Cryptography

Stream cipher

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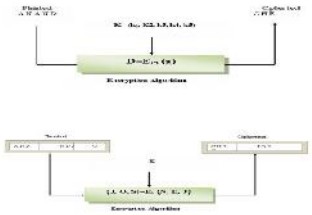
Stream and block cipher



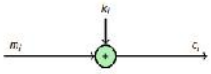
One Time Pad

The One Time Pad is the only theoretically secure cipher

- **Theorem:** The one time pad has perfect secrecy
- You must generate a truly random key sequence equally long as the message, and then find a secure channel for transportation of that key to the intended message recipient
- Your problem is now instead to transfer large quantities of secure key

One Time Pad

- Useful for sending secret data without preserved data integrity
- Uses a long random bitsequence as key
- Adds this to the plaintext to form the next cryptogram
- No error propagation



Stream Cipher

A more practical alternative is a stream cipher

- We generate a pseudorandom "key stream" from a seed, a "real key" much shorter than the full "key stream" added to the message
- We try to make the set of possible seeds, the real keys, so large that exhaustive search is impossible in practice
- We try to eliminate any shortcuts to finding this key from the "key stream"

Stream cipher

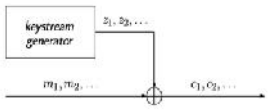
- Design goal is to efficiently produce random-looking sequences that are as "indistinguishable" as possible from truly random sequences.
- Recall the unbreakable Vernam cipher.
- For a synchronous stream cipher, a known-plaintext attack (or chosen-plaintext or chosen-ciphertext) is equivalent to having access to the keystream $z = z_1, z_2, \ldots, z_N$.
- *We assume that an output sequence z of length N from the keystream generator is known to Eve.*

Stream cipher

- Symmetric encryption algorithms are divided into two main categories, *block ciphers and stream ciphers*.
- Block ciphers tend to encrypt a block of characters of a plaintext message using a fixed encryption transformation
- A stream cipher encrypt individual characters of the plaintext using an encryption transformation that varies with time.

A stream cipher built around LFSRs and producing one bit output on each clock = *classic stream cipher design*.

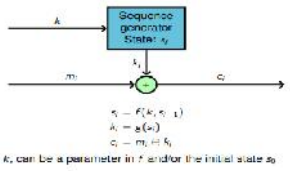
Stream cipher: key generator



- $z = z_1, z_2, \ldots$ *keystream*
- *key* K

Stream Cipher

Additive stream ciphers



The key, k, can be a parameter in f and/or the initial state s_0

Stream Cipher

Pseudorandom generator

- Sender and receiver must generate exactly the same key stream from the seed, so the generator is deterministic
- Real-world generators must be finite, having a fixed total number of states
- Sooner or later the generator is in a state it has been in before
- From then on, the internal states and the output repeats, exactly as the previous time the state was used
- Therefore, the output will be periodic, directly or after some initial output part

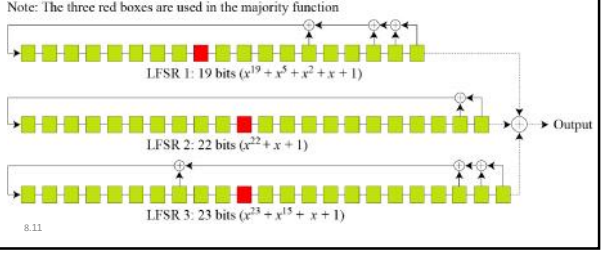
LFSR based stream cipher A5/1

Key Generator

A5/1 uses three LFSRs with 19, 22, and 23 bits.
Key size is 64.

Three LFSR's in A5/1

Note: The three red boxes are used in the majority function



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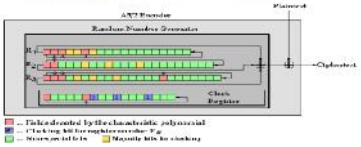
A5/2

A5/2 (Weaker GSM)

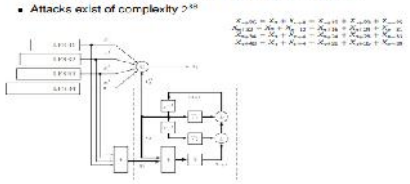
- GSM A5/2 uses four LFSRs, only clock output LFSRs where the majority orange bits agree with the clock LFSR
- Broken the same month 1999 it was published
- Prohibited from implementation in mobiles since 2007



E0(Bluetooth)

E0 (Bluetooth)

- Bluetooth E0 uses four LFSRs and two 2 bit internal states
- Attacks exist of complexity 2^{38}



RC4

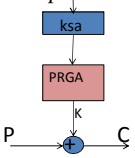
Developed by RSA Labs, RC4 is a symmetric, byte-oriented stream cipher with a variable length key size, in which a byte (8 bits) of a plaintext is exclusive-ored with a byte of key to produce a byte of a ciphertext.

KEY

RC4 HAS two main parts:

KSA (Key Scheduling Algorithm)

PRGA (Pseudo Random Generation Algorithm)



State

RC4 is based on the concept of a state.

S[0] S[1] S[2] ··· S[255]

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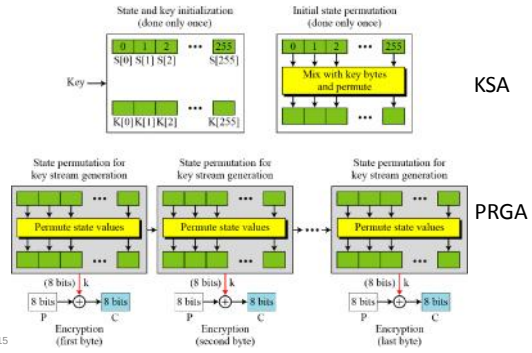
Continued

Figure 8.10 *The idea of RC4 stream cipher*



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RC4 Key Schedule KSA

Starts with an array S of numbers: 0..255

Use key to truly shuffle S

S forms internal state of the cipher

Given a key k of length L bytes

Scrambling Pseudocode :

for i = 0 to 255 do

S[i] = i

j = 0

for i = 0 to 255 do

j = (j + S[i] + k[i]) (mod 256)

swap (S[i], S[j])

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RC4 PRGA and Encryption

Encryption involves XORing data bytes with output of the PRGA

The PRGA initializes i and j to 0 and then loops over 4 basic operations: increase j, increase j using s[i], swap and output s[i]+s[j]

PRGA Pseudocode is:

i = j = 0

for each message byte Mi

i = (i + 1) (mod 256)

j = (j + S[i]) (mod 256)

swap(S[i], S[j])

t = (S[i] + S[j]) (mod 256) ; Ki = S[t]

Encryption : Ci = Mi XOR S[t]

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