Stream ciphers

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Symmetric encryption schemes

A symmetric cipher consists of two algorithms

- encryption algorithm $E: \mathcal{K} \times \mathcal{M} \to \mathcal{C}$
- decryption algorithm $D: \mathcal{K} \times \mathcal{C} \to \mathcal{M}$

st. $\forall k \in \mathcal{K}$, and $\forall m \in \mathcal{M}$, $D(k, E(k, m)) = m$

Kerckhoff's principle

- The encryption (E) and decryption (D) algorithms are public
- The security relies entirely on the secrecy of the key

Adversarie's capabilities - threat model

The attacker may have access to :

- some ciphertexts $c_1, \ldots, c_n$
- some plaintext/ciphertext pairs $(m_1, c_1), \ldots, (m_n, c_n)$ st. $c_i = E(k, m_i))$
- an encryption oracle - he can maybe trick a user to encrypt messages $m_1, \ldots, m_n$ of his choice
- a decryption oracle - he can maybe trick a user to decrypt ciphertexts $c_1, \ldots, c_n$ of his choice
- unlimited, or polynomial, or realistic ($\leq 2^{80}$) computational power

- A cryptographic scheme is secure under some assumptions, that is against a certain type of attacker
- A cryptographic scheme may be vulnerable to certain types of attacks but not others

What is a good encryption scheme?

An encryption scheme is secure against a given adversary, if this adversary cannot

- recover the secret key k
- recover the plaintext m underlying a ciphertext c
- recover any bits of the plaintext m underlying a ciphertext c
- . . .

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\begin{array}{cccccccccc}
k & = & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \\
m & = & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \\
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- Consistency: $D(k, E(k,m)) = k \oplus (k \oplus m) = m$

Perfect secrecy

Definition

A cipher (E, D) over $(\mathcal{M}, \mathcal{C}, \mathcal{K})$ satisfies perfect secrecy if for all messages $m_1, m_2 \in \mathcal{M}$ of same length ($|m_1| = |m_2|$), and for all ciphertexts $c \in \mathcal{C}$

$$|Pr(E(k, m_1) = c) - Pr(E(k, m_2) = c)| \leq \epsilon$$

where $k \xleftarrow{r} \mathcal{K}$ and ϵ is some "negligible quantity".

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Theorem (Shannon 1949)

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<u>Proof:</u> We first note that for all messages $m \in \mathcal{M}$ and all ciphertexts $c \in \mathcal{C}$

$$Pr(E(k, m) = c)$$

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$$|Pr(E(k,m_1)=c) - Pr(E(k,m_2)=c)| \leq \left| \frac{1}{\#\mathcal{K}} - \frac{1}{\#\mathcal{K}} \right| = 0$$

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    given $m_1 \oplus k$ and $m_2 \oplus k$, we can compute
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  - OTP is malleable
    given the ciphertext $c = E(k, m)$ with $m = to\ bob : m_0$, it is possible to compute the ciphertext $c' = E(k, m')$ with
    $m' = to\ eve : m_0$
    $c' := c \oplus "to\ bob : 00 \ldots 00" \oplus "to\ eve : 00 \ldots 00"$

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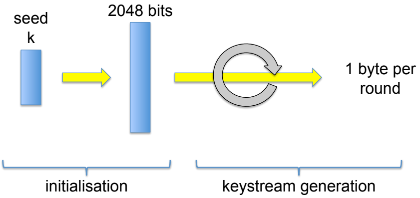

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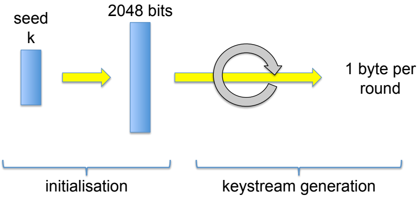

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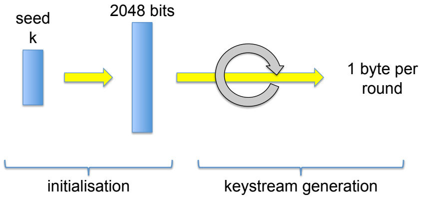

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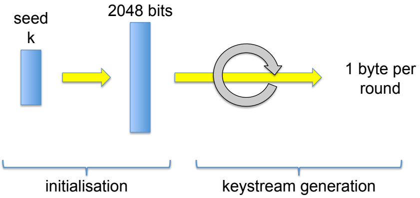

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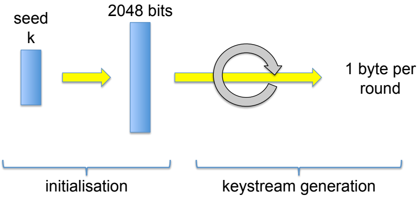

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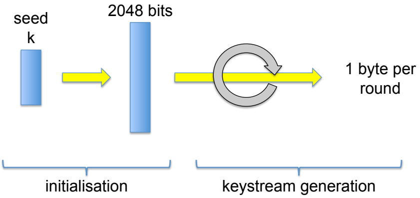

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  - first bytes are biased
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  - subject to related keys attacks
    $\longrightarrow$ choose randomly generated keys as seeds

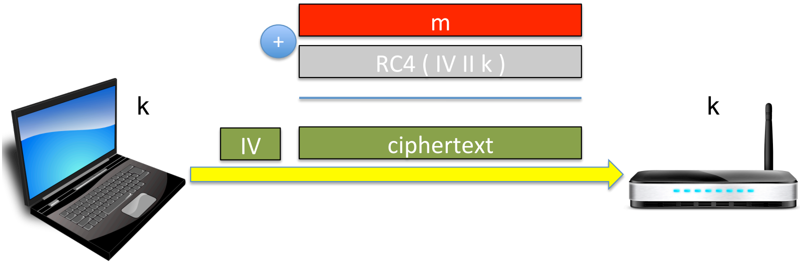
RC4: initialisation

```
for i := 0 to 255 do
    S[i] := i
end
j := 0
for i := 0 to 255 do
    j := (j + S[i] + K[i (mod |K|)]) (mod 256)
    swap(S[i], S[j])
end
i := 0
j := 0
```

RC4: key stream generation

```
while generatingOutput
    i := i + 1(mod 256)
    j := j + S[i](mod 256)
    swap(S[i], S[j])
    output(S[S[i] + S[j](mod 256)])
end
```

WEP uses RC4



Initialisation Vector (IV): 24-bits long string

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Weaknesses of TLS

MUST READ **THESE TEN CITIES ARE HOME TO THE BIGGEST BOTNETS**

RC4 NOMORE crypto exploit used to decrypt user cookies in mere hours

Websites using RC4 encryption need to change their protocols as exploits using design flaws are now far easier to perform.

By Charlie Osborne for Zero Day | July 20, 2015 -- 10:21 GMT (11:21 BST) | Topic: Security

1 | f 33 | in 96

RELATED STORIES

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  taps: $i_1, i_2, \ldots i_\ell$

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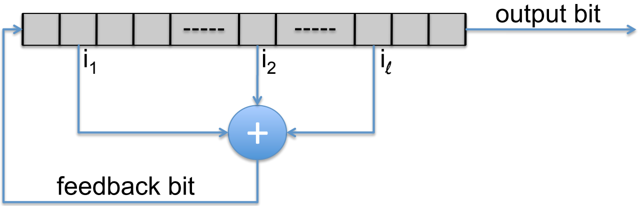

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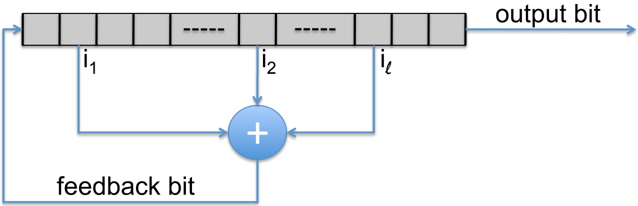

- Broken LFSR-based stream ciphers:
  - DVD encryption: CSS (2 LFSRs)
  - GSM encryption: A5 (3 LFSRs)
  - Bluetooth encryption: E0 (4 LFSRs)

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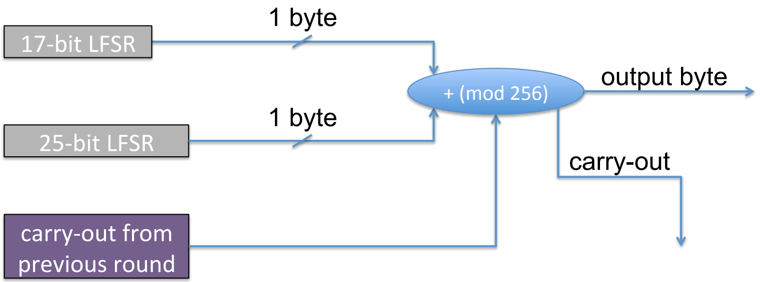

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- Hence also first 20 bytes of keystream are known
- Given output of 17 bit LFSR, can deduce output of 25 bit LFSR by subtraction
- Hence try all 2^{17} possibilities for 17 bit LFSR and if generated 25 bit LFSR produces observed keystream, cipher is cracked

Android BitCoin attack

ars TECHNICA BIZ & IT TECH SCIENCE POLICY CARS GAMING & CULTURE FORUMS SIGN IN

RANDOM THEFT —

All Android-created Bitcoin wallets vulnerable to theft

Android Java SecureRandom function flaw undermines security of Android wallets.

LEE HUTCHINSON - 8/12/2013, 3:15 PM

Xurxo Martinez

Bitcoin.org released a security advisory over the weekend warning the Bitcoin community that any Bitcoin wallet generated on any Android device is insecure and open to theft. The insecurity appears to stem from a flaw in the Android Java SecureRandom class, which under certain circumstances can

Modern stream ciphers

Project eStream: project to "identify new stream ciphers suitable for widespread adoption", organised by the EU ECRYPT network
$\longrightarrow$ HC-128, Rabbit, Salsa20/12, SOSEMANUK,
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Conjecture

These eStream stream ciphers are "secure"

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- The design of crypto primitives is subtle and error prone.
  $\longrightarrow$ use standardised publicly know primitives

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Concluding remarks

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- Many attacks dues to poor implementations of cryptography