Generic Committing Attacks: Zero-Padded Ascon is Less Secure than Expected

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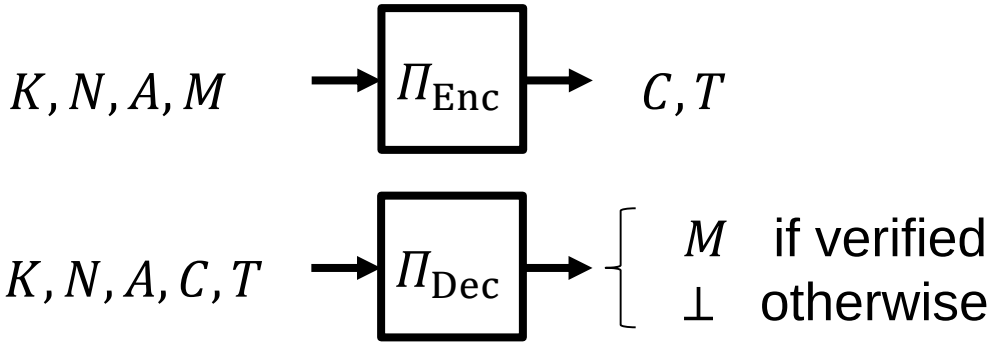
Authenticated Encryption with Associated Data



- AEAD provide both integrity and privacy in a single scheme, enabling high efficiency and design simplicity.
- Security of AEAD is well studied. Schemes usually come with security proofs with formal security notions.
- However, some protocols may use AE beyond the premise of the traditional AE-security guarantee.

Committing Security and Zero-padding

- Committing Security of AEAD [Farshim et al. 2017]

  It should be hard to find two different inputs processed to the same output;
  $(K_1, N_1, A_1, M_1), (K_2, N_2, A_2, M_2)$ s.t. $ENC(K_1, N_1, A_1, M_1) = F(K_2, N_2, A_2, M_2)$.

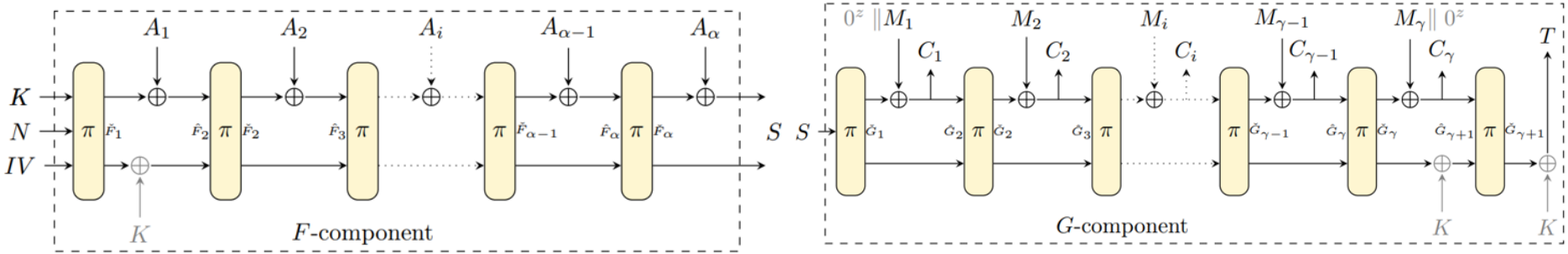
  - Key commitment (CMT-1/CMT-K): $K_1 \neq K_2$
  - Context commitment (CMT-4): $(K_1, N_1, A_1, M_1) \neq (K_2, N_2, A_2, M_2)$
  - CMT-K* [Menda et al. 2023]: $K_1 \neq K_2, A_1 = A_2, N_1 = N_2$

- Zero padding (ZP) [Albertini et al. 2022]
  - Key committing security of GCM is broken in $O(1)$, which increases to $\tau/2$-bit security (under the same nonce) by prepending 0^τ in M.
  - two possibilities of appended bit positions: prefix or suffix

Our Target Construction: Duplex and Ascon

We treat Duplex and Ascon in an integrated way and consider ZP.

- **Duplex**: a permutation based construction
- **Ascon**: NIST standard for lightweight cryptography (SP800-232)
  - State is initialized by a key K, a nonce N, and a fixed constant IV.
  - Key blinding: XORs K to the state, in 3 places
    - › Initial-KB, Final-KB, Tag-KB



Summary of Results

Systematic analysis of generic committing attacks

- Three existing attack approaches: IS / CC / TC
- Analysis under KB and ZP under the notion of CMT-4 and CMT-K*

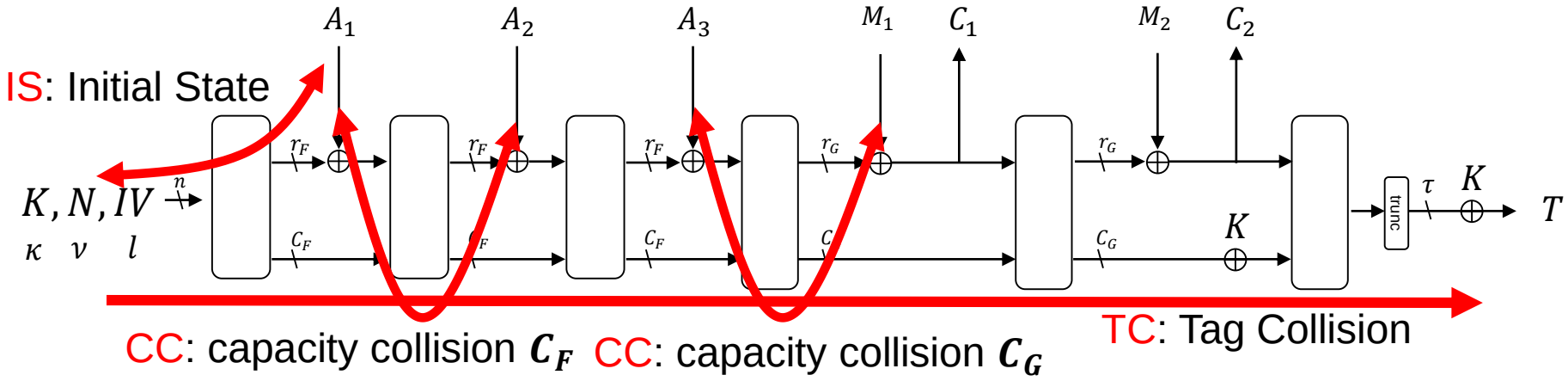
New attacks

- **2S-TC**: separately attack zero-padding and tag collisions
  - › application to tag-truncated Ascon by NIST
  - › counterexample of previous proof on Ascon-like-ZP
- **2R-IS**: extend the applicable parameter range
  - › application to a CAESAR candidate Ketje
- **MitM**: a new attack approaches emerges when only tag KB is used.

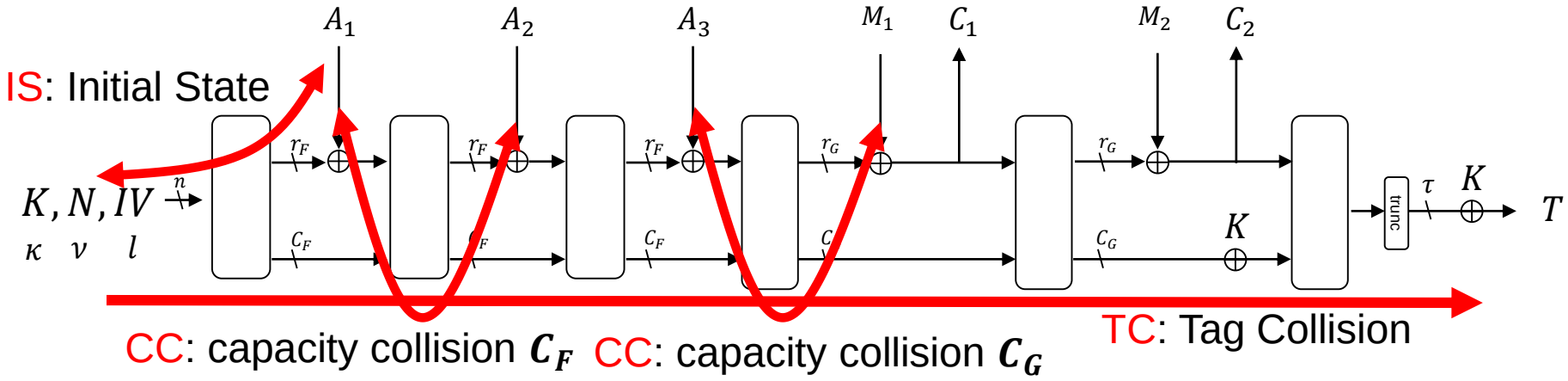
Systematic analysis of generic committing attacks

- A part of analysis on CMT-4 will be explained.
- Please refer to the paper for CMT-K*.

Existing Three Approaches of Attacking CMT-4



Complexity Evaluation with ZP and KB



	IS	CC (prefix ZP)	CC (suffix ZP)	TC
ZP-Duplex	l	$\min(\frac{C_F}{2}, \frac{C_G + z}{2})$	$\min(\frac{C_F}{2}, \frac{C_G}{2})$	$\frac{\tau + z}{2}$
Variants w/ initial-KB	$\frac{\kappa}{2} + l$	$\min(\frac{C_F}{2}, \frac{C_G + z}{2})$	$\min(\frac{C_F}{2}, \frac{C_G}{2})$	$\frac{\tau + z}{2}$

- The cost of TC increases by $\frac{z}{2}$ ⇒ ZP has the same effect as a tag.
- Initial-KB contributes to CMT-4 security.

New Attacks

Overview of Two-Stage Tag Collision: 2S-TC

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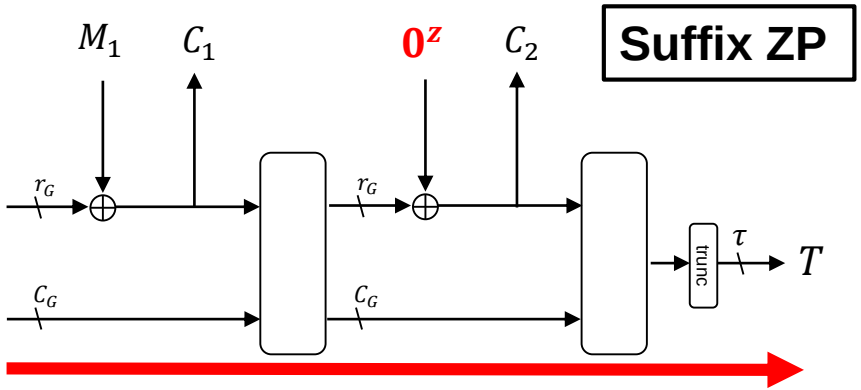
"*ZP has the same effect as a tag*"

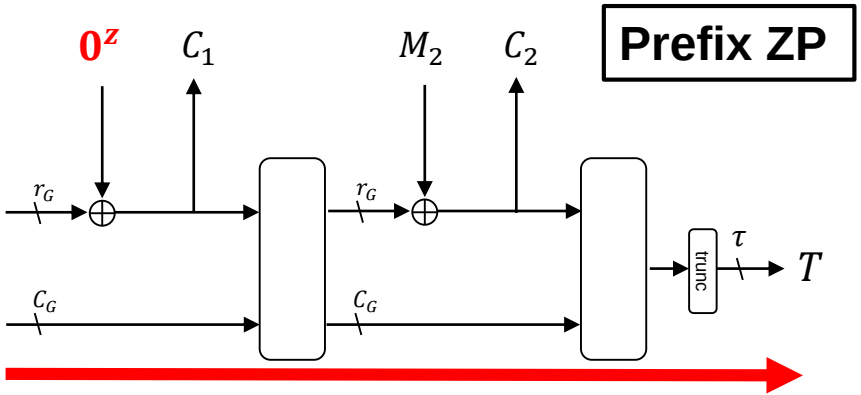
Reasonable for suffix

- Attackers check collision on $C_2||T$ together.
- Cost: $2^{\frac{z+\tau}{2}}$
- matches the proof for suffix [NSS23,Theorem 1]

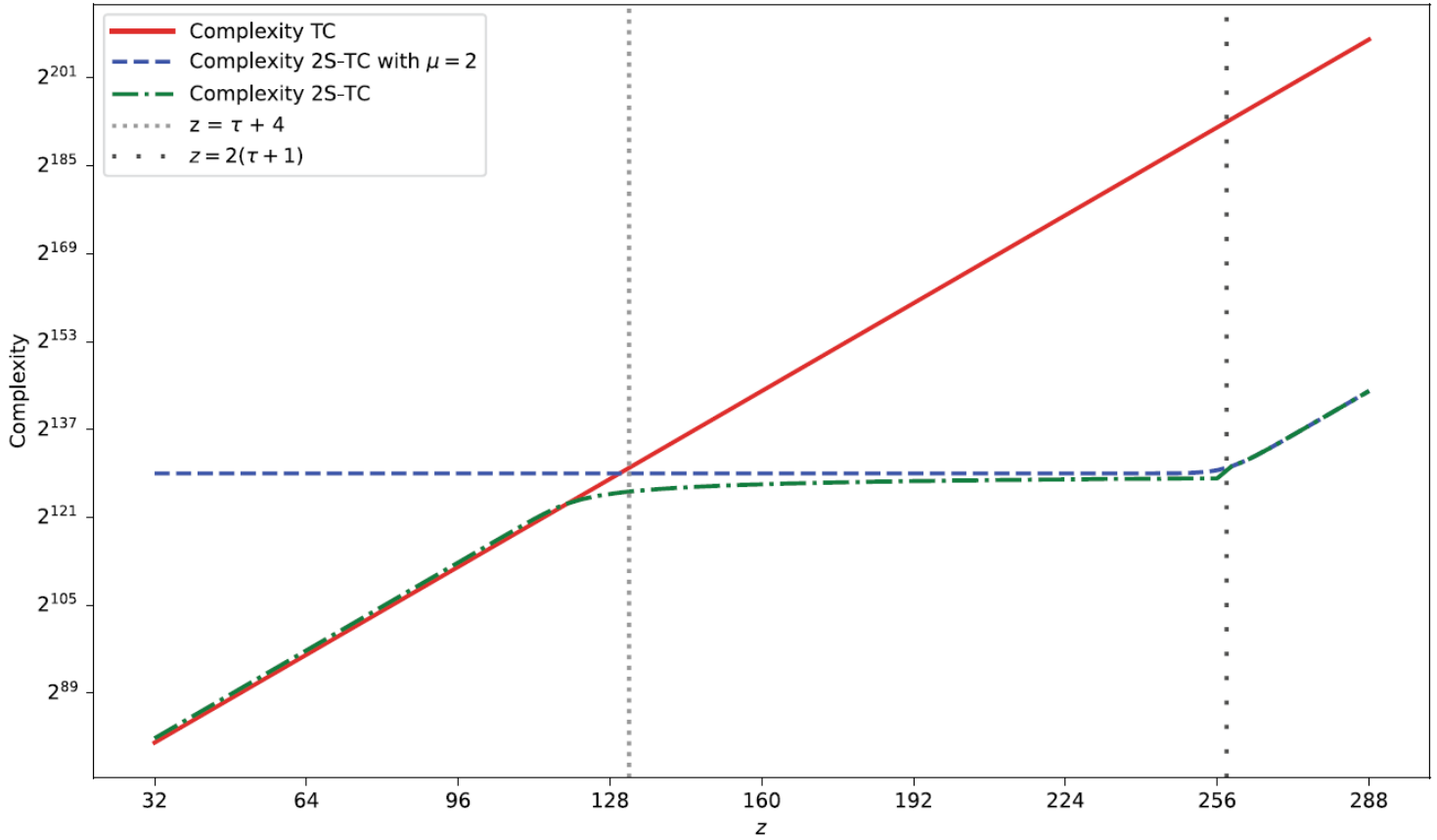


Unreasonable for prefix

- After generating a collision on C_1, a collision on T can be found in a brute-force manner.
- Cost : $2^{\frac{z}{2}} + 2^{\tau}$
- counterexample of [NSS23,Theorem 2] that generalizes the proof for suffix to any encoding

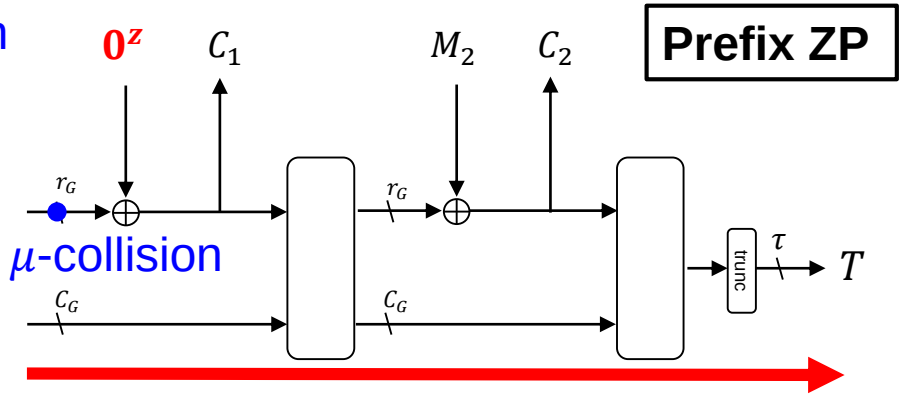


Complexity Comparison for Tag Collisions



Further Improvement of 2S-TC by Multicollisions

- When a C_1-collision is generated, μ-collision can be generated instead.
- The brute-force search on T becomes a collision search over μ choices.
- Cost: $\log(2^{mulcoll(z,\mu)} + 2^{\tau-\log(\mu)})$, can be faster than $2^{\frac{z}{2}} + 2^t$ by a factor of up to $\log z$.



- For certain parameter choices, 2S-TC outperforms existing attacks: IS, CC, TC
  - best attack for Ascon with tag truncation standardized by NIST [SP800-232]
  - best attack for Ascon-128, a primary member of Ascon submission in NIST LWC
- For the default choice of SP800-232, the results by [NSS23] hold.

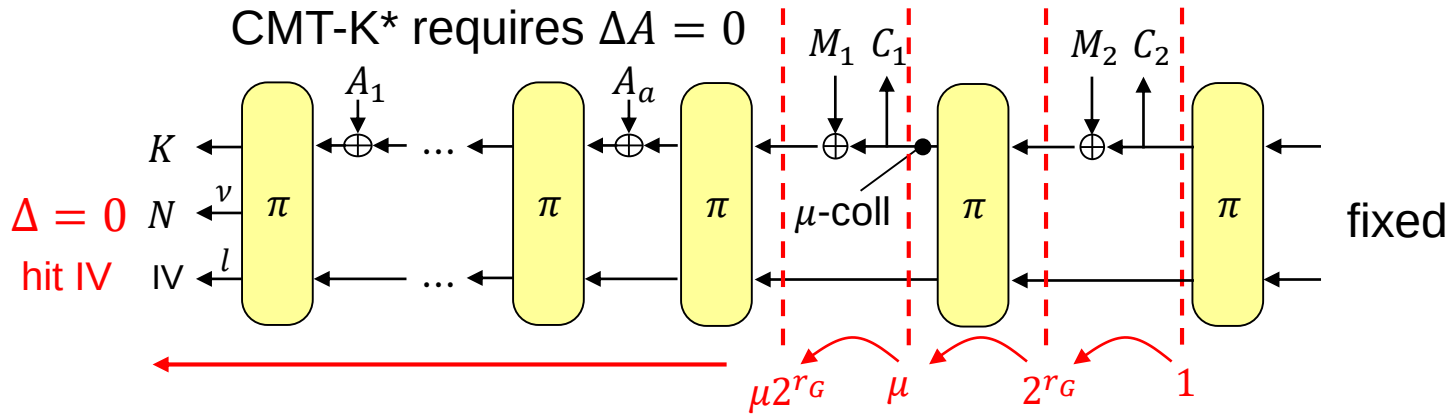
2-Round Initial State (2R-IS)

Existing CMT-K* attack for duplex + suffix ZP

- Requirement is nonce collision & IV hit; the attack cost is $\frac{\nu}{2} + l$
- Degrees of freedom (DoF) is 1 msg block, r_g; deriving the condition $r_g \geq \frac{\nu}{2} + l$.

We improve DoF to μr_g with a multi-collision, enlarge the attacked parameter range.

- Ketje allows a user to choose ν. For some ν, 2R-IS outperforms existing attack.



New MitM Attack only with Tag-KB

- Construction adopted by a NIST LWC finalist SCHWAEMM.
- With $\Delta M \neq 0$, Tag-KB can lower the security of Duplex. (see ePrint2026/1160)

Without tag-KB

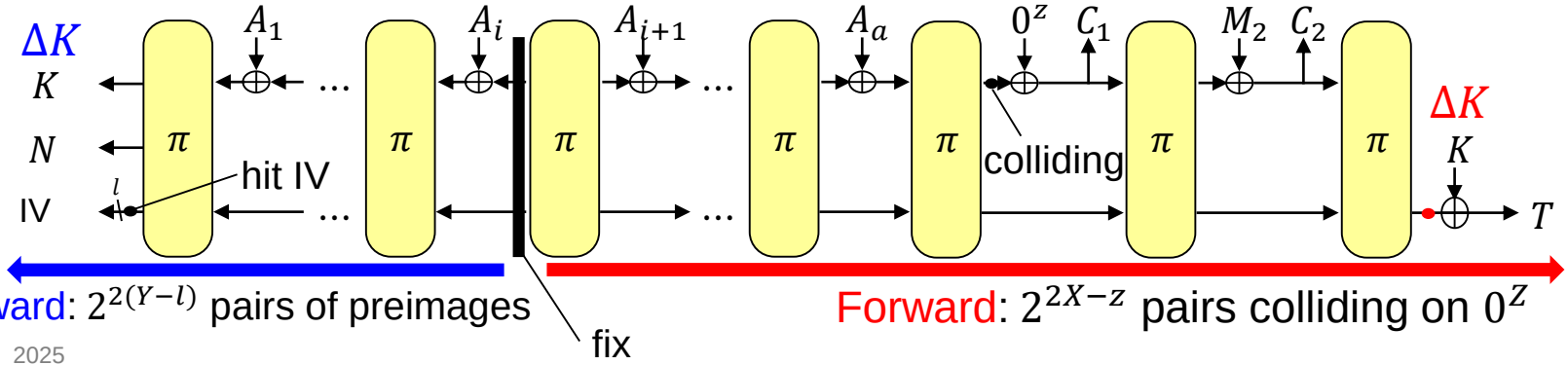
Collision on tag

Cost: $2^{\frac{z+\tau}{2}}$

With tag-KB

match ΔK independently computed in two directions

Cost: $2^{\frac{z+\tau}{4}+\frac{l}{2}+1}$



Conclusion

Systematic analysis:

- 3 attacks IS / CC / TC for each KB / ZP w.r.t. CMT-4 / CMT-K*

Takeaway from New Attacks:

- 2S-TC shows that Zero-padding ≠ simply a longer tag
- Impact of multicollision needs to be considered carefully
  - It may lower the attack cost or enlarge the attackable parameters
  - Impact on Ascon tag truncation by NIST, Ascon-128, KetJe
- Committing security is parameter- and structure-sensitive
  - Padding position matters
  - Tag KB blocks some attacks, but can enable a new MitM attack

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