Stream Ciphers

BİL 448/548

Internet Security Protocols

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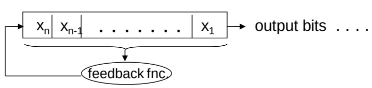
Stream Ciphers

- Generate a *pseudo-random* key stream & xor to the plaintext.
- Key: The seed of the PRNG
- Traditional PRNGs (e.g. those used for simulations) are not secure.
  E.g., the linear congruential generator:
  $X_i = a X_{i-1} + b \mod m$
  for some fixed a, b, m.
- It passes the randomness tests, but it is predictable if previous output bytes are known.

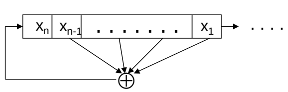
Linear Feedback Shift Registers

- Feedback shift register:



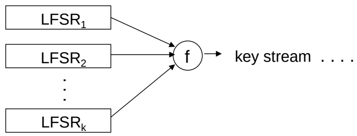
("register", "feedback", "shift")

- LFSR: Feedback fnc. is linear over Z_2 (i.e., an xor):



- Very compact & efficient in hardware (e.g., SIM cards)

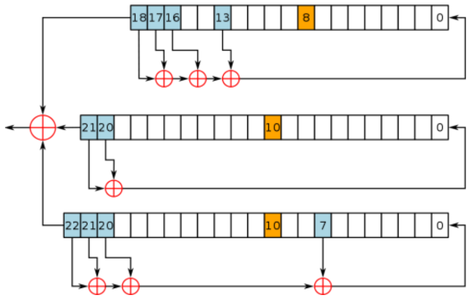
Stream Ciphers from LFSRs



Desirable properties of f:

- high non-linearity
- long "cycle period" $(\sim 2^{n1+n2+...+nk})$
- low correlation with the input bits

GSM A5/1



- The A5/1 stream cipher uses three LFSRs.
- A register is clocked if its clocking bit (orange) agrees with one or both of the clocking bits of the other two registers. (majority match)

Software-Oriented Stream Ciphers

- LFSRs are slow in software
- Alternatives:
  - Block ciphers (or hash functions) in CFB, OFB, CTR modes.
  - Stream ciphers designed for software:
    RC4, SEAL, SALSA20, SOSEMANUK…

RC4
(Rivest, 1987)

- Simple, byte-oriented, fast in s/w.
- Popular: Google, MS-Windows, Apple, Oracle Secure SQL, WEP, WPA, etc.

Algorithm:

- Works on n-bit words. (typically, n = 8)
- State of the cipher: A permutation of {0,1,...,N-1}, where $N = 2^n$, stored at S[0,1,...,N-1].
- Key schedule: Expands the ℓ-byte key (typically 40-256 bits) into the initial state table S.

RC4 Key Schedule

The key schedule (i.e., initialization) algorithm:

```
// typically n = 8, ℓ = 16
for i = 1 to 2^n – 1 do:
   S[i] ← i
i ← 0, j ← 0
for i = 1 to 2^n – 1 do: {
  j ← j + S[i] + K[i mod ℓ]
  S[i] ↔ S[j]
}
```

RC4 Encryption

The encryption (i.e., the PRNG) algorithm:

```
i ← 0, j ← 0
loop: {
  i ← i + 1
  j ← j + S[i]
  S[i] ↔ S[j]
  output S[S[i] + S[j]]
}
```


IV for Stream Ciphers

- Use of an initialization vector is crucial in a stream cipher.
- Otherwise, the same stream will be produced each time the key is used (i.e., for each packet).
- The cipher may specify how to incorporate the IV. e.g., A5/1 mixes 22-bit frame no. into registers.
- Otherwise, ad hoc methods are used.
  e.g., WEP uses RC4 with 128-bit K' = (IV || K) for a 24-bit IV and a 104-bit K.

Speed of Software Stream Ciphers

(Crypto++ 5.6 benchmarks, 2.2 GHz AMD Opteron 8354. March 2009.)

Algorithm	Speed (MiByte/s.)
3DES / CTR	17
AES-128 / CBC	148
AES-128 / CTR	198
RC4	124
SEAL	447
SOSEMANUK	767
SALSA20	953