EWCDM: An Efficient, Beyond-Birthday Secure, Nonce-Misuse Resistant MAC

Benoît Cogliati[1] Yannick Seurin[2]

[1]University of Versailles, France

[2]ANSSI, France

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Summary of our Contribution

We propose a new Wegman-Carter-style MAC, called

Encrypted Wegman Carter with Davies-Meyer,

based on a xor-universal hash function and a block cipher, with the following properties:

1. it is efficient (two block cipher calls, one of which can be computed in parallel to the hash)
2. it is secure beyond the birthday-bound when nonces are not repeated
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Background on Wegman-Carter MACs

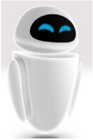
The EWCDM Construction

Security Result and Proof Sketch

Conclusion

(Nonce-Based) Message Authentication Codes

(N, M, T) →



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$\mathrm{MAC}_K(N, M) = T$?

Security Definition

The adversary is allowed

- q_m MAC queries $T = \mathrm{MAC}_K(N, M)$
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and is successful if one of the verification queries (N', M', T') passes and no previous MAC query (N', M') returned T'.

The adversary is said nonce-respecting if it does not repeat nonces in MAC queries.

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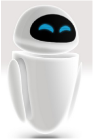

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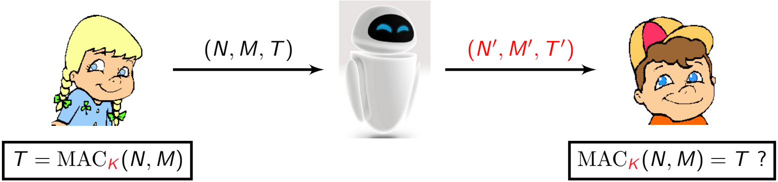

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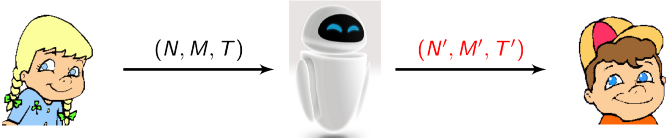

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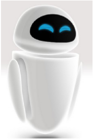

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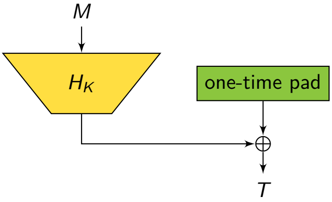

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- in practice, OTPs are replaced by a PRF applied to a nonce N
- H usually based on polynomial evaluation (GCM, Poly1305)
- "optimal" security:

$$\mathbf{Adv}_{\mathrm{WC}}^{\mathrm{MAC}}(q_m, q_v) \leq \varepsilon q_v + \mathbf{Adv}_F^{\mathrm{PRF}}(q_m + q_v)$$

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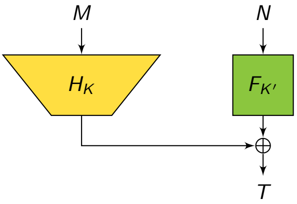

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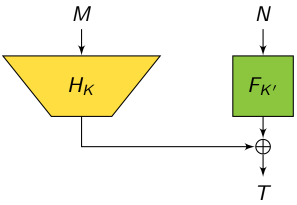

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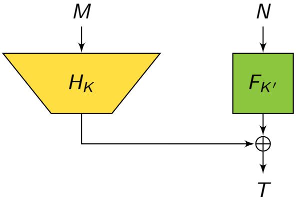

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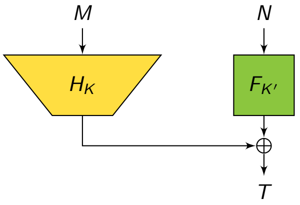

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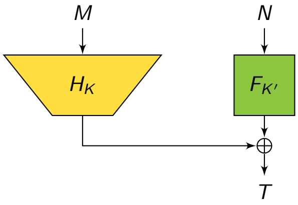

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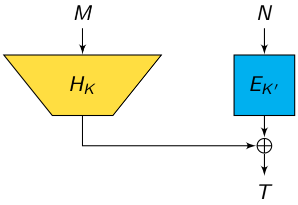

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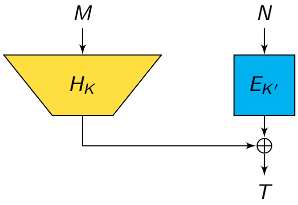

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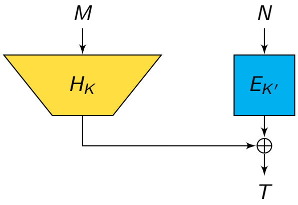

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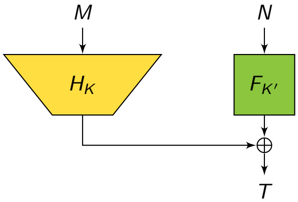

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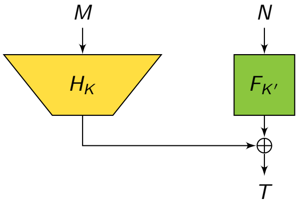

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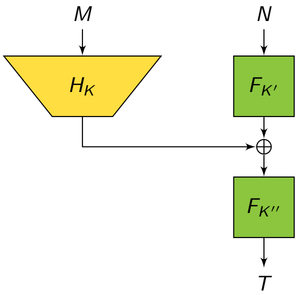

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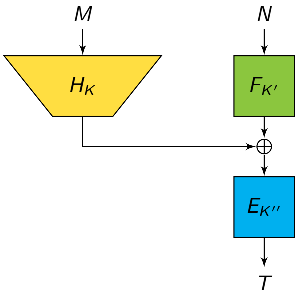

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Our Goal: BBB-security + Nonce-Misuse Resistance

Problem

Design an efficient Wegman-Carter-like MAC:

1. based on a block cipher
2. secure beyond the birthday bound (BBB) in the nonce-respecting case
3. nonce-misuse resistant (at least up to the birthday bound)

State-of-art solution:
Encrypted Wegman-Carter (EWC)
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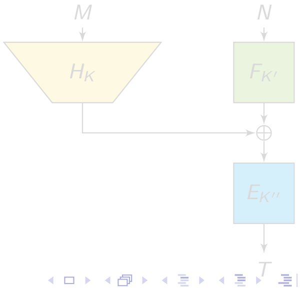

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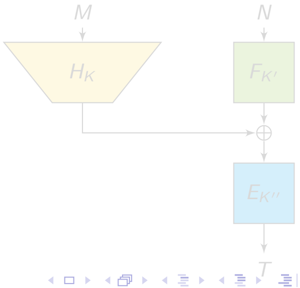

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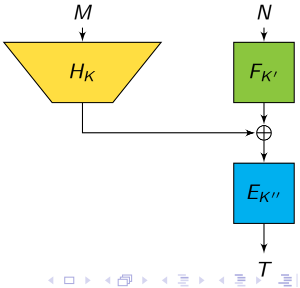

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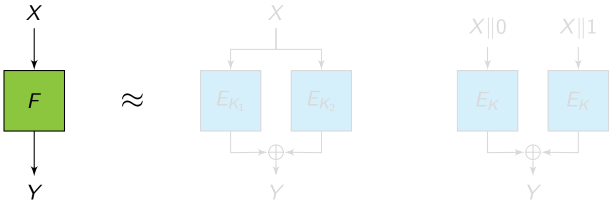

A (keyed) n-to-n-bit construction based on a block cipher E is a secure PRP-to-PRF conversion method [BKR98] if it is indist. from a uniformly random function (ideally up to 2^n queries), e.g.:

- E itself is a secure PRF up to $2^{n/2}$ queries
- truncation [HWKS98, BI99]
- XOR construction [Luc00, Pat08a]: $E_{K_1}(X) \oplus E_{K_2}(X)$
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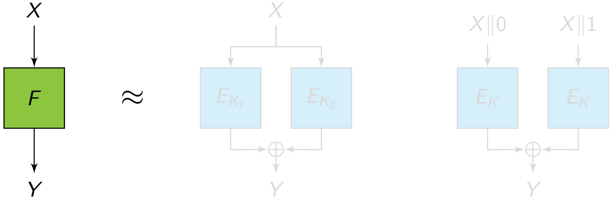

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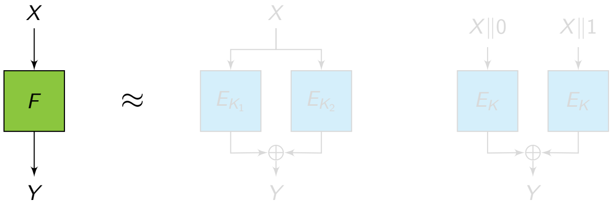

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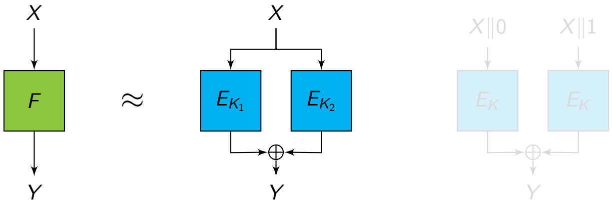

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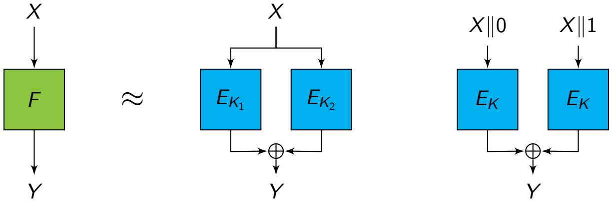

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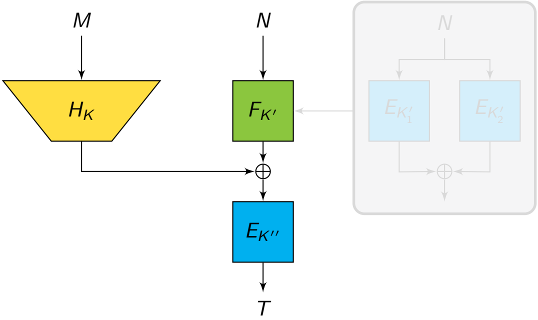

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- but requires at least three BC calls
- is it possible to do better?

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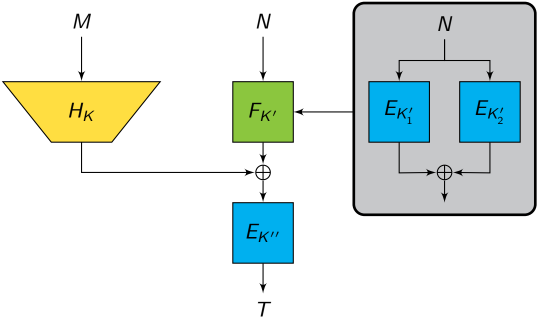

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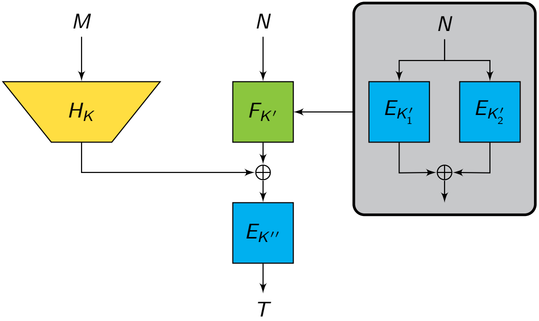

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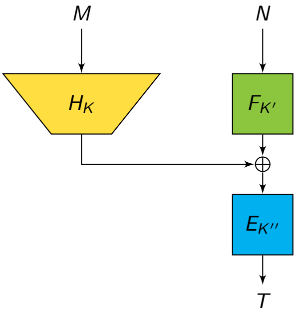
Encrypted Wegman-Carter (EWC) + Davies-Meyer (DM)



- what if we instantiate $F_{K'}$ with the Davies-Meyer construction $\mathrm{DM}[E]_{K'}(N) = E_{K'}(N) \oplus N$?
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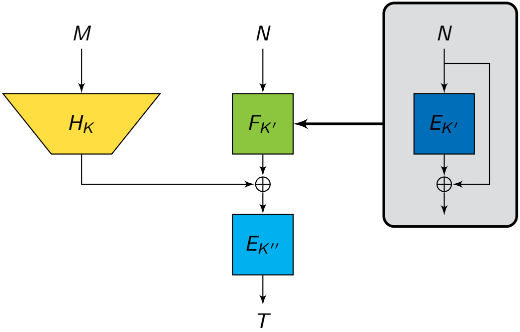

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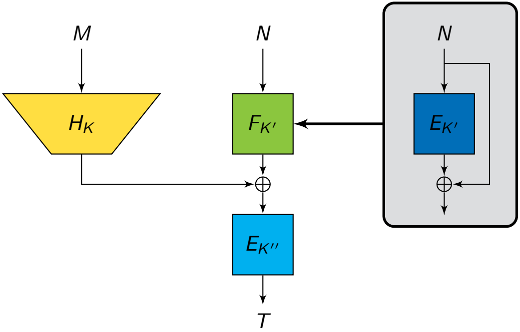

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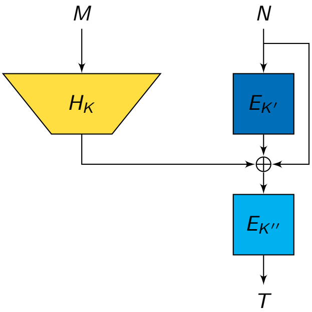

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Outline

Background on Wegman-Carter MACs

The EWCDM Construction

Security Result and Proof Sketch

Conclusion

Security Result for EWCDM

- n = block-length of the BC = tag-length
- L_{max} = maximal message-length (in n bit blocks)

Theorem (Nonce-respecting security of EWCDM)

$$\mathbf{Adv}^{\mathrm{MAC}}_{\mathrm{EWCDM}}(q_m, q_v) \le \frac{5q_m^{3/2}}{2^n} + \frac{\varepsilon q_m}{2} + \frac{6q_v}{2^n} + \varepsilon q_v.$$

(Security up to $q_m \simeq \min\{2^{2n/3}, \varepsilon^{-1}\}$ and $q_v \simeq \varepsilon^{-1} \simeq 2^n/L_{\max}$)

Theorem (Nonce-misusing security of EWCDM)

$$\mathbf{Adv}^{\mathrm{MAC}}_{\mathrm{EWCDM}}(q_m, q_v) \le \frac{2(q_m + q_v)^2}{2^n} + \frac{\varepsilon(q_m + q_v)^2}{2}.$$

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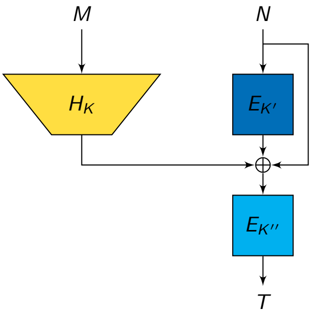
The Encrypted Davies-Meyer PRP-to-PRF Construction



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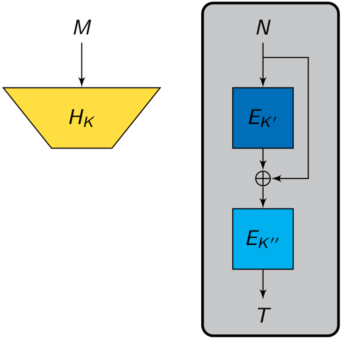

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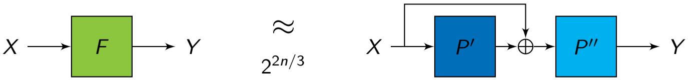

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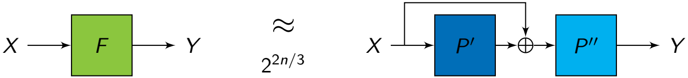

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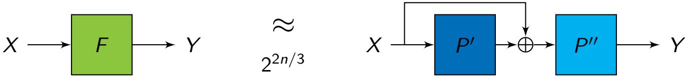

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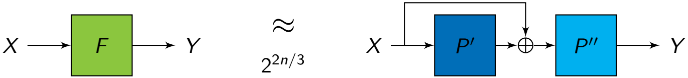

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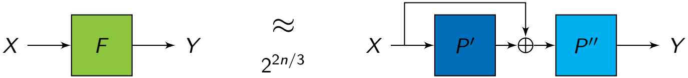

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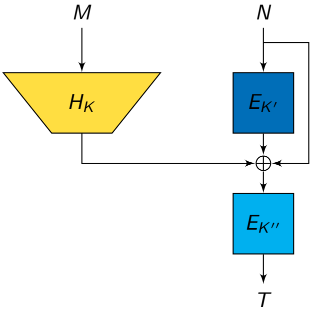

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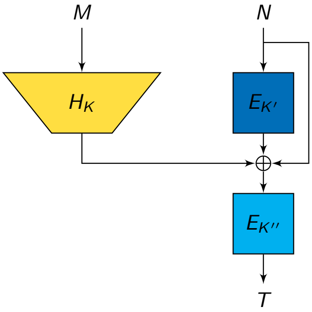

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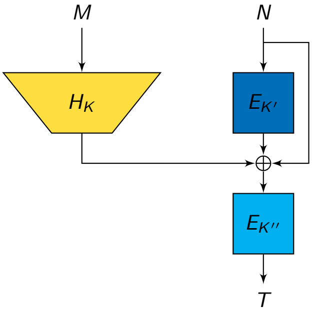

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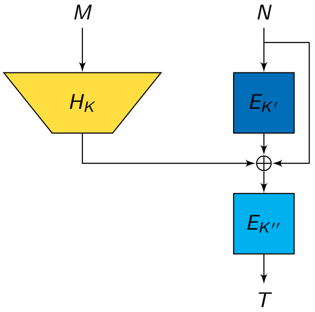

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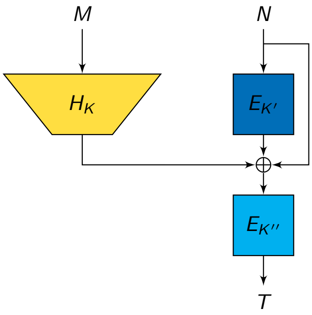

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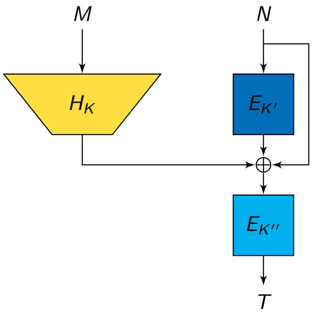

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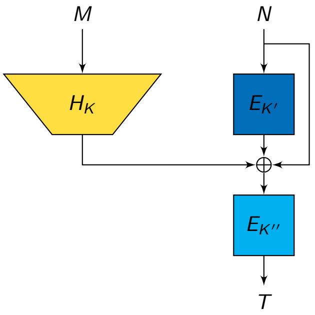

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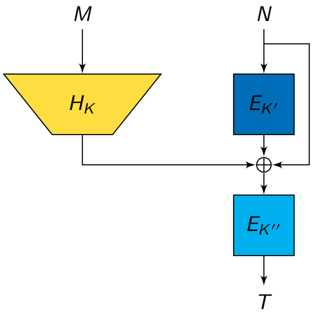

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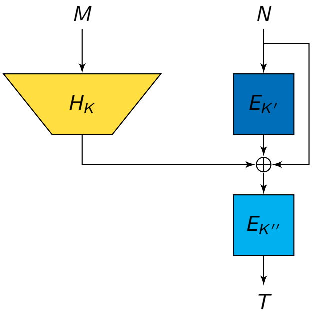

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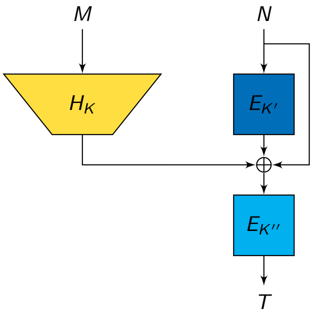

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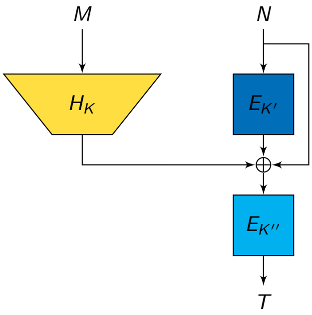

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The end...

Thanks for your attention!

Comments or questions?

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