaller than T
  - T mod E is not zero
- Pick a private key D
  - Condition: DxE mod T = 1
- Exercise:
  - Let P=17, Q=23
  - Let public key E be 113
  - Find the matching private key ?

RSA: Encryption, decryption

- Sender: Given message m, compute $c = m^E \bmod N$. This is the ciphertext.
- Receiver: Given ciphertext c, compute $m = c^D \bmod N$.
- Theorem: $(m^e \bmod n)^d \bmod n = m$.

Encryption / Decryption

- Cipher = (Plain^E) mod N
- Plain = (Cipher^D) mod N

Other side is given:

- N ("Modulus")
- E ("Exponent")
- In order to break the private key, N must be broken to P and Q . If I have P and Q, then I have T, and since I have E, it is easy to calculate D as in the previous slides. The difficulty is factoring N.

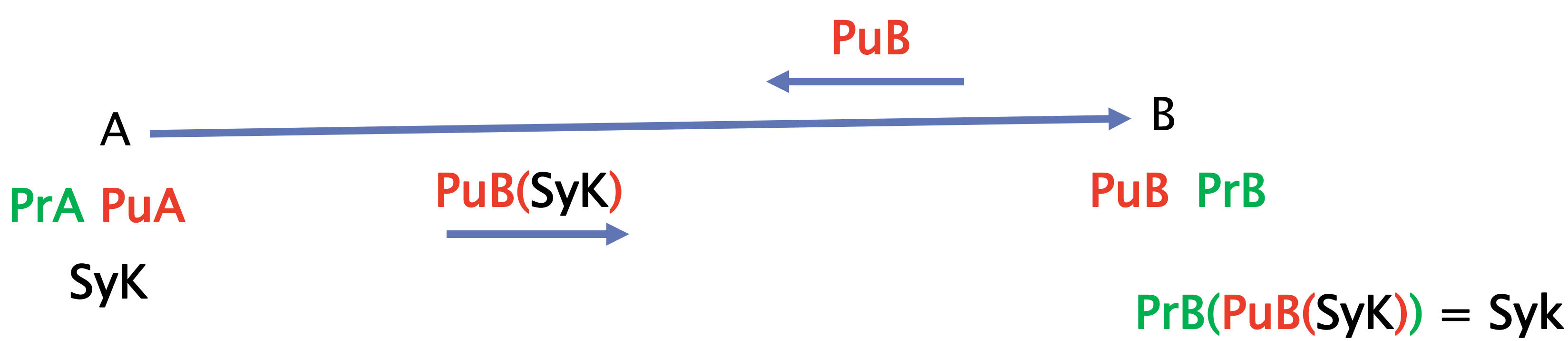
P = 17
Q = 23
N = 391 (PxQ)
T = 352 (P−1)(Q−1)
E = 113 (Public)
D = 81 (Private)

Pros and Cons

- Symmetric encryption
  - Faster than asymmetric
  - Key must be shared between sender and recipient
  - How can both sides share the key?
- Asymmetric encryption:
  - Slower than symmetric
  - No need to share keys

Exchange of Symmetric Keys

- Common usage of RSA:
  - Alice creates a key for symmetric encryption
  - Alice encrypts the key with Bob's public key
  - Bob decrypts the key with his corresponding private key
  - Now Alice and Bob share the same key



Non-Repudiation

- Sender cannot deny sending a message
- Logically, a result of:
  - No one is able to impersonate the sender
  - No one is able to change the message
- How can that be achieved?

Non-Repudiation

- Alice calculates hash of message
- Alice signs the message and encrypts hash with private key
- Alice's public key is known, so Bob can decrypt the digital signature
- Bob calculates the hash and compares the result to the decrypted hash
- If both are equal, Alice cannot deny sending the message
- … Unless her private key is broken

$$A \xrightarrow{C} B$$

PrA PuA

C = Mes + PrA(Hash(Mes))

PuB PrB

Mes + PrA(Hash(Mes))

Hash(Mes)) =? PuA(PrA(Hash(Mes)))

RSA Summary

Encryption – possible, slow

Symmetric key exchange

Authentication = Non-Repudiation + Integrity

Diffie-Hellman Key Exchange

- Usage – creating a shared secret
  - Not an encryption algorithm
  - DH is commonly used to coordinate symmetric key

DH Algorithm

Private = 7

Private = 8

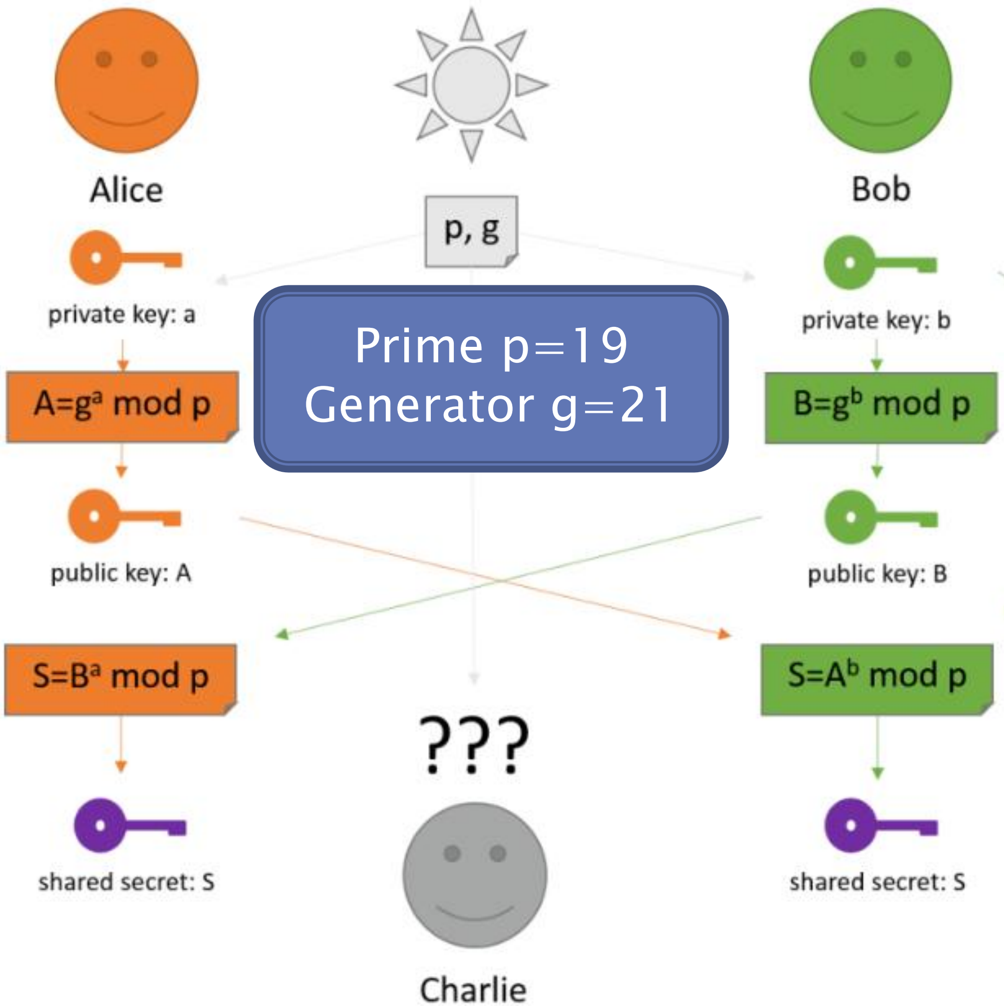
Prime p=19
Generator g=21

A = 21^7 mod 19
= 14

B = 21^8 mod 19
= 9

S = 9^7 mod 19
= 4

S = 14^8 mod 19
= 4



https://blog.noser.com/asymmetric-cryptography-diffie-hellman-key-exchange/ מקור

Symmetric Encryptions in TLS

- Lesson focus:
  - AES
  - GCM vs CBC

- CHACHA20
- AES 256 GCM
- AES 128 GCM
- AES 256 CBC
- AES 128 CBC
- 3DES CBC
- RC4 128
- DES CBC

AES

- Advanced Encryption System 1998
- Block cipher
  - Input 128 bits into 4x4 byte matrix
- Repeat:
  - XOR with key
  - Substitution cipher
  - Switch rows
  - Switch columns

AES –cont.

- Problem 1: same input will always result in same output

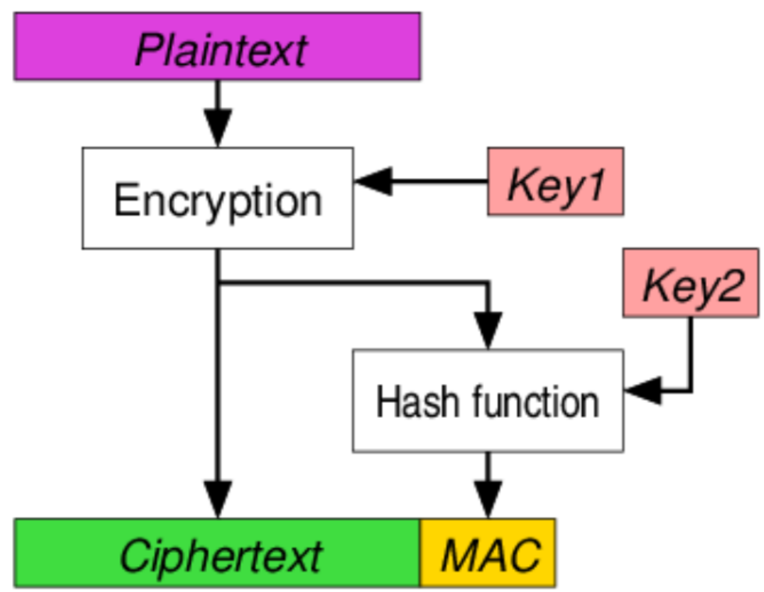
Source :Wikipedia, Block Cipher

AES – cont.

- Solutions:
  - CBC – Cipher Block Chaining – last bytes of previous block are used for generating new key for next block
    - Blocks can't be decrypted in parallel
  - CTR – Counter Mode. Initial key, every block uses last key + counter
    - Parallel decryption possible

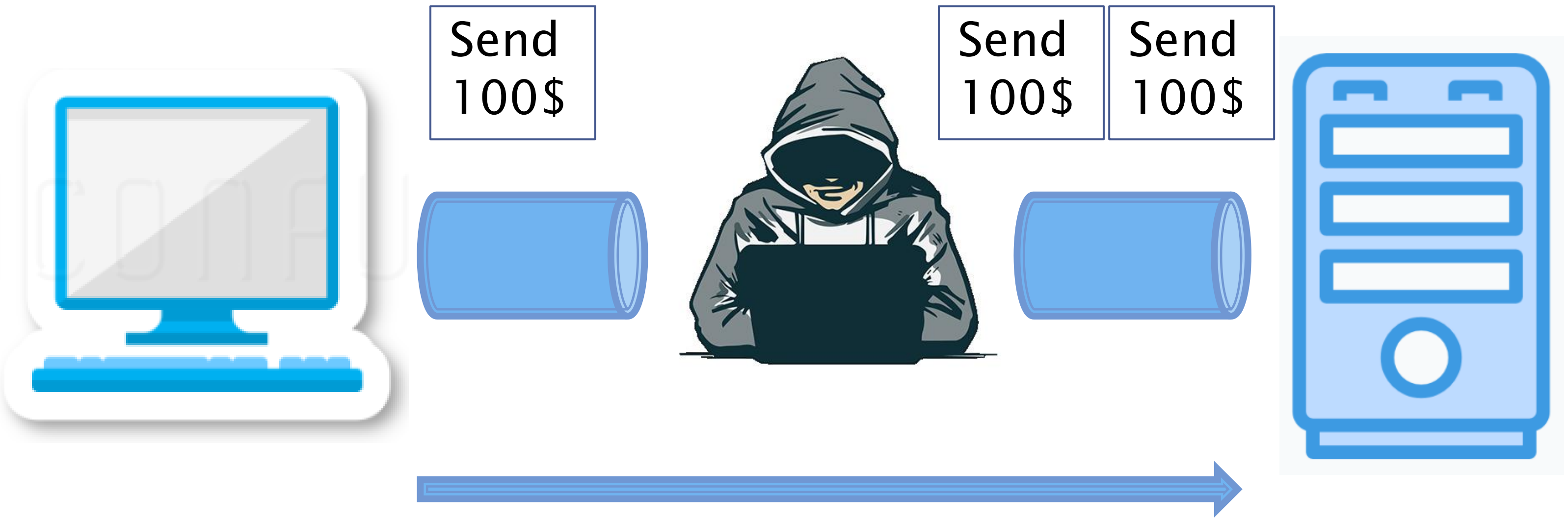
AES – cont.

- Problem 2: CTR does not include –
  - Integrity
  - Authentication
- Solution: combine encryption & authentication
  - Encrypt-then-MAC
  - MAC-then-encrypt
  - AEAD (future lesson)



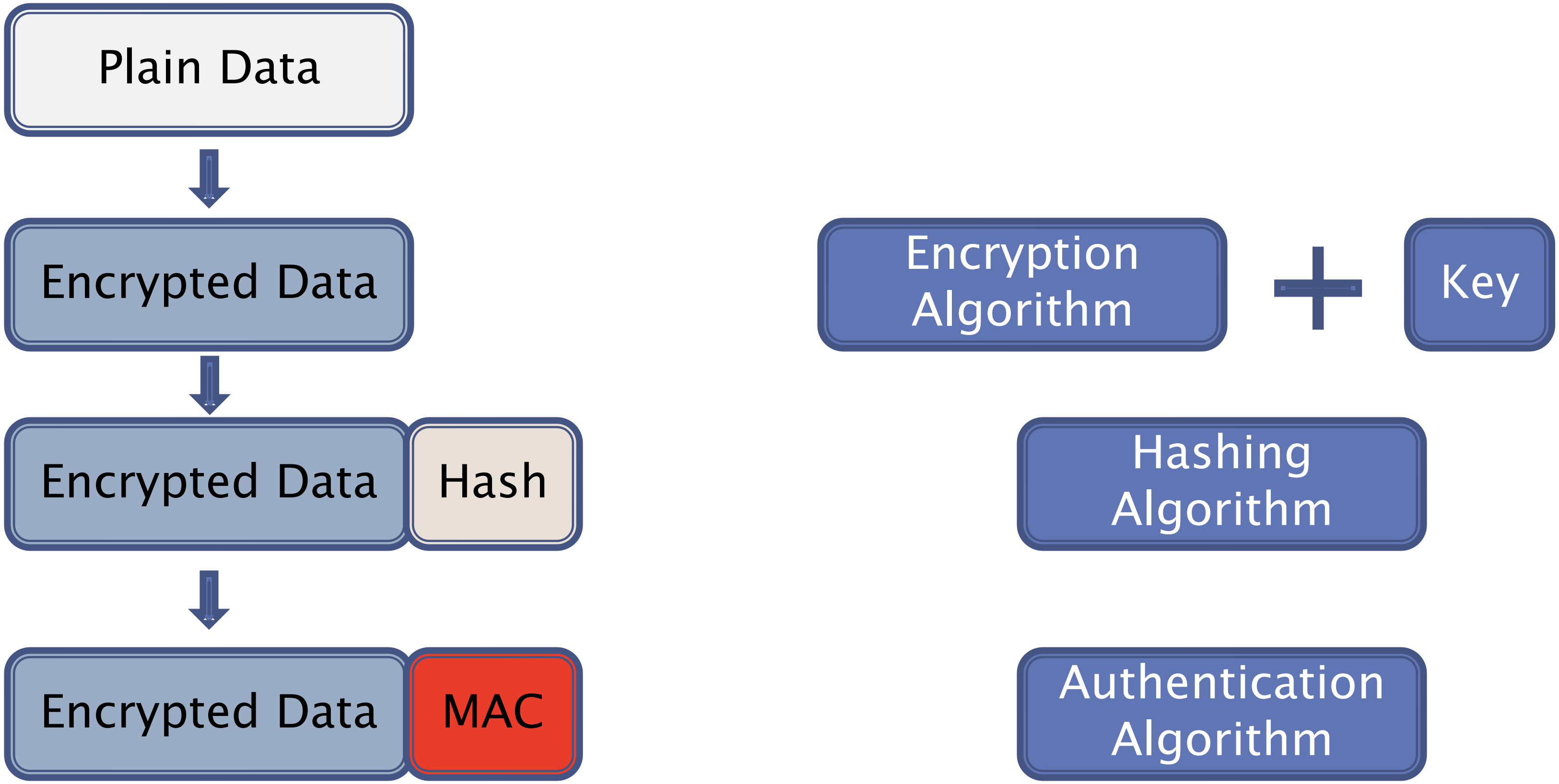
Source :Wikipedia, Authenticated Encryption

Anti-replay



- The copied message will be rejected
  - Every message will be decrypted with a different key
  - The MAC will not be correct

Cipher Suites



TLS Cipher Suites

- Client – Server should coordinate 4 issues
- Format:
- TLS_x_y_with_z_w
  - X – Key Exchange
  - Y – Authentication
  - Z – Encryption
  - W – Hashing

```
Cipher Suite: TLS_ECDHE_ECDSA_WITH_AES_256_CBC_SHA
Cipher Suite: TLS_ECDHE_ECDSA_WITH_AES_128_CBC_SHA
  Cipher Suite: TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA
  Cipher Suite: TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA
```

Summary

- The scheme allows:
  - Sharing a key with other side
  - Know that the message was sent by the key owner
  - Know that the message was not changed on way
- But what if the keys were exchanged with an imposter?