Classification of AEAD

Avik Chakraborti[1], Nilanjan Datta[2], Ashwin Jha[1] and Mridul Nandi[1]

1. Indian Statistical Institute, Kolkata
2. Institute for Advancing Intelligence, TCG CREST

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Content

- Desired Features of lightweight AEAD Modes
- Classification of lightweight AEAD Modes

Some Relevant Features of AEAD Modes

Single-Pass

Makes only one pass through the data, simultaneously doing what is needed to ensure both privacy and authenticity.

State-size

A theoretic estimate of the register size that directly corresponds to the size of memory.

Inverse-Free

Both the encryption and verified decryption algorithm does not invoke the inverse of the primitive.

Some Relevant Features of AEAD Modes

On-line

Encryption produces cipher-text blocks on the fly, and before subsequent plain-text blocks are known.

High Rate

Rate is defined as number of message blocks processed per primitive invocation, constructions with higher rate reduces latency, and particularly beneficial to obtain higher speed.

Optimal (Primitive Invocation)

Uses the minimum possible number of non-linear invocations making the construction efficient for short messages and reduces the latency.

Some Relevant Features of AEAD Modes

Nonce Misuse Resistance

- Provides security even if nonce is repeated, or even without nonce
- Well suited for lightweight applications where storing counter or generating random number may be difficult to implement

Integrity under RUP

- Small buffer size may force decryption algo to release plaintext before verification
- This gives an adversary additional power, which may be exploited for forging

AEAD Mode Classification

- Parallel Mode
- Feedback based Mode
- SIV Mode
- Sponge Mode
- Stream Cipher Mode

Parallel Modes

- All the ciphertext blocks can be computed in parallel, allowing both hardware and software acceleration proportional to the available computational units.
- The inputs to the block ciphers depend on the current plaintext blocks, and not on the previous block cipher outputs or ciphertexts.
- Hence, *parallelizability* is achieved in the computation between *distinct block cipher calls*.

Parallel Modes: Target Applications

- Typically Used in low-latency scenarios as well as for obtaining good performance from both high-speed hardware and commodity processors
- The parallel design allows to efficiently process subsequent message blocks exploiting the CPU pipeline and multi-threading techniques.
- Useful in real-time streaming protocols (SRTP, SRTCP, SSH), where ciphertext/plaintext are released on-the-fly to reduce the end-to-end latency.

Parallel Modes: Design Principle

Typical Choices:

- Xor-Encrypt-Xor paradigm
- tweakable block ciphers with tweak defined as a pair (nonce, block number)

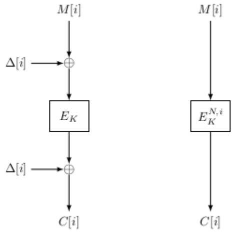
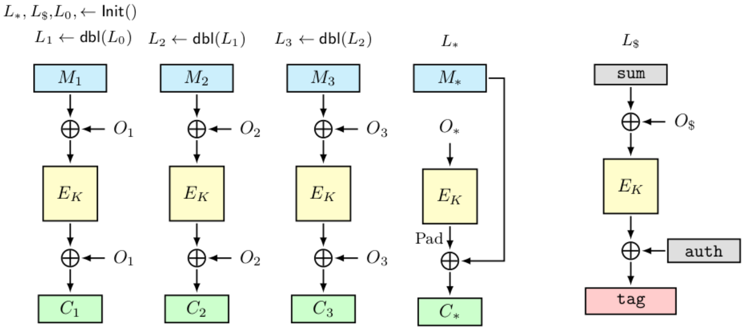


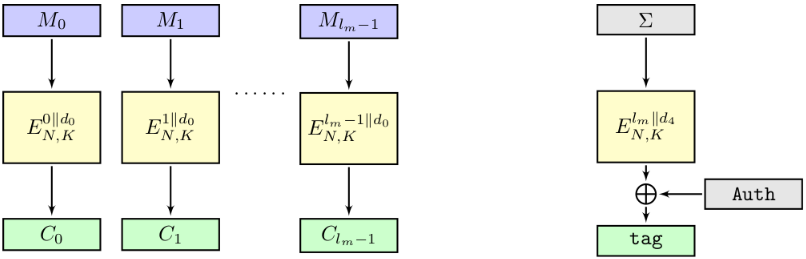
Figure: Parallel Mode of Encryption: (a) OCB, (b) ΘCB

Example1: Pyjamask (OCB Style Encryption)



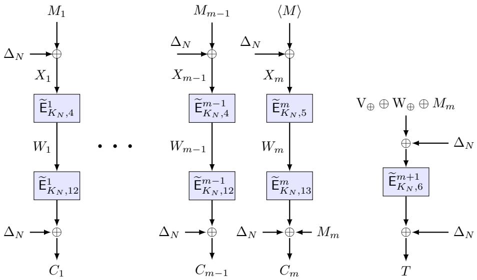
- Block Cipher based, Parallel, Online, Rate-1
- Birthday bound secure, No RUP Security

Example2: Skinny AEAD (ΘCB Style Encryption)



- Tweakable Block Cipher based, Parallel, Online, Rate-1
- Full security (Privacy Bound - 0), No RUP Security

Example3: LOCUS-AEAD
(OCB Style with Intermediate checksum)



- Short-tweak TBC based, Parallel, Online, Rate-1/2
- Nonce-derived key for full security, Intermediate checksum to achieve RUP security

Feedback based Modes

- Uses an affine function that takes a block cipher output and a plain text block to produce the corresponding cipher text block and an updated state which is used as the next block cipher input
- Reduce the state memory, at the cost of losing parallelizability

Target Applications

- This is one of the most popular method of constructing area-efficient block cipher based AE.
- Primarily targeted for resource constrained environments such as RFID tags, sensor networks.
- Typically inverse-free and area-efficient for combined enc-dec implementations.

Types of Feedback

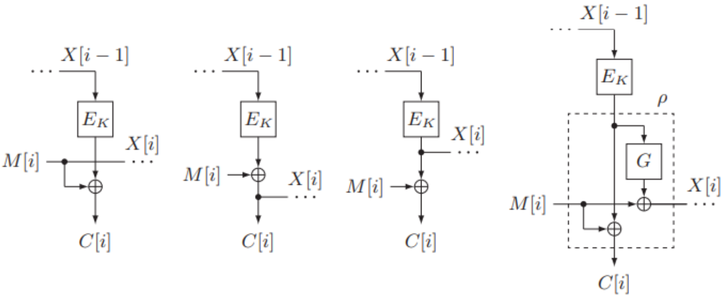


Figure: Hybrid Feedback functions: (a) PFB, (b) CFB, (c) OFB, (d) CoFB

Types of Hybrid Feedback

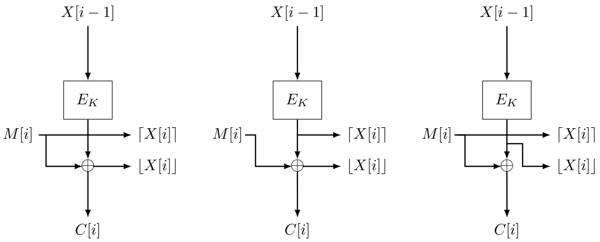


Figure: (a) PFB+CFB, (b) OFB+CFB, (c) OFB+PFB

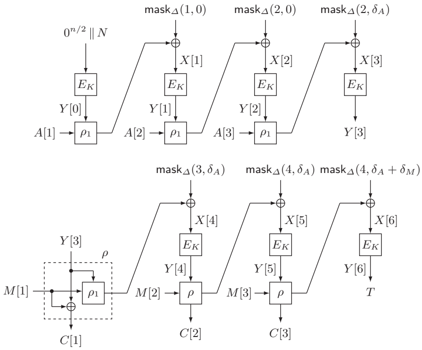
Security of Rate-1 Feedback based AE

Encryption	Decryption	Additional states to achieve Security
PFB	CFB	n-bits
CFB	PFB	-
OFB	OFB	-
CoFB	CoFB	$n/2$-bits
HyFB (CFB+PFB)	HyFB (PFB+CFB)	$n/2$-bits
HyFB (CFB+OFB)	HyFB (PFB+OFB)	-
HyFB (PFB+OFB)	HyFB (CFB+OFB)	-

From Combined to Hybrid: Making Feedback-based AE Even Smaller [Chakraborti et al., ToSC 2020]

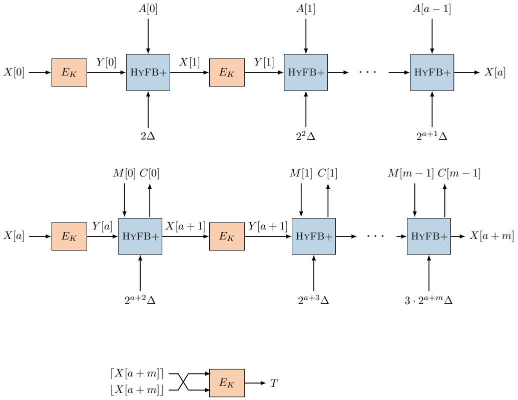
For any rate-1 feedback-based AE with additional state of τ-bits, there is an adversary that breaks the construction with query complexity 2^τ

Example1: COFB
(A Mode with Combined Feedback)



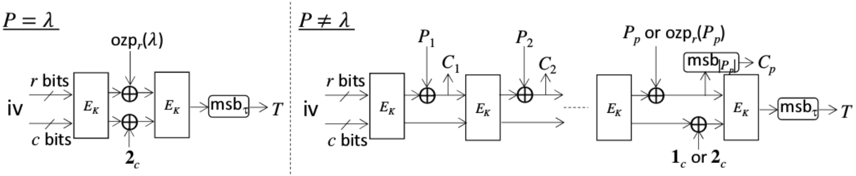
- Inverse-free, Rate-1, State size: $1.5n$-bit (optimal for rate-1)

Example2: HyENA
(A Mode with Hybrid Feedback)



- Inverse-free, Rate-1, State size: 1.5n-bit (optimal for rate-1)

Example3: SAEAES
(A Block-cipher based Sponge Variant)



- Inverse-free, Rate-1/2, State size: only n-bit (at the cost of reduced rate)

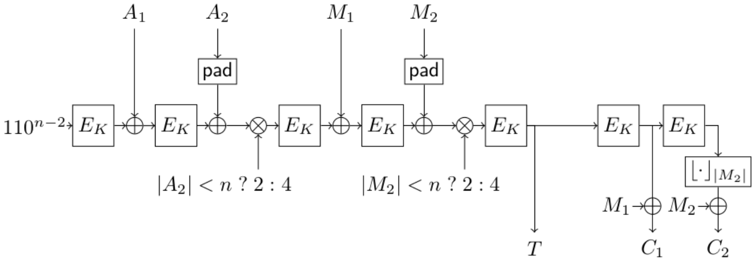
SIV based Modes

- Deterministic Authenticated Encryption.
- Follows MAC-then-Encrypt structure, and hence two pass mode
- Typically obtain single-state implementation

Target Applications

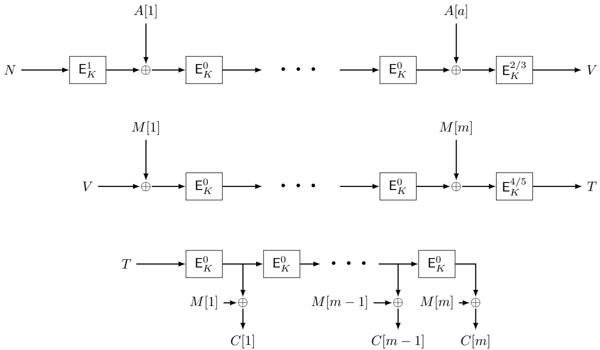
- Provides defense in depth, i.e., maximal robustness even in undesired environment such as when nonces are repeated.
- Supports efficient short input data processing, while minimizing the memory consumption and precomputation. In use cases with tight requirements on delay and latency, the typical packet sizes are small (way less than 1 KB)
- Excellent choice for energy efficient designs, used in devices that operate on a tight energy budget such as handheld devices, medical implants or RFID tags.

Example1: SUNDAE



- Use CBC MAC with OFB encryption
- Single-state, Inverse-free, efficient for short messages

Example2: ESTATE



- Single-state, Inverse-free, efficient for short messages
- Use tBC to ensure RUP security, optimal block-cipher invocations

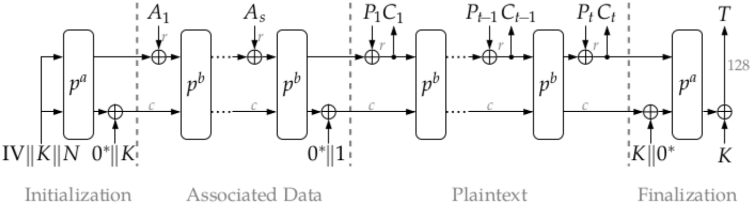
Sponge Modes

- Use public permutation instead of keyed permutation
- Employs duplex mode of operation - absorbs the data and then squeeze the ciphertext
- Has the advantage of key agility: no key-scheduling

Target Application

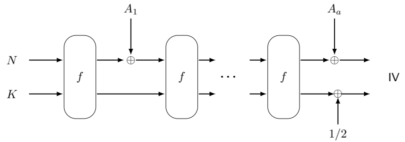
- Well suited for achieving a balance between hardware cost and software efficiency.
- Versatile in nature and can be tuned to achieve good performance in any domain, including high speed implementation, memory-restricted environment and usual desktop computers.

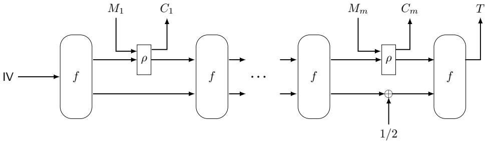
Example1: ASCON (Simple Duplex type Sponge Mode)



- Duplex-sponge with rate 64-bit and capacity 256-bit
- Achieves security of 128-bit

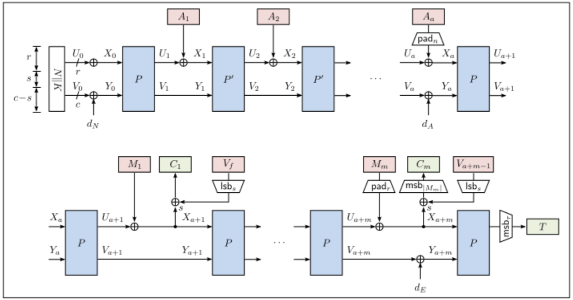
Example2: PHOTON-Beetle
(Duplex Sponge Mode with Feedback)





- Duplex-sponge with a feedback function ρ, rate 128-bit, capacity 128-bit
- ρ plays the key role to achieve 121-bit security keeping the capacity to 128-bit

Example3: Oribatida
(Sponge with Ciphertext Masking)



- A sponge with rate 128-bit and capacity 128-bit with 64-bit ciphertext masking
- The masking boosts the security and ensures resilience in RUP settings

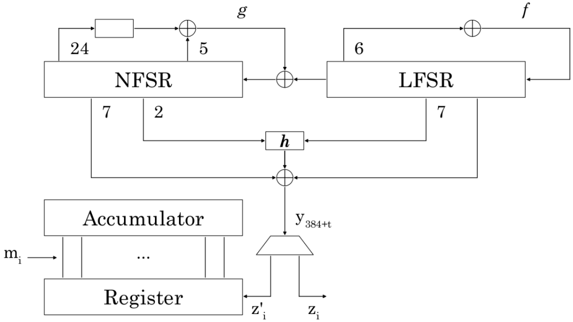
Stream Cipher Modes

- Use the principle of generating two key streams from a short key, and use keystream one for encryption and the other for authentication.
- The encryption function simply adds the encryption keystream to the message stream to generate a ciphertext stream.
- The authentication module takes the authentication key stream, message stream or ciphertext stream to generate the tag using universal hash, shift register, permutation, or block cipher modes

Target Applications

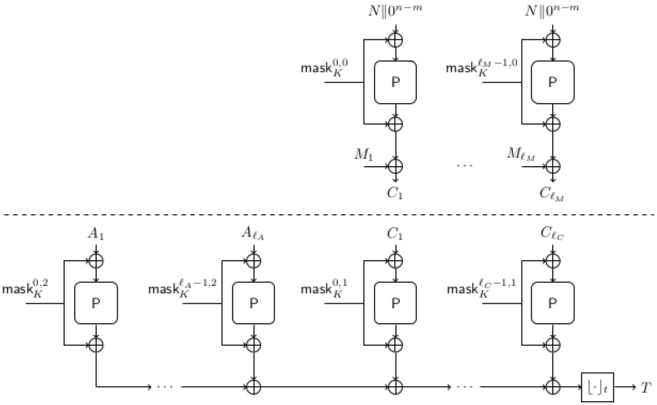
- Designed specifically to speed up the data process as well as to have low circuit complexity. More precisely, these designs target to achieve high area efficiency maintaining a high speed.
- Best choice for applications where plaintext comes with unknown length like a secure wireless connection.
- Excellent choice to process long messages.

Example1: Grain AEAD



- Adopts the design of Grain-128 and Grain v1 and extends it for authentication

Example2: Elephant



- Use public-permutation to generate the key stream

Classification of NIST Round-2 Candidates

- Parallel Mode: LOTUS-AEAD and LOCUS-AEAD, PAEF (ForkAE), Pyjamask, SKINNY-AEAD
- Feedback based Mode: Comet, GIFT-COFB, HyENA, mixFeed, Romulus-N, SAEAES, SAEF (ForkAE), TinyJAMBU
- SIV Mode: ESTATE, Romulus-M, Sundae-GIFT
- Sponge Mode: ACE, Ascon, DryGASCON, Gimli, ISAP, KNOT, Orange, Oribatida, PHOTON-Beetle, Sparkle, Spix, Spoc, Spook, Subterrain, Wage, Xoodyak
- Stream Cipher Mode: Elephant, Grain-128 AEAD, Saturnin

Thank You..!!! Questions???