ACORN v2
A Lightweight Authenticated Cipher

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ACORN

Different Design Approaches:

Fast
- AES-NI (AEGIS)
- SIMD (MORUS)

Lightweight
- Mode (JAMBU)
- Dedicated (**ACORN**)

ACORN: design

- ACORN-128
  - Based on **bit-oriented stream cipher**
  - **Encryption and authentication share the same state**
  - Small state
    - 293-bit (the minimum is 256-bit)
  - IV should not be reused
  - 128-bit key, 128-bit IV, 128-bit tag

ACORN: design

- Tweaks
  - Key is introduced into 1664 steps in initialization in v2 (128 steps in v1)

  - Initialization: 1792 steps (v2) : 1536 steps (v1)
  - Assoc. Data Padding: 256 steps (v2) : 512 steps (v1)
  - Message padding: 256 steps (v2) : 512 steps (v1)
  - Finalization: 768 steps (v2) : 256 steps (v1)

- Rationale for tweaks: to **provide protection against nonce-reuse**
  - **Non-invertible initialization** so that the key cannot be recovered directly from the state (the state can be recovered when nonce is reused in encryption/decryption)
  - More steps in the initialization so as to increase the difficulty of recovering the key from the state

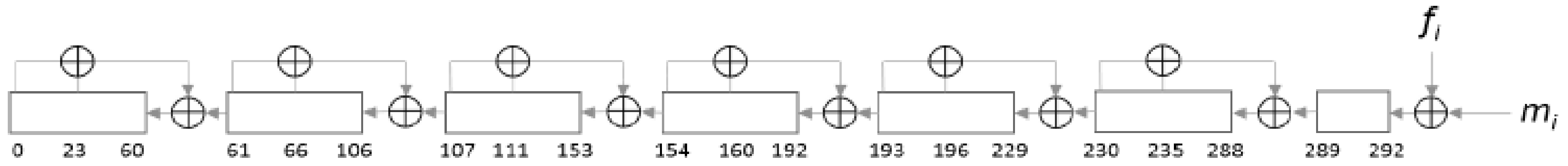
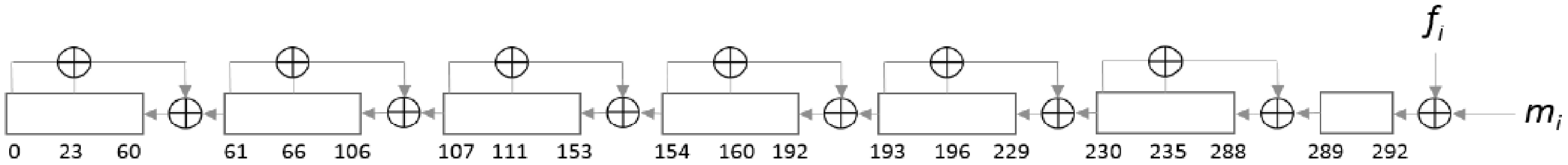


Figure 1.1: The concatenation of 6 LFSRs in ACORN-128. f_i indicates the overall feedback bit for the ith step; m_i indicates the message bit for the ith step.

- Initialization
  - Key and IV are injected into the state bit by bit
  - Consists of 1792 steps
- Process associated data
  - Each step one bit
  - Padding is fixed as 256 bits: $1\,0^{255}$ (without padding to fixed length block, so suitable for bit-oriented hardware implementation)
- Process plaintext
  - Each step one bit
  - Padding is fixed as 256 bits: $1\,0^{255}$
- Finalization
  - Run the cipher for 768 steps
  - The last 128 keystream bits are the tag
- **Two control bits are applied to the cipher to separate associated data, plaintext and the finalization**

ACORN: Security

- Encryption: Analysis is the same as stream cipher analysis (no security weakness found when nonce is not reused)
- Authentication: with the use of the concatenated LFSRs, the security analysis of authentication can be done much easier
  - To eliminate the difference being injected into the state, the success rate is 2^{-189}



ACORN: Performance

- Hardware
  - Bit-oriented design, suitable for hardware implementation
    - Expected to be slightly more costly than Trivium (hardware area)
  - Fast implementation is possible due to 32 parallel steps
  - Small state-size: 293 bits
  - Energy efficient
    - Simple circuits
    - Encryption and authentication share most of the operations
- Major difference between ACORN and TriviA-ck
  - ACORN's encryption and authentication share the same state and operations
    => **smaller state and less computations**

ACORN: Performance

- Software speed on Sandy Bridge

64B	128B	256B	512B	1024B	2048B	4096B
72.1	41.5	26.3	18.6	14.7	12.8	11.9

Conclusions

- ACORN
  - A new design very different from the other candidates
  - Lightweight
  - Reasonably fast due to 32 parallel steps
  - ACORN-128 provides 128-bit encryption and authentication security
- ACORN v2
  - Protection against nonce-reuse in encryption/decryption so that the key cannot be directly recovered from the state
- ACORN provides a new approach to design lightweight MAC (using bit-oriented registers)