Radboud University

Innovations in permutation-based encryption & authentication

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based on joint work with
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Outline

Pseudo-random functions

PRF modes

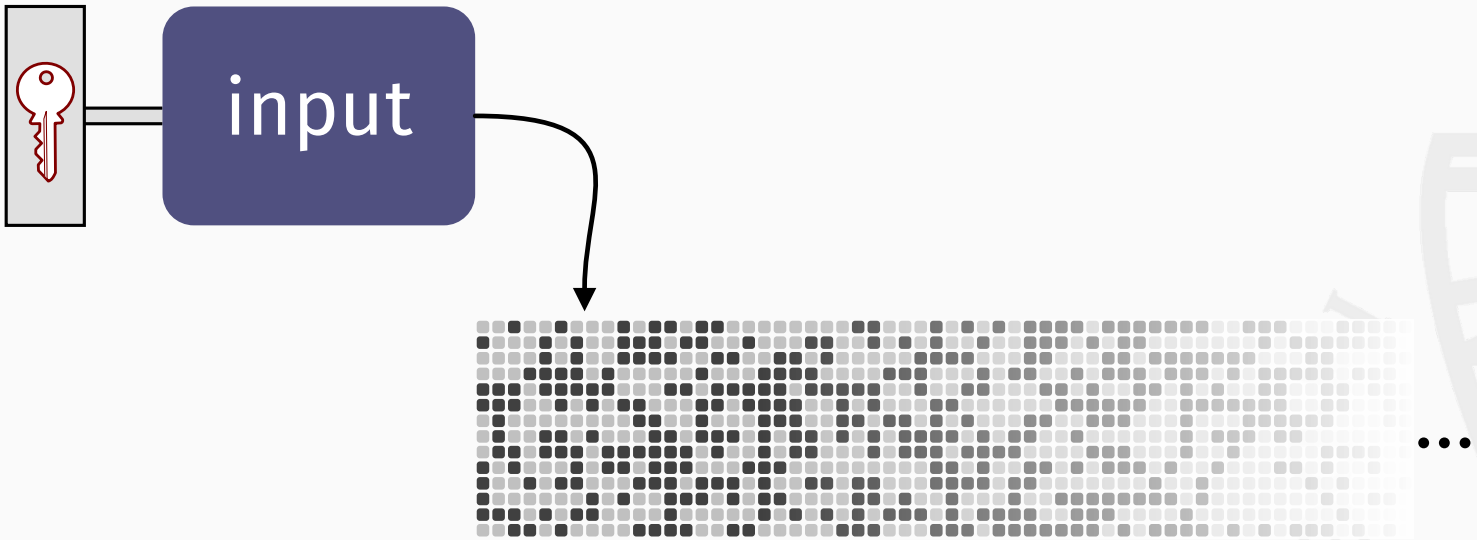
Sponge

Farfalle

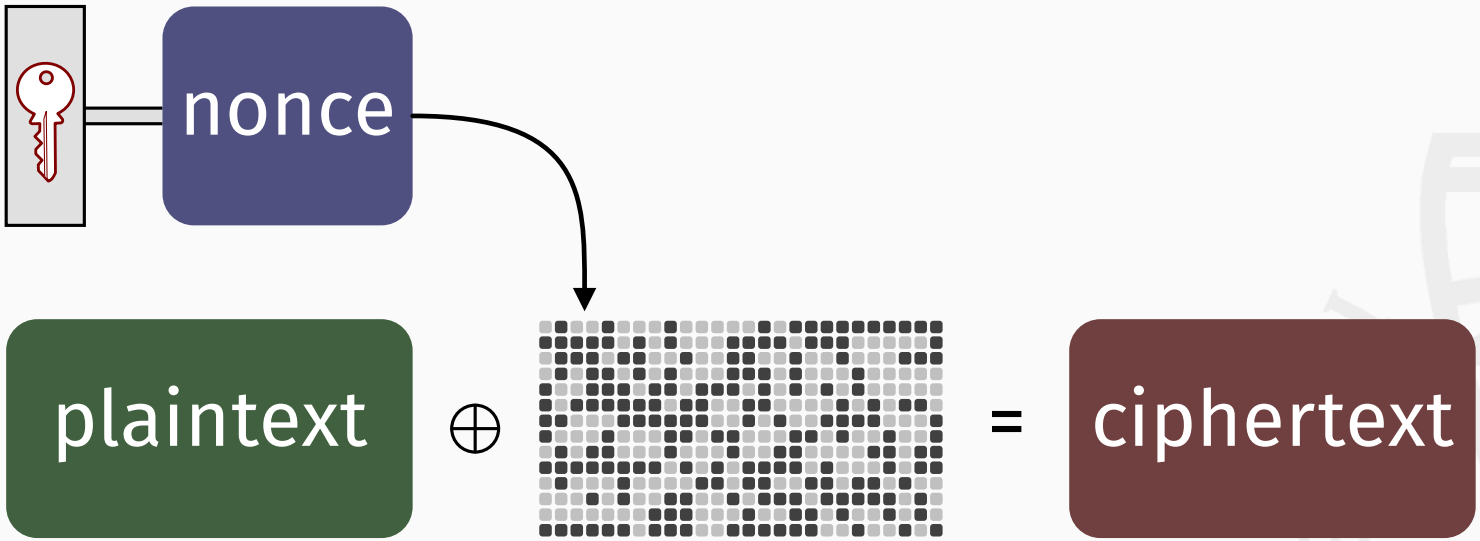
Kravatte

Outline

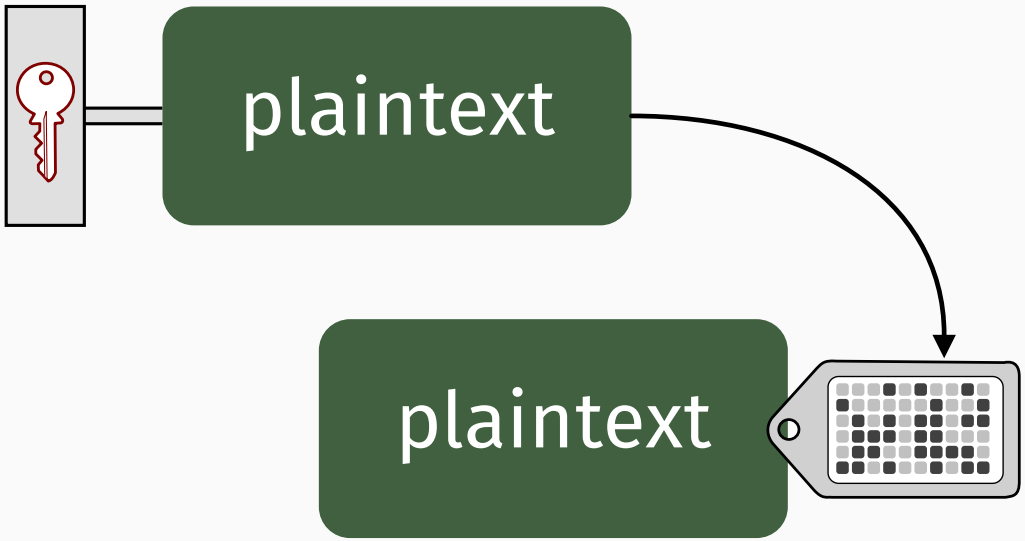
Pseudo-random function (PRF)



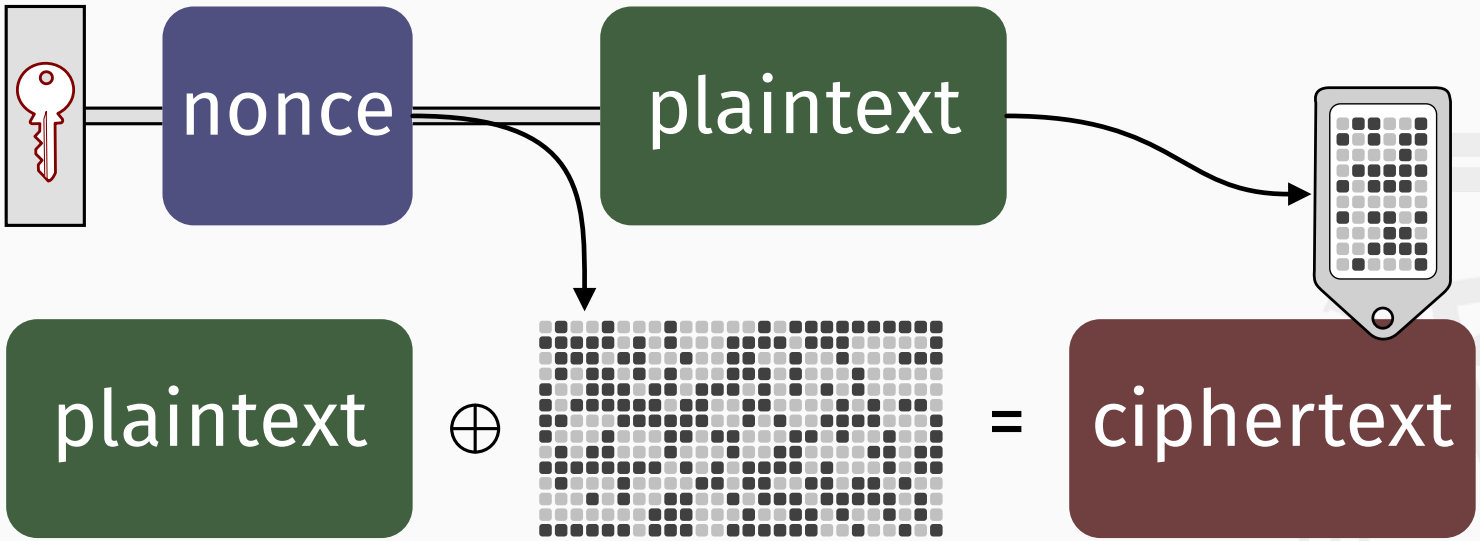
Stream encryption



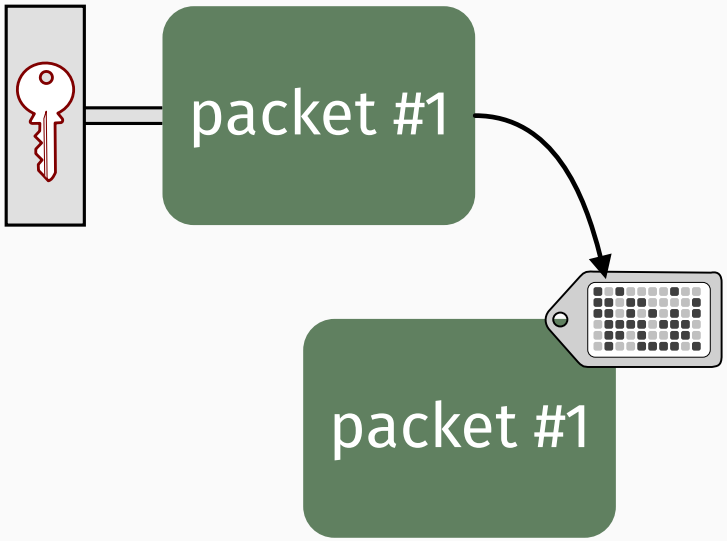
Message authentication (MAC)



Authenticated encryption

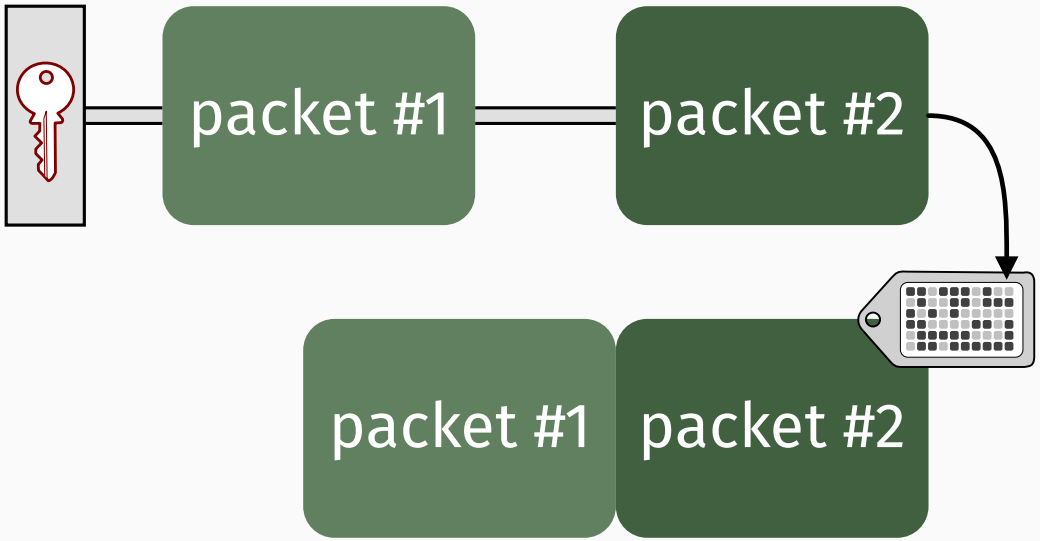


String sequence input and incrementality



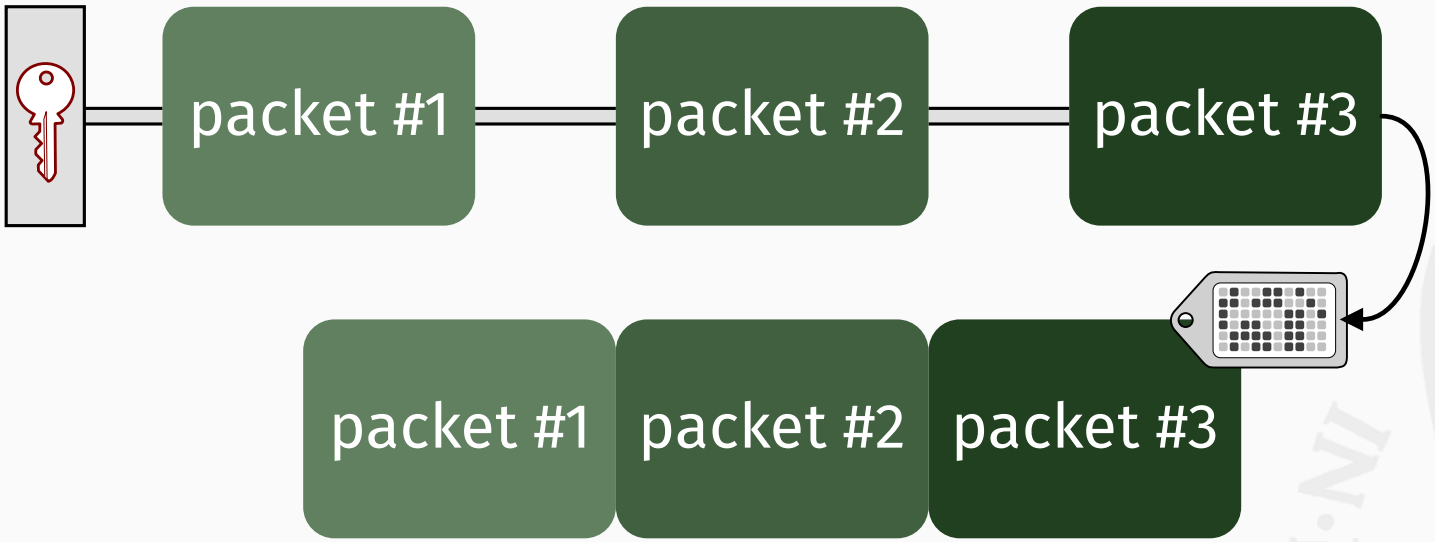
$$F_K\left(P^{(1)}\right)$$

String sequence input and incrementality



$$F_K\left(P^{(2)} \circ P^{(1)}\right)$$

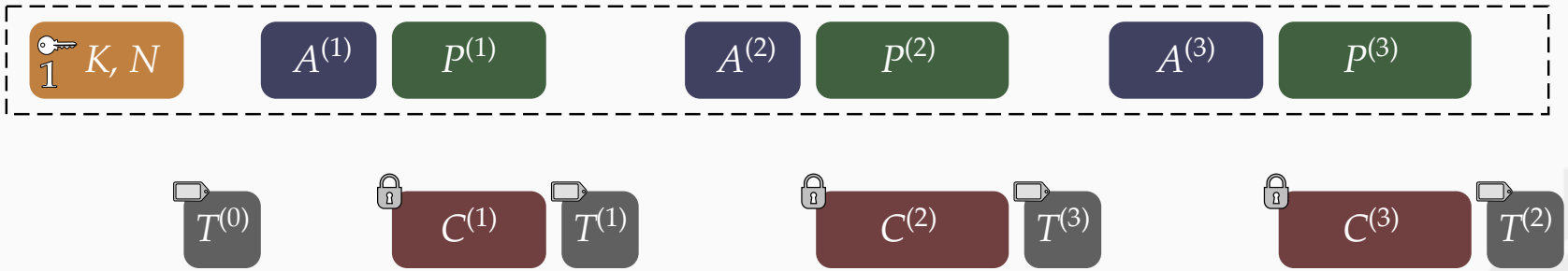
String sequence input and incrementality



$$F_K\left(P^{(3)} \circ P^{(2)} \circ P^{(1)}\right)$$

Outline

Session authenticated encryption (SAE) [Keccak Team, SAC 2011]



Initialization taking nonce N

$T \leftarrow 0^t + F_K(N)$

$\mathrm{history} \leftarrow N$

return tag T of length t

Wrap taking metadata A and plaintext P

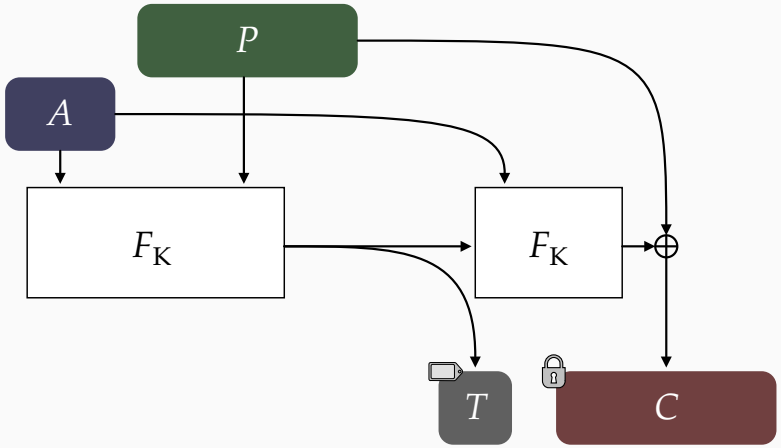
$C \leftarrow P + F_K(A \circ \mathrm{history})$

$T \leftarrow 0^t + F_K(C \circ A \circ \mathrm{history})$

$\mathrm{history} \leftarrow C \circ A \circ \mathrm{history}$

return ciphertext C of length $|P|$ and tag T of length t

Synthetic initialization value (SIV), as in [Keccak Team, eprint 2016/1188]



Wrap taking metadata A and plaintext P
$T \leftarrow 0^t + F_K(P \circ A)$
$C \leftarrow P + F_K(T \circ A)$
return ciphertext C of length $|P|$ and tag T

Unwrap taking metadata A, ciphertext C and tag T
$P \leftarrow C + F_K(T \circ A)$
$\tau \leftarrow 0^t + F_K(P \circ A)$
if $\tau \neq T$ **then return** error!
else return plaintext P of length $|C|$

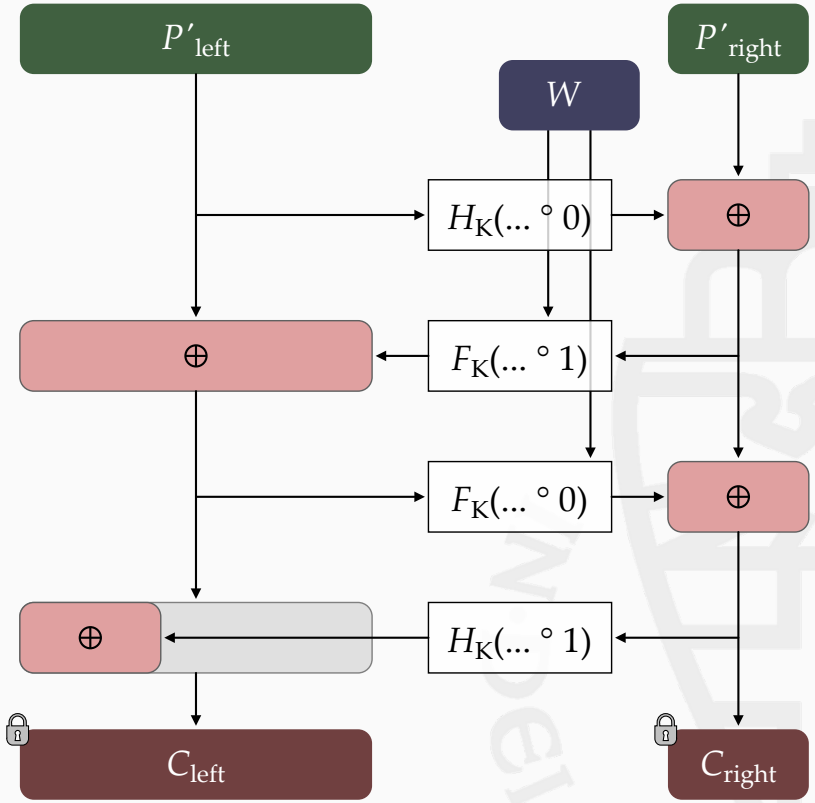
Variant of SIV of [Rogaway & Shrimpton, EC 2006]

Wide block cipher (WBC), as in [Keccak Team, eprint 2016/1188]

Encipher P with K and tweak W

$$
\begin{array}{llll}
(L, R) & \leftarrow & & \mathrm{split}(P) \\
R_0 & \leftarrow R_0 & + & H_K(L \circ 0) \\
L & \leftarrow L & + & F_K(R \circ W \circ 1) \\
R & \leftarrow R & + & F_K(L \circ W \circ 0) \\
L_0 & \leftarrow L_0 & + & H_K(R \circ 1) \\
C & \leftarrow L & || & R
\end{array}
$$

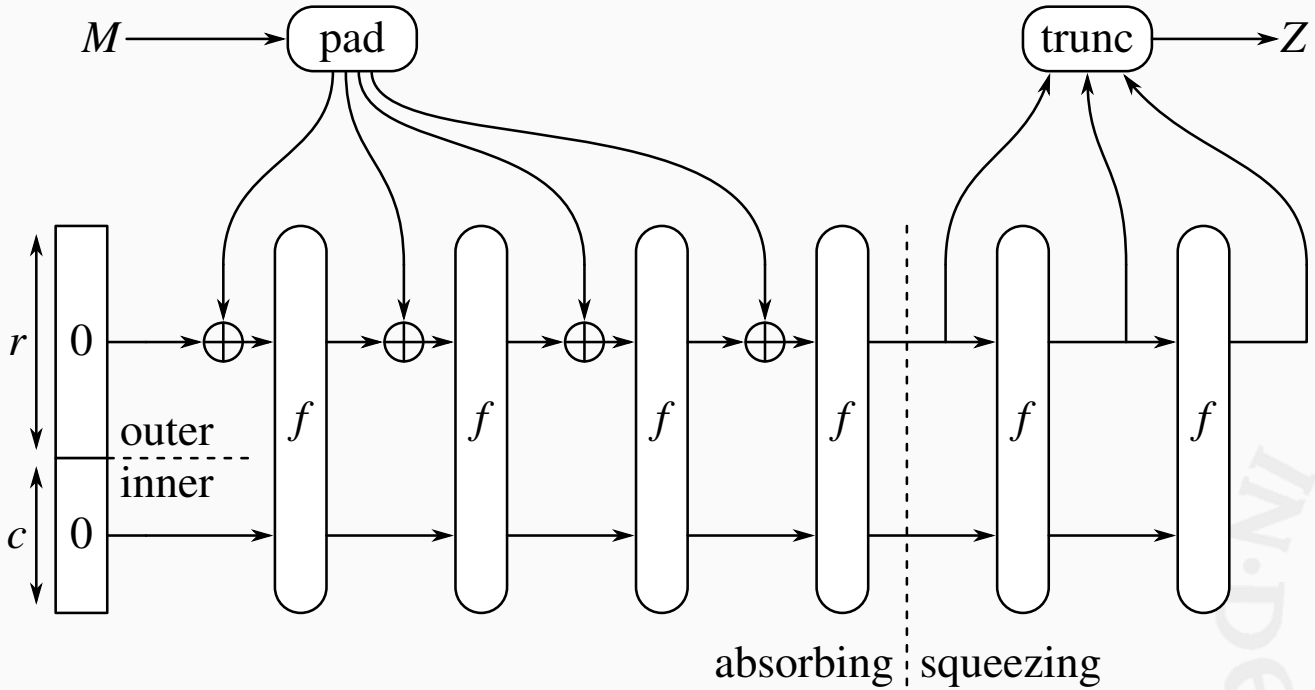
return ciphertext C of length $|P|$



Instance of HHFHFH of [Bernstein, Nandi & Sarkar, Dagstuhl 2016]

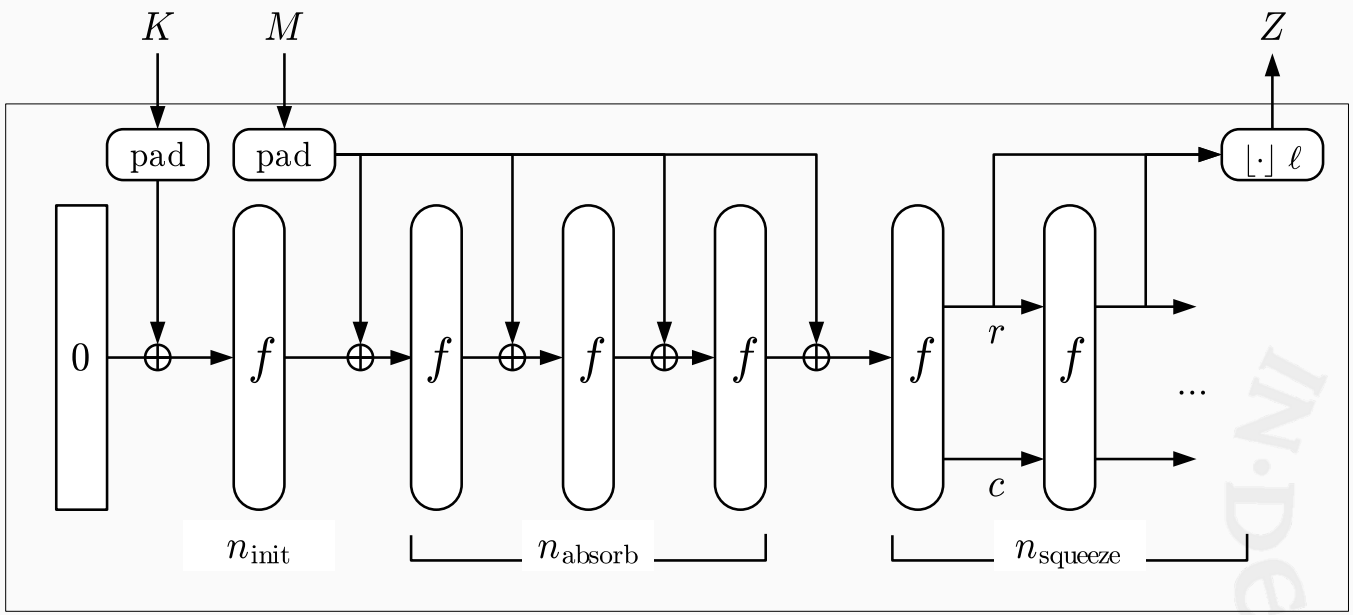
Outline

Sponge [Keccak Team, Ecrypt 2008]



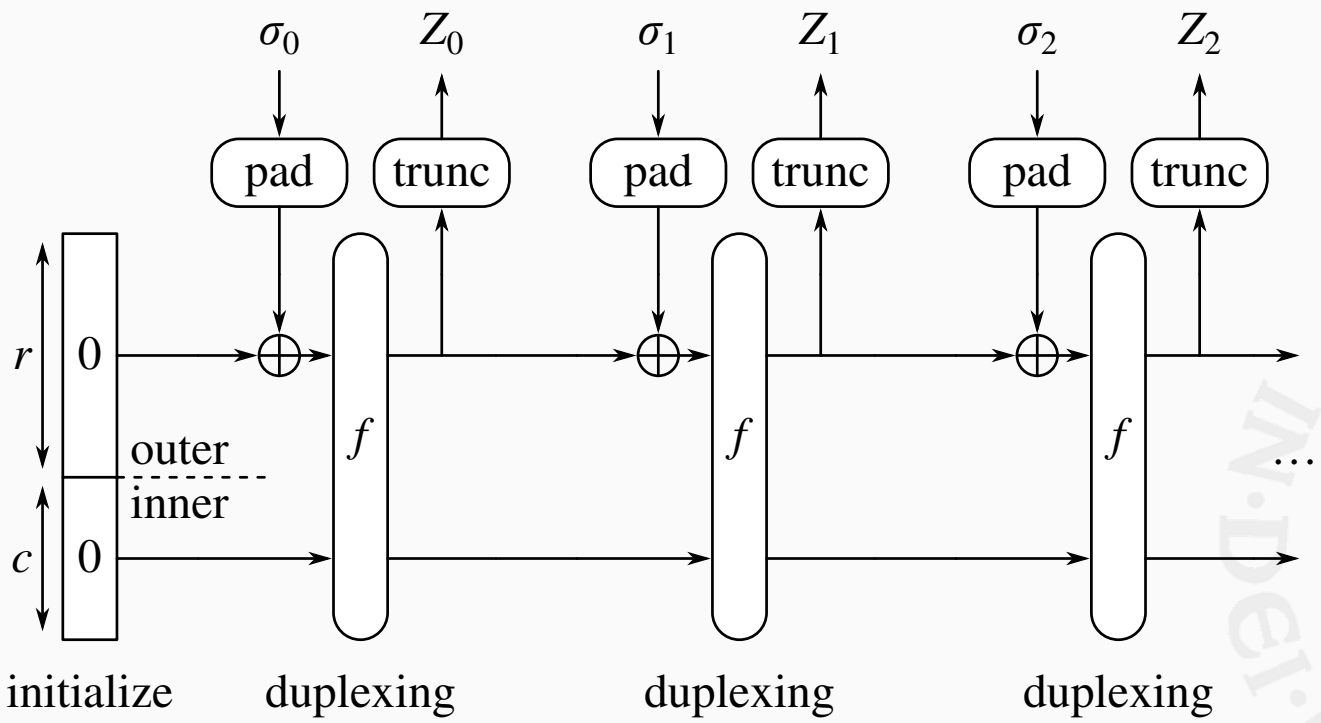
- Pre-pending M with K gives PRF

More efficient: donkeySponge [Keccak Team, DIAC 2012]

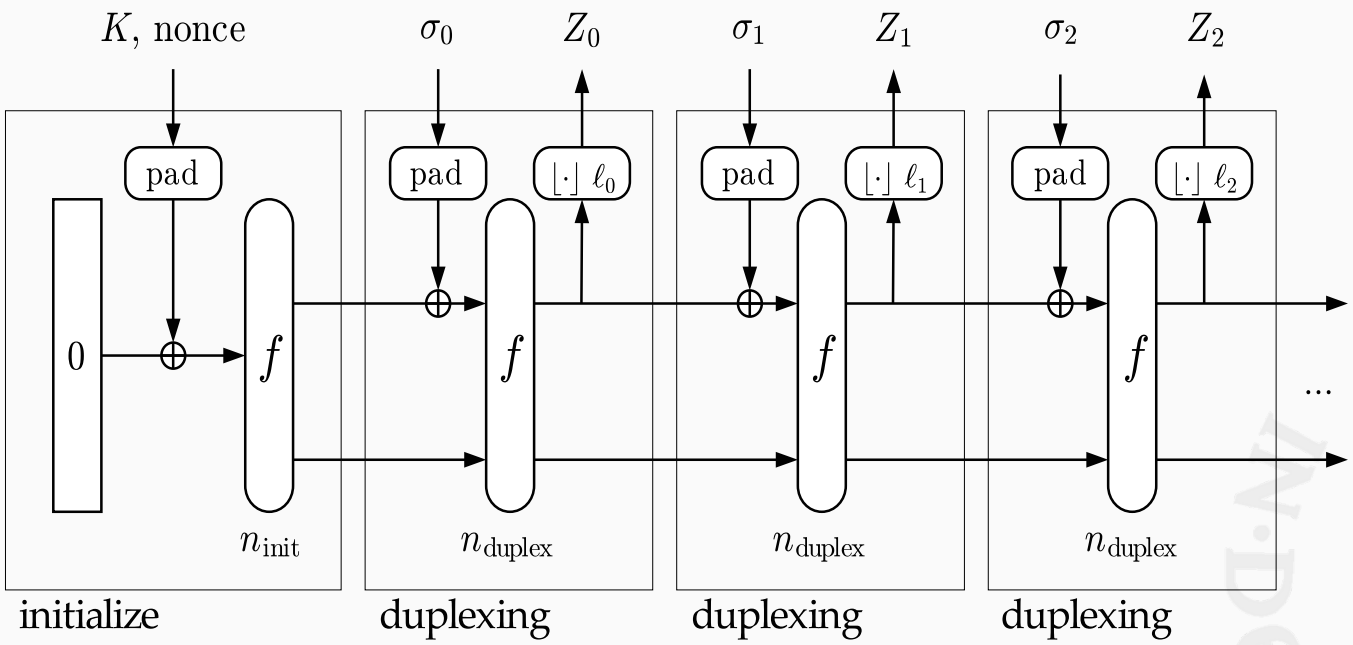


donkey sponge

Incrementality: duplex [Keccak Team, SAC 2011]

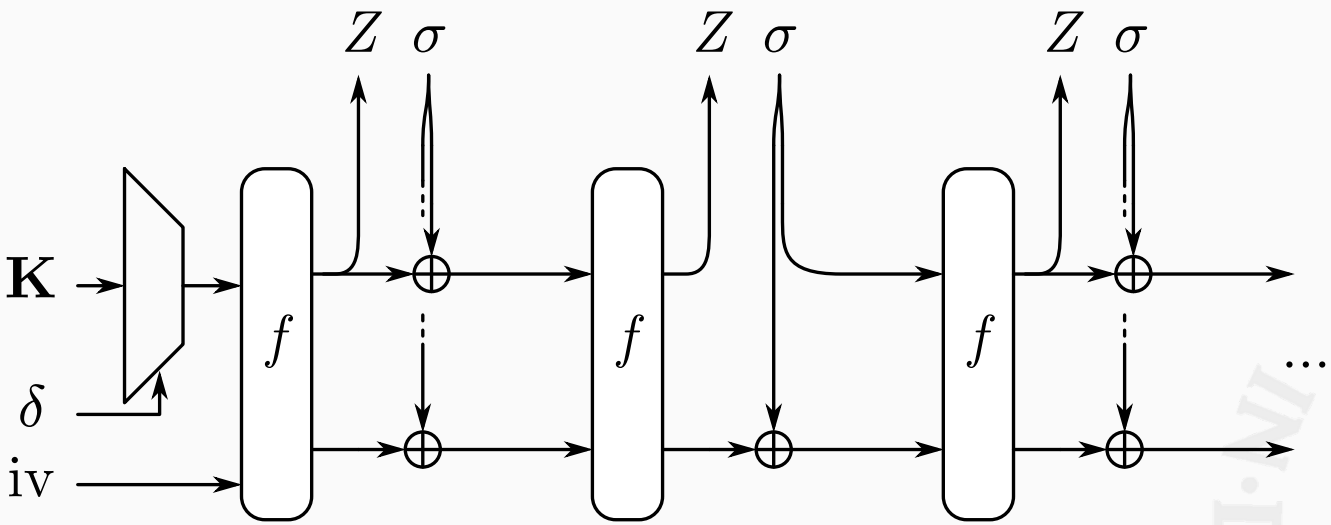


More efficient: MonkeyDuplex [Keccak Team, DIAC 2012]



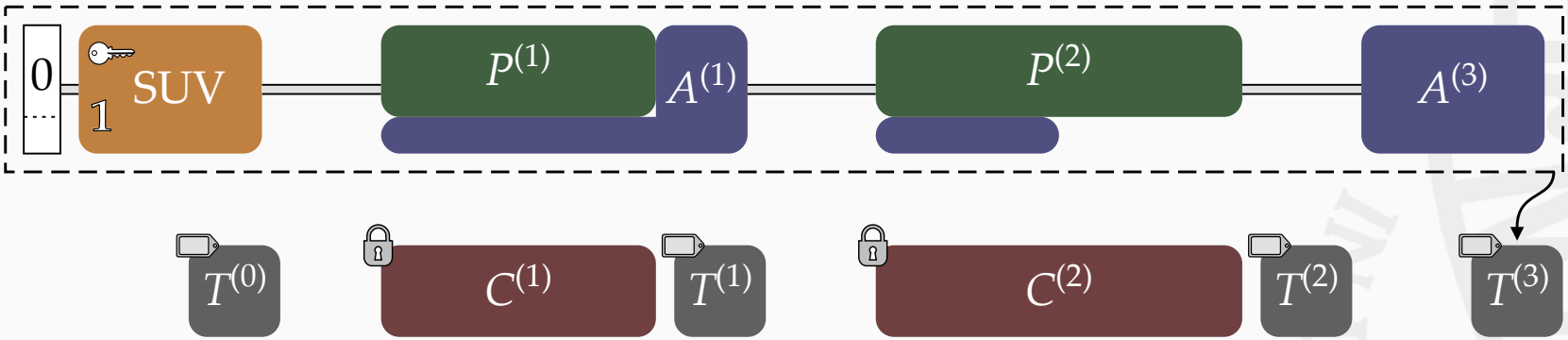
Instances: KETJE + half a dozen other CAESAR submissions

Consolidation: Full-state keyed duplex



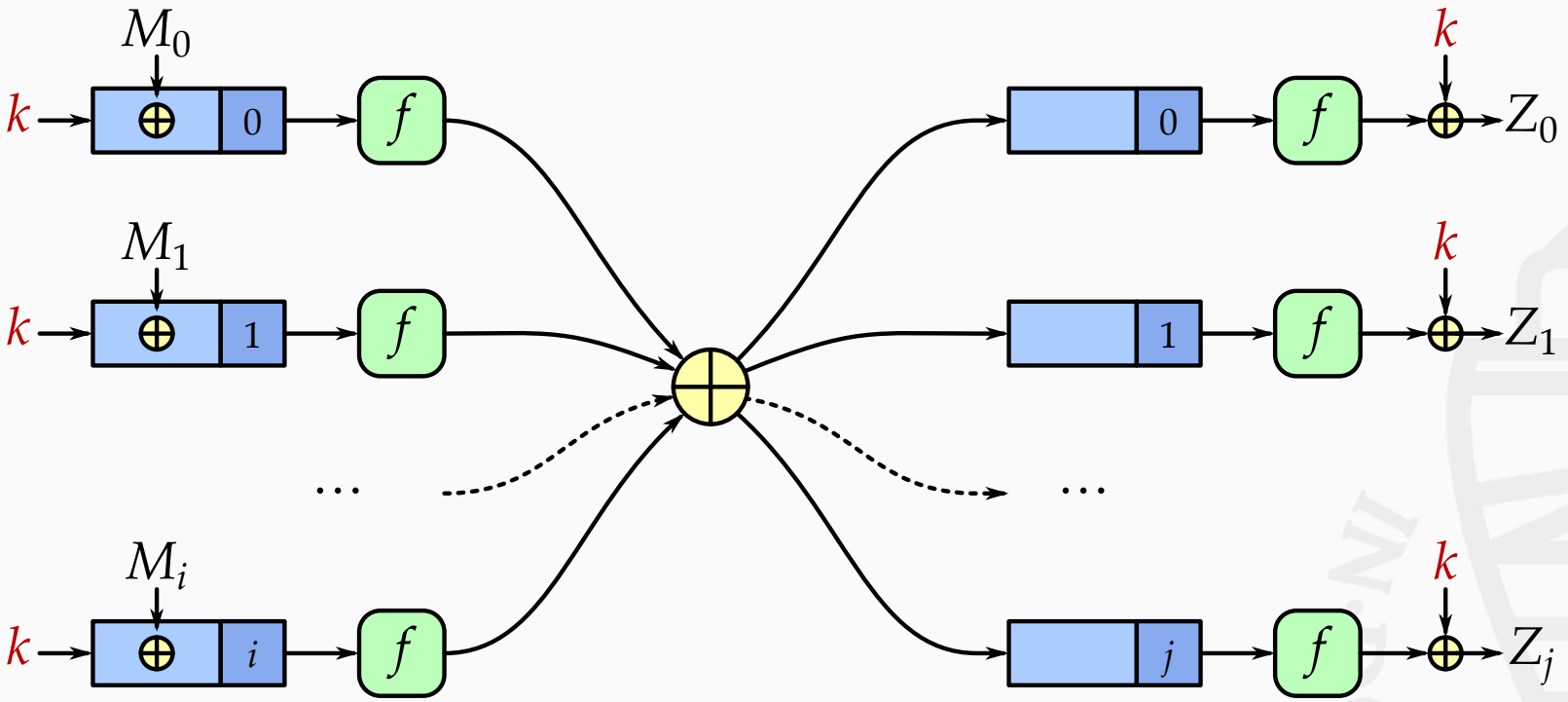
[Mennink, Reyhanitabar, & Vizar, AC 2015], [Keccak Team & Mennink, 2016-2017]

SAE with full-state keyed duplex: Motorist [Keccak Team, Keyak 2015]



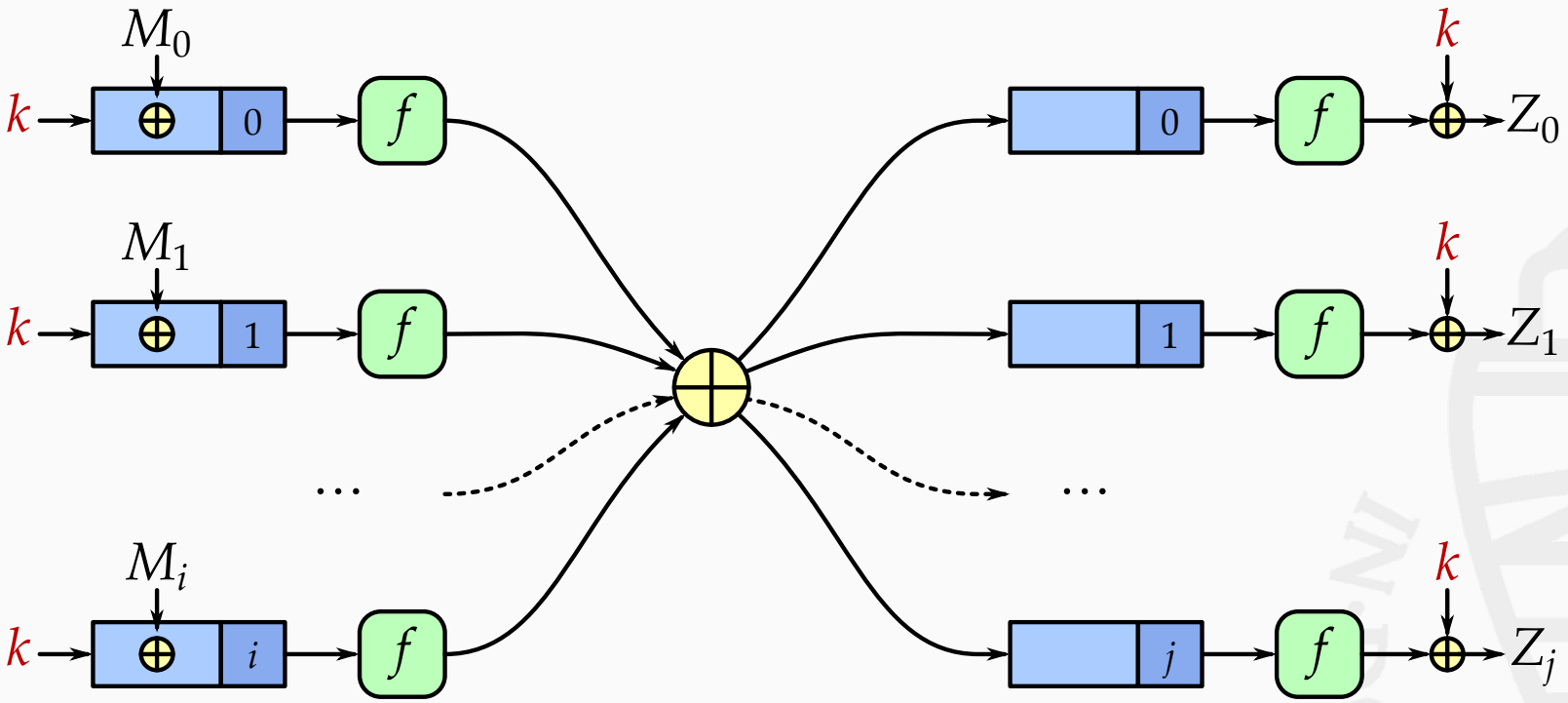
Outline

A parallel sponge variant: early attempt [Keccak Team 2014-2016]



Similar to Protected Counter Sums [Bernstein, "stretch", JOC 1999]

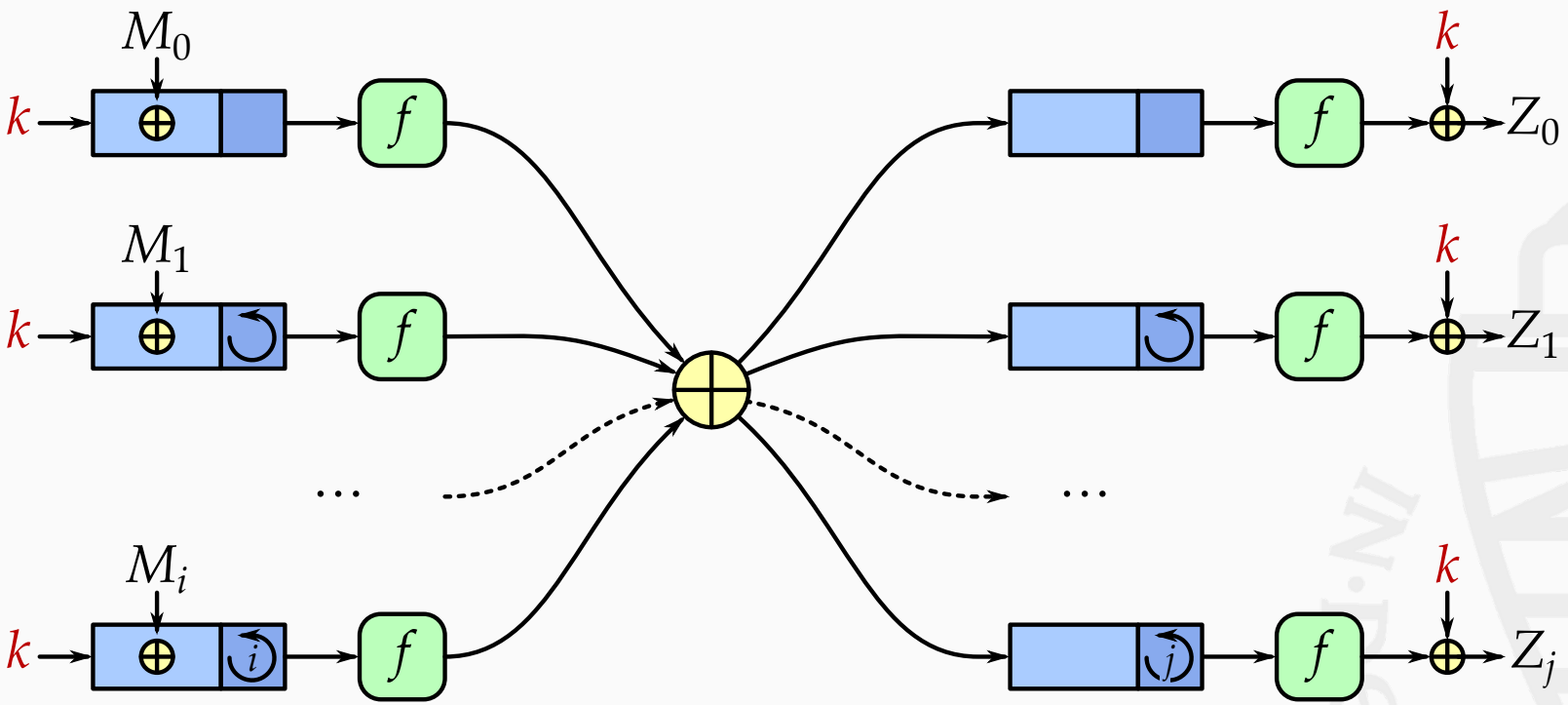
A parallel sponge variant: early attempt [Keccak Team 2014-2016]



Similar to Protected Counter Sums [Bernstein, "stretch", JOC 1999]

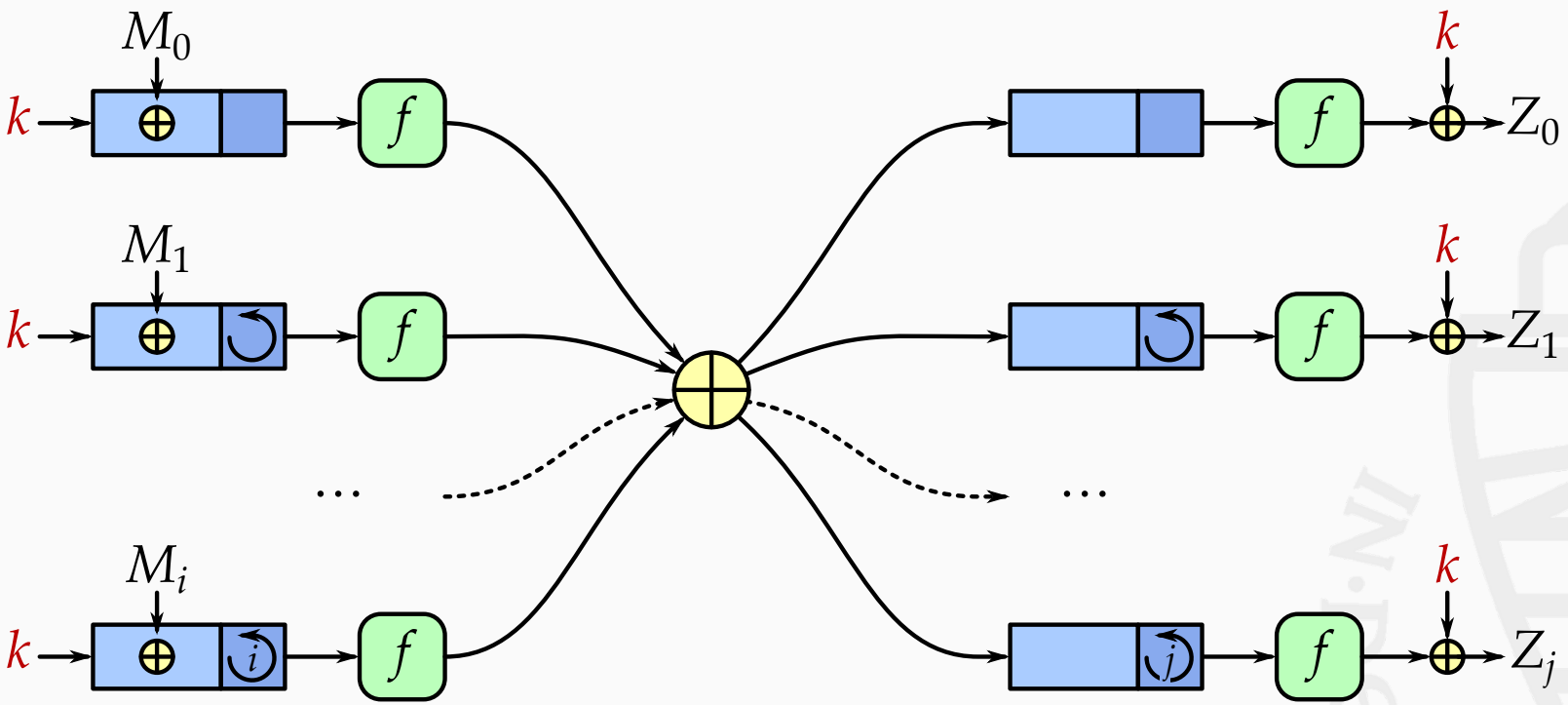
Problem: collisions with higher-order differentials if f has low degree

Farfalle as in [Keccak Team, eprint 2016/1188]



with k derived from arbitrary-length K using compression layer

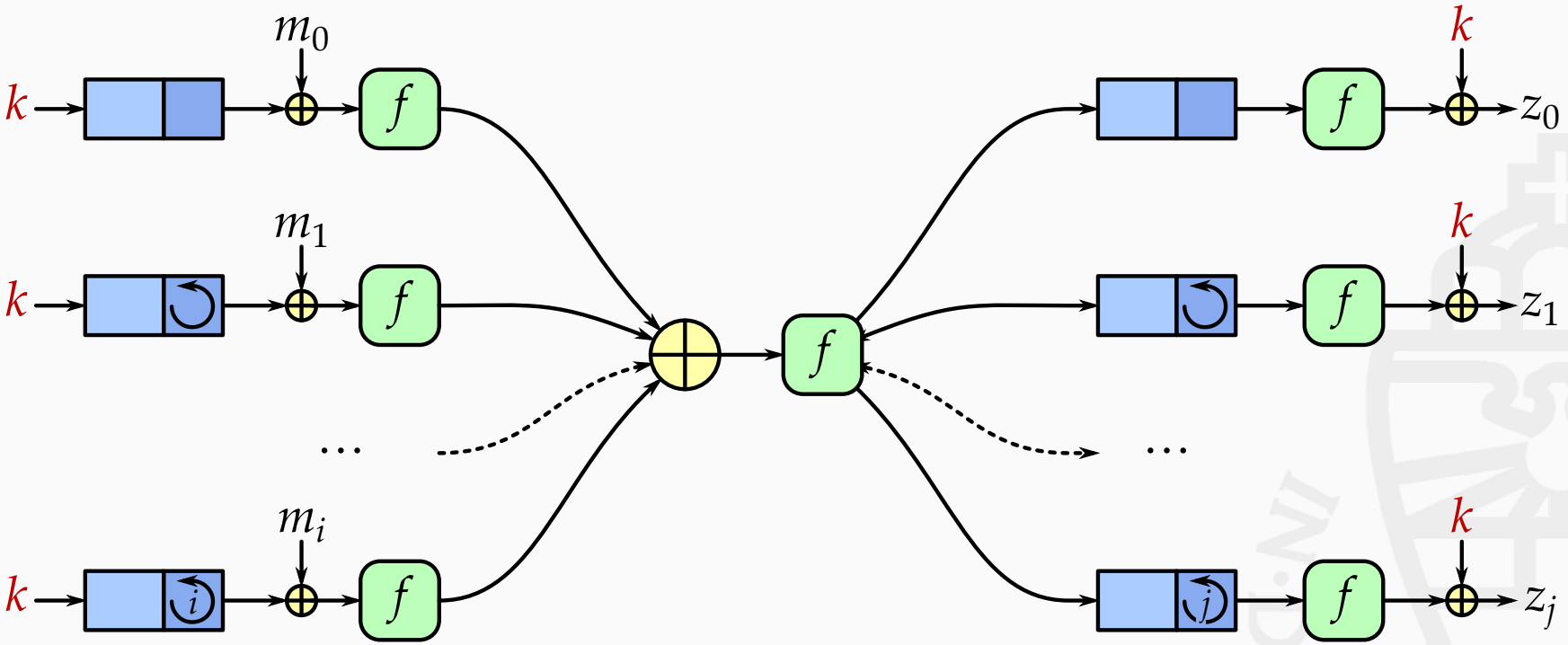
Farfalle as in [Keccak Team, eprint 2016/1188]



with k derived from arbitrary-length K using compression layer

Problem: generic higher-order differential attack if f at right has low-degree

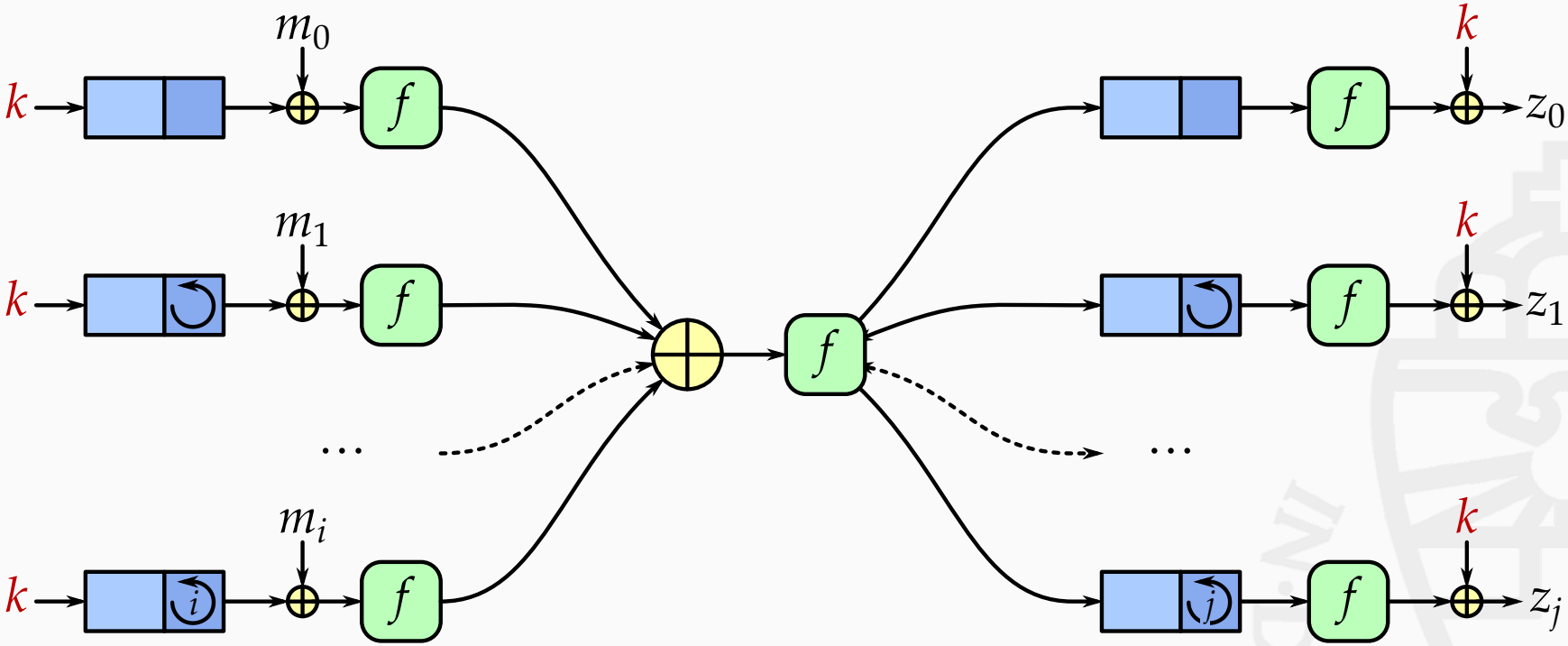
Farfalle now [Keccak Team, eprint 2016/1188, update TODO]



- Input mask rolling and f against accumulator collisions
- State rolling, f and output mask against state retrieval from output
- Middle f against higher-order DC
- Input-output attacks would span 3 f layers

Outline

KRAVATTE = Farfalle with KECCAK-p



- Target security: 128 bits, incl. multi-target (claimed $c = 256$)
- $f = \text{KECCAK-}p[1600, n_r]$ with $n_r = 6, 4, 4$
- Rolling function: operates on 4 lanes only, linear with order $2^{256} - 1$
  - lightweight, taken from [Granger, Jovanonvic, Mennink & Neves, EC 2016]
  - protects against higher-order DC

Thanks for your attention!