A New Conditional Cube Attack on Reduced-Round Ascon-128a in a Nonce-misuse Setting

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Extended Abstract

Ascon [DEMS21] is one of the finalists of the National Institute of Standards and Technology (NIST) lightweight cryptography standardization process. The Ascon family is a permutation-based design that uses monkeyDuplex construction [BDPA12] with extra key additions during initialization and finalization to prevent key-recovery and forgery attacks even after the internal state is recovered by an attacker during the encryption. The family includes three AEAD variants; Ascon-128 (primary), Ascon-128a, and Ascon-80pq. The Ascon family received a significant amount of third party analysis (e.g., [LDW17, LZWW17, RHSS21, RAD19, JM19, ZDW19, DEMS15, Tez16].

The secondary version Ascon-128a claims to provide 128-bit security of privacy and authenticity when unique nonce values are used for the encryption under the same key. The maximum available data to the attacker is limited to 2^{64} 64-bit blocks per key. In a nonce-misuse setting, the designers claimed that Ascon-128a provides 128-bit security of privacy and authenticity if nonces are reused a few times by accident as long as the combination of nonce and associated data stays unique. A key recovery attacks for Ascon-128a with complexity significantly below 2^{96} even after a secret state is recovered by an implementation attack is not expected, due to the extra key additions during the initialization and the finalization.

In 2009, Dinur and Shamir introduced the *cube attacks* to algebraically analyze symmetric-key ciphers. Cube attacks aim to recover secret key bits from the polynomial called *superpoly* by summing the output values over a subset of public variables (e.g., initialization vector or tweak) called the *cube*. Cube attacks were applied to a number of primitives (e.g., [DMP+15, LDB+19, DS11]) The main idea can be considered as a generalization of earlier attacks using higher-order differentials (e.g., include examples). Later, additional variants of the attacks were developed (e.g., dynamic cube attacks [DS11], conditional cube attacks [HWX+17], correlation cube attacks [LYWL18], deterministic cube attacks [YT18], and IV-representation based cube attack [FWDM18] division property-based cube attacks [TIHM17]). The developments in cube attacks is summarized in [COOP22].

In this study, we analyse the security of Ascon-128a in a nonce-misuse setting using conditional cube attacks. Table 1 summarizes the existing cube attacks on Ascon-128a. We present new state and key recovery attacks on a reduced-round Ascon-128a in which the internal permutation for associated data and message processing is reduced from 8 to 7 rounds (the number of rounds for initialization and finalization remain unchanged)[1].

[1] The number of rounds is represented as a 3-tuple representing the number of rounds during initialization,

The state-recovery attack requires 2^{117} data and 2^{118} time with negligible memory. After recovering the state, again in a nonce-misuse scenario, secret key can be recovered with additional 2^{32} data, $2^{97.6}$ time and 2^{32} memory complexities.

Table 1: Summary of cube attacks on Ascon-128a

Attack type	Method	Rounds [1] (12, 8, 12)	Data	Time	Memory	Nonce misuse	Ref.
Key recovery	Conditional cube	$6,\star,\star$	2^{40}	2^{40}	-	No	[LDW17]
	Cube	$7,\star,\star$	$2^{77.2}$	$2^{103.92}$	-	No	[LDW17]
	Cube	$7,\star,\star$	2^{64}	2^{123}	-	No	[RHSS21]
	Cube	$7,5,\star$	2^{33}	2^{97}	-	Yes	[LZWW17]
	Conditional cube	$\star,7,\star$	2^{117}	2^{118}	2^{32}	Yes	this study
Forgery	Cube	$\star,\star,5$	2^{17}	2^{17}	-	Yes	[LZWW17]
	Cube	$\star,\star,6$	2^{33}	2^{33}	-	Yes	[LZWW17]
State-recovery	Conditional cube	$\star,7,\star$	2^{117}	2^{118}	-	Yes	this study

Although the presented attacks do not violate the security claims of the designers, they are helpful to understand the security margin of Ascon-128a in nonce-misuse setting.

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the number of rounds during associated data or message processing, and the number of rounds during finalization, respectively. The number represented as $\star$ can be arbitrary.

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