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Populating the Zoo of Rugged Pseudorandom Permutations

Jean Paul Degabriele [1]

Vukašin Karadžić [2]

[1] Technology Innovation Institute, UAE

[2] Technische Universität Darmstadt, Germany

Background on Rugged Pseudorandom Permutations and their Applications

Rugged Pseudorandom Permutation (RPRP)

- Security notion for variable-length tweakable ciphers [DK22].

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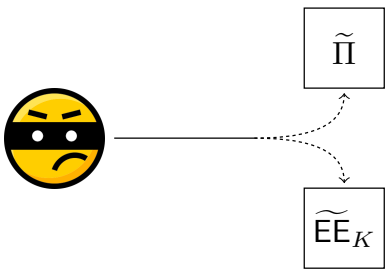
PRP



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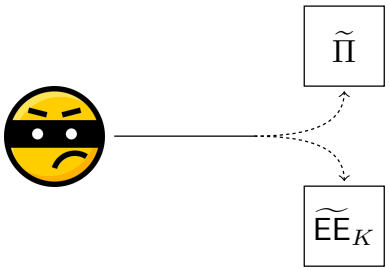
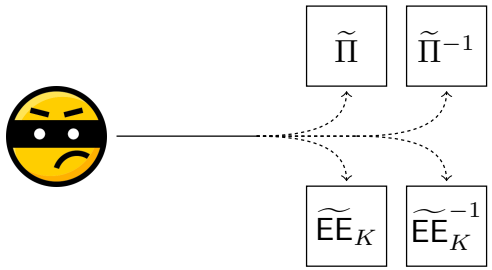


SPRP



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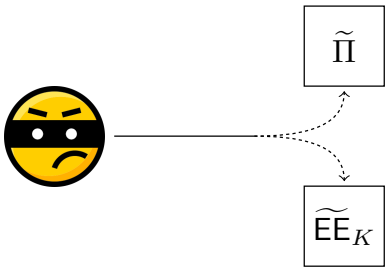

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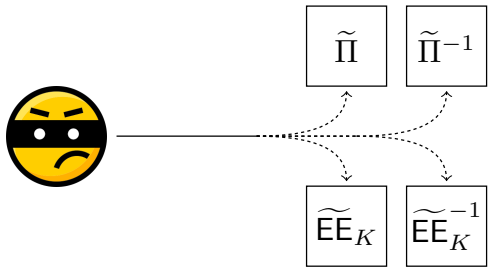

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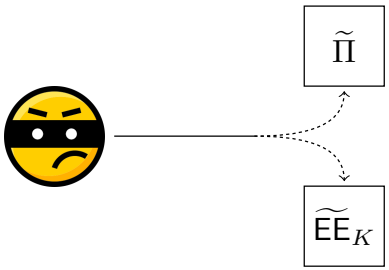

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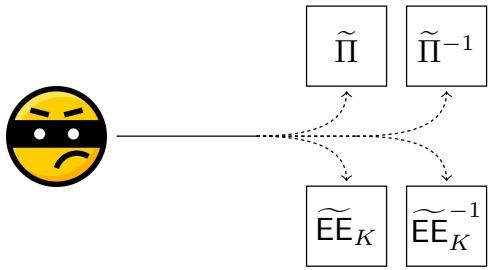

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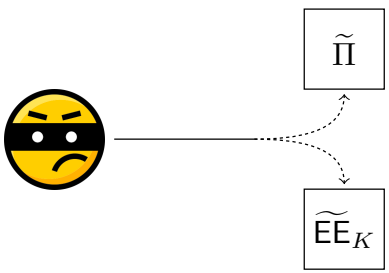

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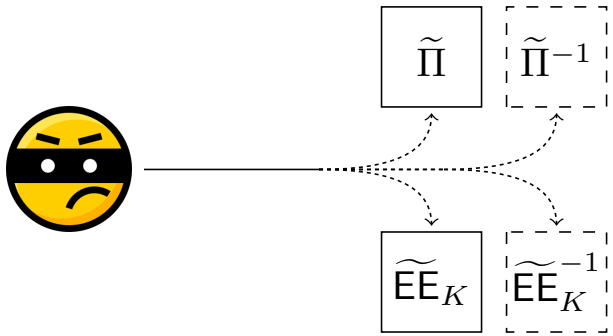

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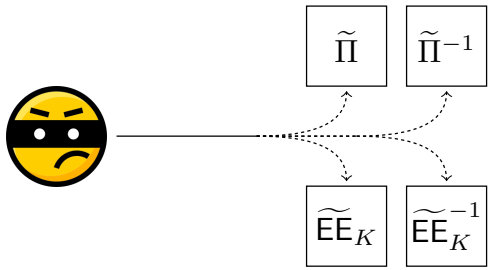

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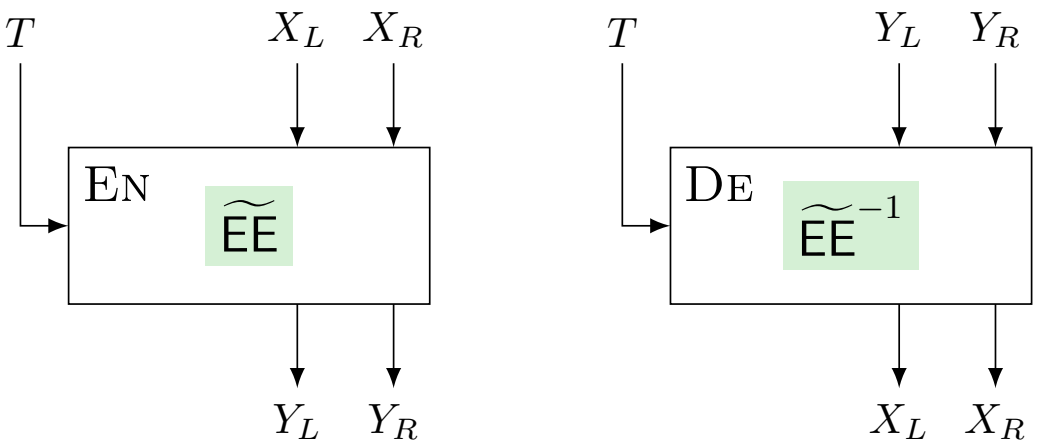

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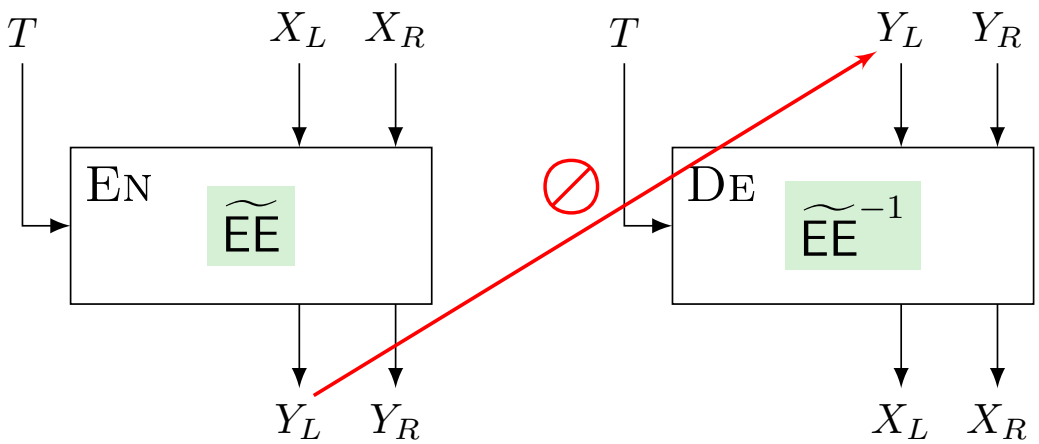

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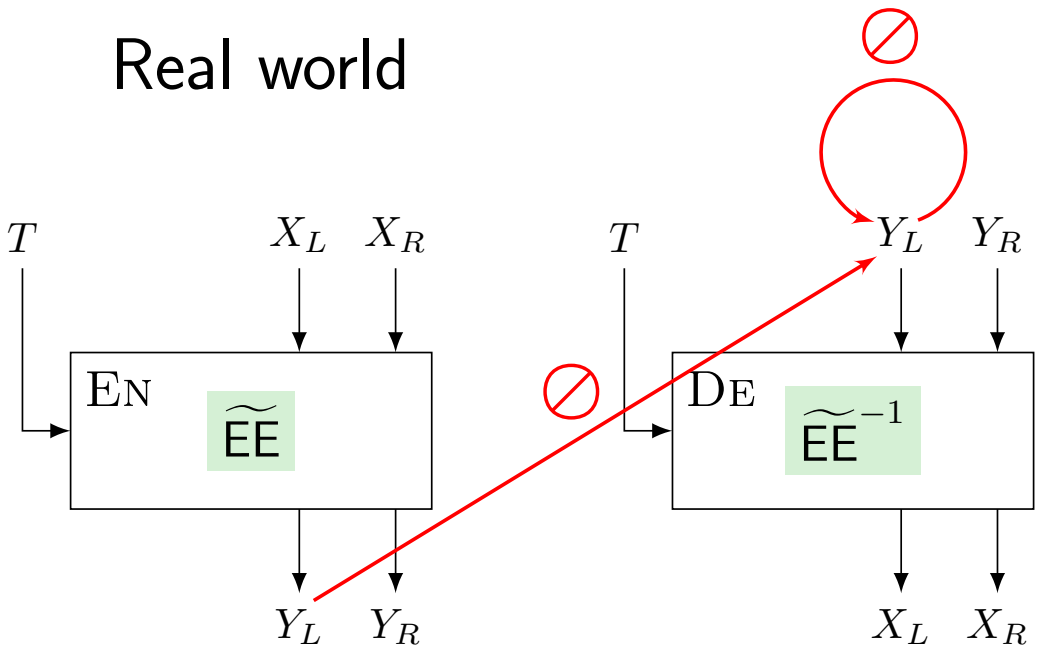

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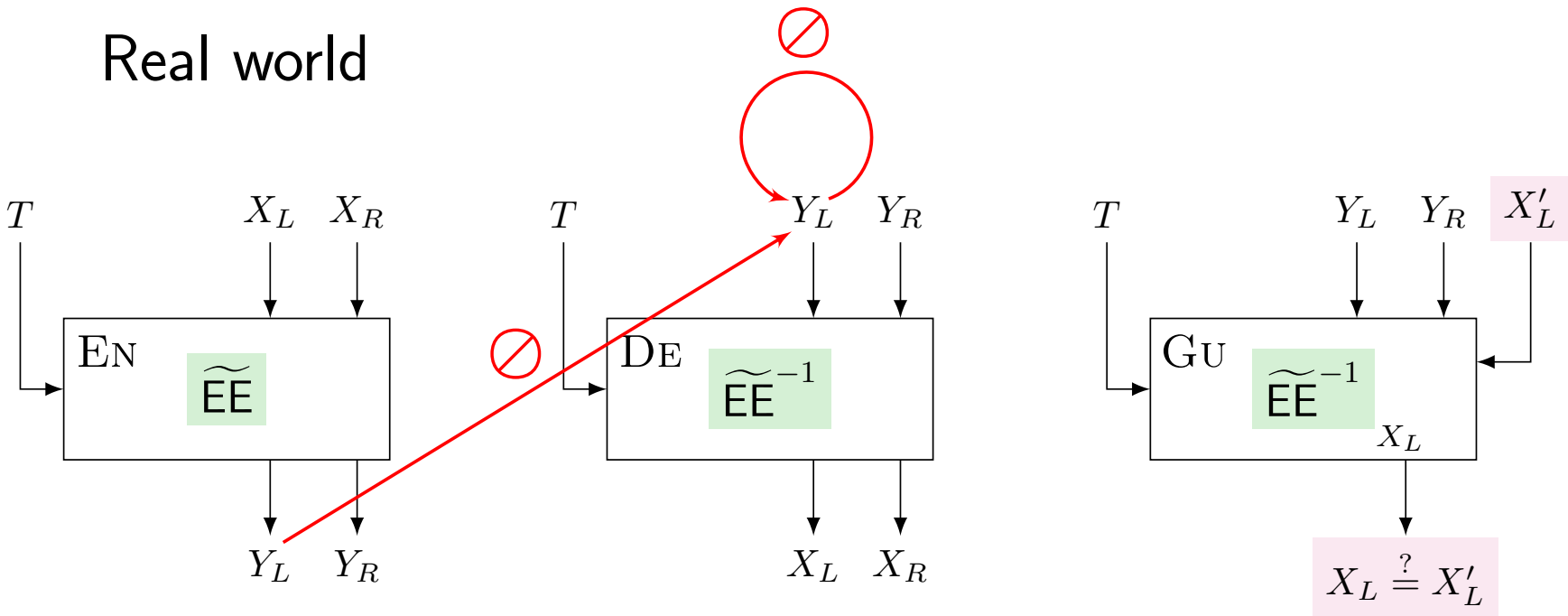

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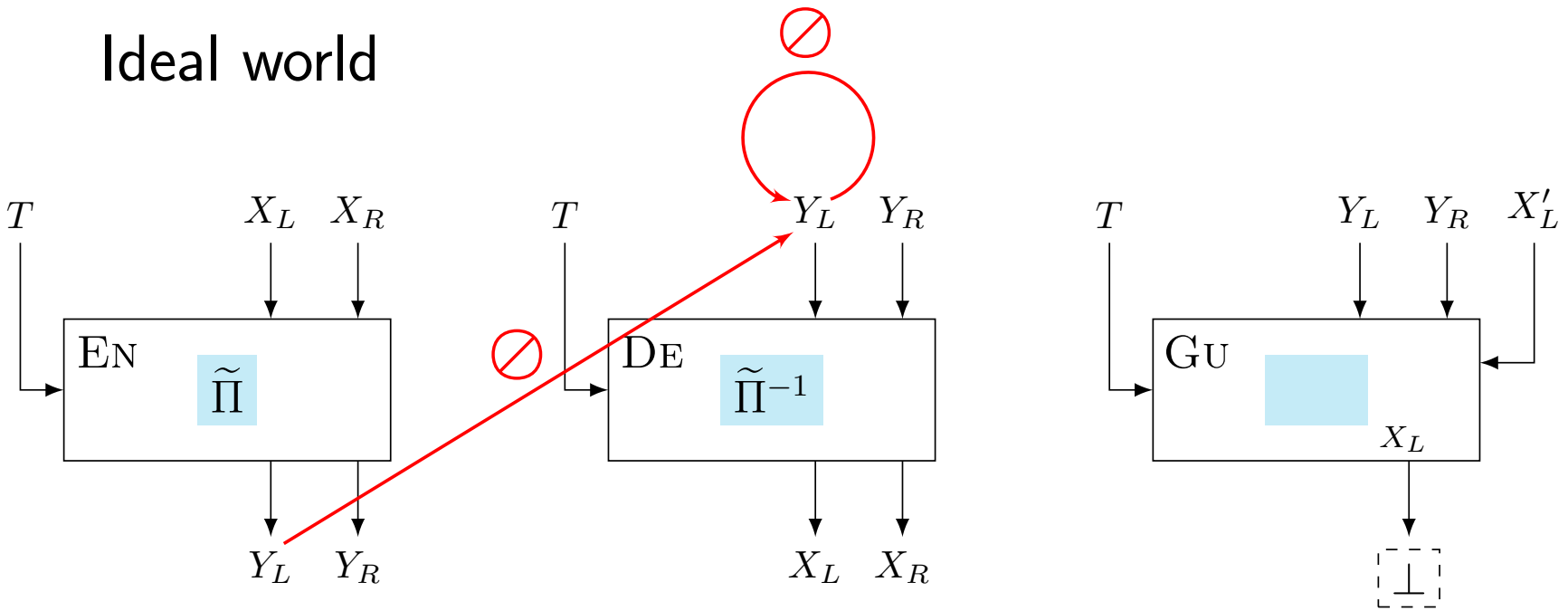

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✓ More efficient than SPRP, but still **very** useful

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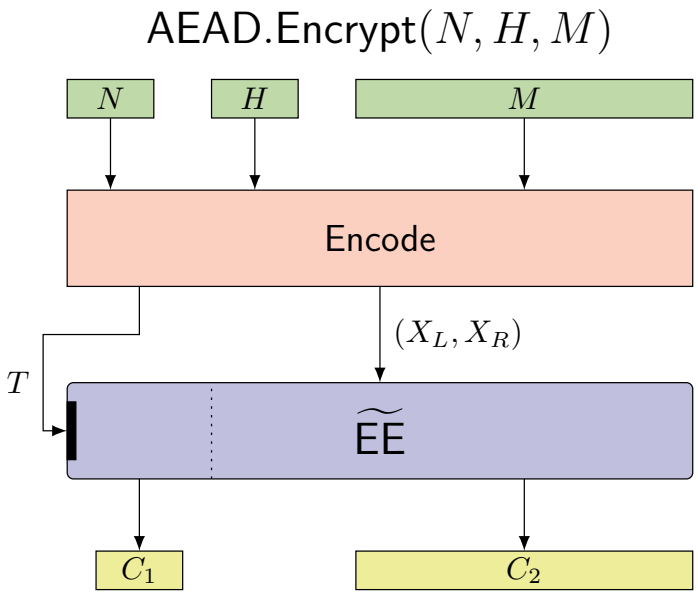

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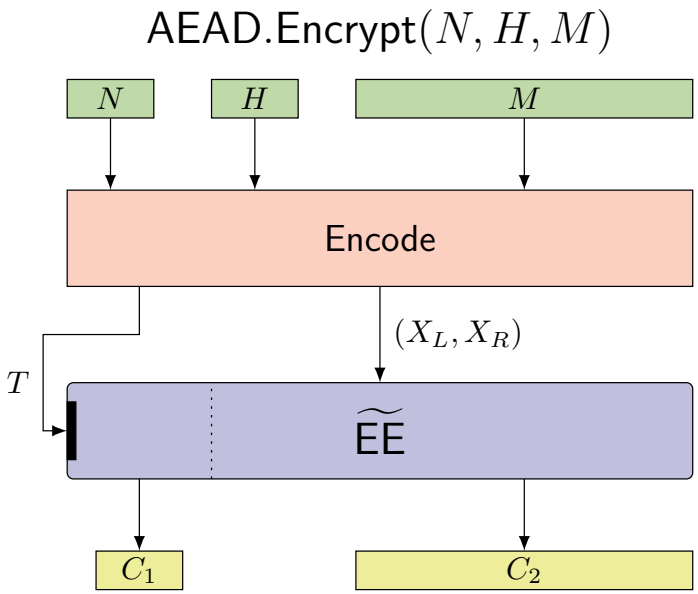

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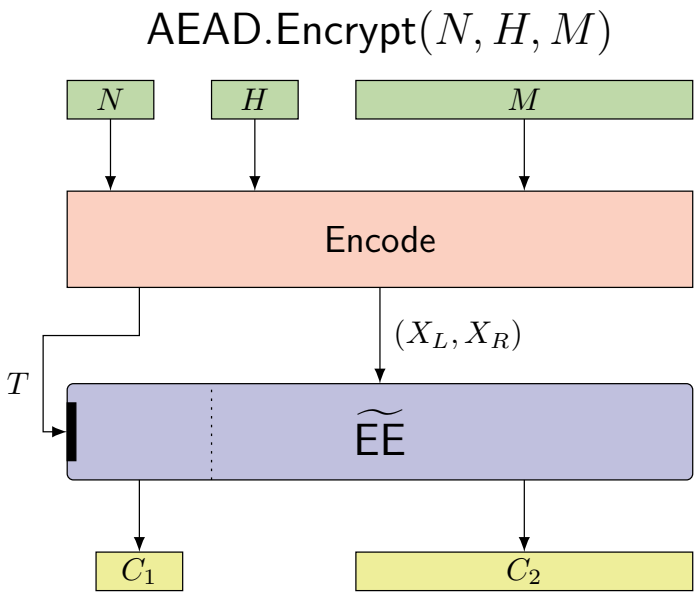

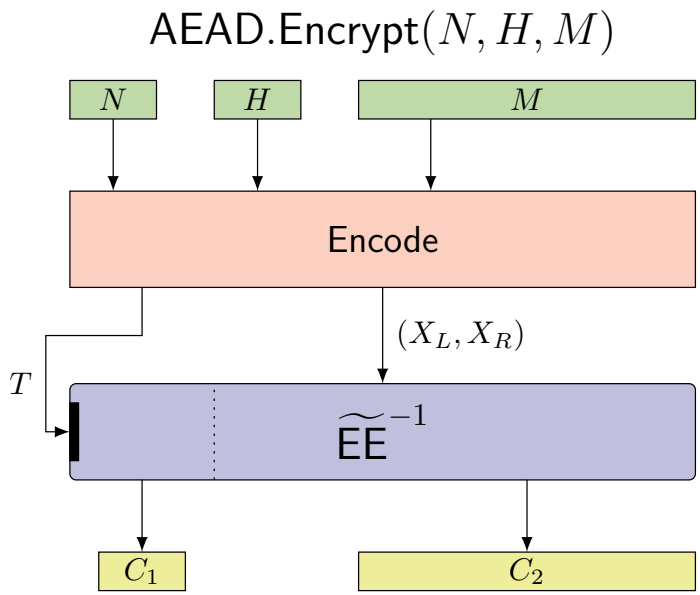

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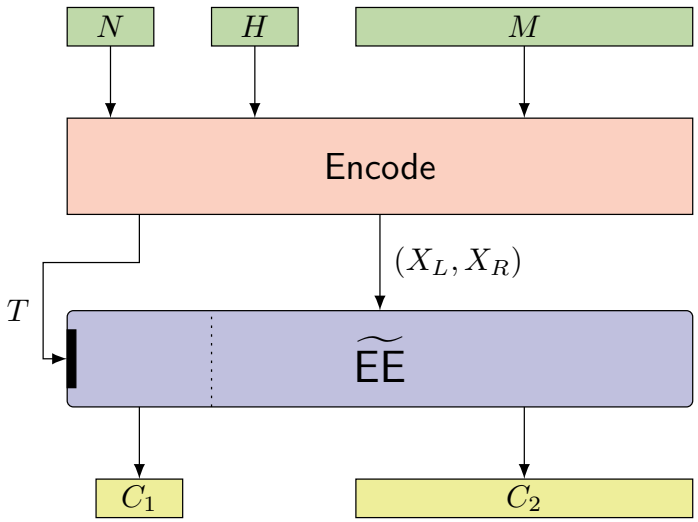

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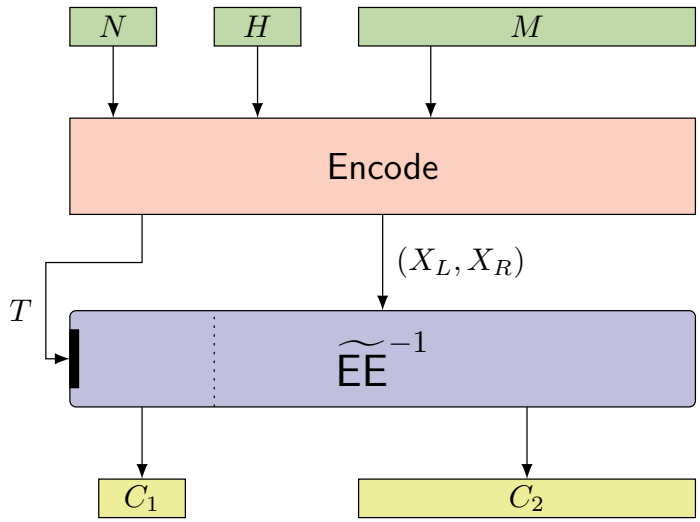

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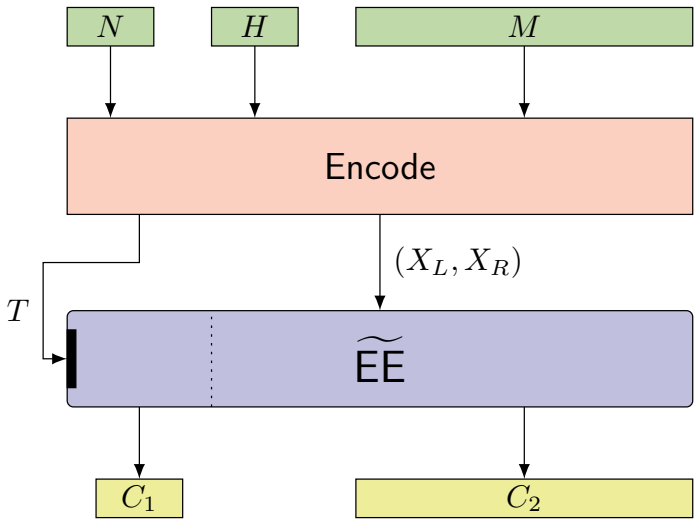

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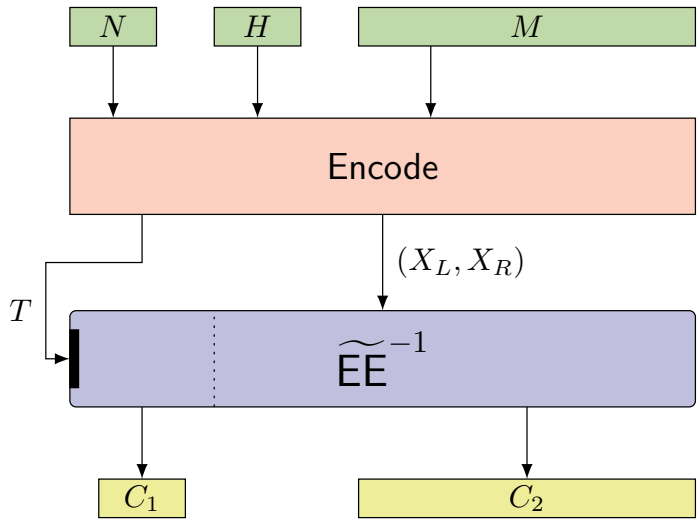

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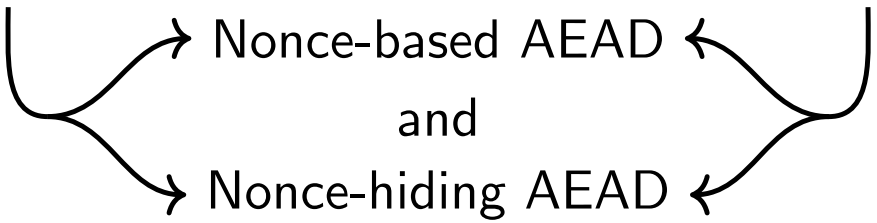

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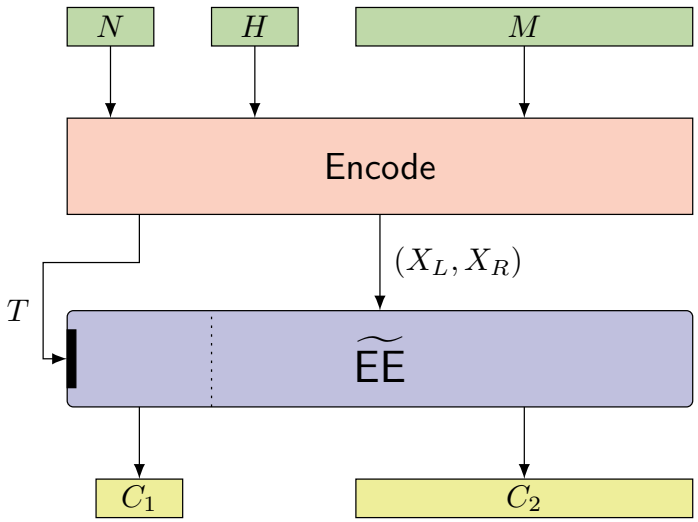

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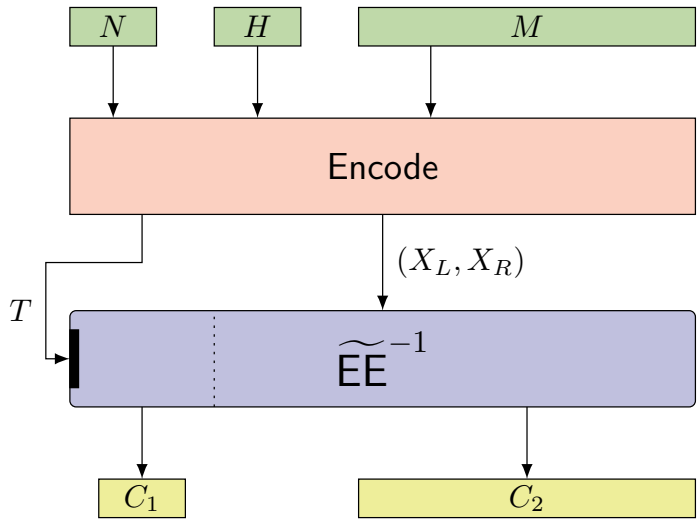

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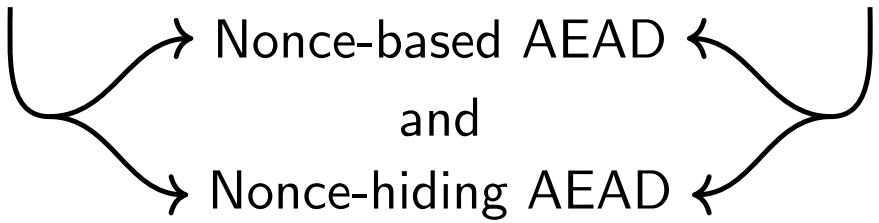
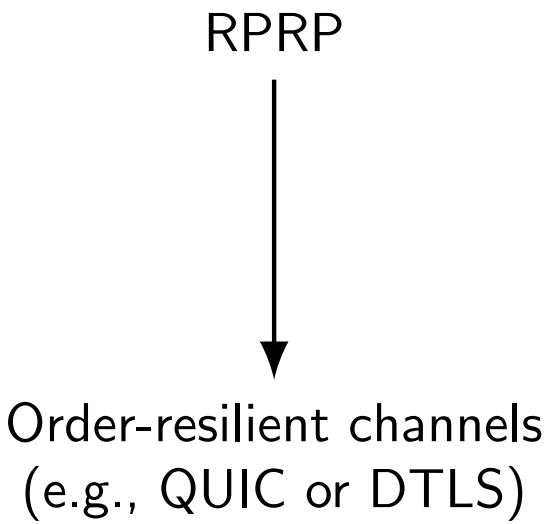


4 AEAD schemes!

RPRP Applications: Order-Resilient Channels [DK22]



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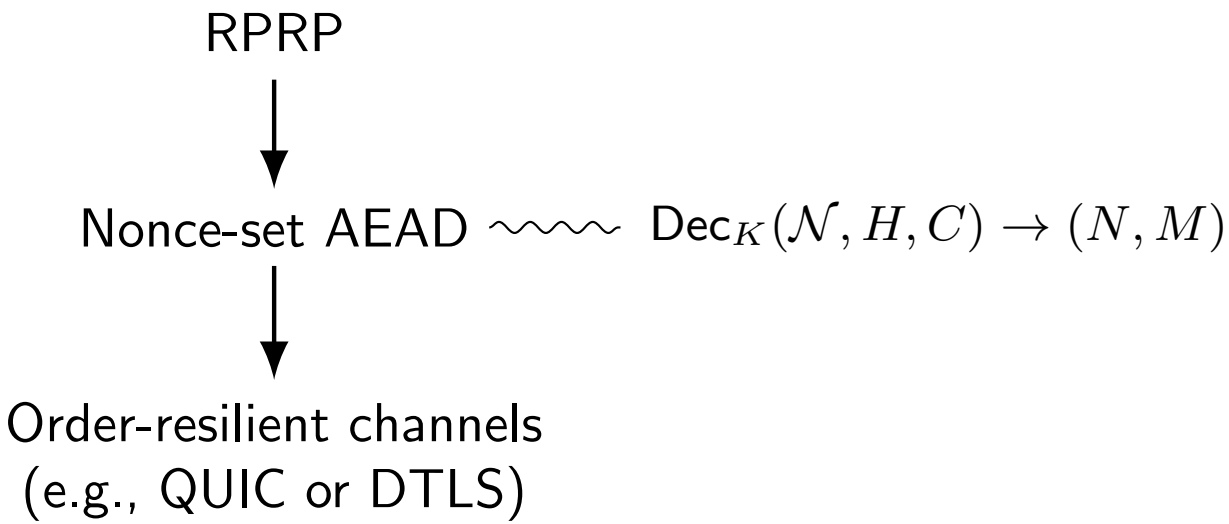

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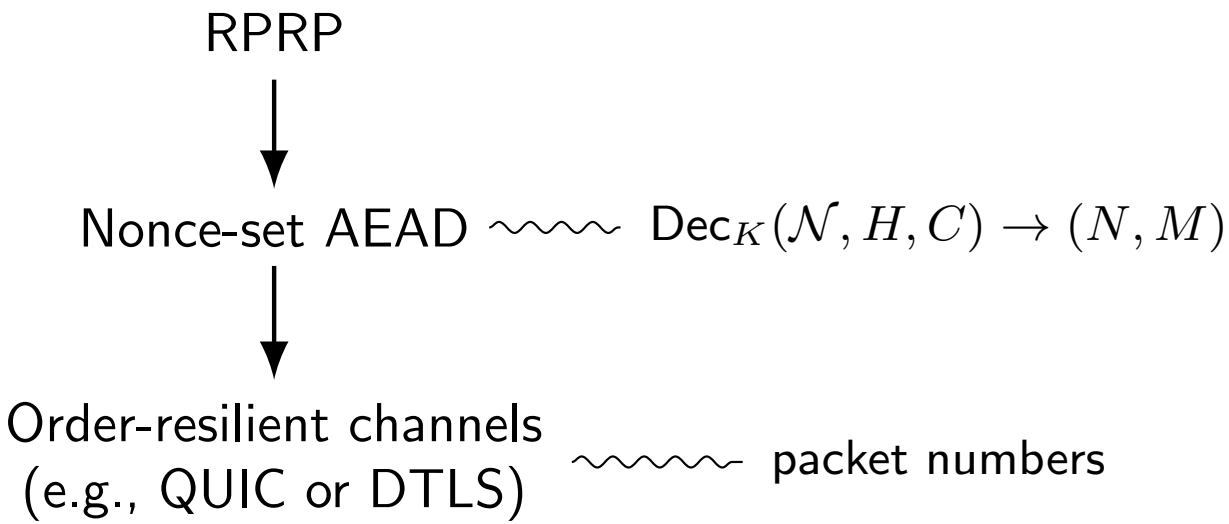

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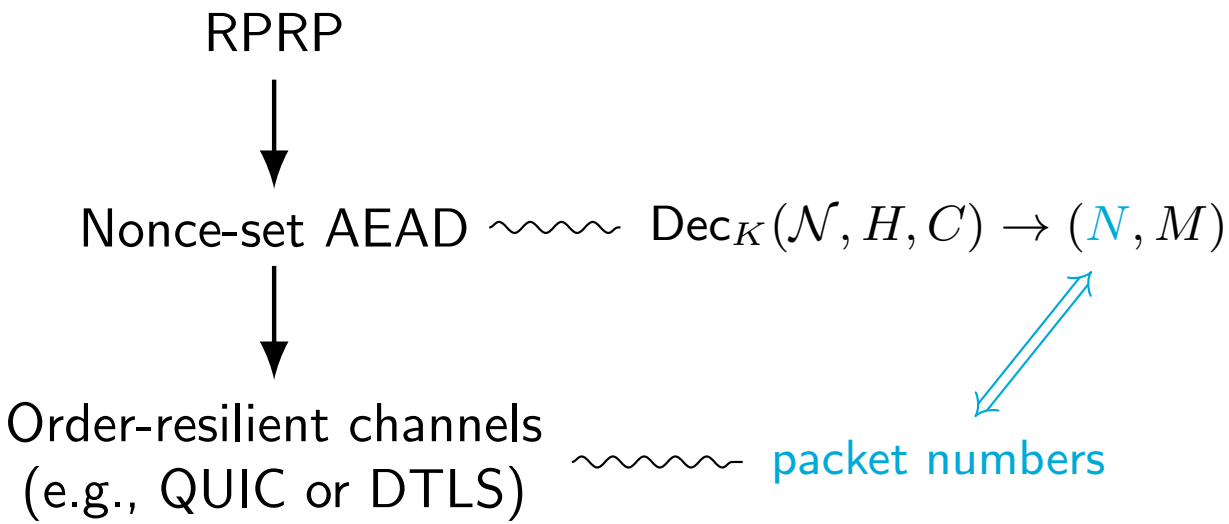

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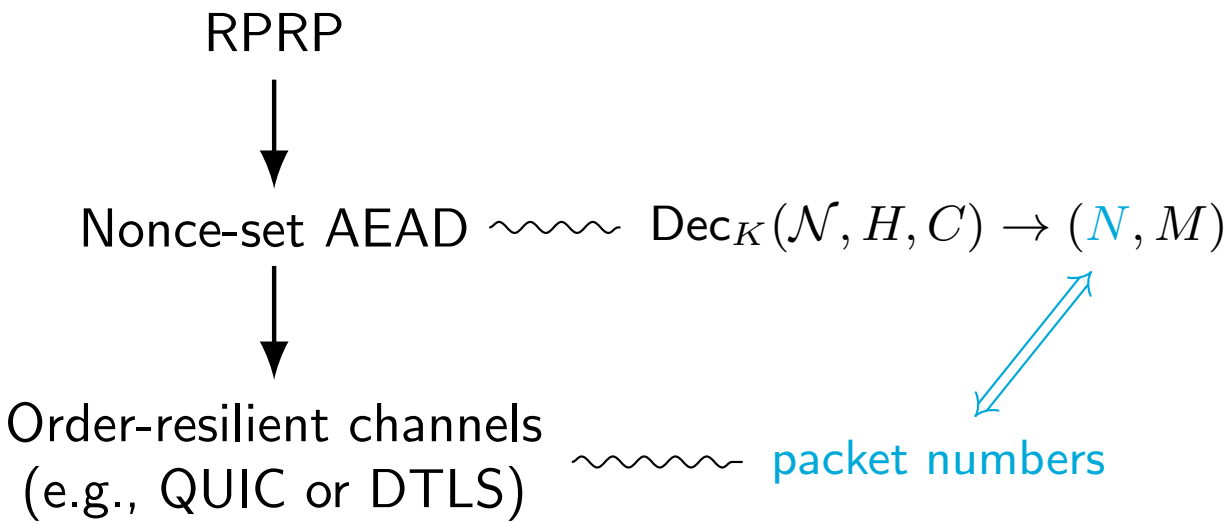

Encrypted packet numbers

✓ and

More compact ciphertext
(than, e.g., NH transforms [BNT19])

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✓ Performance competitive to the Tor's current onion encryption

Revisiting the Rugged Pseudorandom Permutation Definition

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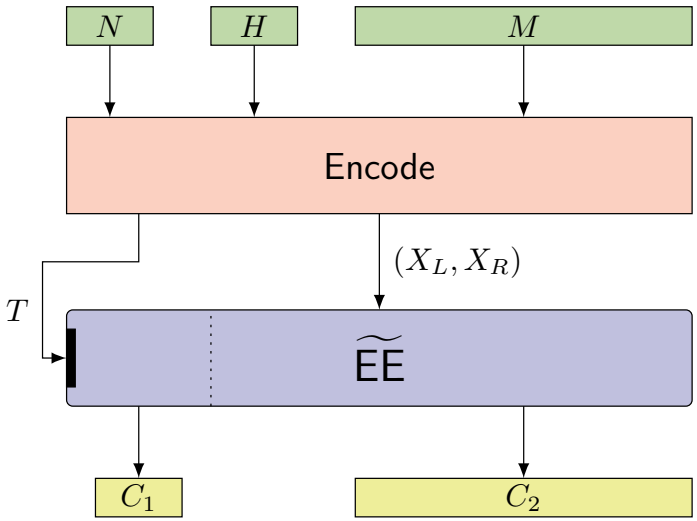

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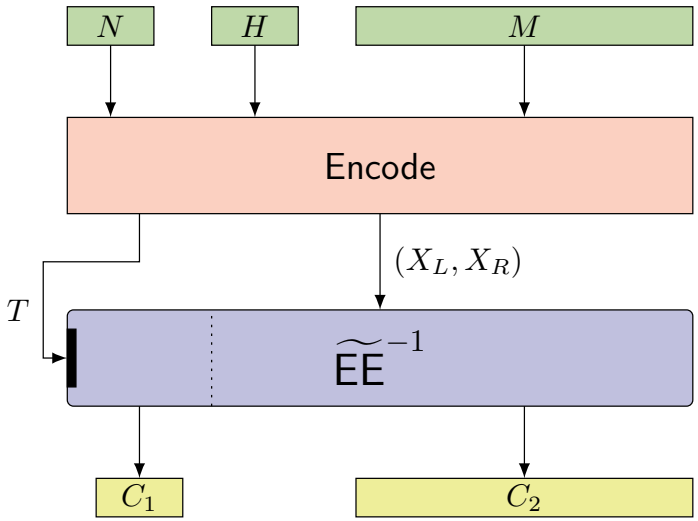

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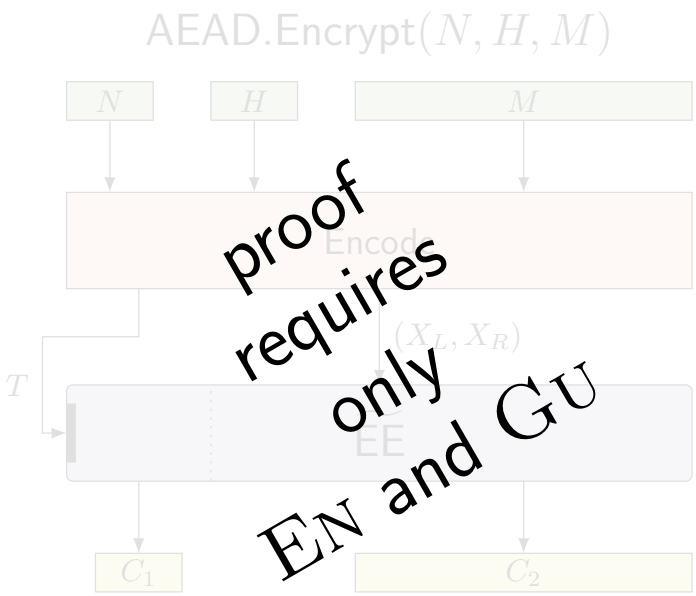

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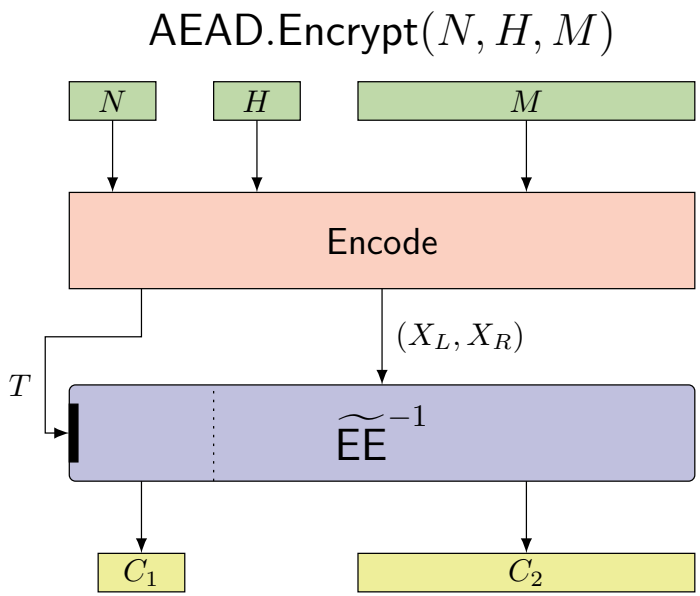

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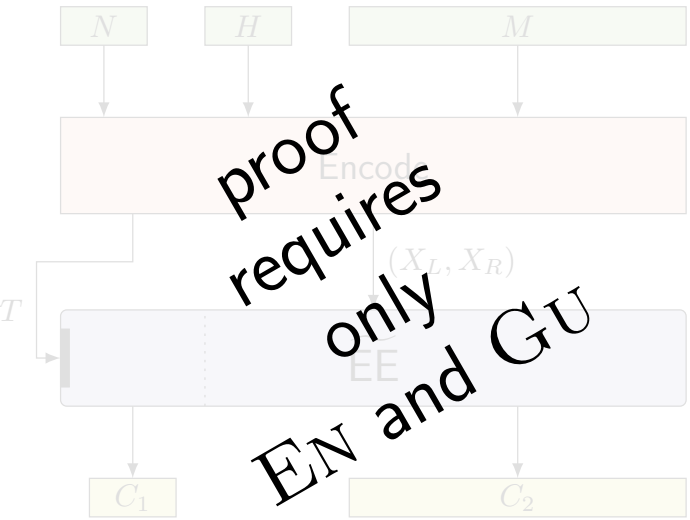

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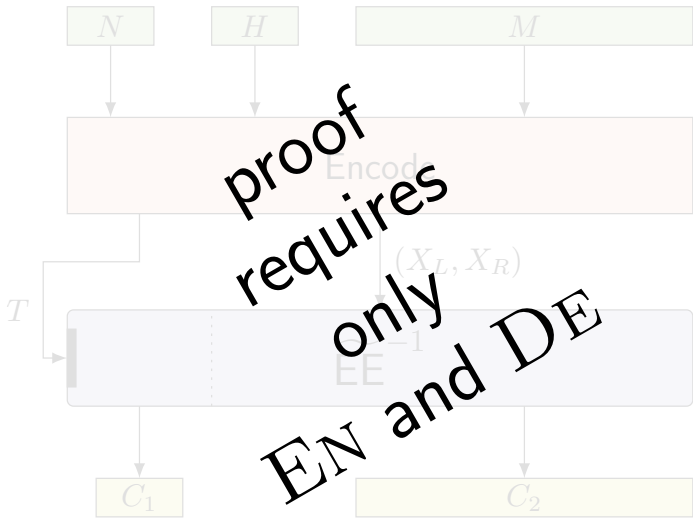

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RPRP Definition Variants

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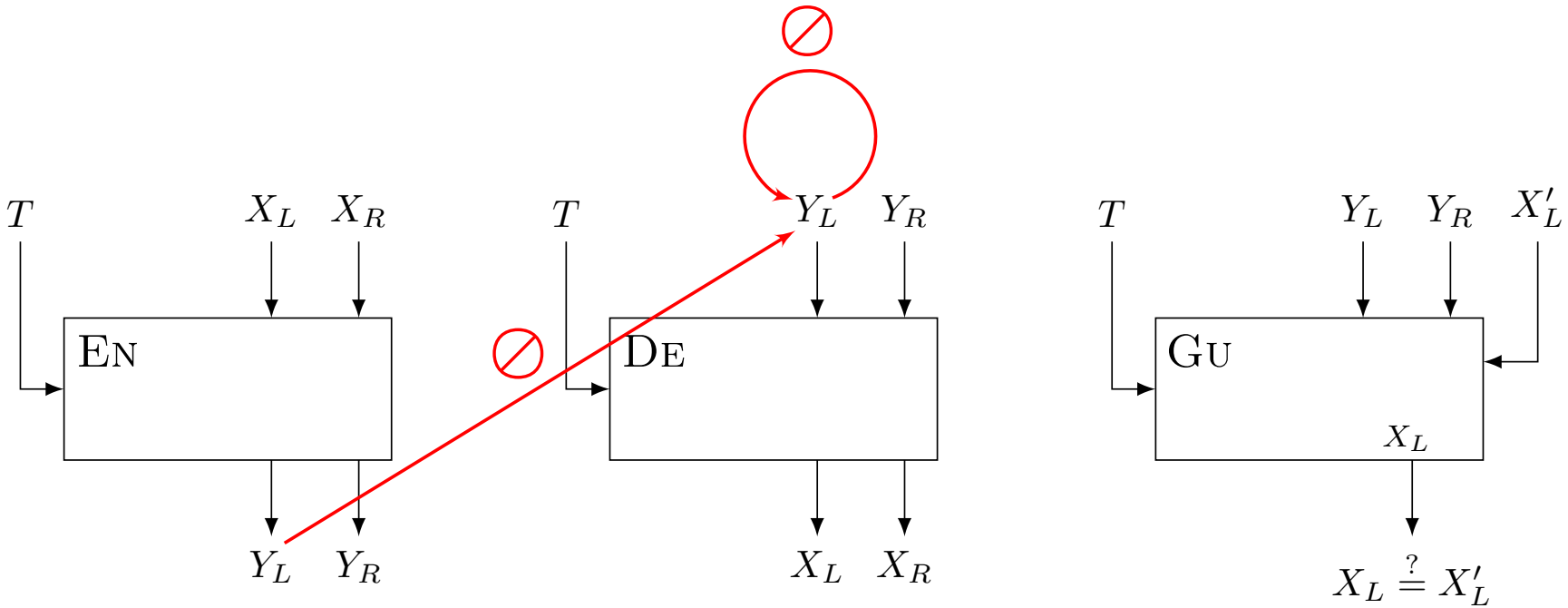

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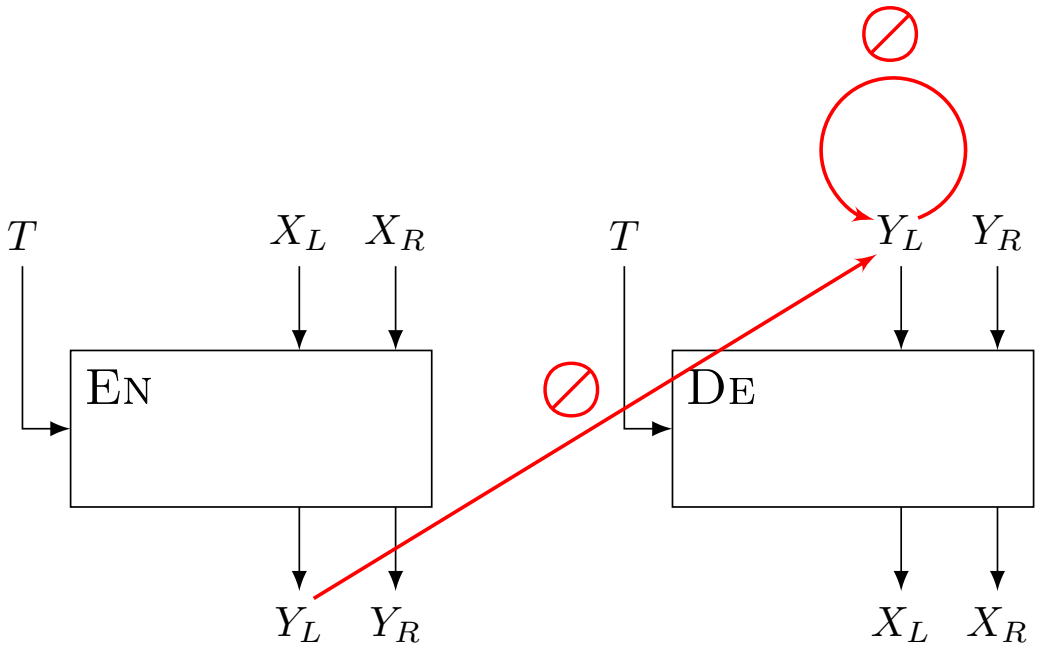

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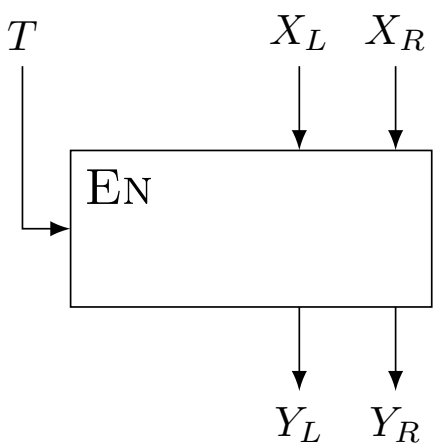

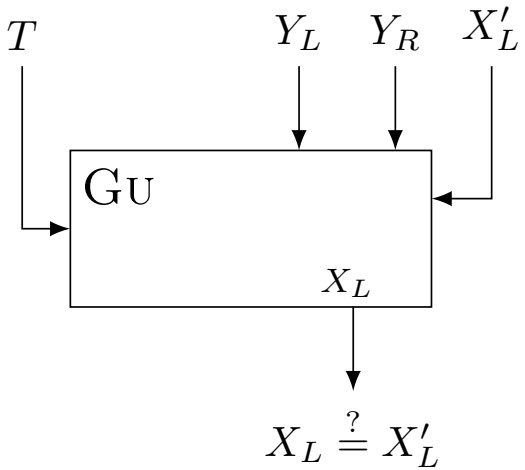

RPRP Definitions Relations

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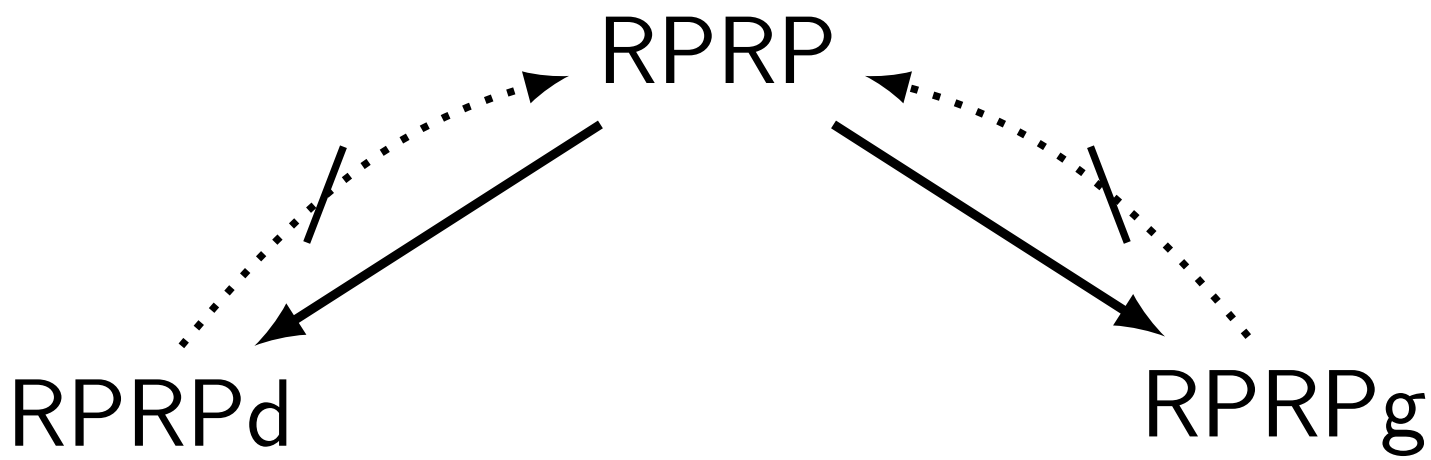

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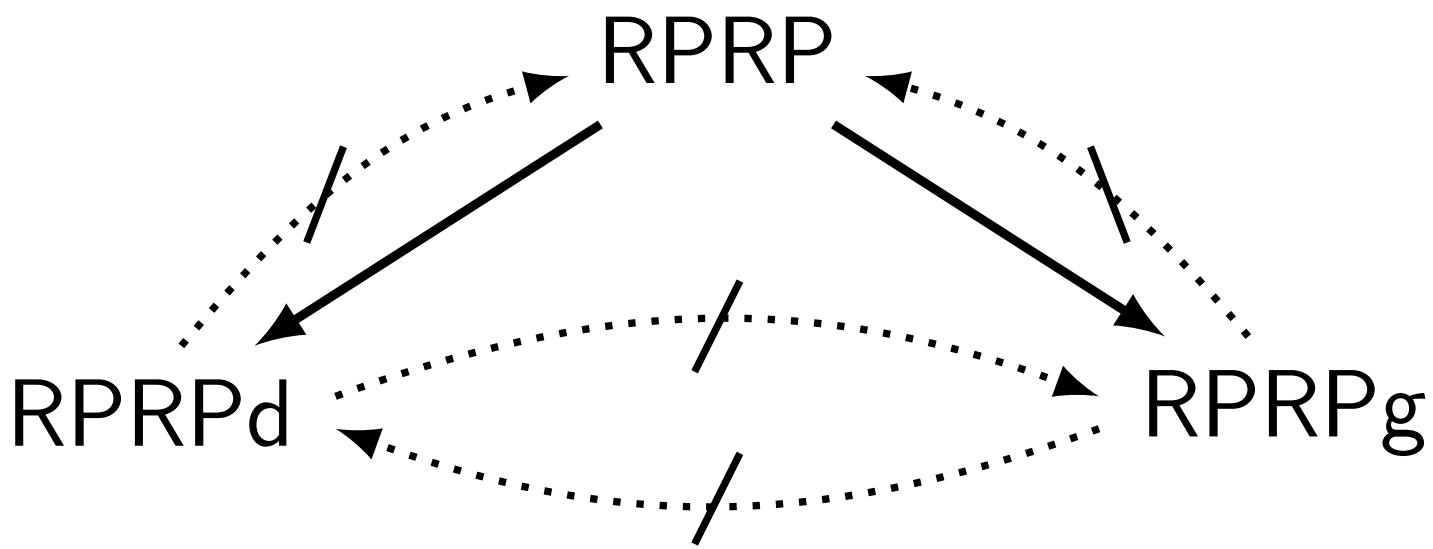

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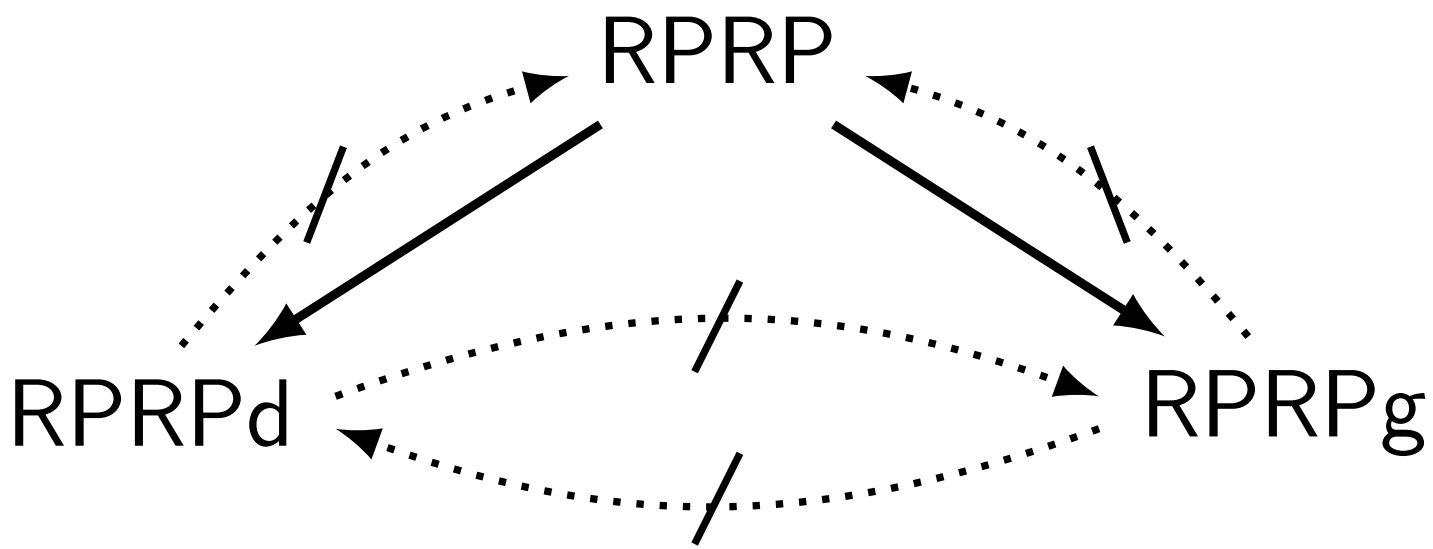

Minimized requirements
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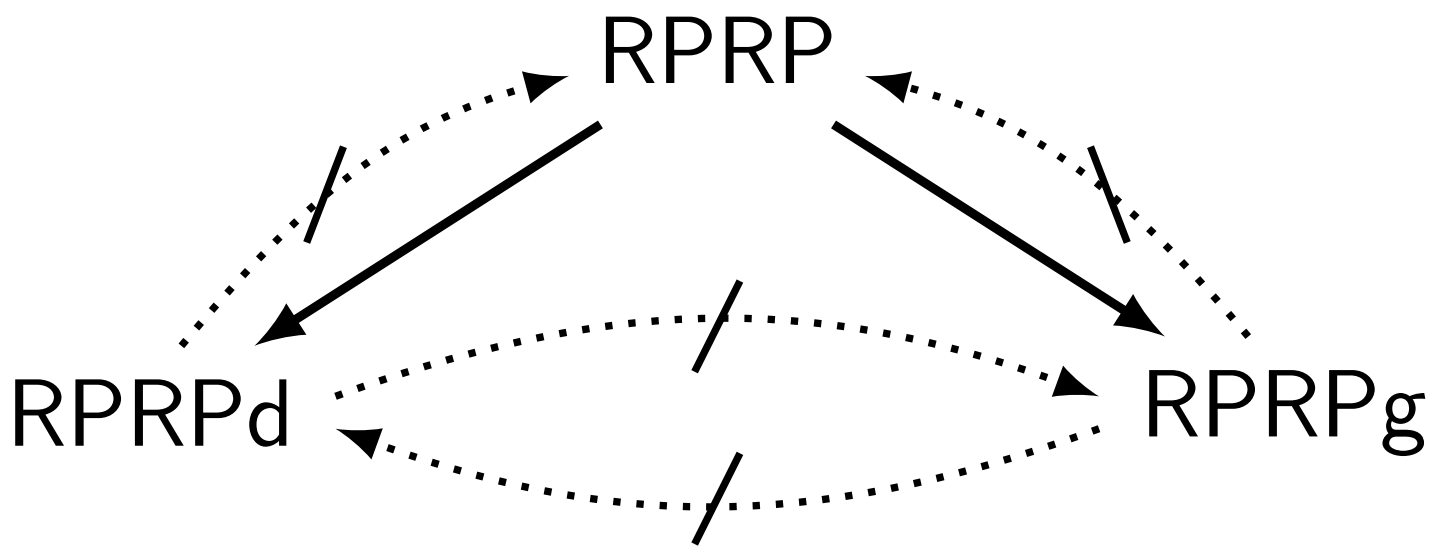

RPRP notion is still desirable!

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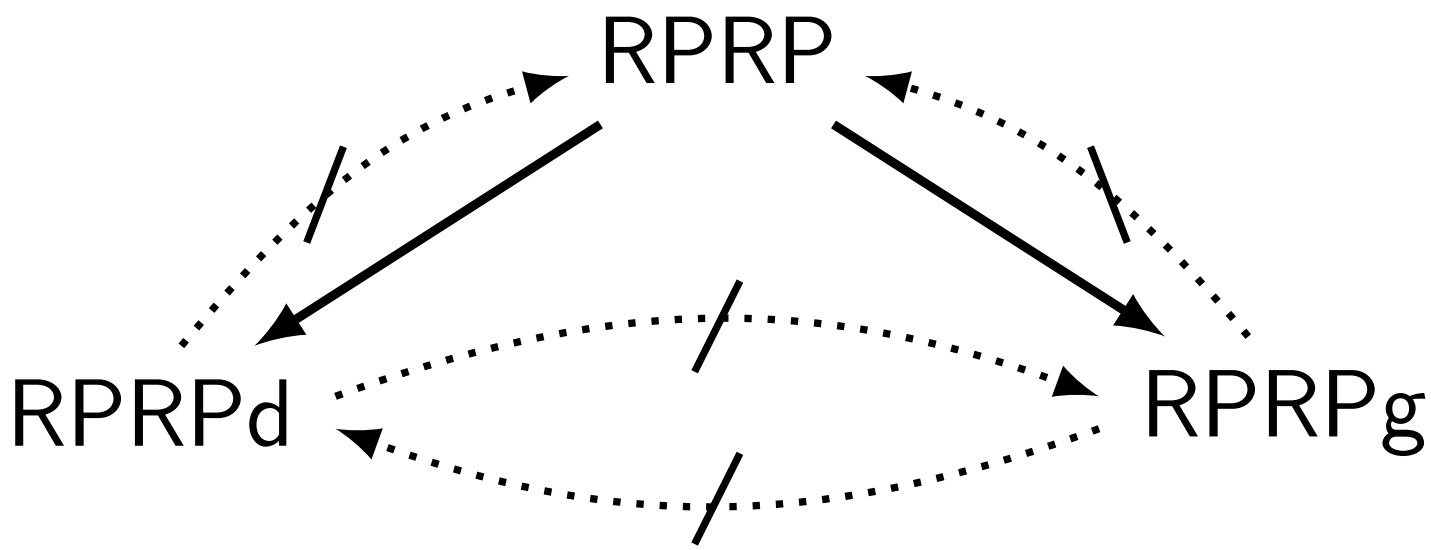

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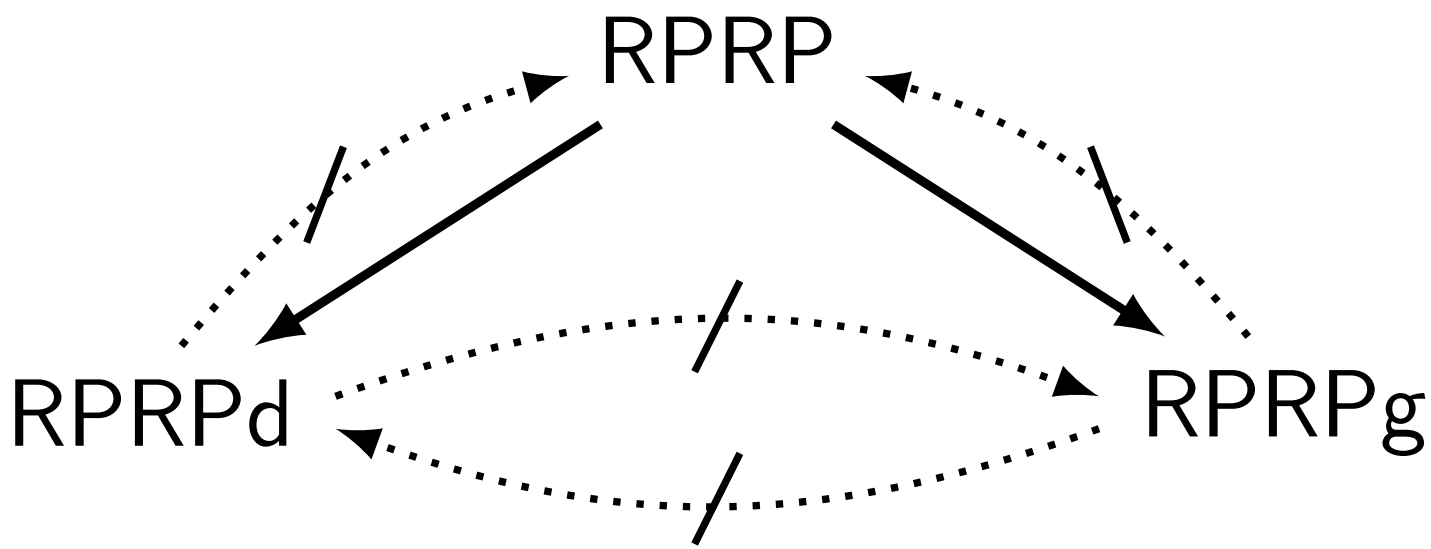

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Onion encryption use case

Looking at the Constructions

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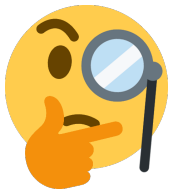

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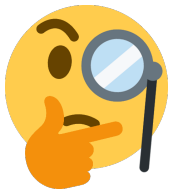

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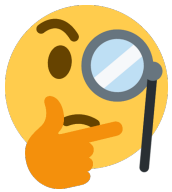

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3 new constructions

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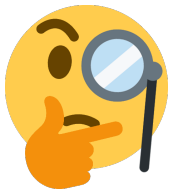

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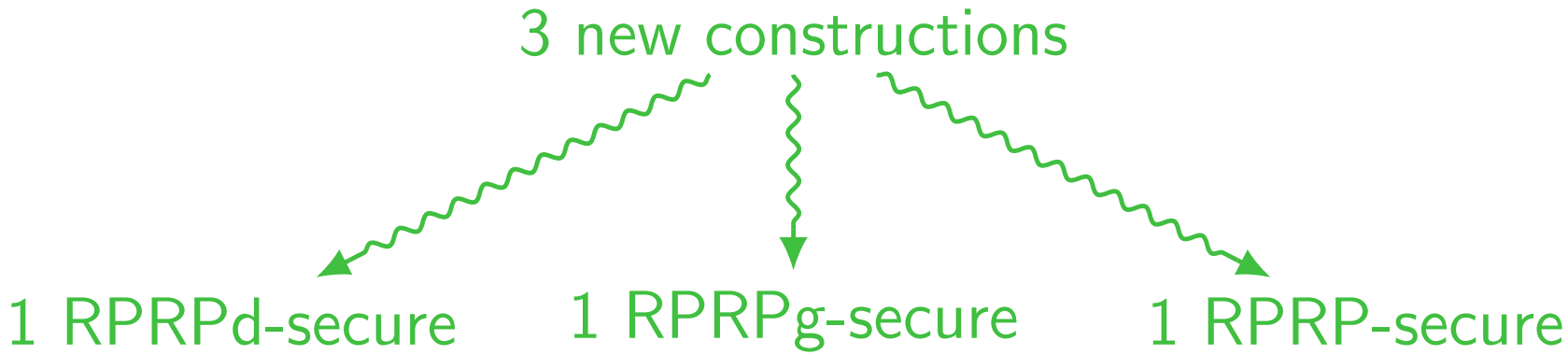

Three-Round Feistel Constructions

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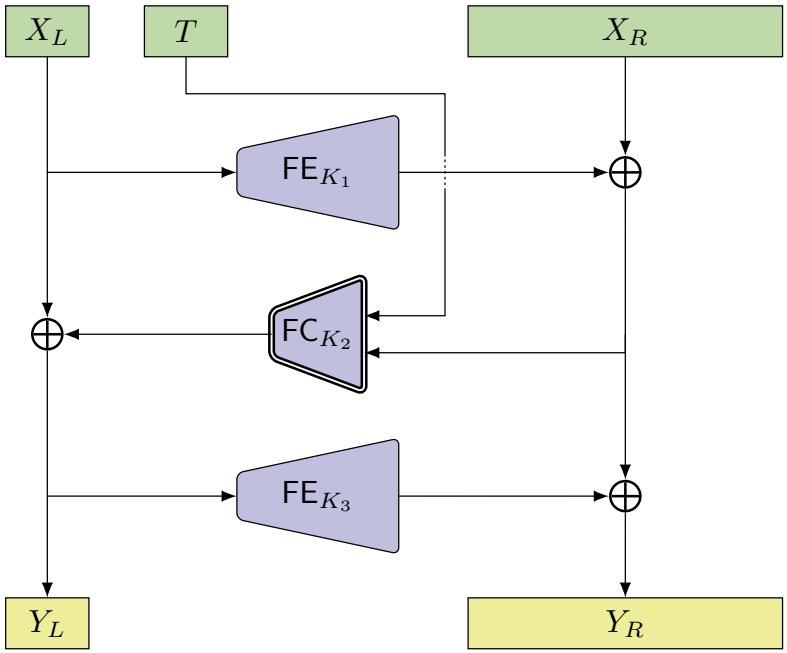
ECE (Expand-Compress-Expand)



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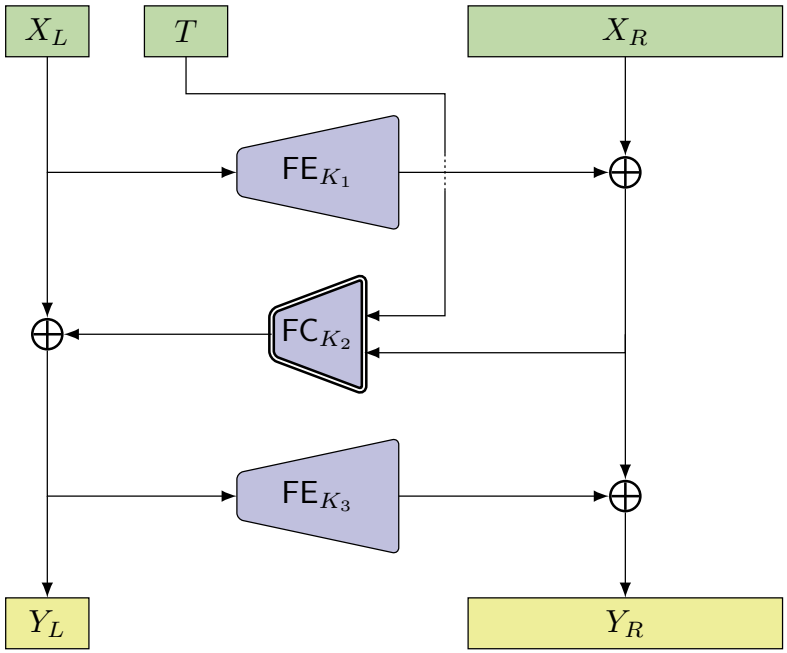

RPRPd secure

proof

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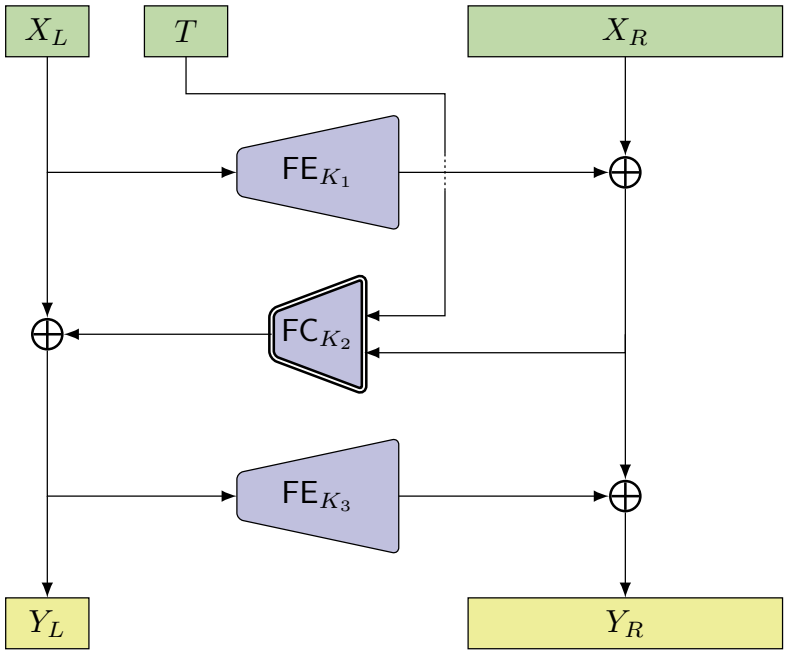

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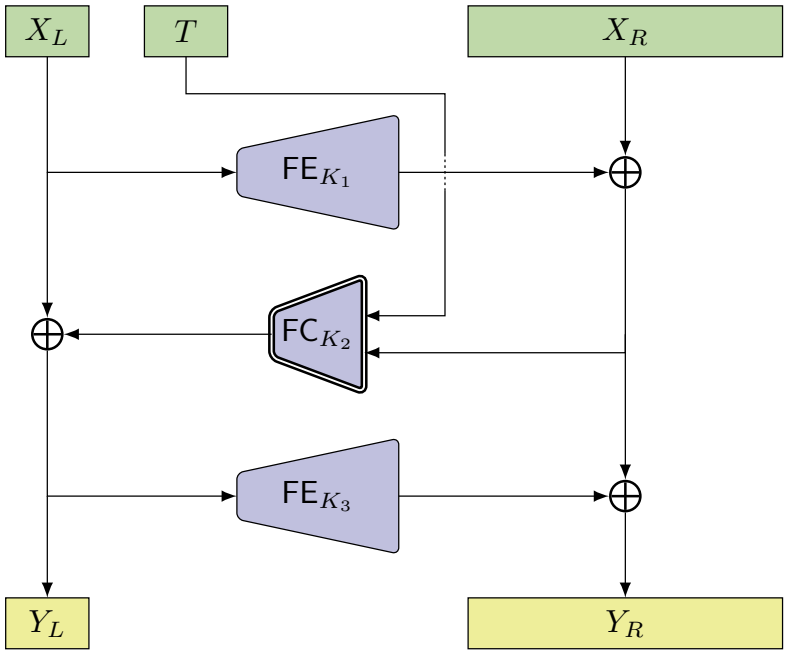

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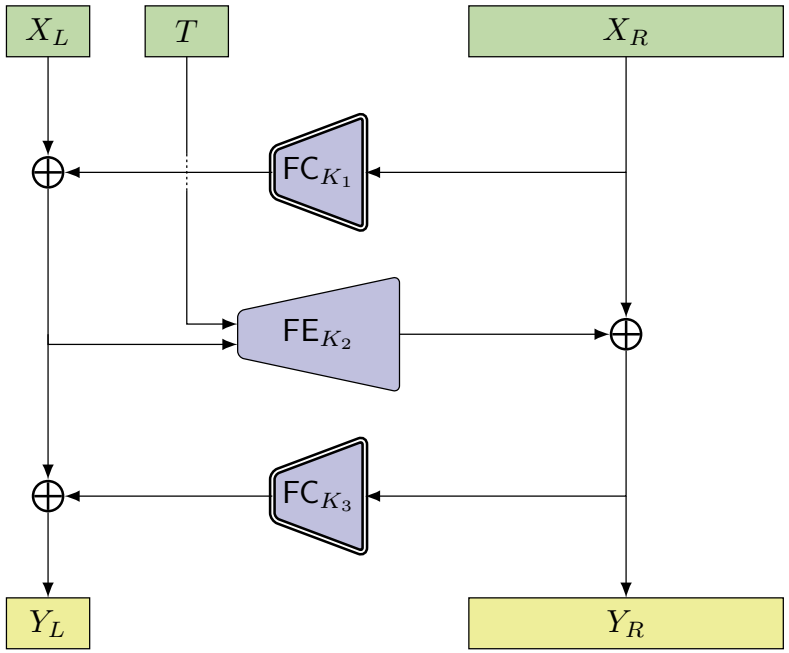

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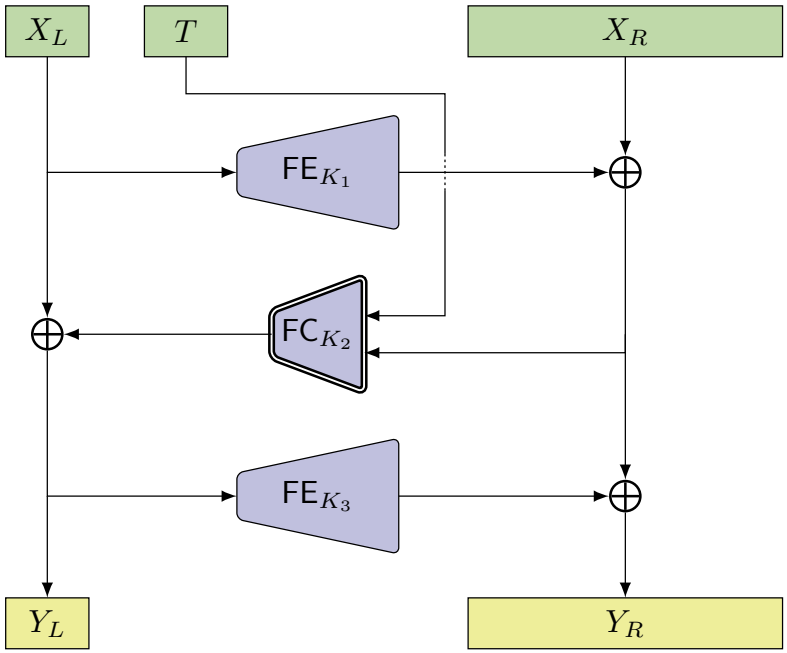

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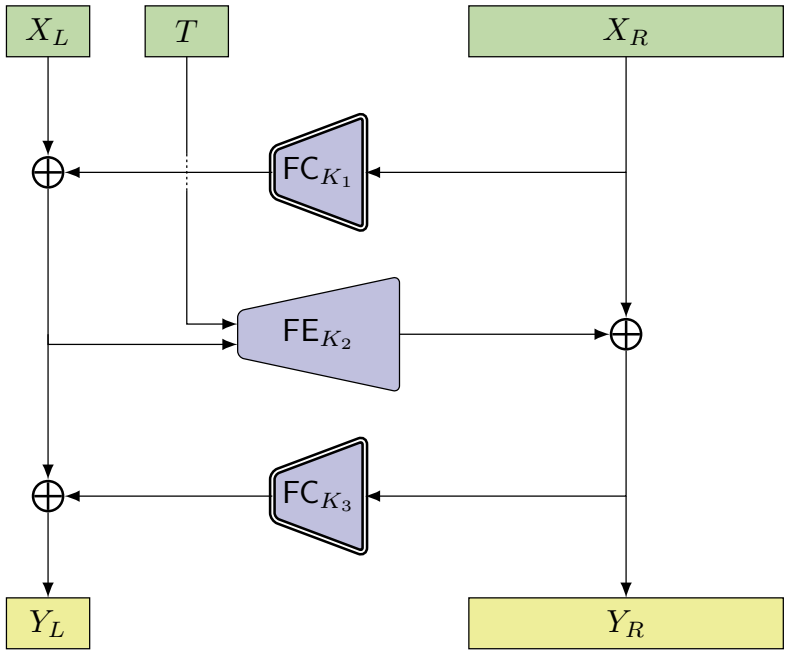

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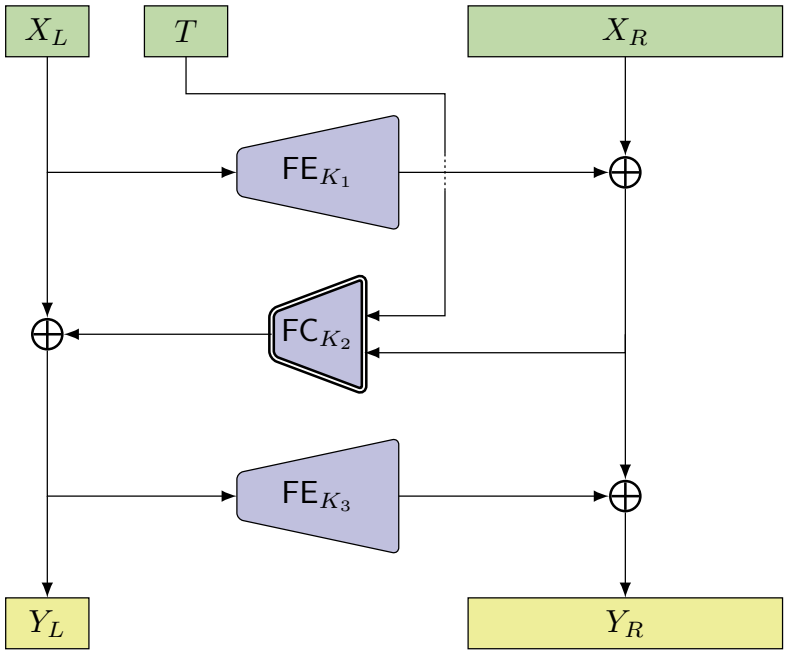

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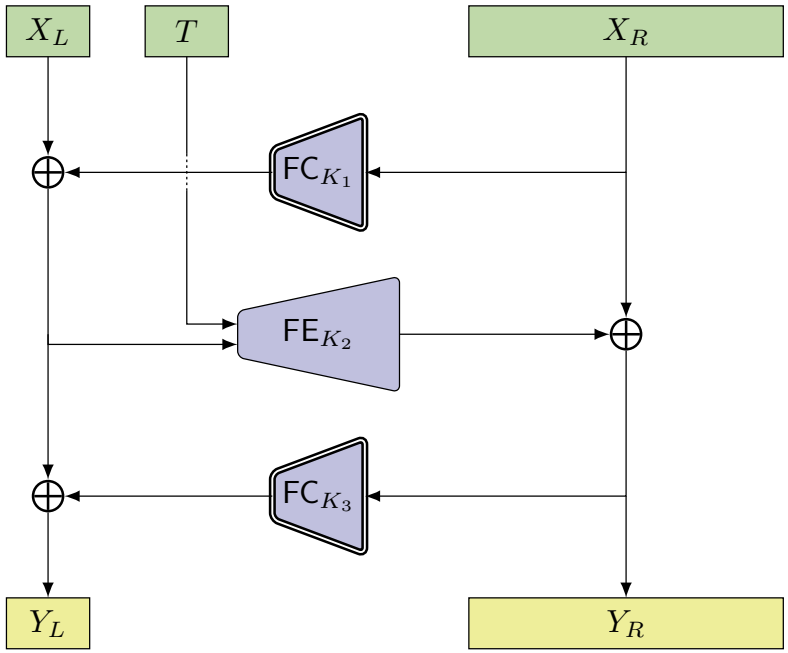

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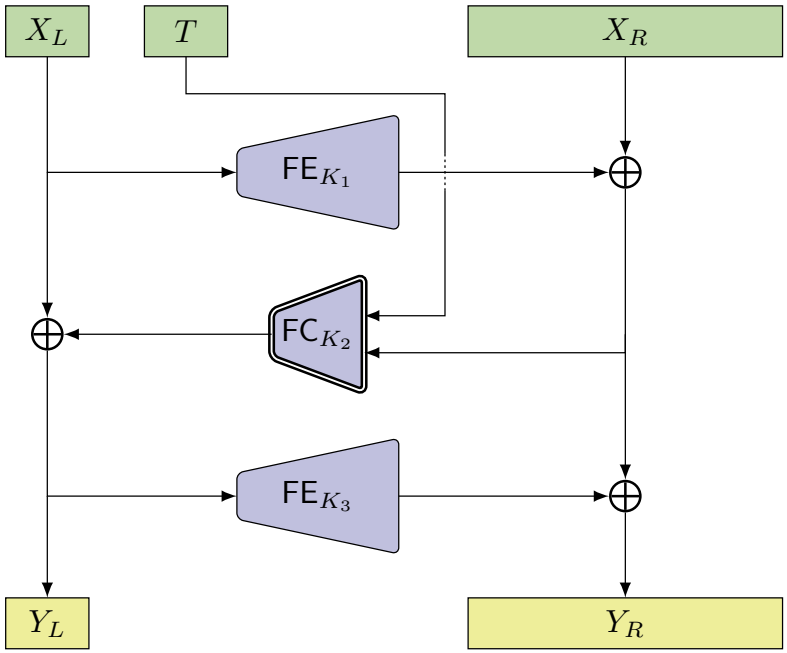

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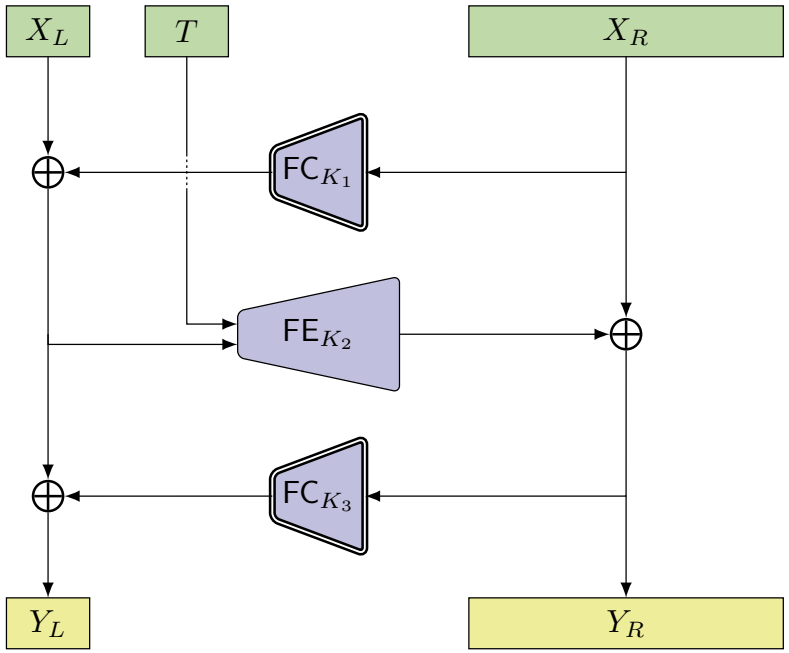

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- Three-round Feistel achieves (cipher-based) notion **stronger** than PRP [LR88].

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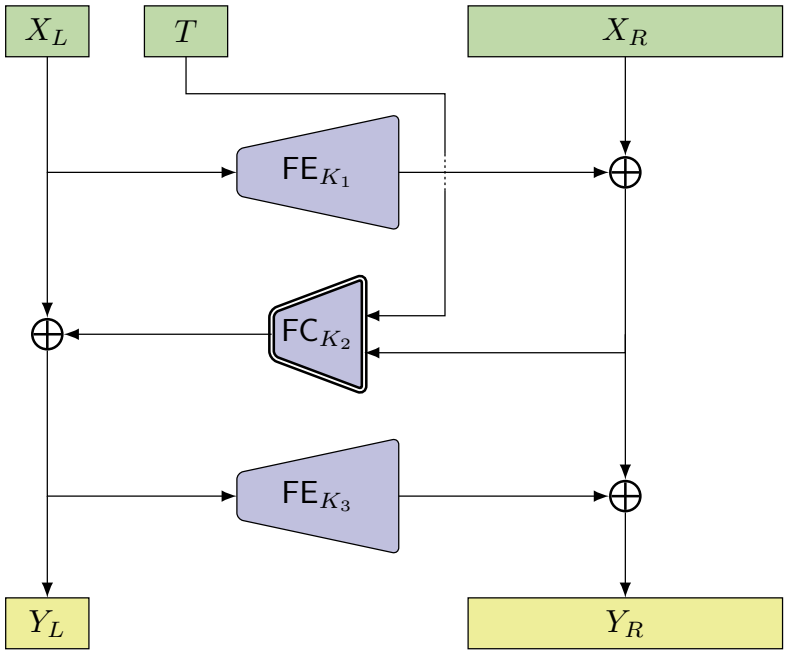

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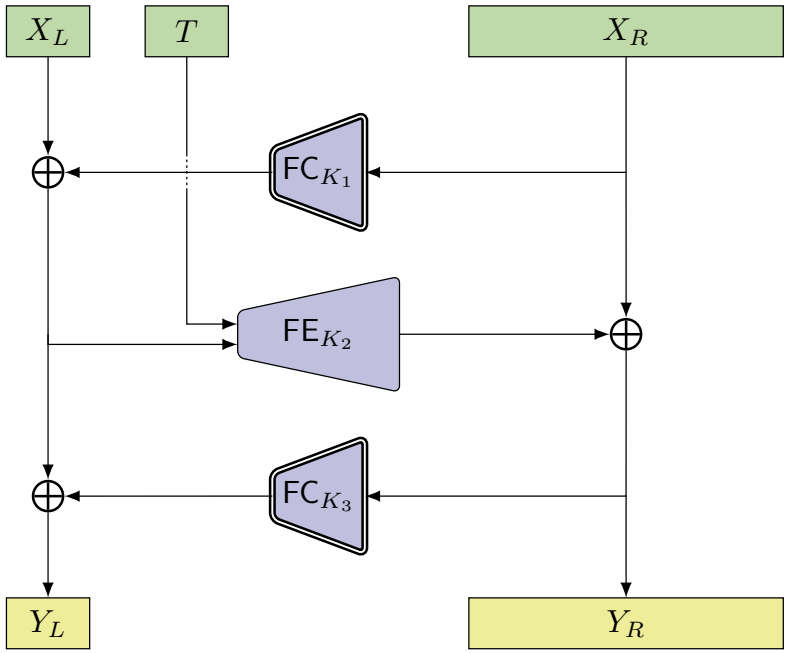

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- Fast instantiations possible with deck functions [BDHAK22].

HEC Construction

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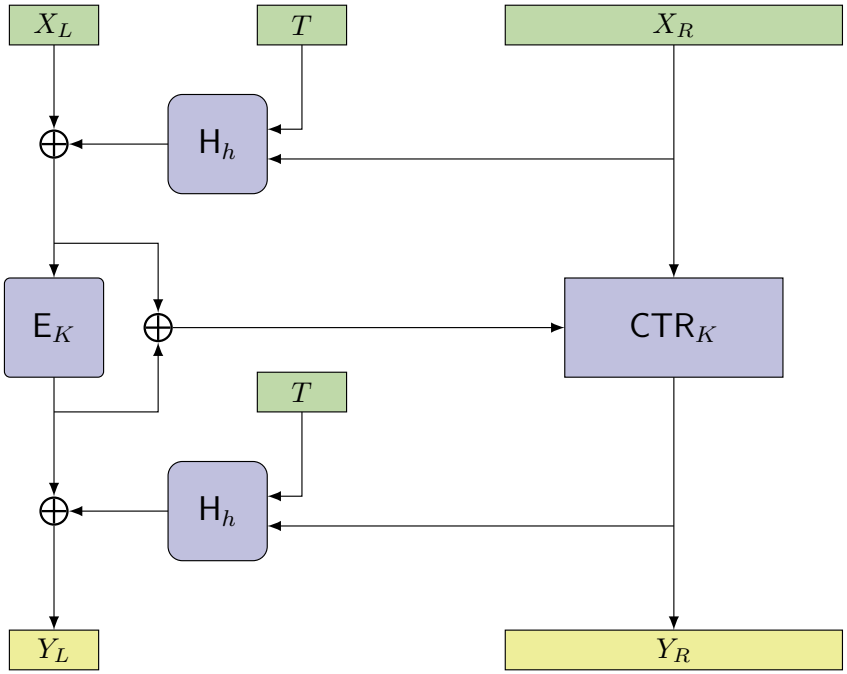

- HCTR construction [WFW05] as a base.

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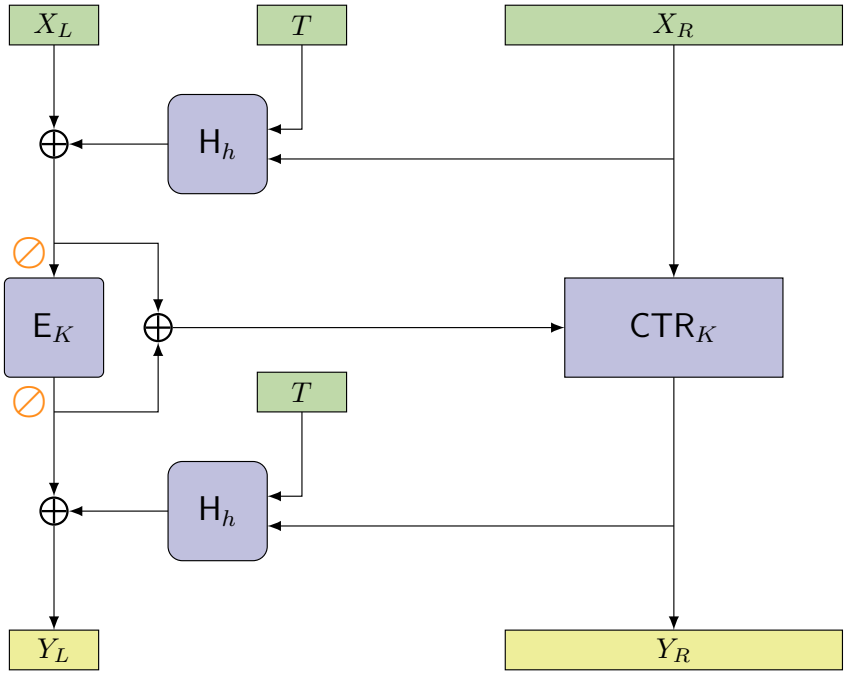

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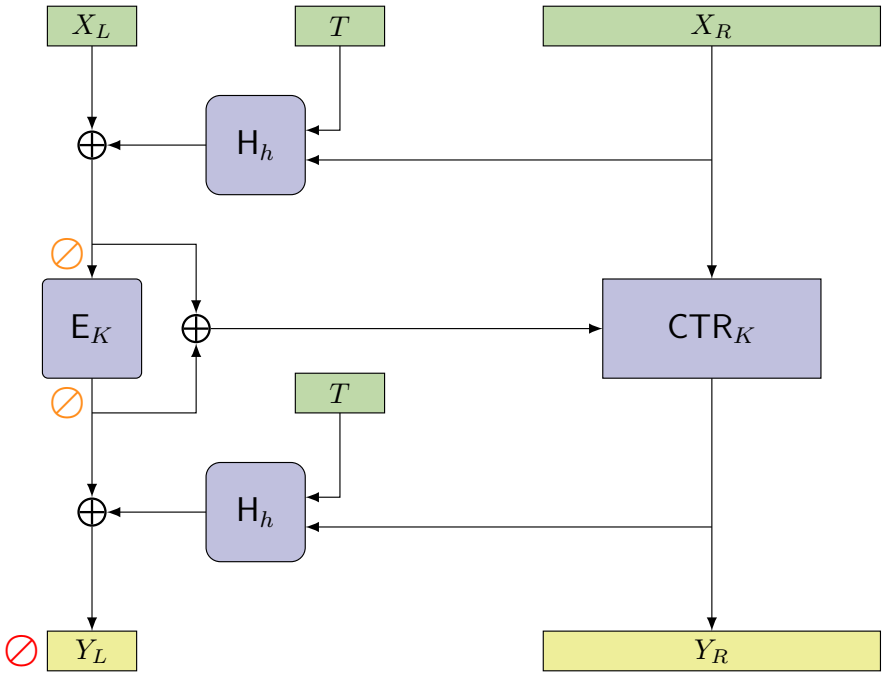

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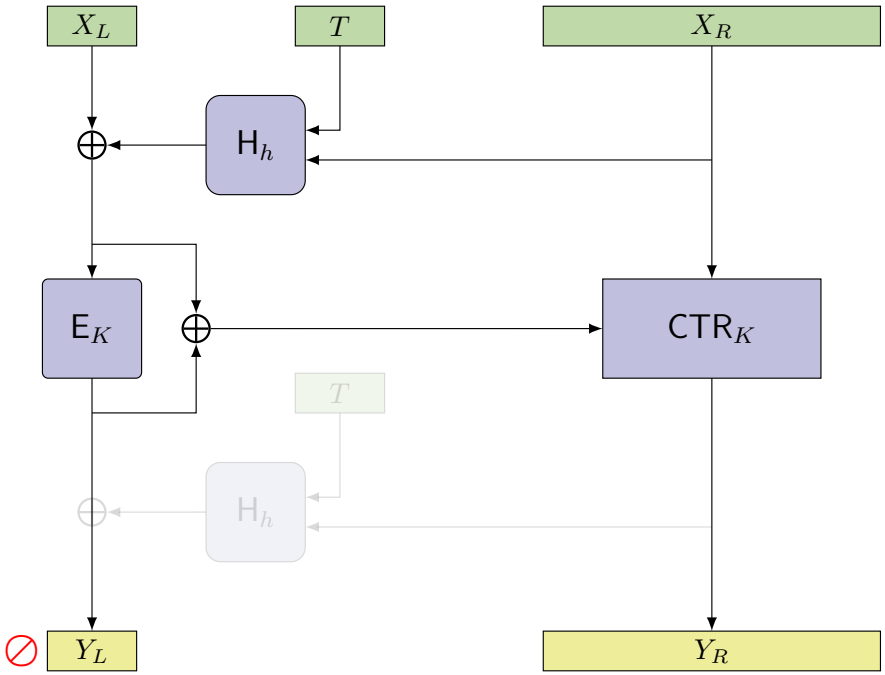

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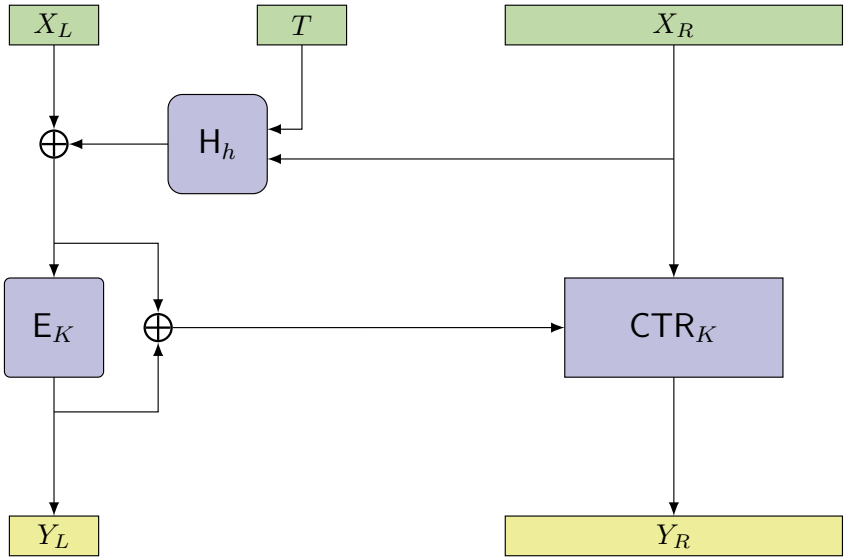

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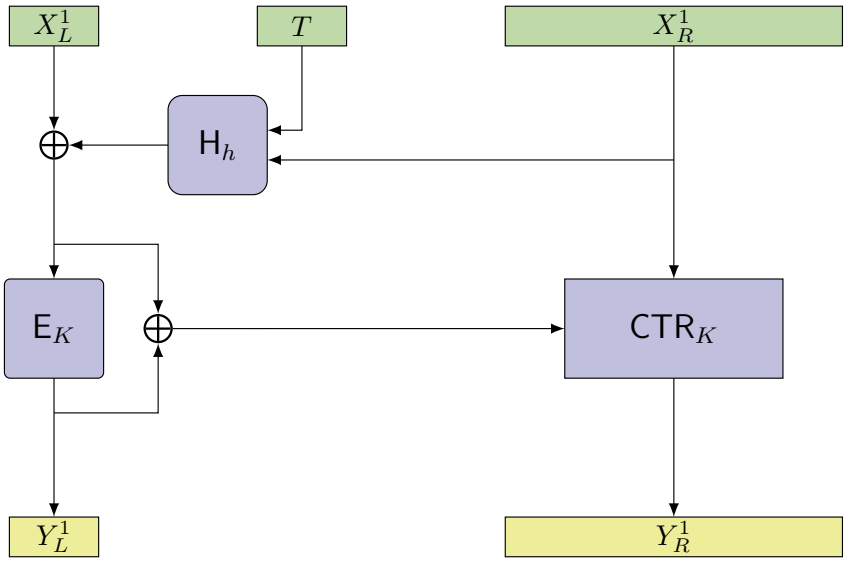

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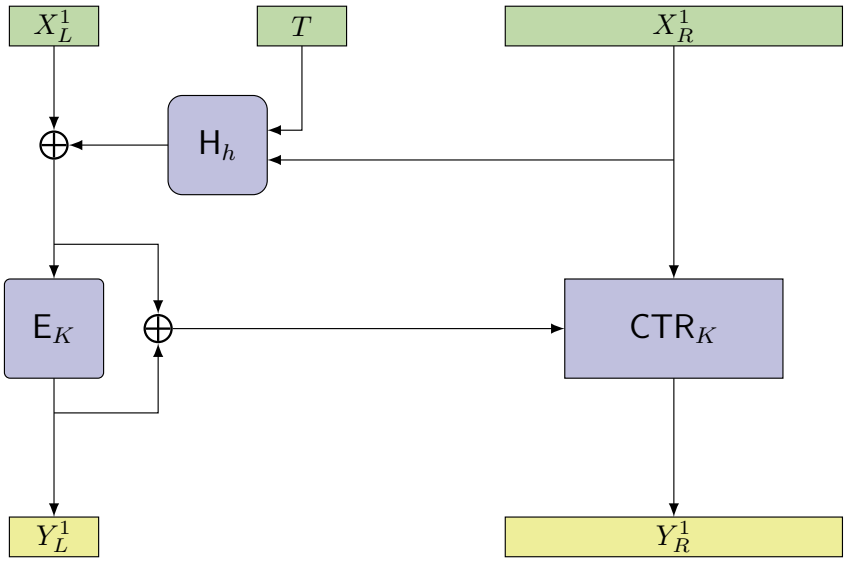

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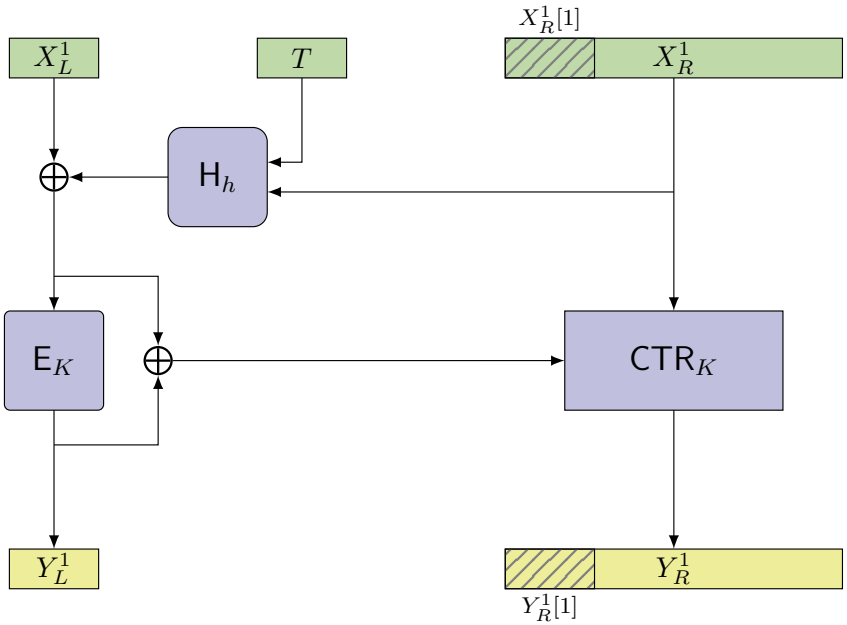

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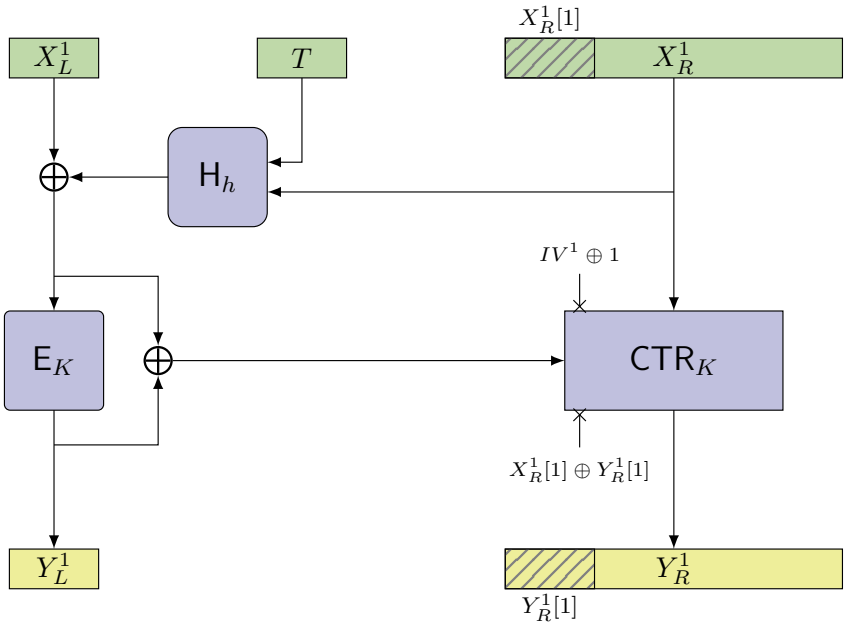

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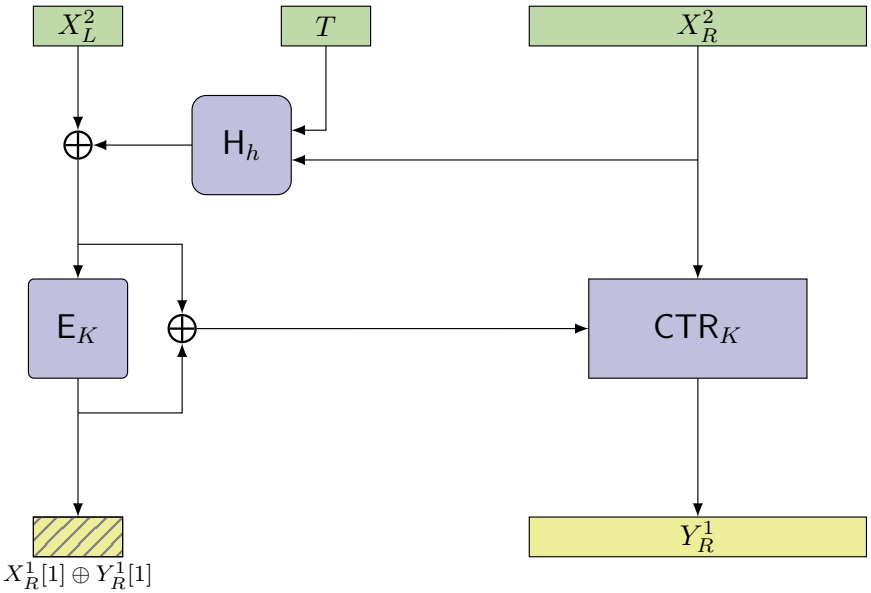

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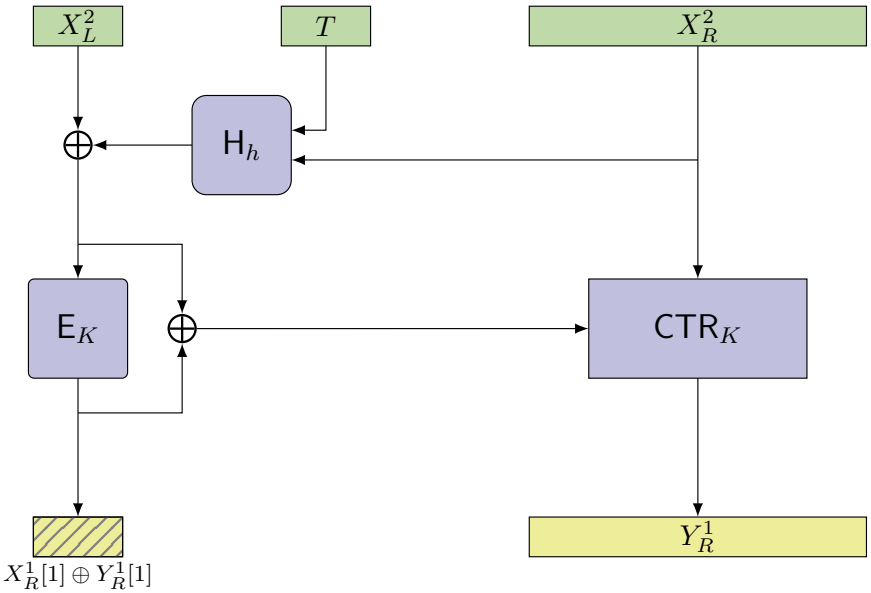

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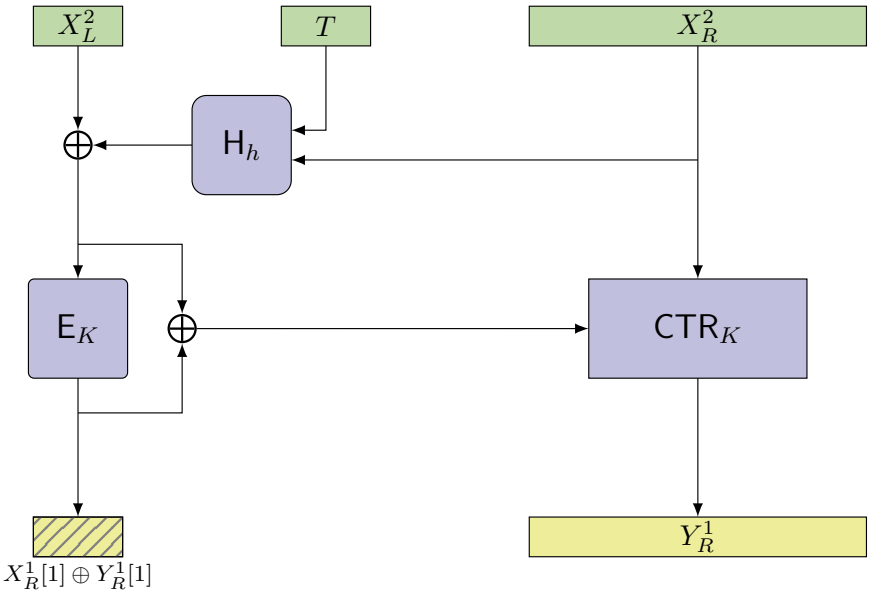

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3. Calculate $H_h(T, X_R^1) \oplus H_h(T, X_R^2)$ and extract key h.

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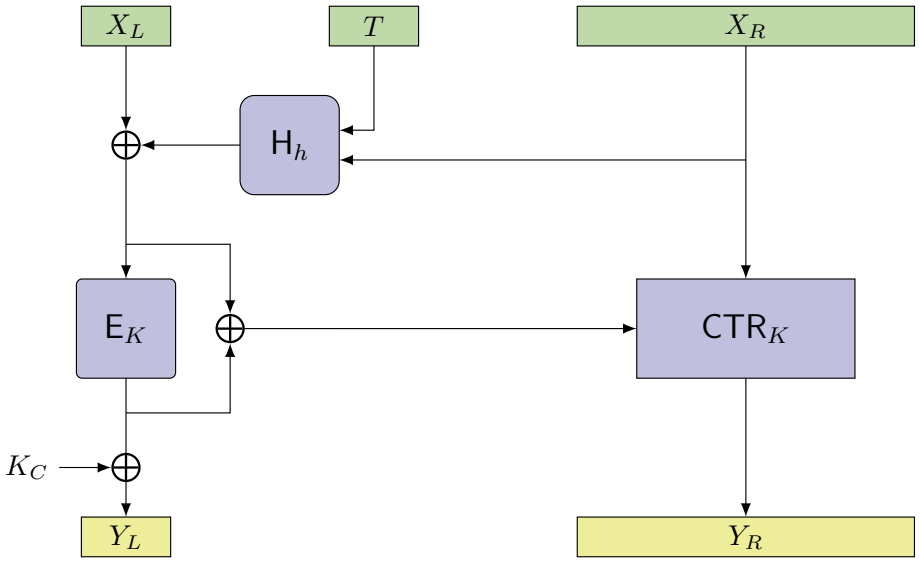
HEC Construction

HEC (Hash-Encipher-Counter)



RPRP secure

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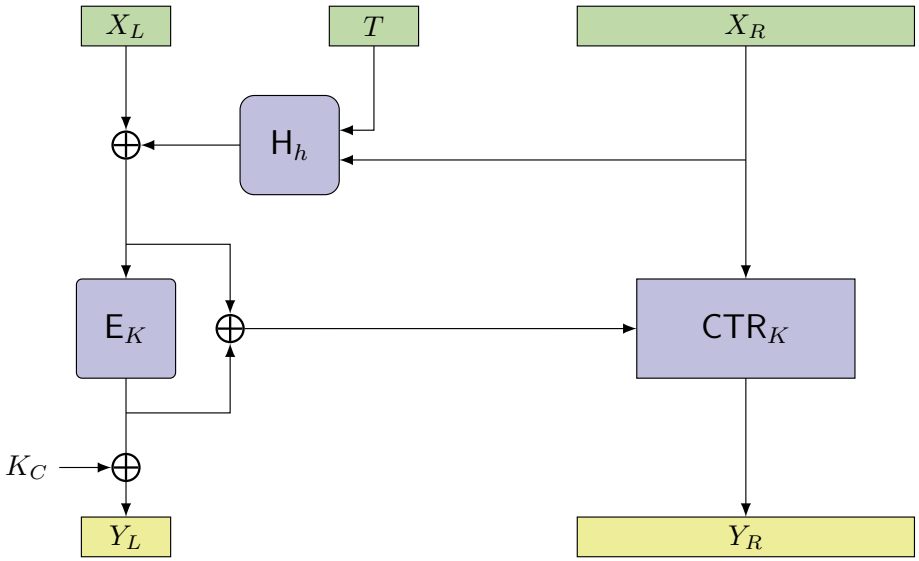

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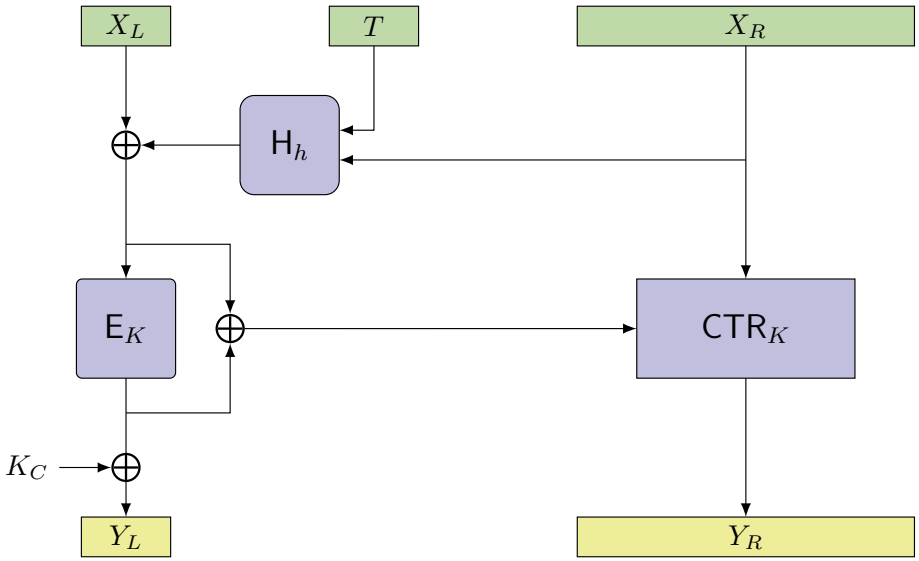

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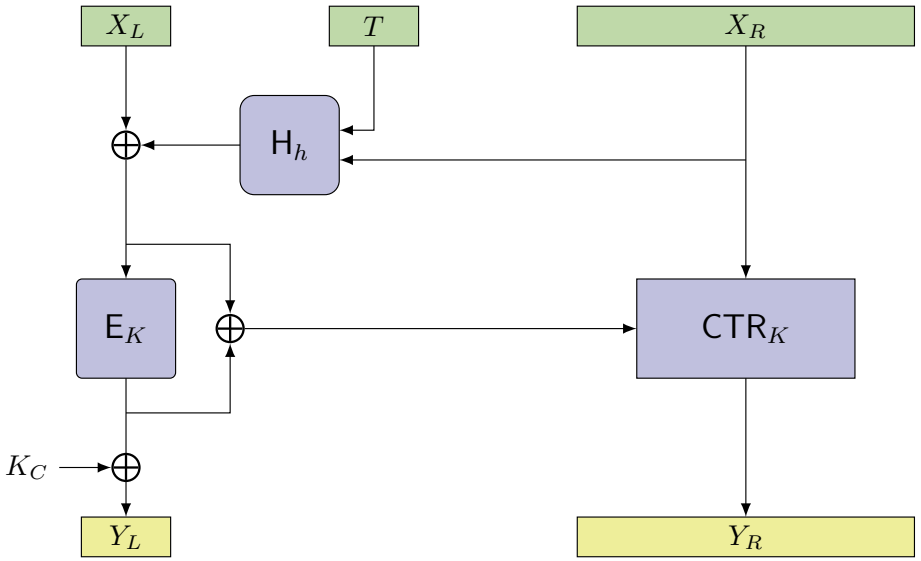

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- H-Coefficient technique proof with birthday bound security.

Extending the Left Domain

Motivation for Domain Extension

- Integrity term in the security bound when building order-resilient channels from an RPRP:

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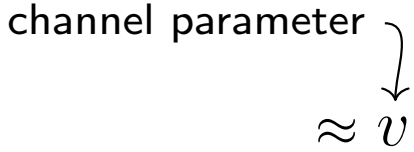

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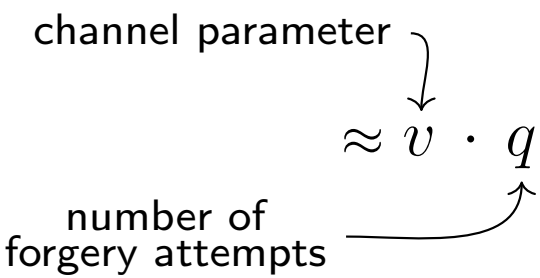

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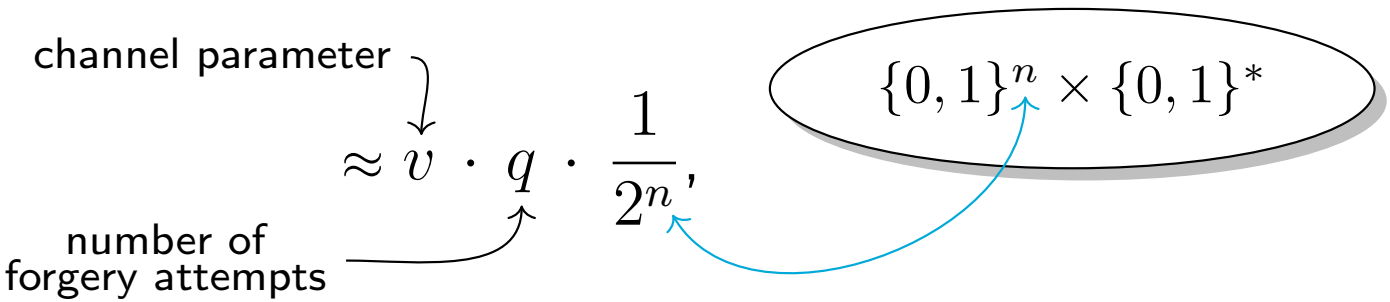

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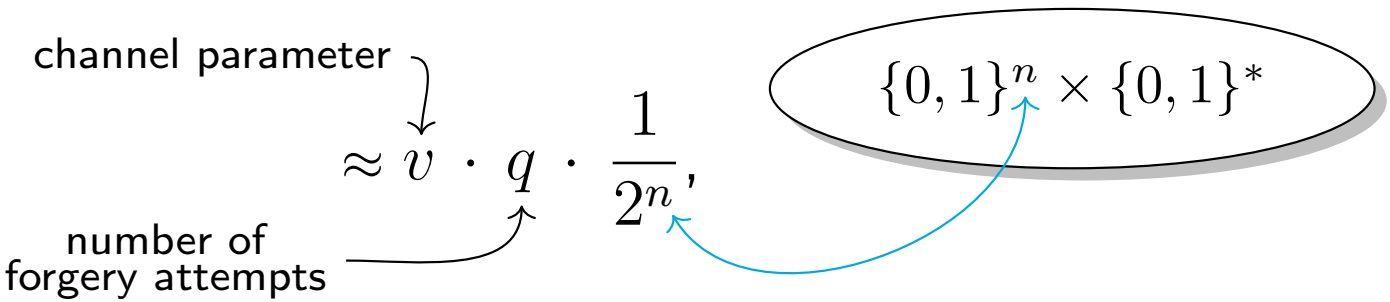

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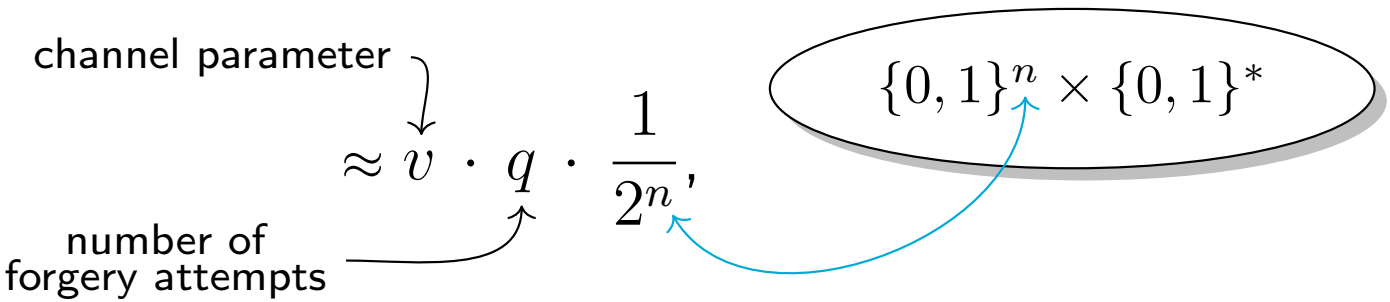
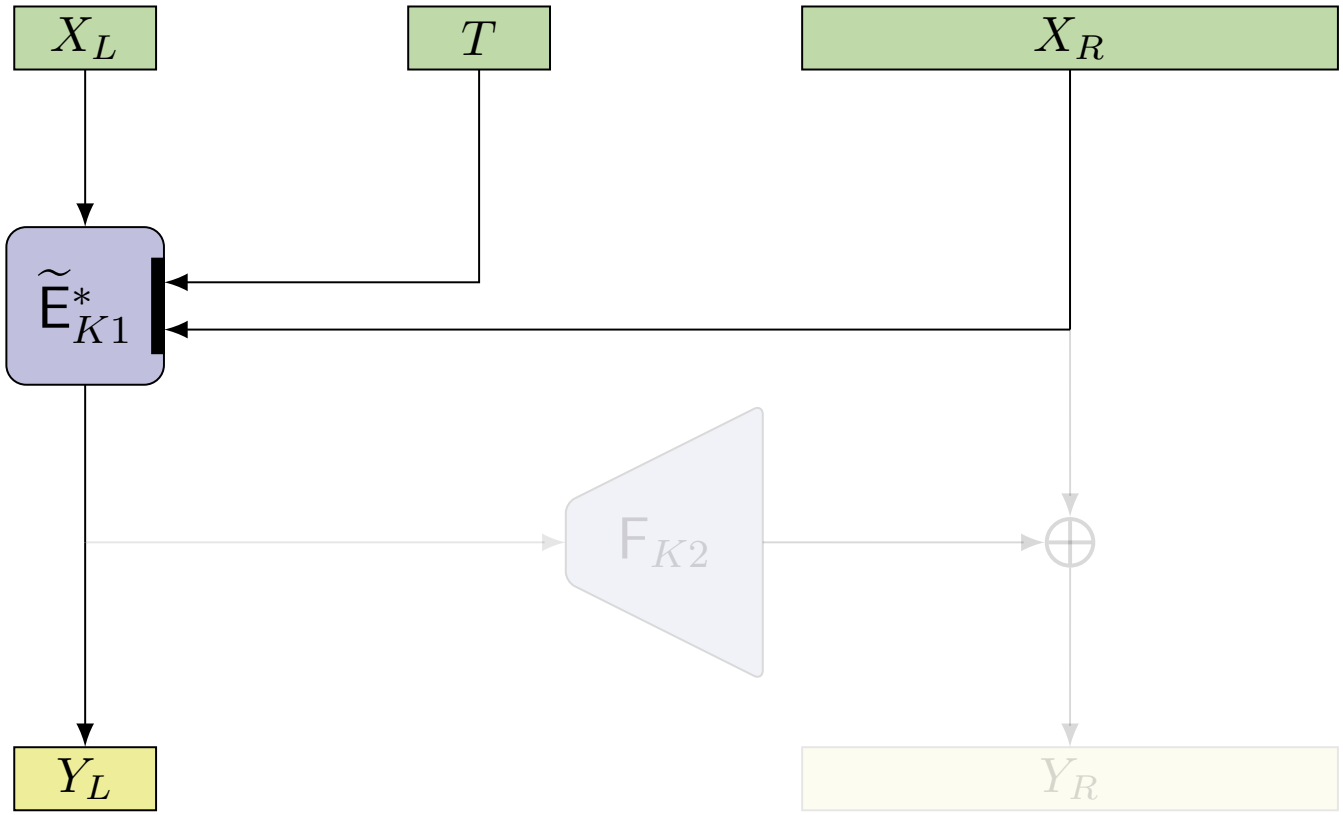


1. n usually corresponds to blocksize b of some (tweakable) blockcipher $\rightarrow n = 128$.
2. In certain cases both v and q can be large (e.g., up to 2^{64}), so $\frac{vq}{2^{128}}$ may not be enough.

Extending the left domain of UIV [DK22]



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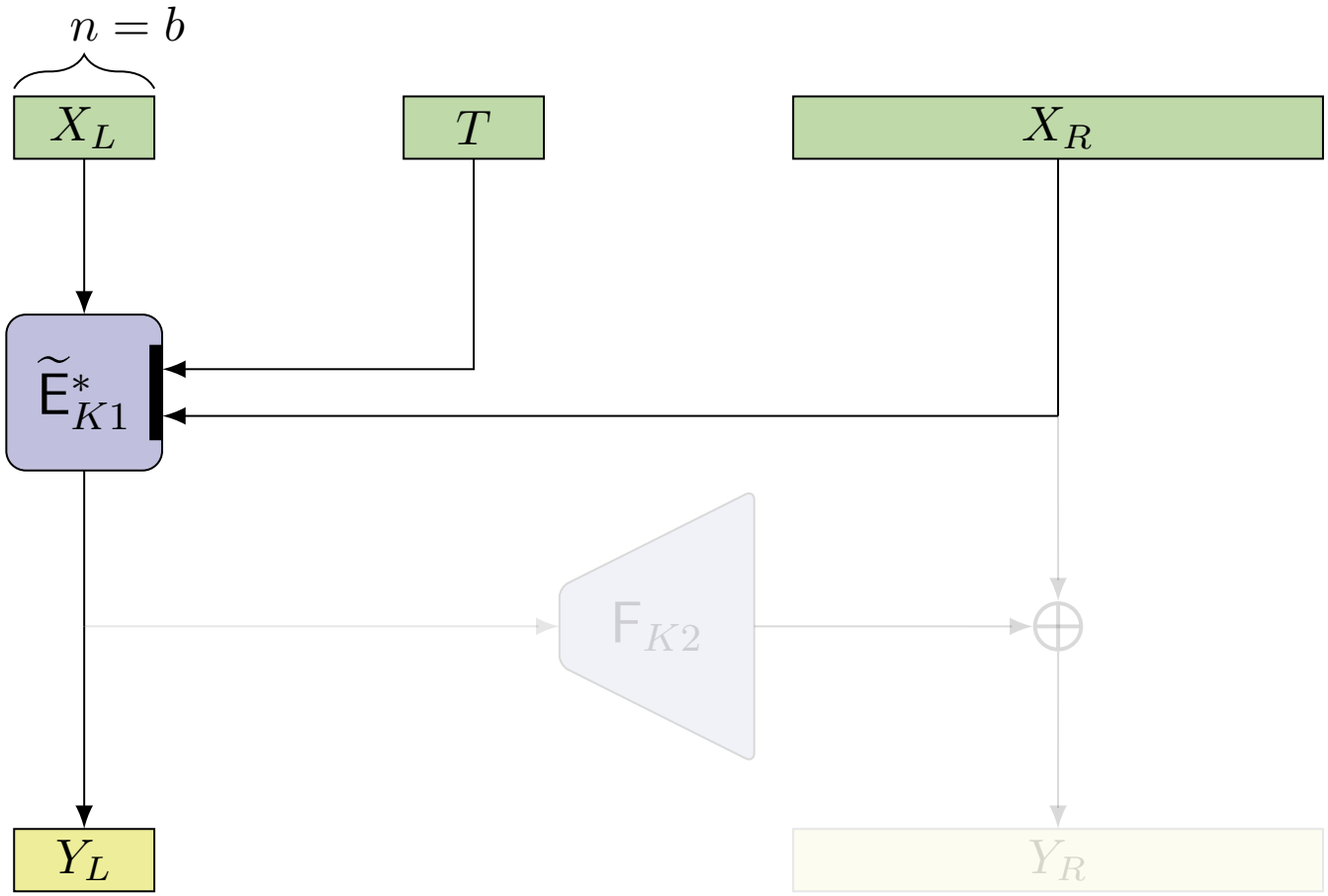

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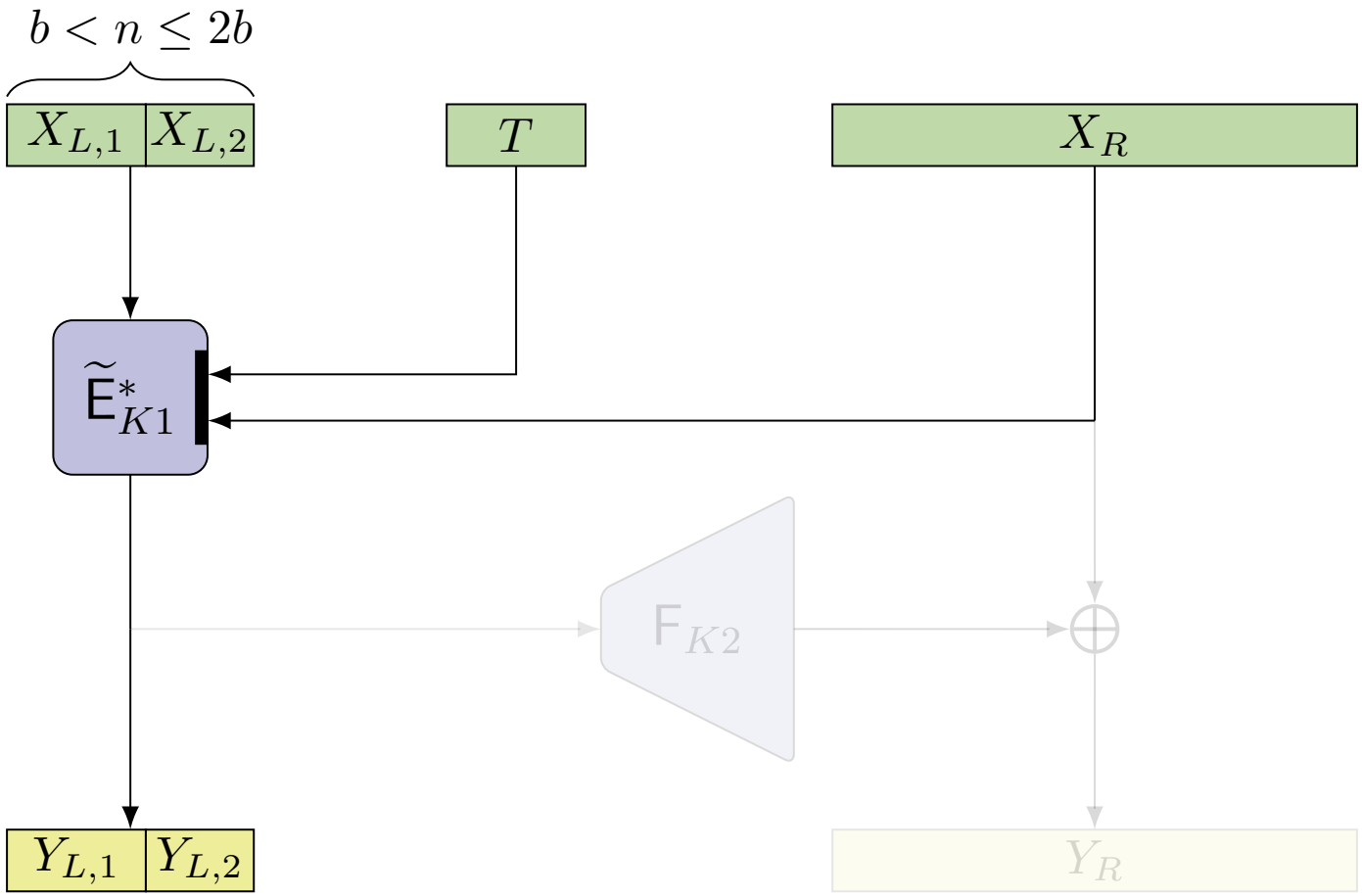

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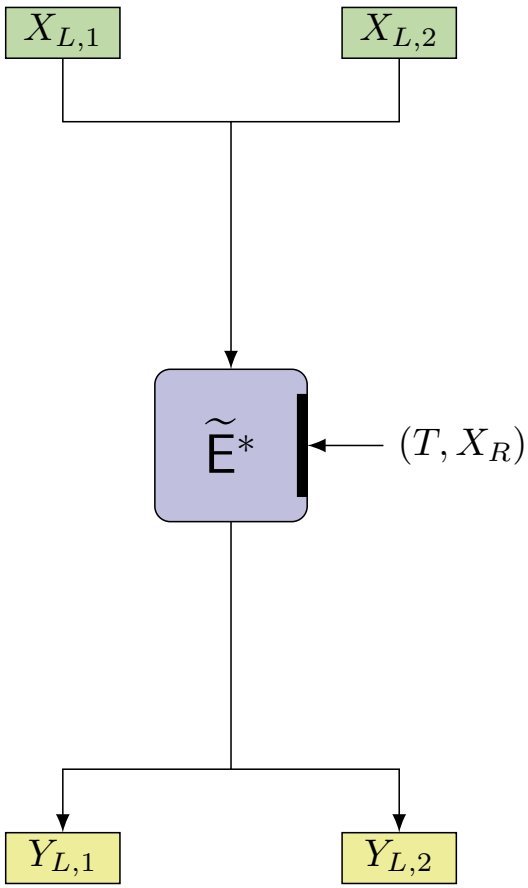

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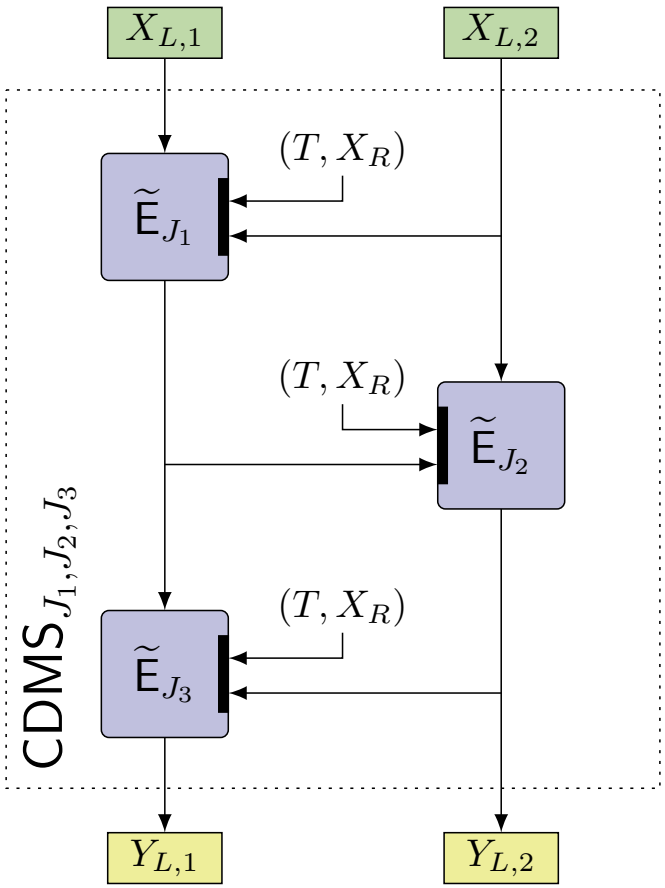
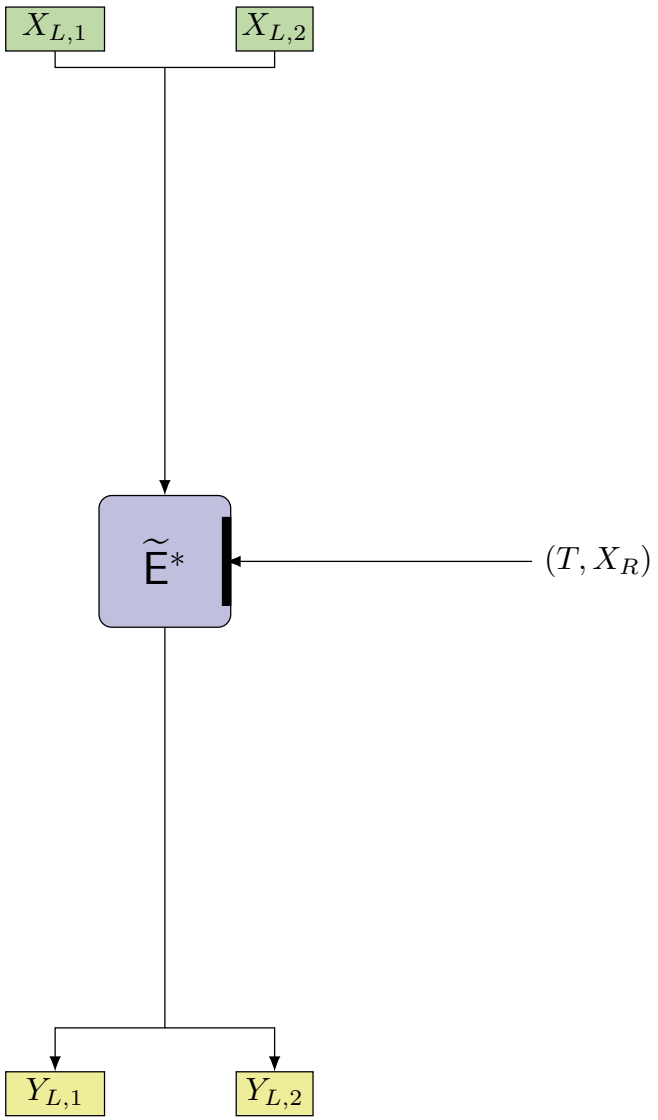


Extend left domain $b \to 2b$.

- CDMS by Coron et al. [CDMS10].
- $2b$-bit TBC $\widetilde{\mathsf{E}}^*$ from b-bit TBC $\widetilde{\mathsf{E}}$

Extending the left domain of UIV: $b < n < 2b$



Extend left domain $b \to b + s$,
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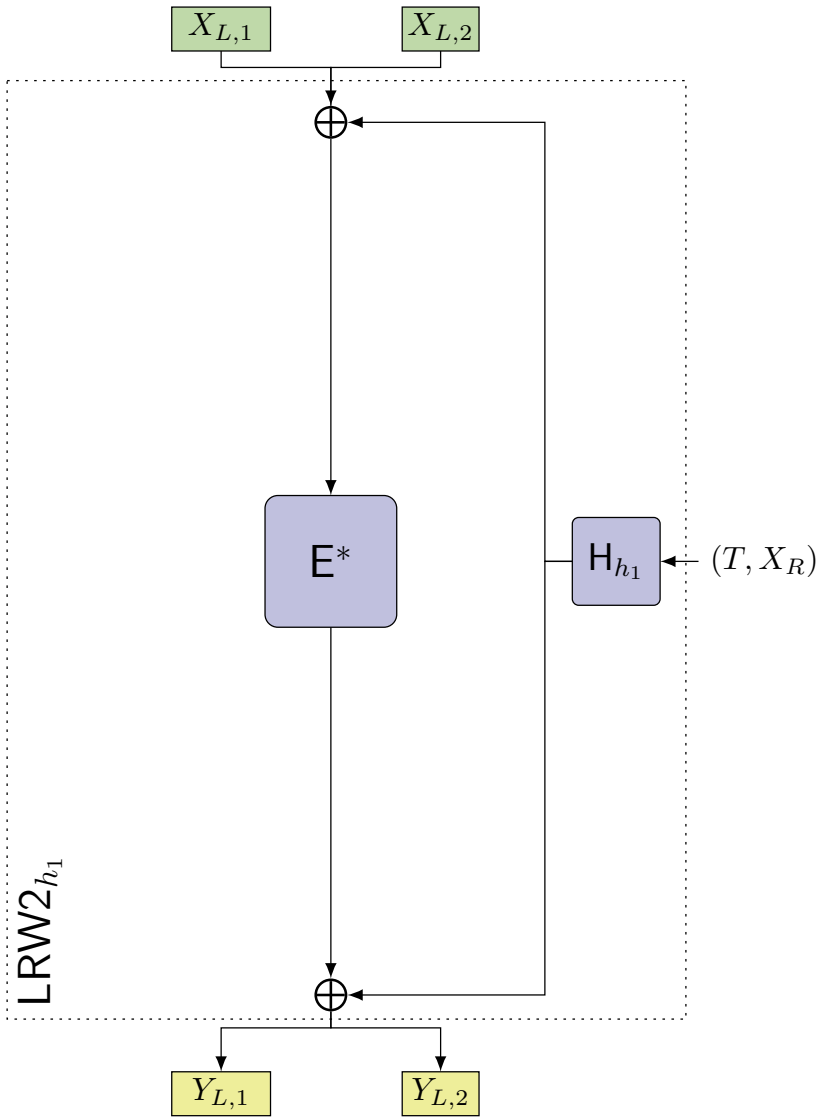

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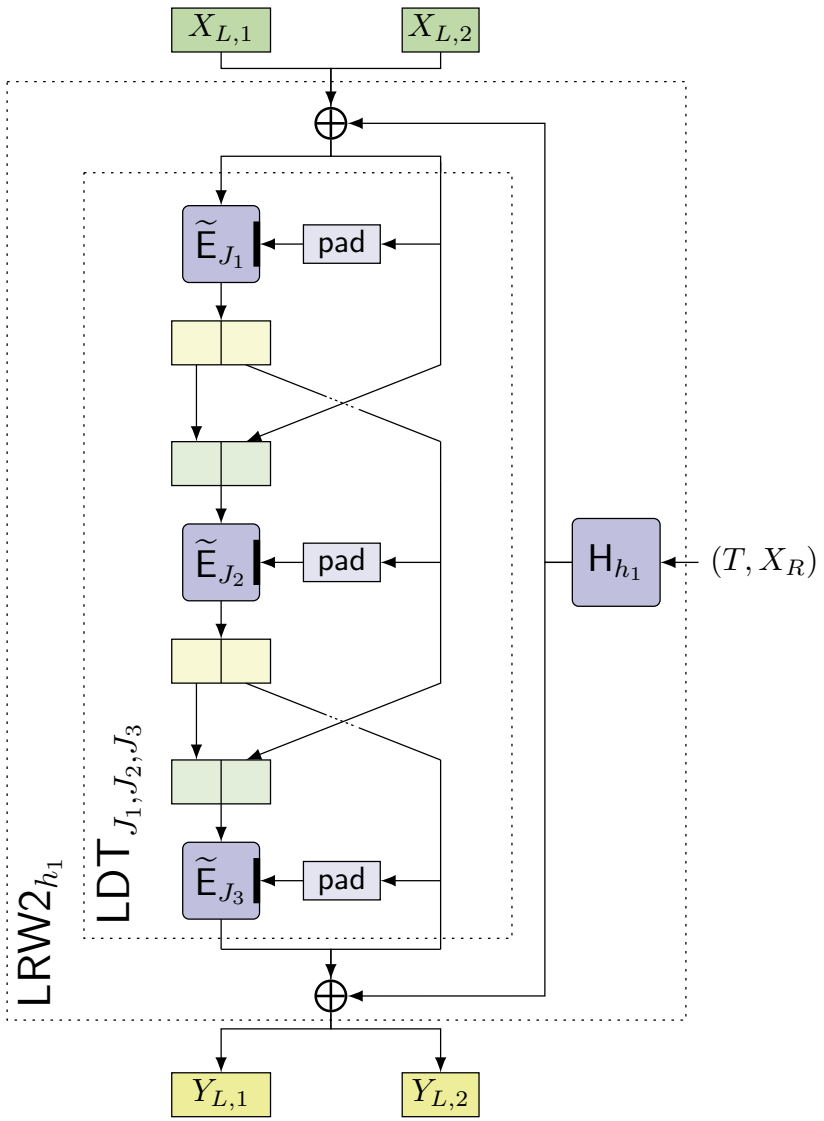

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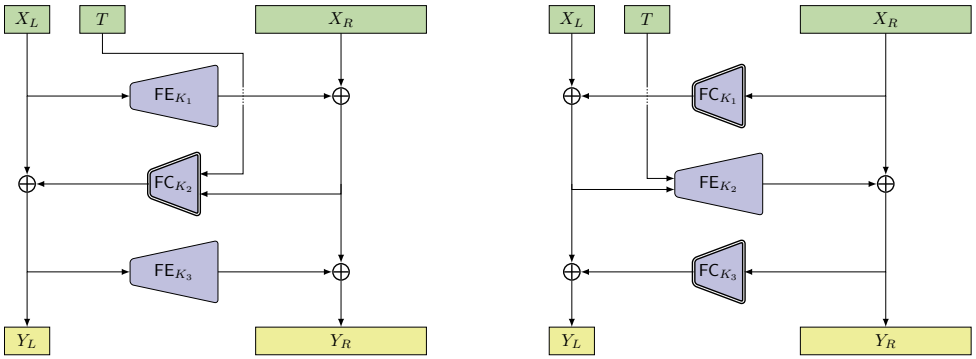

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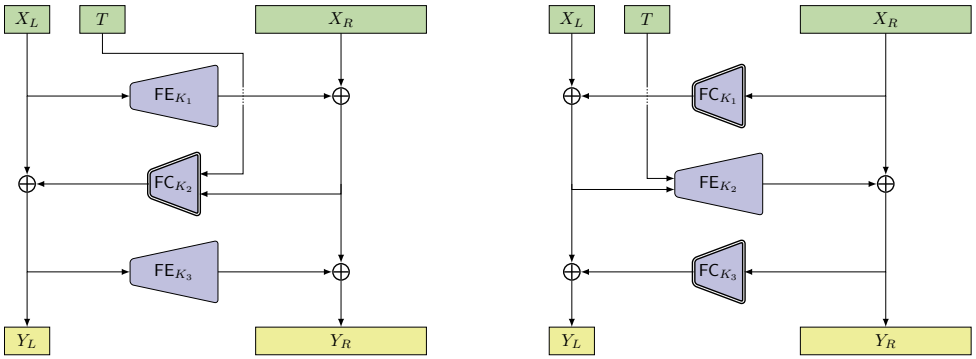

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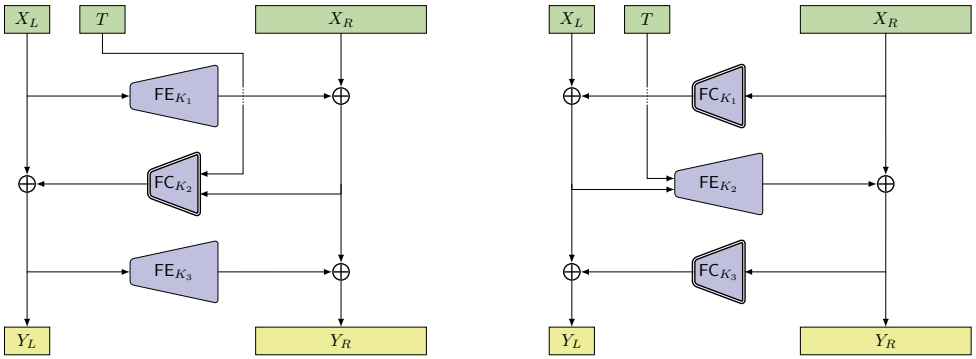

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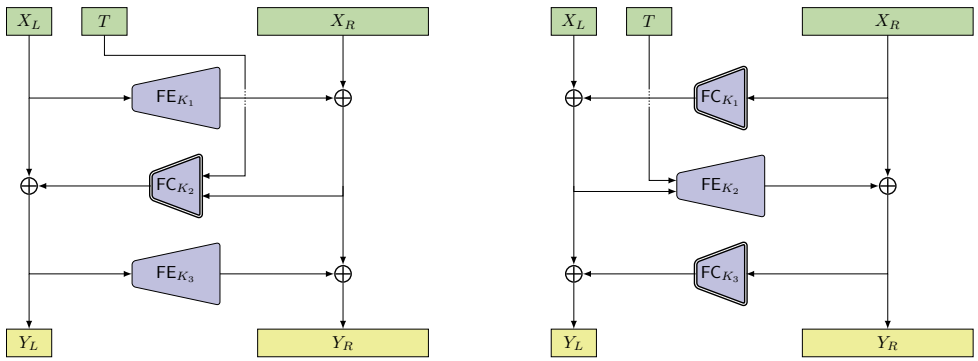
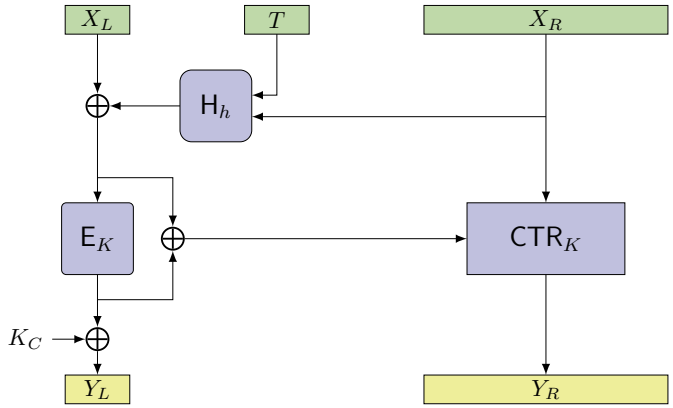


HEC:



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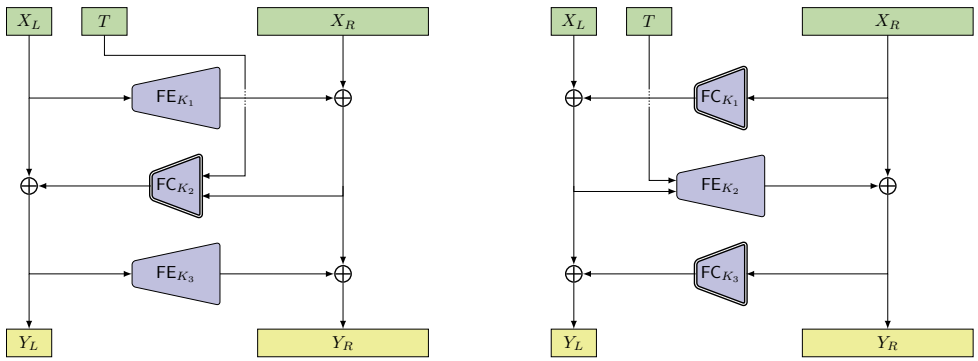

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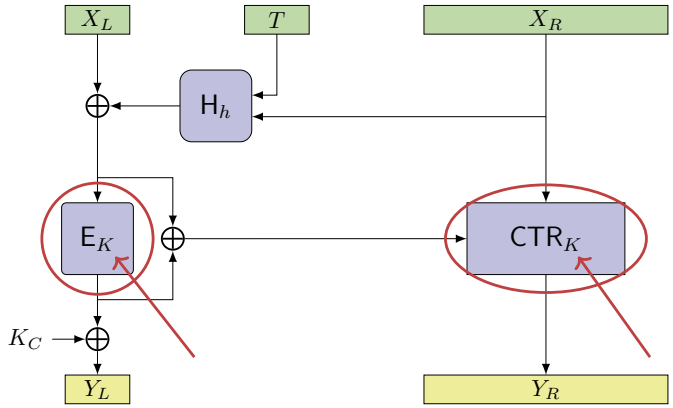

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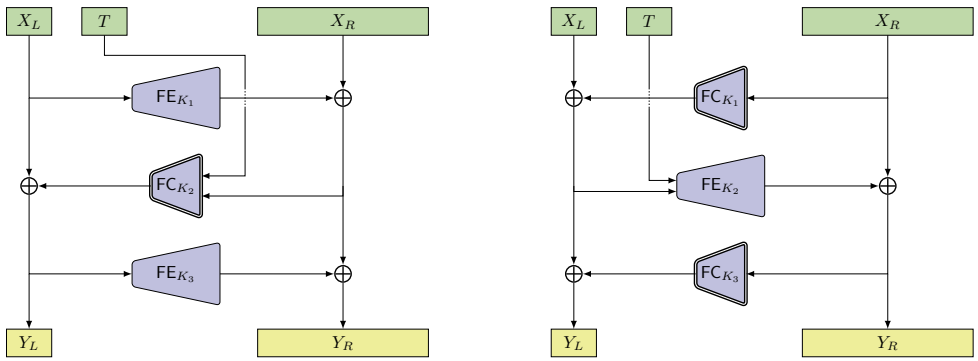

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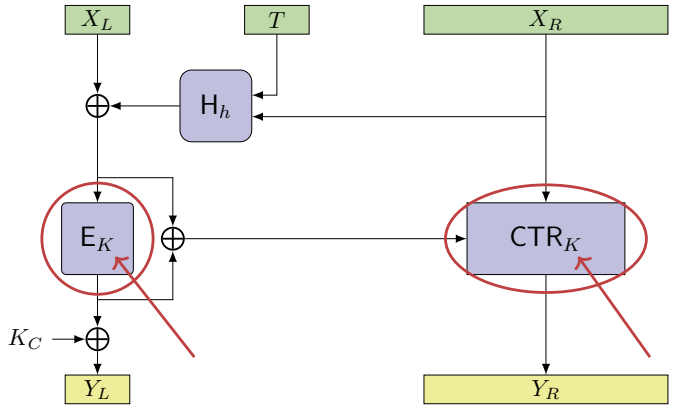

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- Future work: dedicated domain extender for HEC.

Summary

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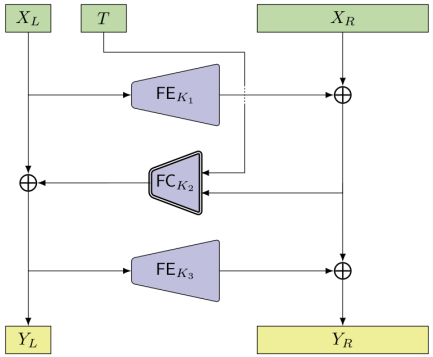

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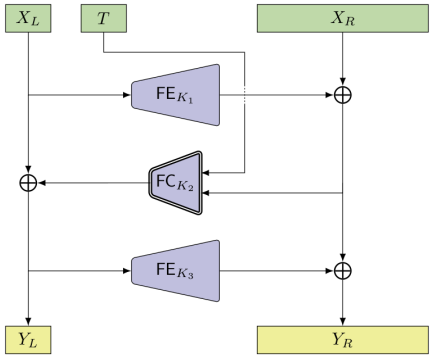

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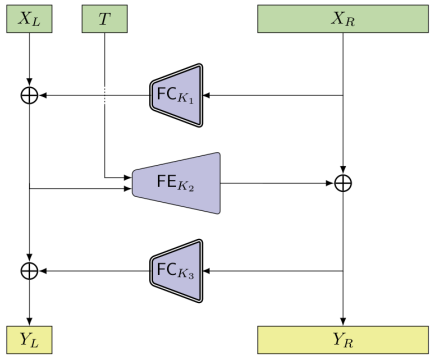

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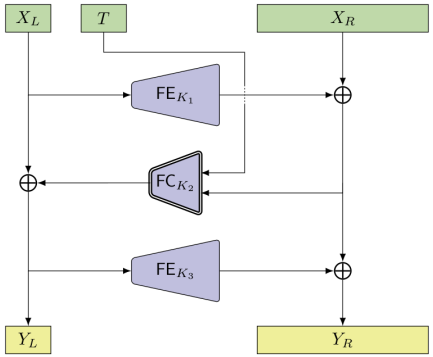

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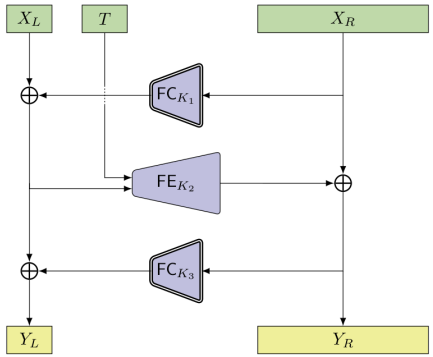

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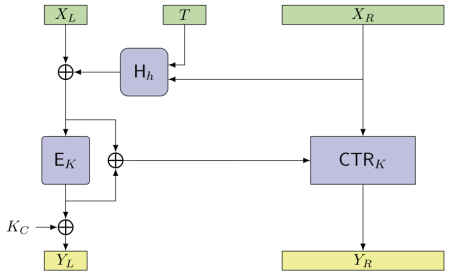

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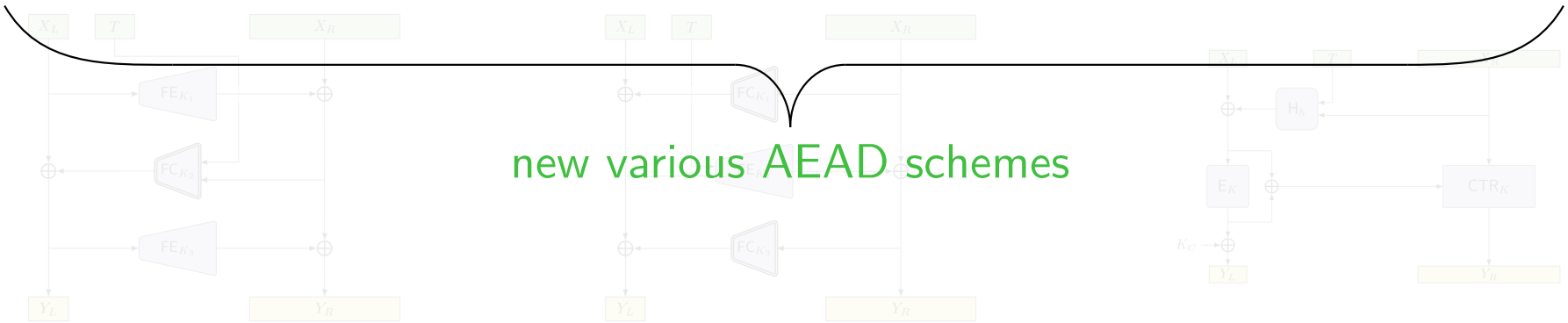

new various AEAD schemes

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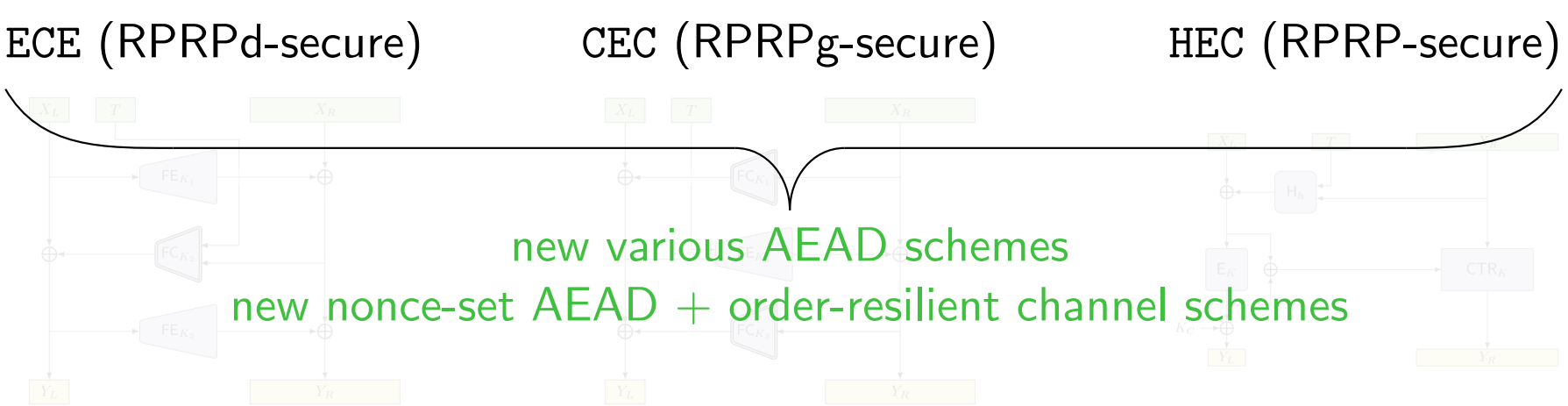
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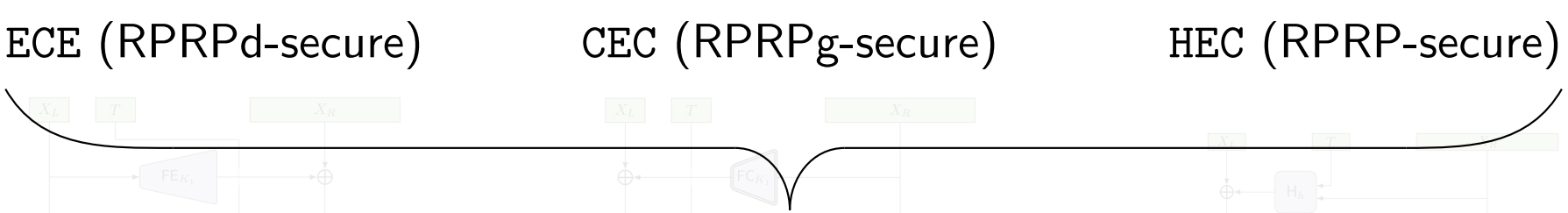

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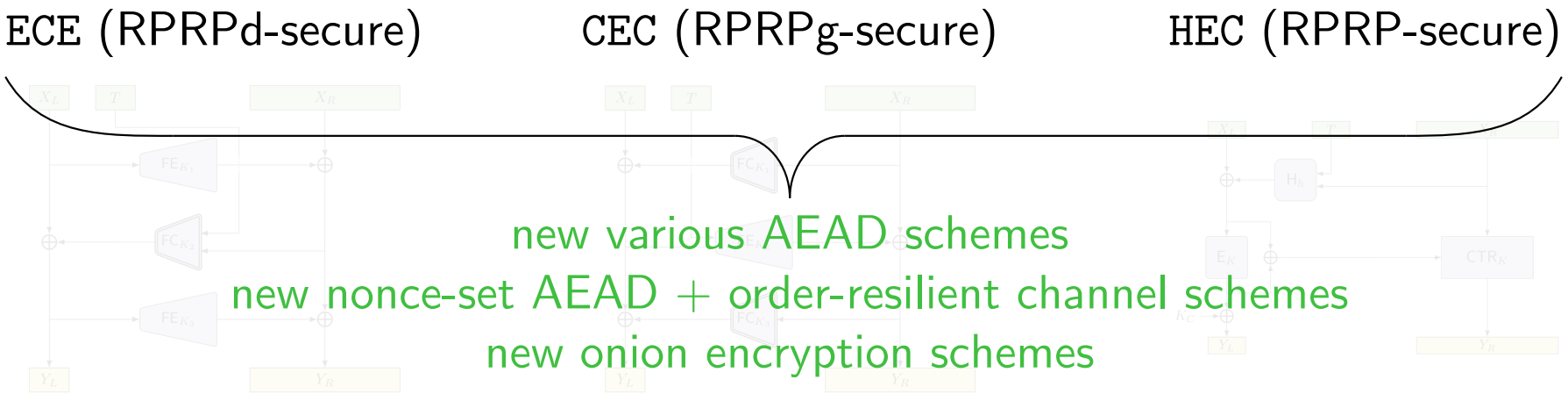

RPRPs are indeed natural!

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ia.cr/2023/1432

Thank you for listening.

Questions?

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