en_US

Samsung Research

SSTF 2021 | Hacker's Playground

Tutorial Guide

RC four

Crypto

Cryptography and Security

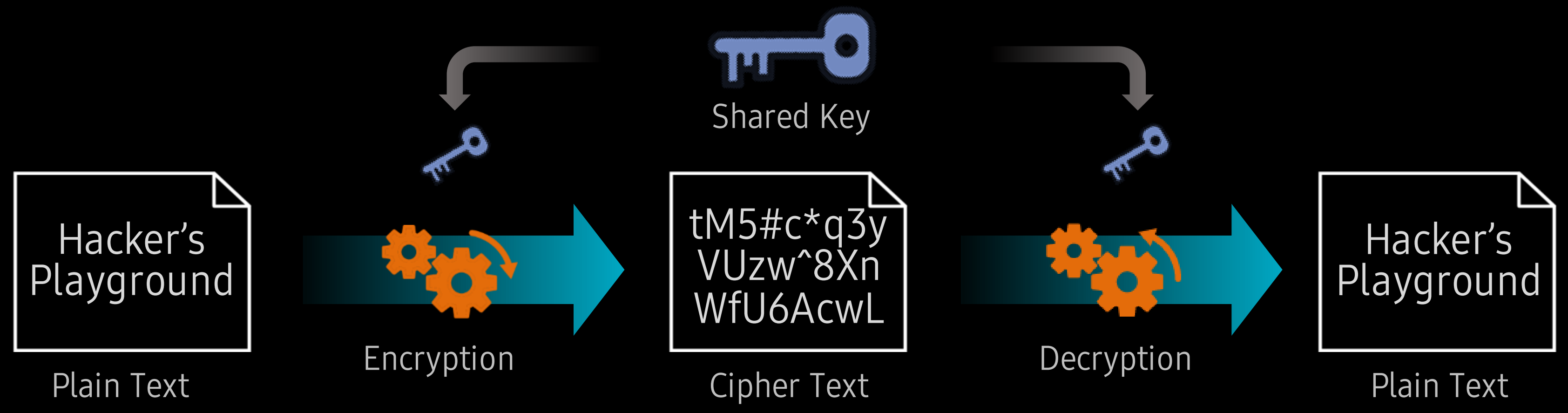
- Most security systems are based on cryptography.
  - From authentication and protection systems on your cell phone, to HTTPS, Wifi, banking, and most web based services that require a login, you use cryptographic algorithms on a daily life whether you are aware of it or not.
- It is not just about keys and data.
  - Cryptographic algorithms that have been proven to be secure based on mathematical models can be completely defeated by even a minor misuse.
- In this tutorial,
  - you will learn the concept of cryptography and the attacks that can occur if cryptographic algorithms are misused.

Two kinds of encryption

	Symmetric Encryption	Asymmetric Encryption
Key	One shared key for encryption and decryption	Mathematically coupled public key and private key
Typical Key Size	128~256 bits	1024~3072 bits (for RSA)
Performance	High	Low, because it's a complex mathematical computation
Main Purpose	Data Encryption	Digital Signature/Certificate
Representative Algorithms	DES, AES, RC4	RSA, DSA, ECC

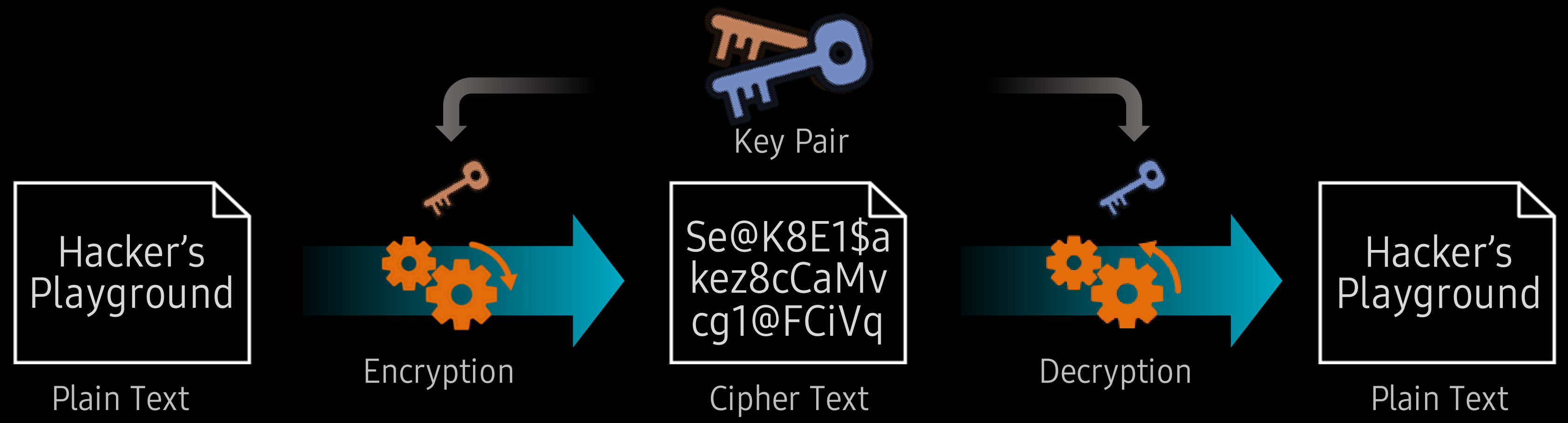
Two kinds of encryptions

Symmetric Encryption



One key used for both encryption and decryption

Asymmetric Encryption

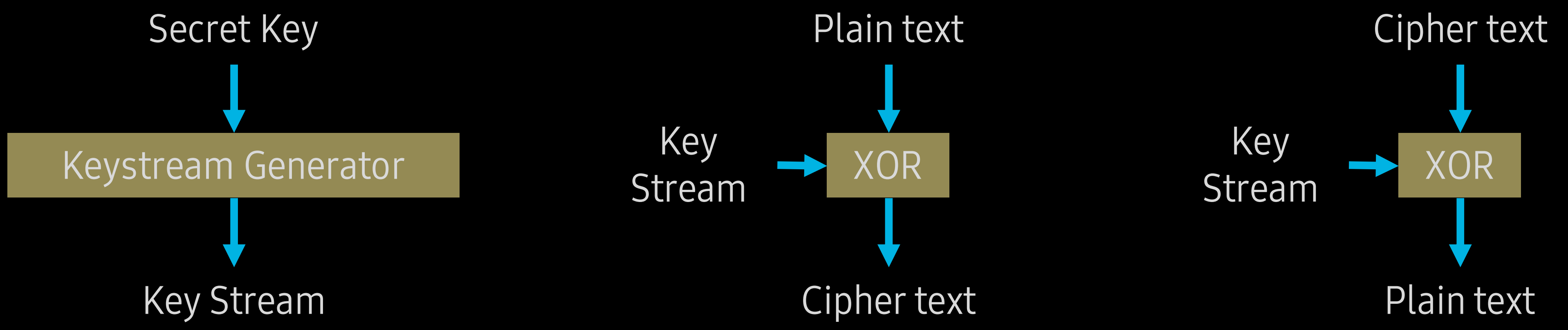


Key Pair consisting of encryption key and decryption key

RC4 (a.k.a ARC4)

- A representative stream cipher
  - Stream cipher is a branch of symmetric key cipher.
  - XOR-based common encryption/decryption processing

- Working



Step 1. Key stream generation

Step 2-1. Encryption

Step 2-2. Decryption

Let's solve
Crypto quiz!

Quiz #1
& solution

Quiz #1

```
KeyStream_From_RC4 ="<y4)ky&=zuw(8*#3*<q4Quw)o+"
RC4_CipherText ="k6cv36tb1<9ogcplby#qpT"
```

Download the source code HERE.

- Simple python code
- Can you get the plaintext?
- Try it before you see the solution.

Solution for Quiz #1

- It's quite simple. To decrypt the RC4 ciphertext, just XOR it with the key stream.

```python
KeyStream_From_RC4 = "<y4)ky&=zuw(8*#3*<q4Quw)o+"
RC4_CipherText = "k6cv36tb1<9ogcplby#qpT"

plaintext = ""
for k, c in zip(KeyStream_From_RC4, RC4_CipherText):
    plaintext += chr(ord(k) ^ ord(c))
print(plaintext)
```

Bytewise XORing of ciphertext and key stream

- And you did it!

```
$ python3 ex.py
WOW_XOR_KING_IS_HERE!!
$
```

Quiz #2

& solution

Quiz #2

```python
from Crypto.Cipher import ARC4
from binascii import hexlify
from secret import key, flag

def encrypt(data):
    return ARC4.new(key).encrypt(data)

ct = b""
for ch in flag:
    ct += encrypt(ch)

print("Ciphertext = ", hexlify(ct).decode())

'''
$ python3 challenge.py
Ciphertext = 6f47474c06086f47085c47085c404d08464d505c085b5c494f4d09
'''
```

Download the source code HERE.

- ARC4 module generates key stream and XOR with the input.
- RC4 ciphertext is given, but key is not known.
- Can you get the plaintext?
- Try it before you see the solution.
- HINT: You may need a little bit brute-forcing.

Solution for Quiz #2

```python
from Crypto.Cipher import ARC4
from binascii import hexlify
from secret import key, flag

def encrypt(data):
    return ARC4.new(key).encrypt(data)

ct = b""
for ch in flag:
    ct += encrypt(ch)

print("Ciphertext = ", hexlify(ct).decode())

'''
$ python3 challenge.py
Ciphertext = 6f47474c06086f47085c47085c404d08464d505c085b5c494f4d09
'''
```

- **According to the source code...**
  - The flag is not encrypted at once.
  - It's split for each byte, encrypted, and put back together.
- **Each letter of the flag is XORed with the first byte of the key stream.**
  - Only one byte of the key stream is used.
  - The entire flag data can be recovered by finding the value of the one byte.

Solution for Quiz #2

- **Try every possible case.**
  - 1 byte is group of 8 bits, so there can be $2^8 = 256$ cases

```python
from binascii import unhexlify

Ciphertext = unhexlify("6f47474c06086f47085c47085c404d08464d505c085b5c494f4d09")

for i in range(256):
    flag = ""
    for ch in Ciphertext:
        flag += chr(ch ^ i)
    else:
        print(i, flag)
```

Try XORing for every possible case

- **We got a meaningful sentence among them.**

```
38 Iaaj .Ia.za.zfk.`kvz.}zoik/
39 H``k!/H`/{`/{gj/ajw{/|{nhj.
40 Good. Go to the next stage!
41 Fnne/!Fn!un!uid!odyu!ru`fd
42 Emmf,"Em"vm"vjg"lgzv"qvceg#
```

Let's practice

Solve the tutorial challenge

Challenge Definition

```python
from Crypto.Cipher import ARC4
from secret import key, flag
from binascii import hexlify

#RC4 encrypt function with "key" variable.
def encrypt(data):
    #check the key is long enough
    assert(len(key) > 128)

    #make RC4 instance
    cipher = ARC4.new(key)

    #We don't use the first 1024 bytes from the key stream.
    #Actually this is not important for this challenge. Just ignore.
    cipher.encrypt("0"*1024)

    #encrypt given data, and return it.
    return cipher.encrypt(data)

msg = "RC4 is a Stream Cipher, which is very simple and fast."

print (hexlify(encrypt(msg)).decode())
print (hexlify(encrypt(flag)).decode())
```

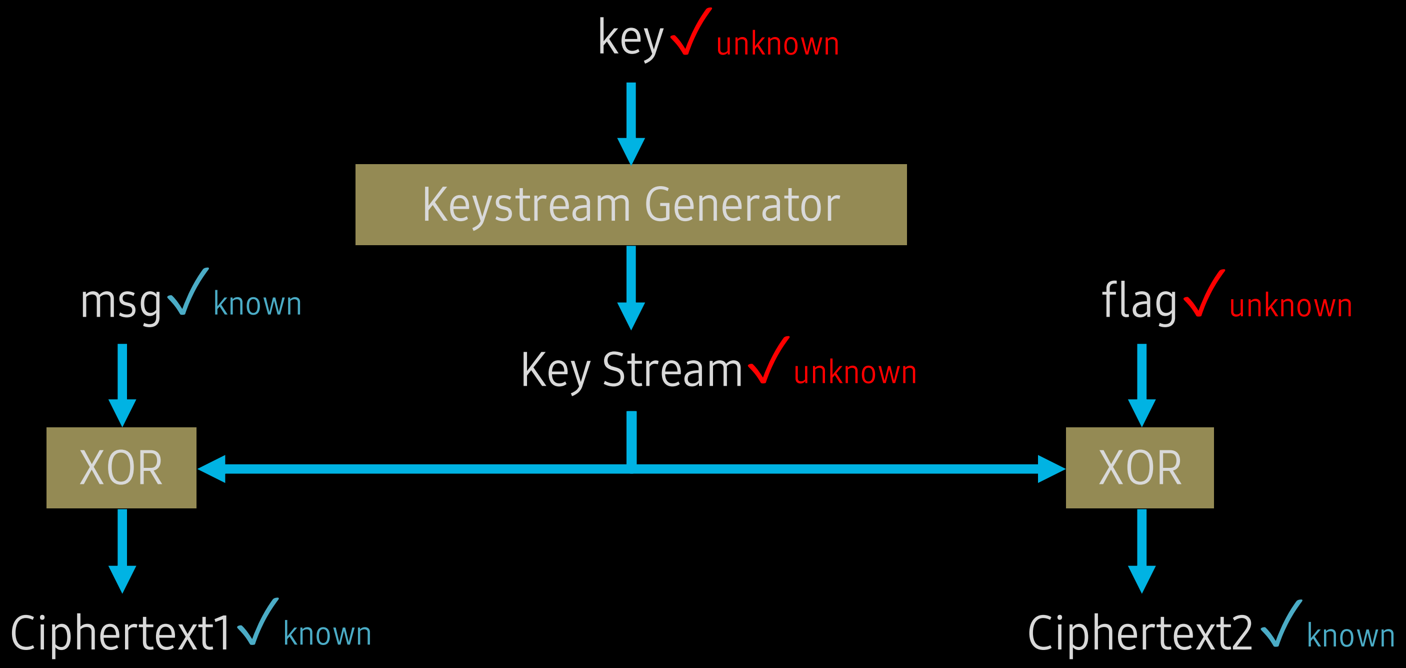
✔ There are

- one key,
  unknown
- two plaintexts
  flag: unknown
  msg: known
- and two ciphertexts.
  Both of them are known

```
$ cat output.txt
634c3323bd82581d9e5bbfaaeb17212eebfc975b29e3f4452eefc08c09063308a35257f1831d9eb80a583b8e28c6e4d2028df5d53df8
624c5345afb3494cdd6394bbbf06043ddacad35d28ceed112bb4c8823e45332beb4160dca862d8a80a45649f7a96e9cb
```

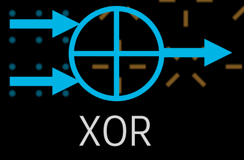
→ Ciphertext1
→ Ciphertext2

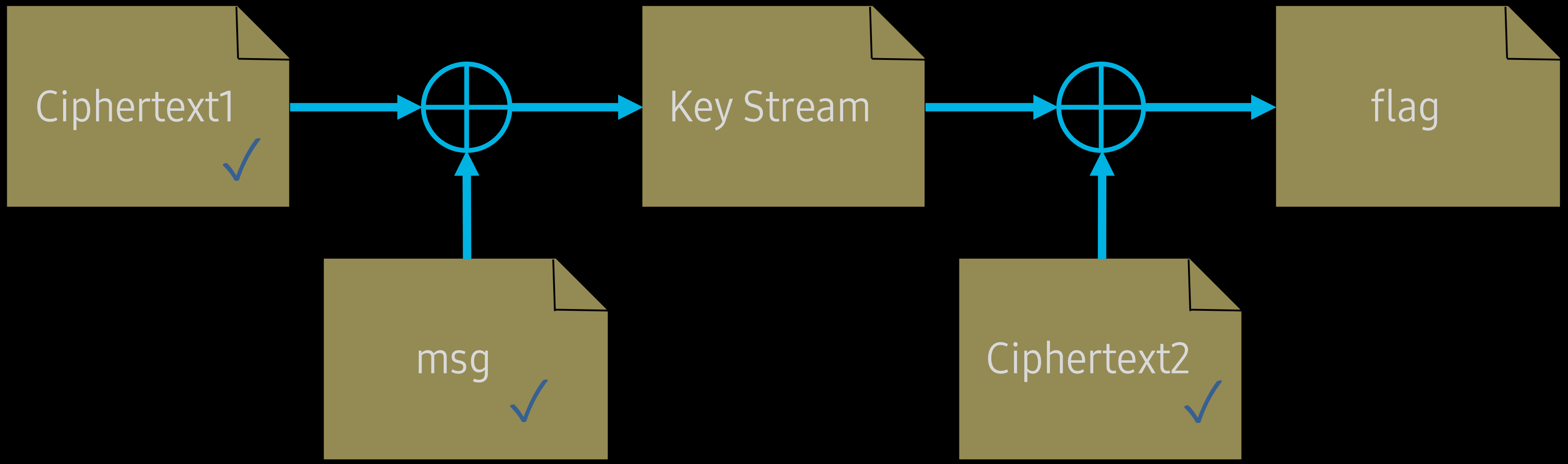
Let's see



- Can you see? We can find the **flag**, even without **key**!
  - Because when a *xor* b = c, a *xor* c = b.

It's an easy logic!





- Step 1. We can recover the Key Stream from the known plain text and cipher text pair.
- Step 2. We can decrypt the Ciphertext2 because now we know the Key Stream.
- Step 3. Now we got the flag!! :)

Does it really work?

```python
from binascii import unhexlify

ct1, ct2 = open("output.txt").read().strip().split("\n")
msg = b"RC4 is a Stream Cipher, which is very simple and fast."

ct1 = unhexlify(ct1)
ct2 = unhexlify(ct2)

l = min(len(ct1), len(ct2))
r = ""
for (c1, m, c2) in zip(ct1[:l], msg[:l], ct2[:l]):
    r += chr((c1 ^ m) ^ c2)

print (r)
```

Bytewise XORing of ct1, msg, and ct2

✔ Yes, it does!

```
$ python solve.py
SCTF{[illegible]}
```

Try it yourself!