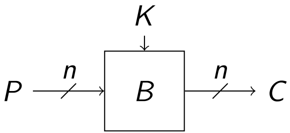
Deck-Based Wide Block Cipher Modes*

Aldo Gunsing, Joan Daemen and Bart Mennink

The Third NIST Workshop on Block Cipher Modes of Operation 2023

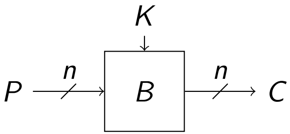
* Contribution is based on the publication *Deck-Based Wide Block Cipher Modes and an Exposition of the Blinded Keyed Hashing Model* at ToSC 2019(4)

Block cipher



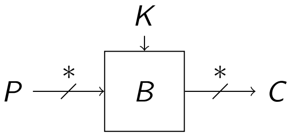
- Plaintext P encrypted to ciphertext C with secret key K
- Fixed block size

Block cipher



- Plaintext P encrypted to ciphertext C with secret key K
- Fixed block size
- In order to encrypt variable sized messages, we need a mode of operation
  - These modes require a nonce

Wide block cipher



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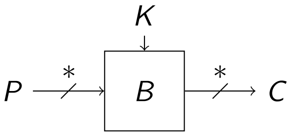
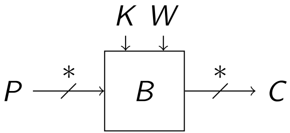


- Alternatively, we can design a wide block cipher
- A wide block cipher is a block cipher with a variable block size
- Every part of the output (ideally) depends on every part of the input

Tweakable wide block cipher



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- Tweak W public, ciphertext completely changes with a different tweak

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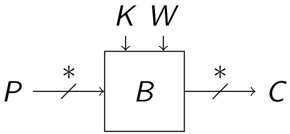

- A tweakable wide block cipher additionally has a tweak
- Tweak W public, ciphertext completely changes with a different tweak
- Useful for e.g. disk encryption, where every sector gets its own tweak

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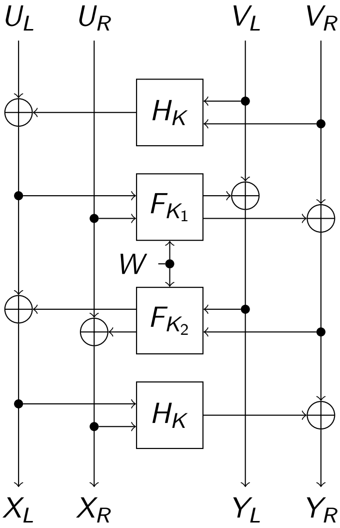
In contrast to block ciphers, these primitives are not invertible and do not need to be, which allows for a more flexible design

Double-decker



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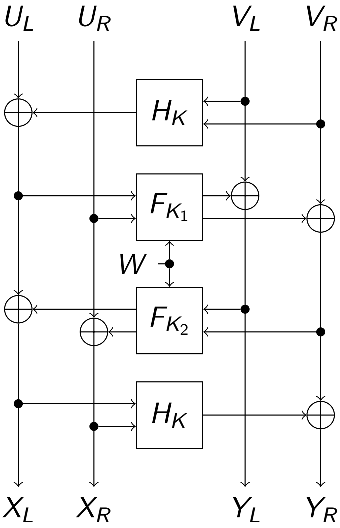

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- Feistel-like structure

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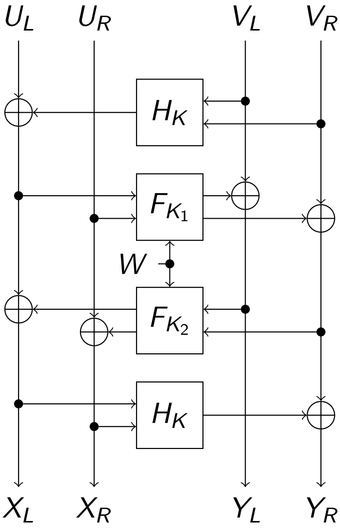

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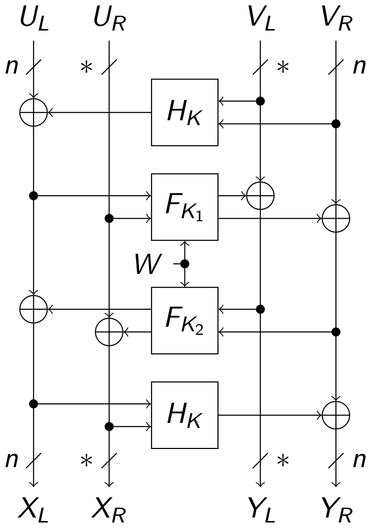

- Generalization of Farfalle-WBC by Bertoni et al. (2017)
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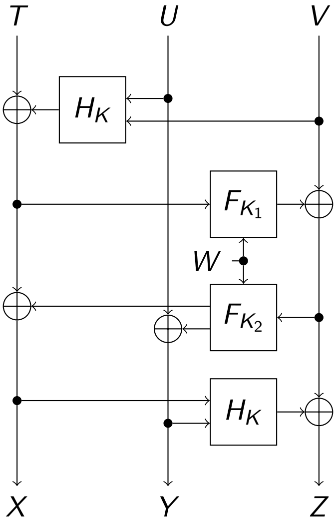
- Two keyed hashes *H* on the outside, two deck functions *F* on the inside
- Outer lanes of fixed size
- Inner lanes of variable size

Docked-double-decker



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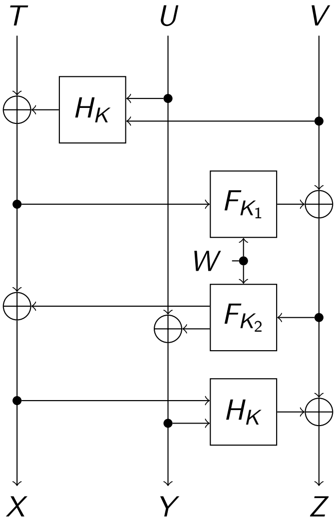

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- One lane less

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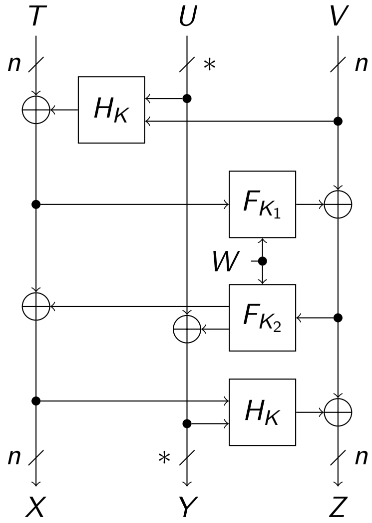

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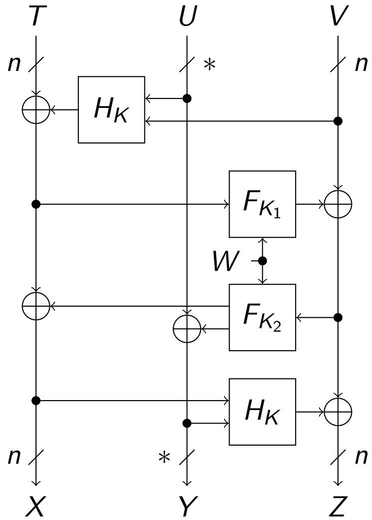

- Variant of double-decker
- One lane less
- Outer lanes of fixed size
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- Deck functions F get fixed sized input, so they conceptually become stream ciphers

XOR-universality

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- For q queries the bound becomes $\binom{q}{2}\varepsilon$
- However:
  - ε is the worst-case bound on all possible $x \neq x'$
  - For some functions not all query pairs have similar probabilities

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- We consider blinded keyed hash (bkh) security to achieve a more accurate estimate when multiple queries are taken into account

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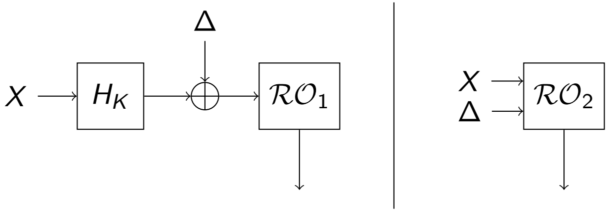
- The keyed hash function H is bkh secure if it is indistinguishable in the following setup



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- We cannot apply the bkh model directly to our construction
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- We show that the two double-deckers are secure when:
  - The keyed hash H is bkh secure
  - The deck function F is prf secure
- Furthermore, by applying the tweak to the deck functions the bound of H becomes tweak-separated
  - Deck functions behave independently for different tweaks
  - Significantly improves security bound for certain settings

Power of tweak-separation

- Consider a ε-XOR-universal keyed hash function H
- Consider q queries and q_W queries with tweak W

loss on H	naive	actual
general bound	$\binom{q}{2}\varepsilon$	
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- Double-decker is very suitable for disk encryption
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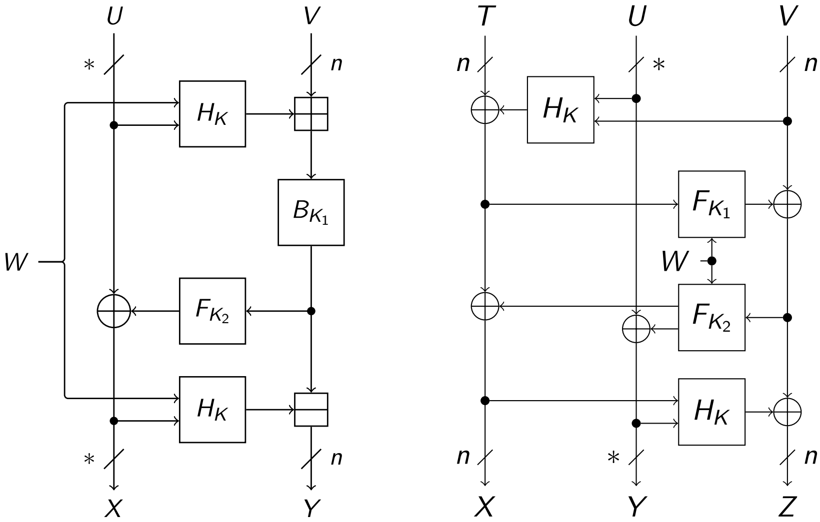
- Without tweak-separation secure when $2\binom{500N}{2}\varepsilon \approx 2^{74}\varepsilon \ll 1$
- With tweak-separation this improves to $2N\binom{500}{2}\varepsilon \approx 2^{46}\varepsilon \ll 1$

Comparison with Adiantum



Adiantum (FSE 2019) Docked-double-decker

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Thank you for your attention!