How To Securely Release Unverified Plaintext in Authenticated Encryption

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Elena Andreeva Andrey Bogdanov Atul Luykx
Bart Mennink Nicky Mouha Kan Yasuda

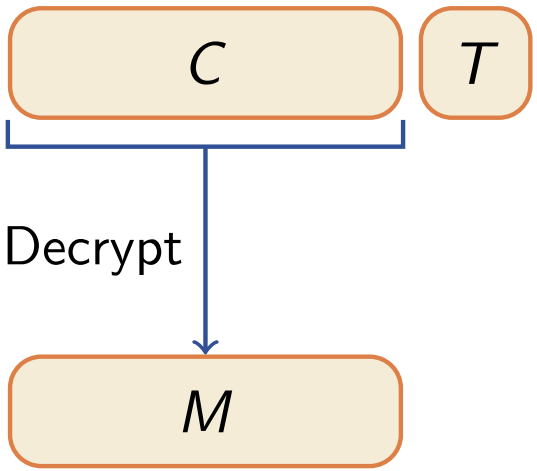
Authenticated Decryption

Decrypt-then-Verify

Verify-then-Decrypt

Authenticated Decryption

Decrypt-then-Verify



Verify-then-Decrypt

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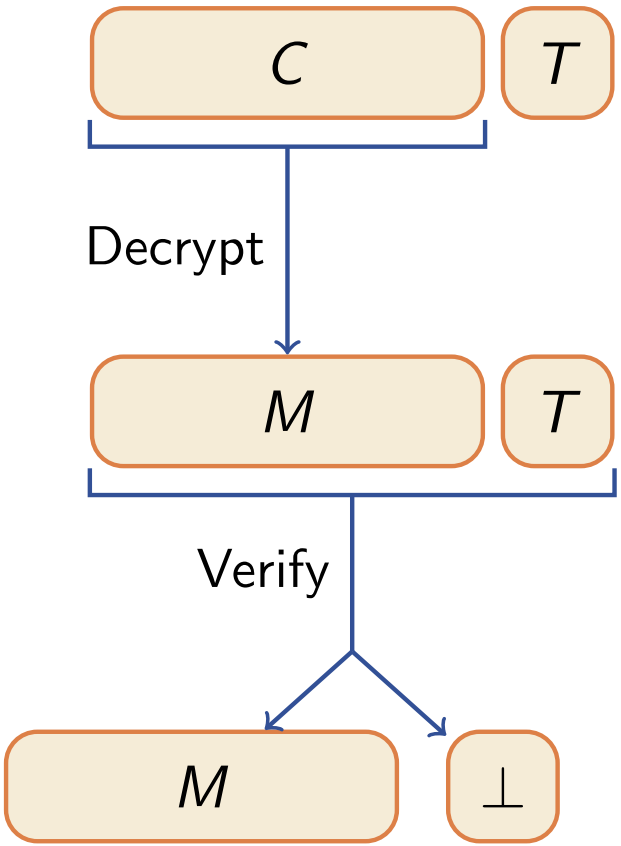
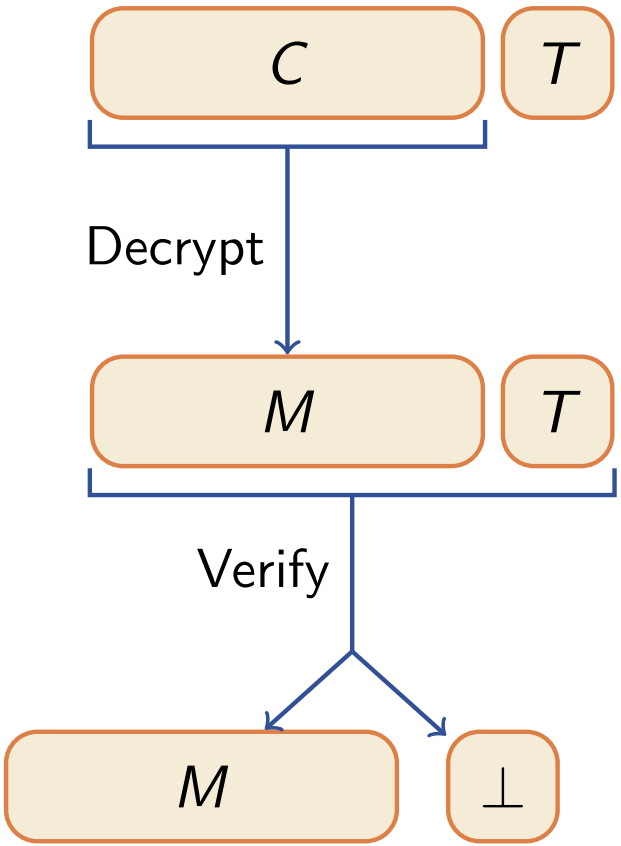
Decrypt-then-Verify



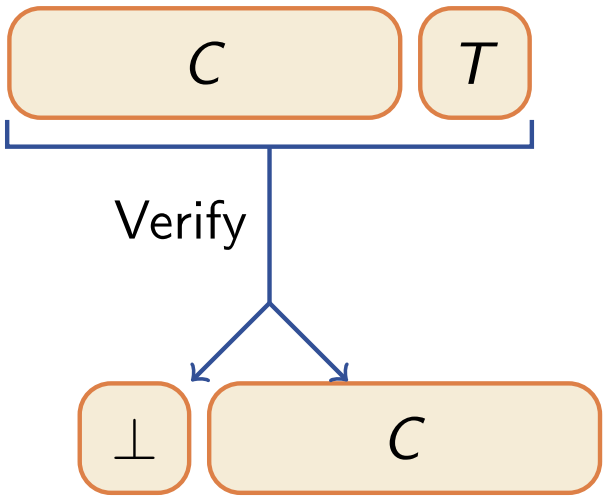
Verify-then-Decrypt

Authenticated Decryption

Decrypt-then-Verify

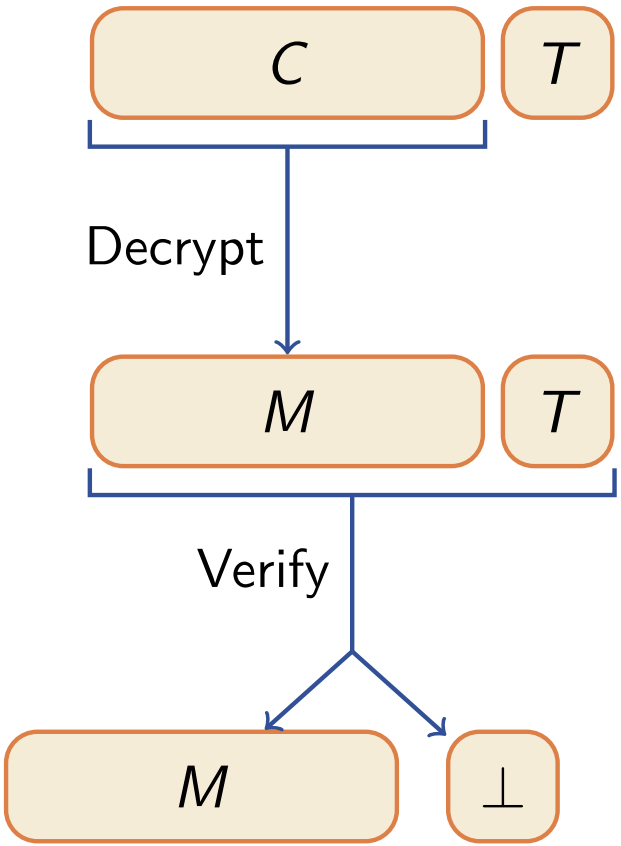


Verify-then-Decrypt

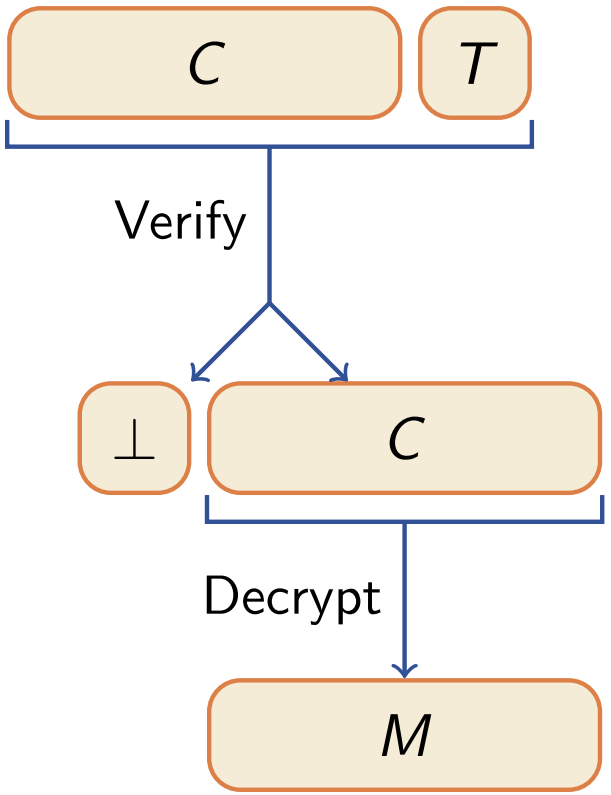


Authenticated Decryption

Decrypt-then-Verify



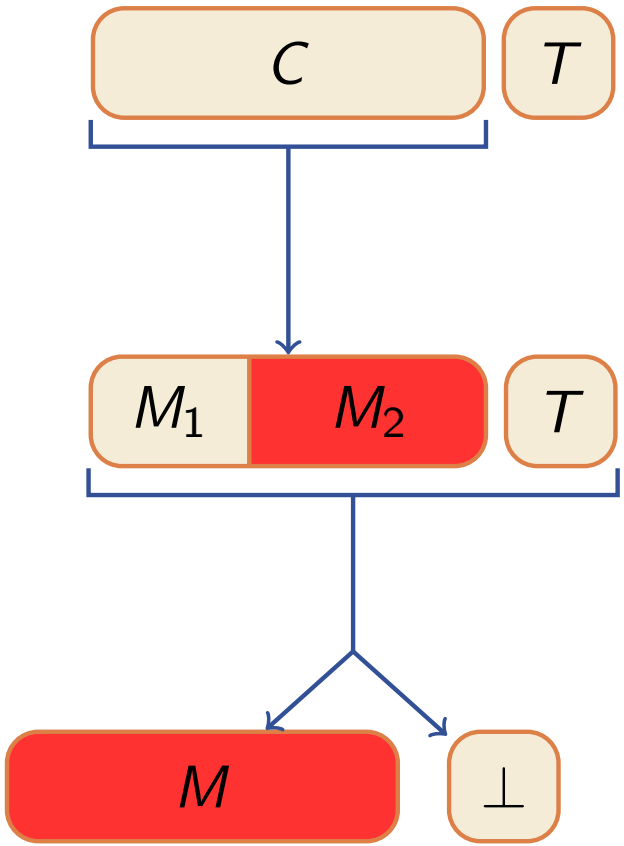
Verify-then-Decrypt



Releasing Unverified Plaintext
3 Scenarios

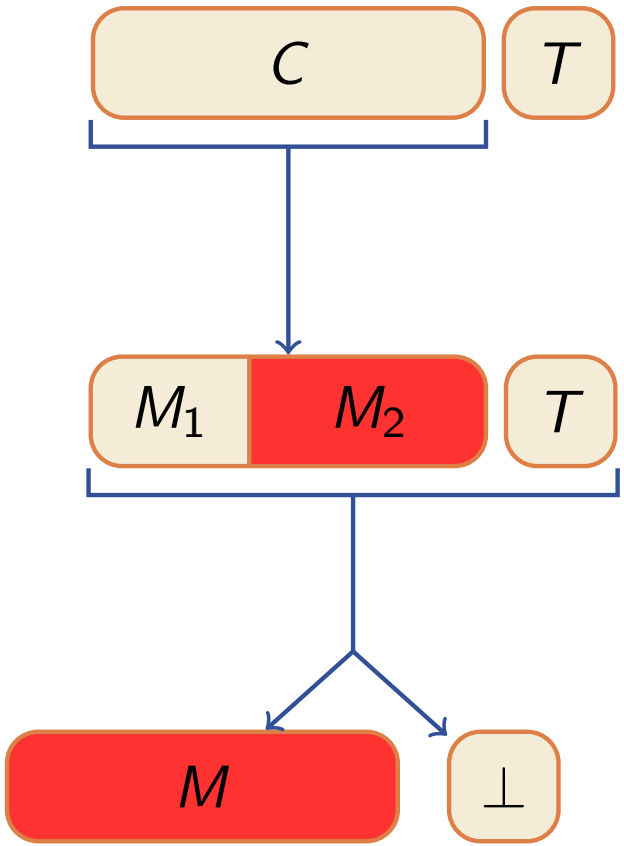
Motivation: Insecure Memory

Decrypt-then-Verify

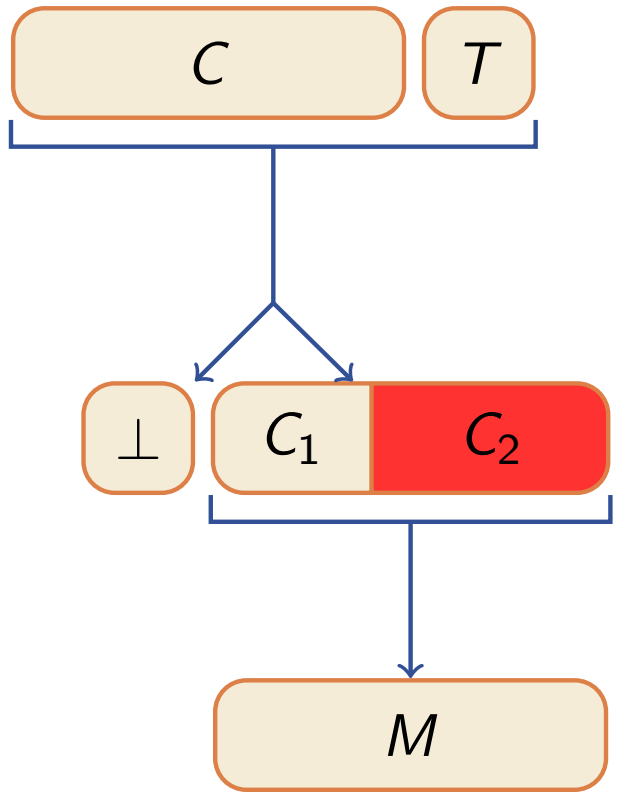


Motivation: Insecure Memory

Decrypt-then-Verify

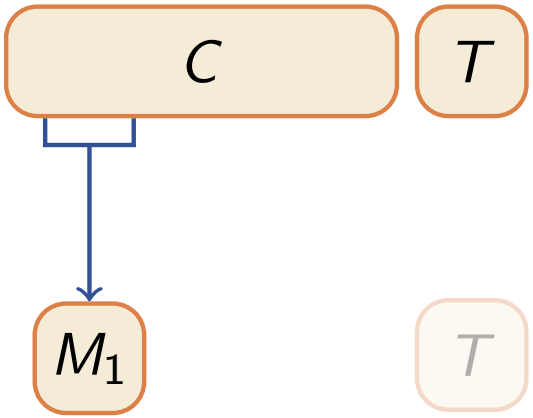


Verify-then-Decrypt



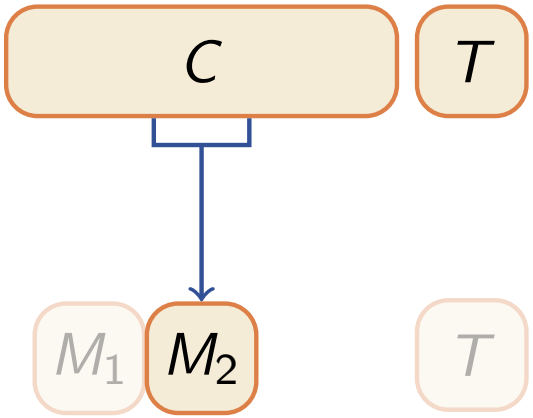
Motivation: Small Buffer

Decrypt-then-Verify



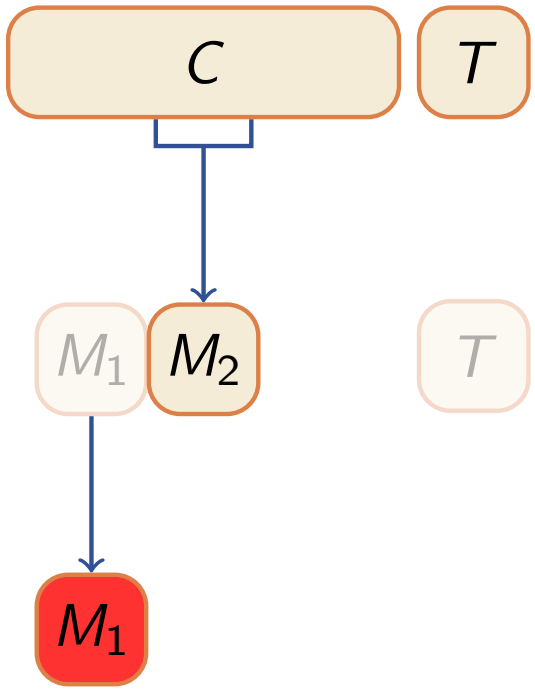
Motivation: Small Buffer

Decrypt-then-Verify



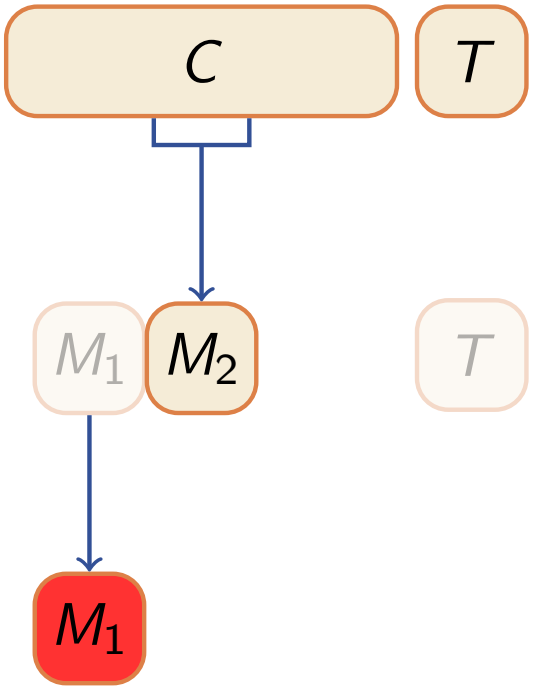
Motivation: Small Buffer

Decrypt-then-Verify

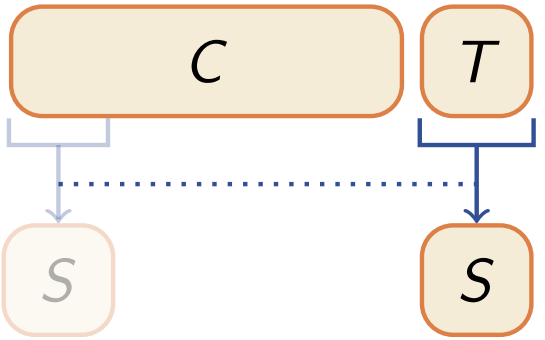


Motivation: Small Buffer

Decrypt-then-Verify

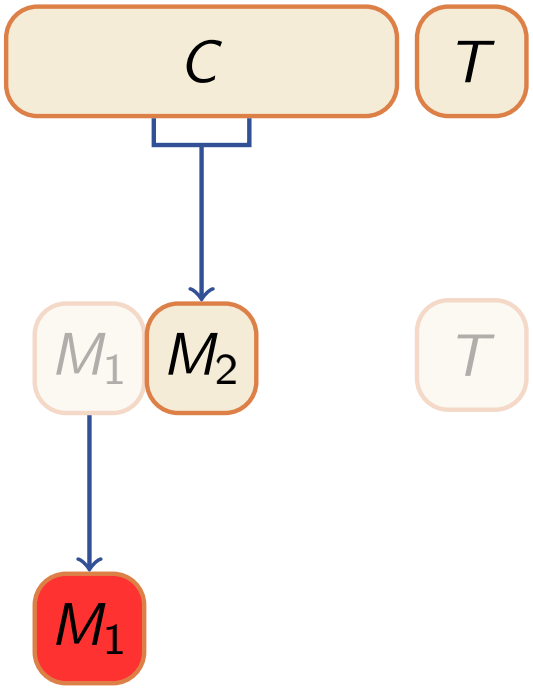


Verify-then-Decrypt

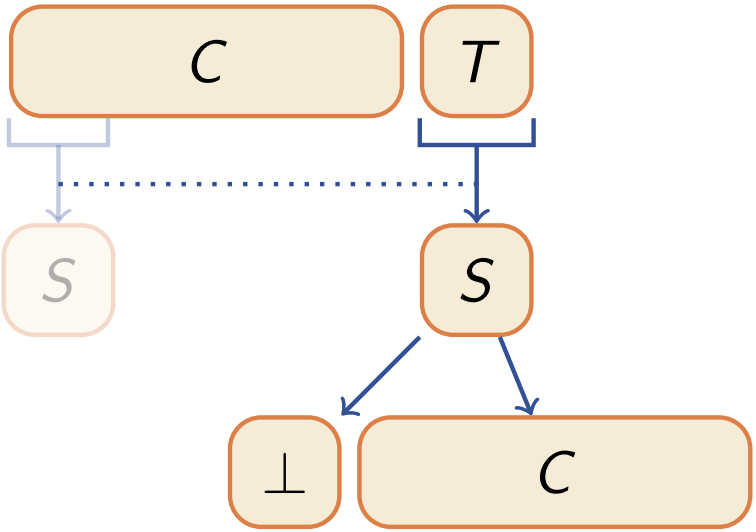


Motivation: Small Buffer

Decrypt-then-Verify

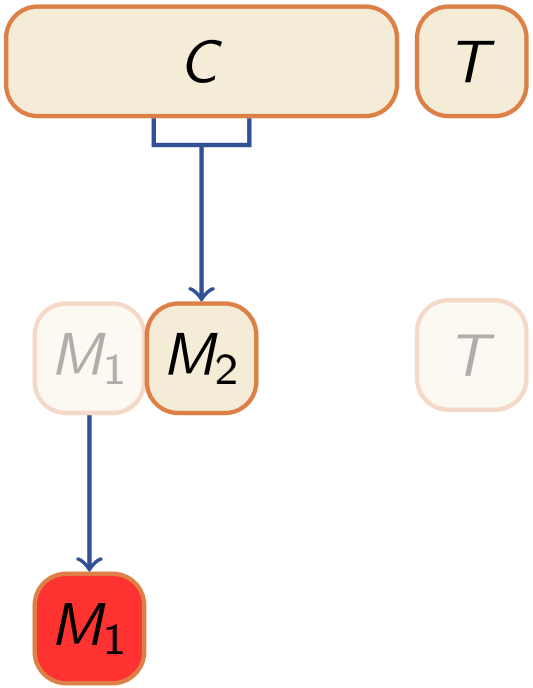


Verify-then-Decrypt

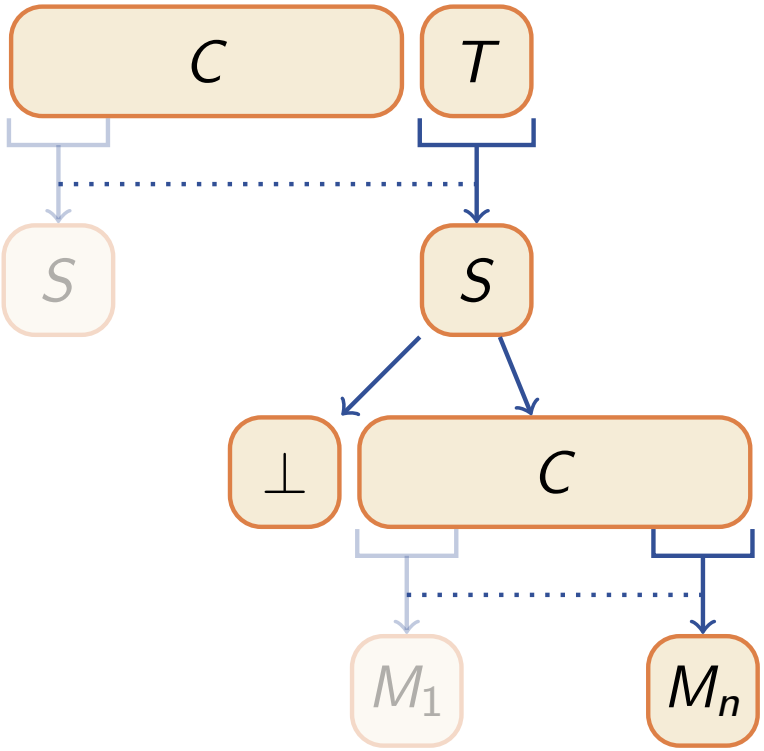


Motivation: Small Buffer

Decrypt-then-Verify

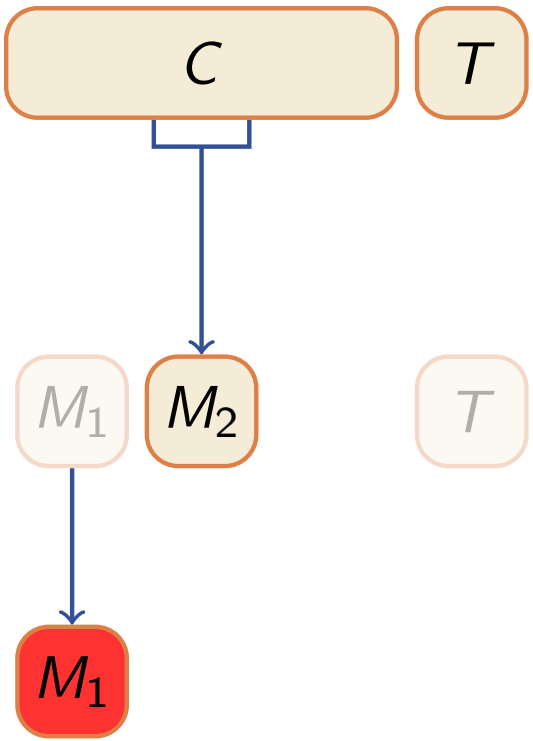


Verify-then-Decrypt



Motivation: Real-time Output

Decrypt-then-Verify



Motivation: Real-time Output

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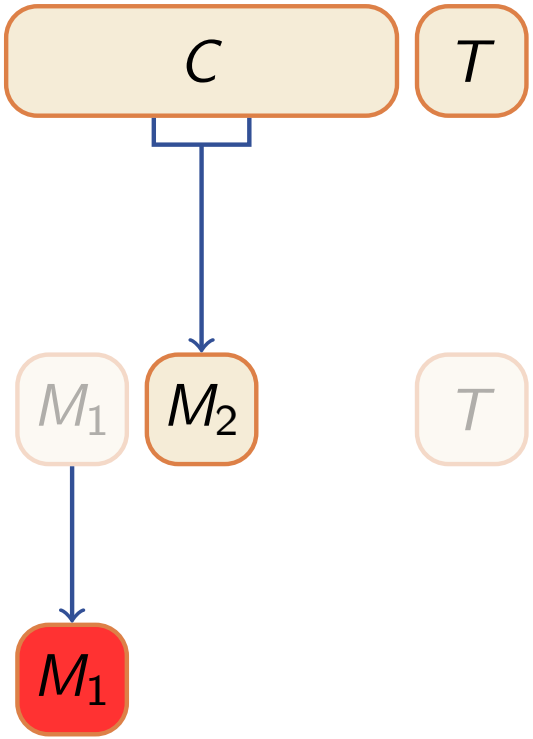
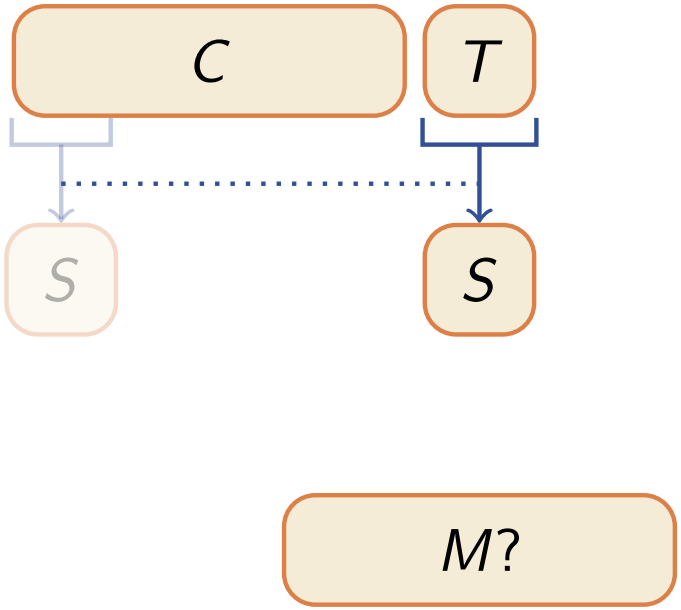
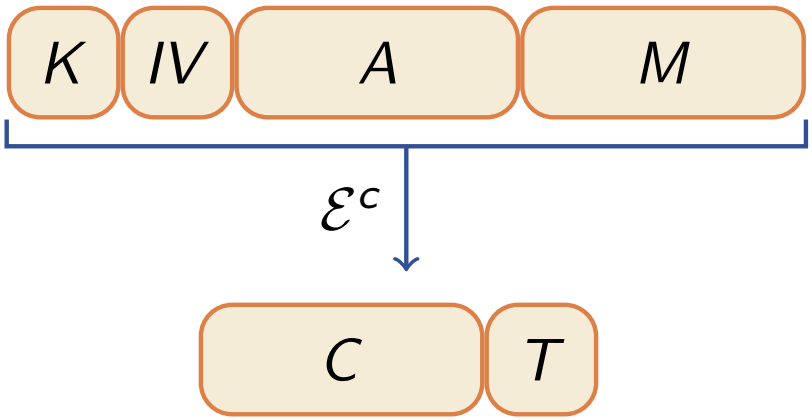


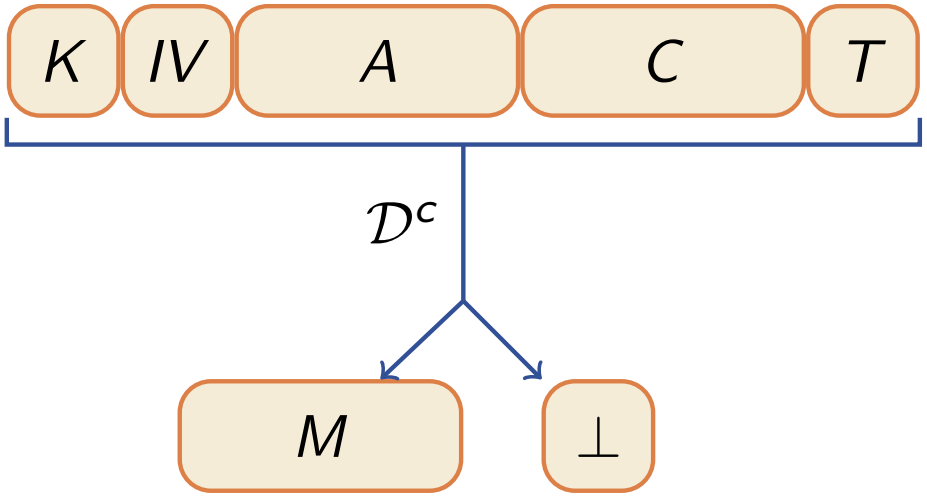
Verify-then-Decrypt



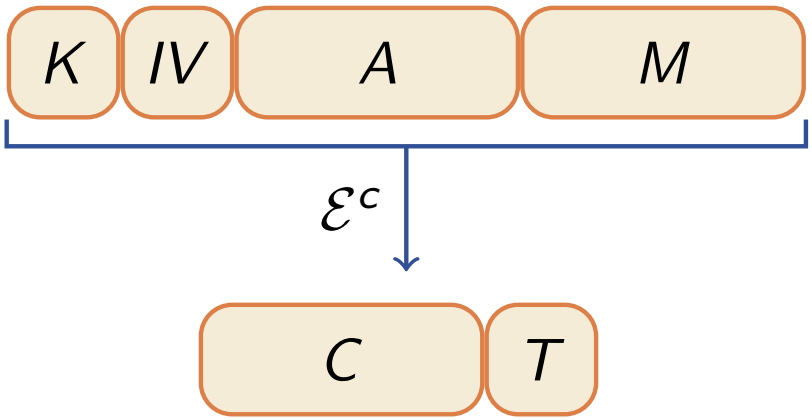
Formalization of RUP Integrity and Confidentiality

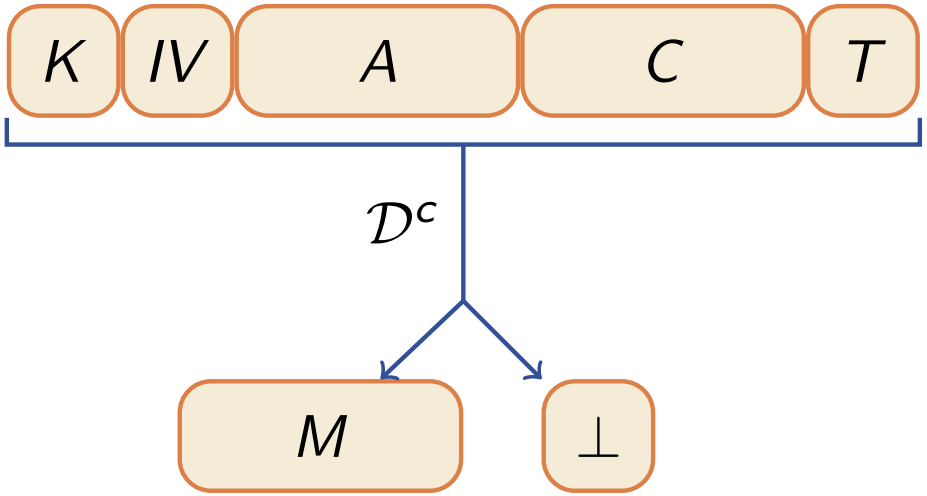
Conventional AE Syntax





Conventional AE Syntax

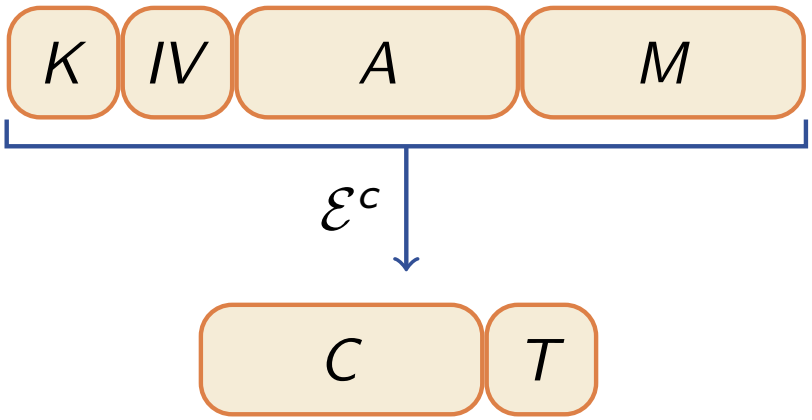


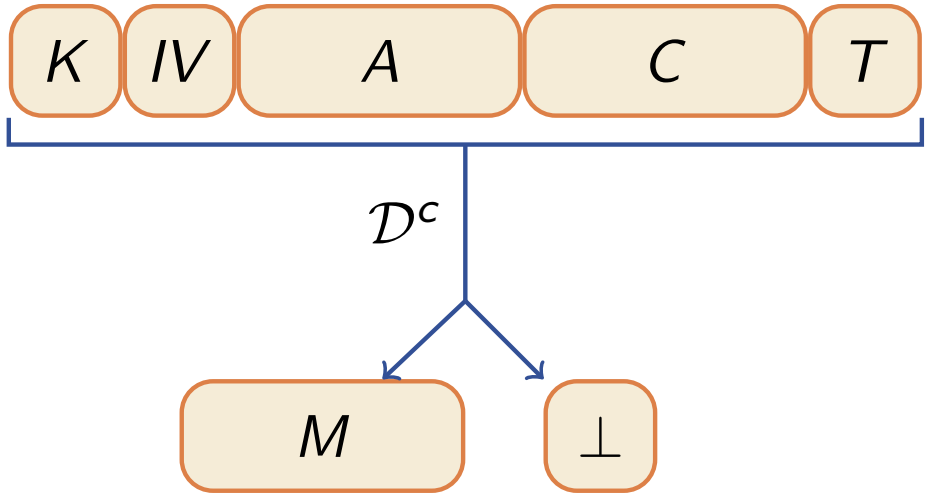


IV:

1. random
2. nonce
3. arbitrary

Conventional AE Syntax



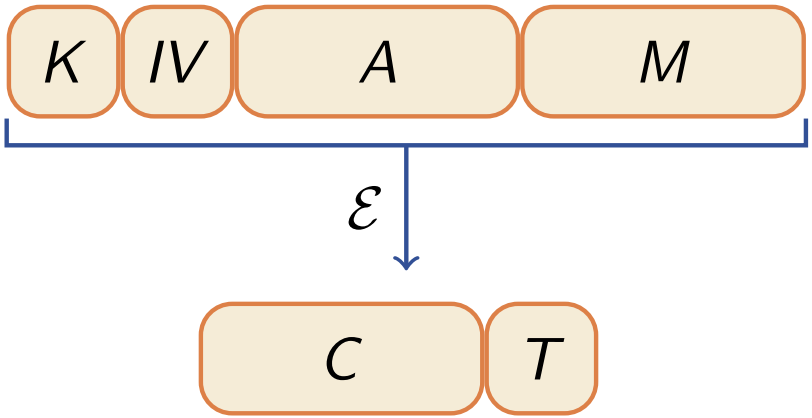


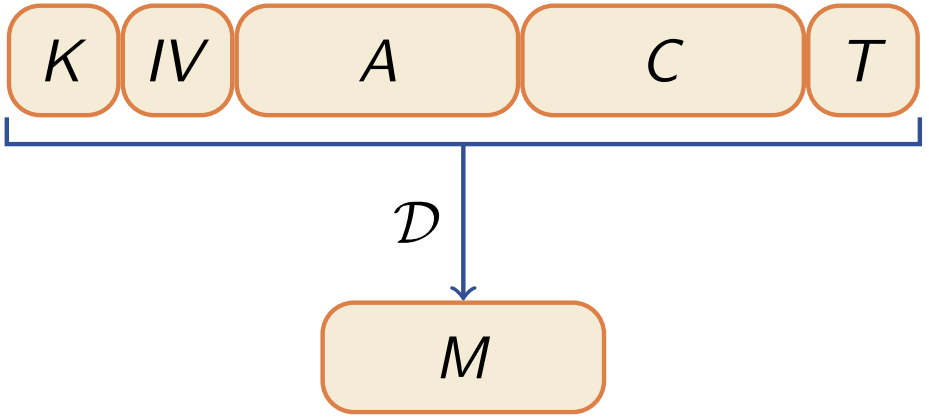
IV:

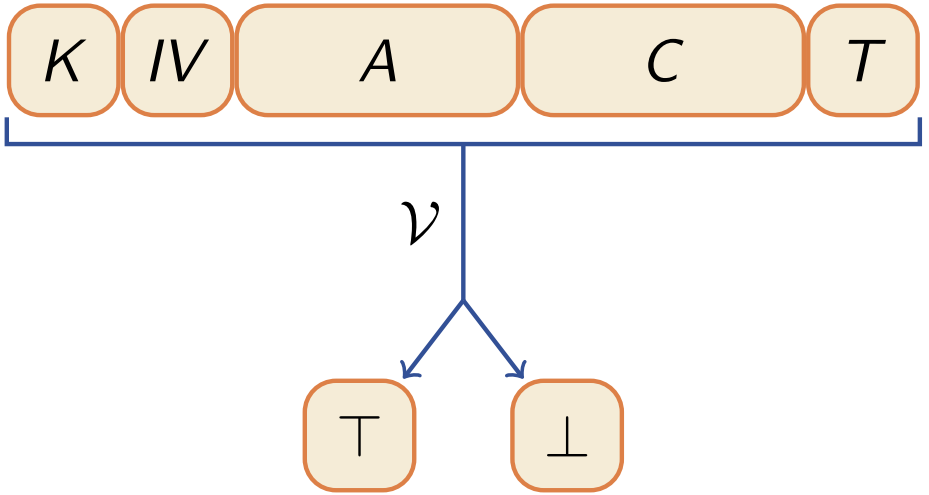
1. random
2. nonce
3. arbitrary

IV always arbitrary

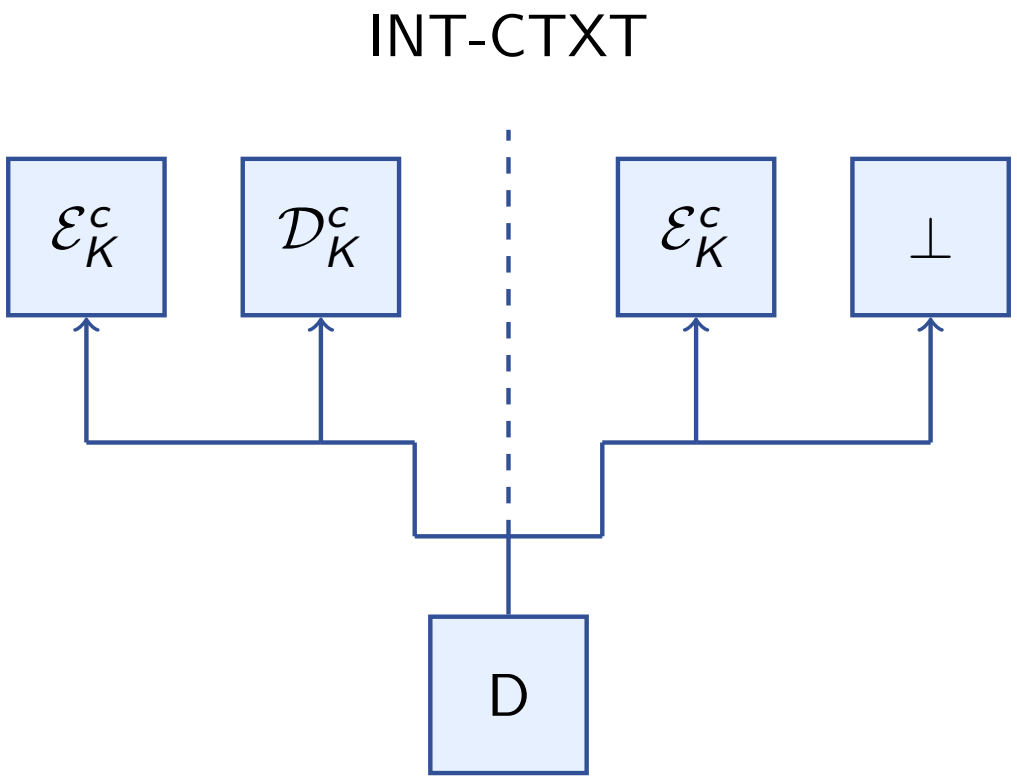
Split AE Syntax



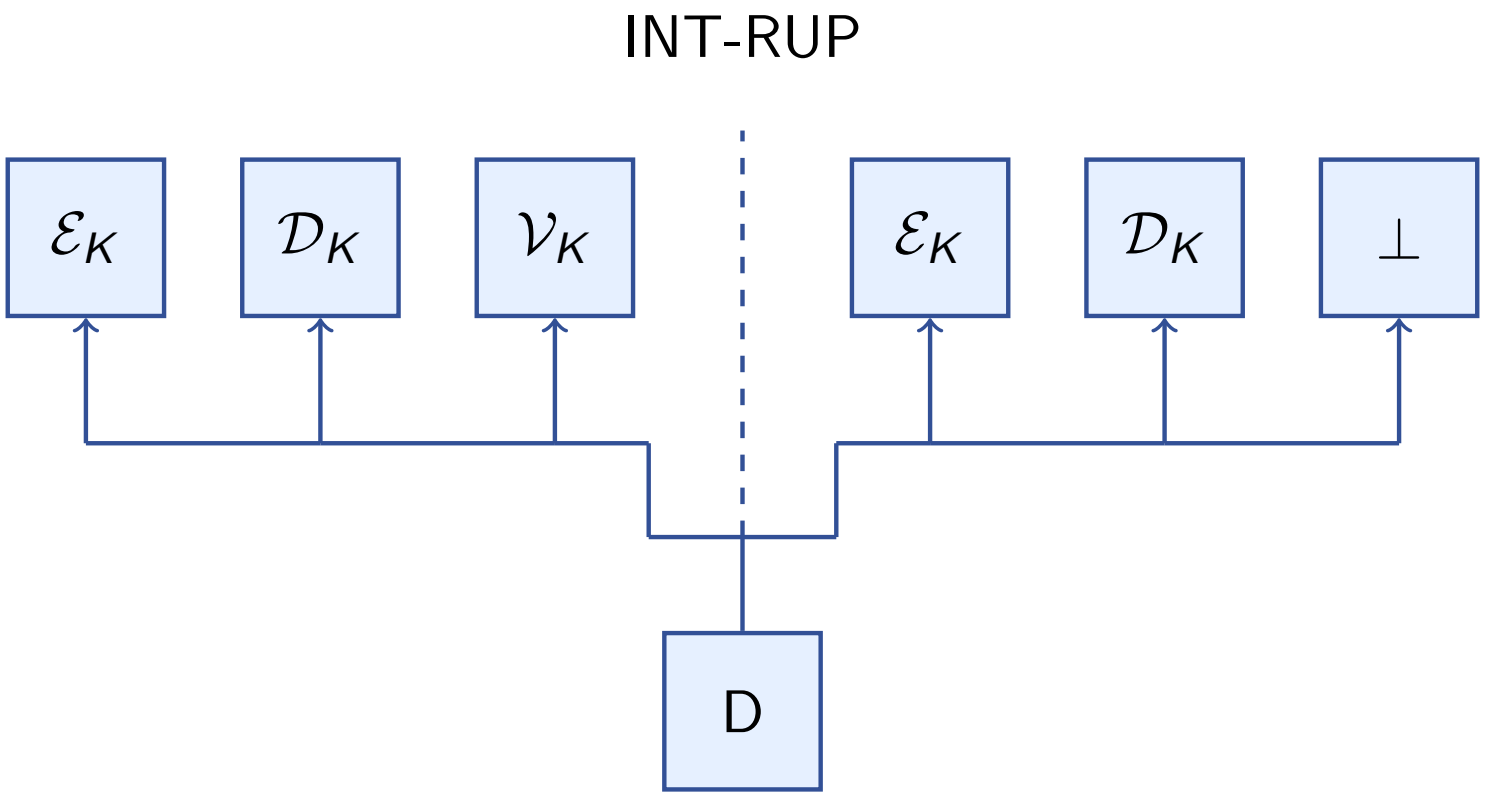




Conventional Integrity

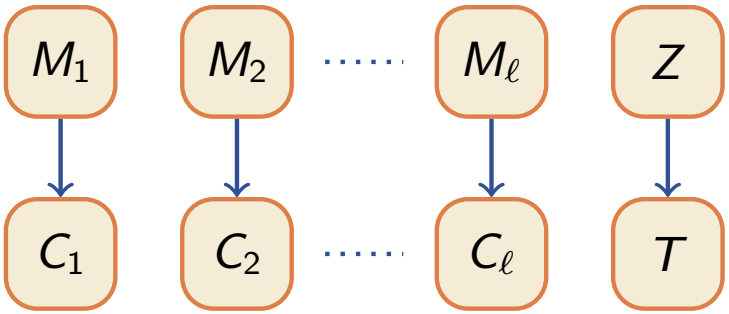


RUP Integrity



OCB Attack

1. $\mathcal{E}_K$-query, $Z := \bigoplus_{i=1}^{\ell} M_i$



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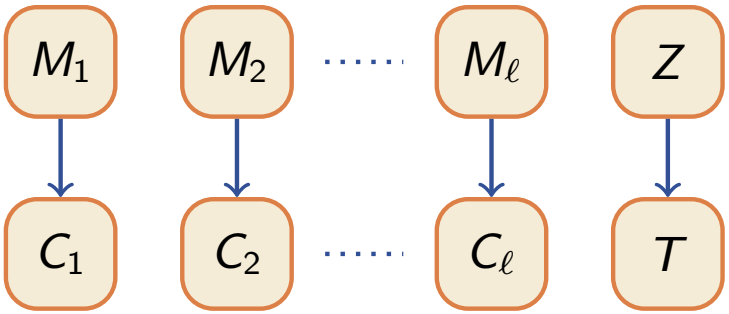
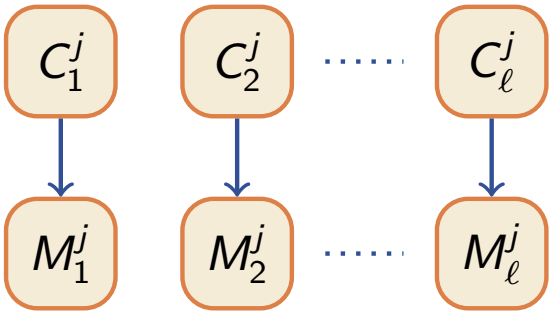


2. Two $\mathcal{D}_K$-queries, $j = 0, 1$:



$C_i \neq C_i^j, C_i^1 \neq C_i^0$ for all i, j

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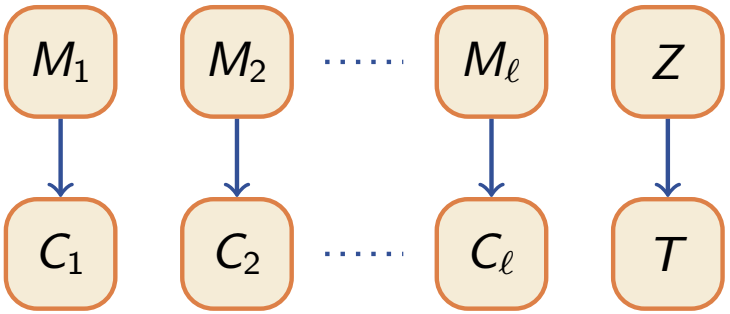

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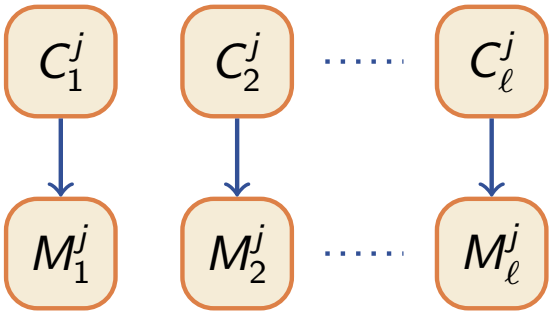

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3. Solve system of equations

$$\begin{pmatrix} z'_1 \\ z'_2 \\ \vdots \\ z'_n \end{pmatrix} = \begin{pmatrix} M_1^0 \oplus M_1^1 & \cdots & M_\ell^0 \oplus M_\ell^1 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_\ell \end{pmatrix}$$

where $Z' = \bigoplus_{i=1}^{\ell} M_i^1 \oplus Z$

OCB Attack

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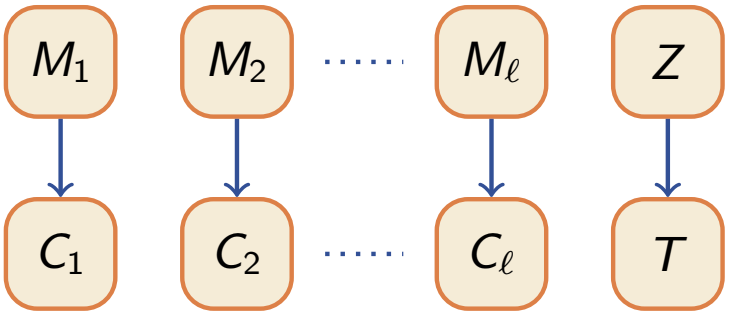

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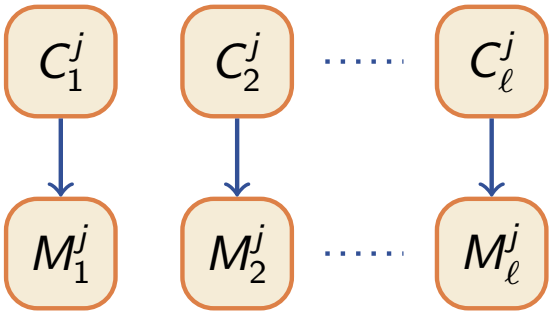

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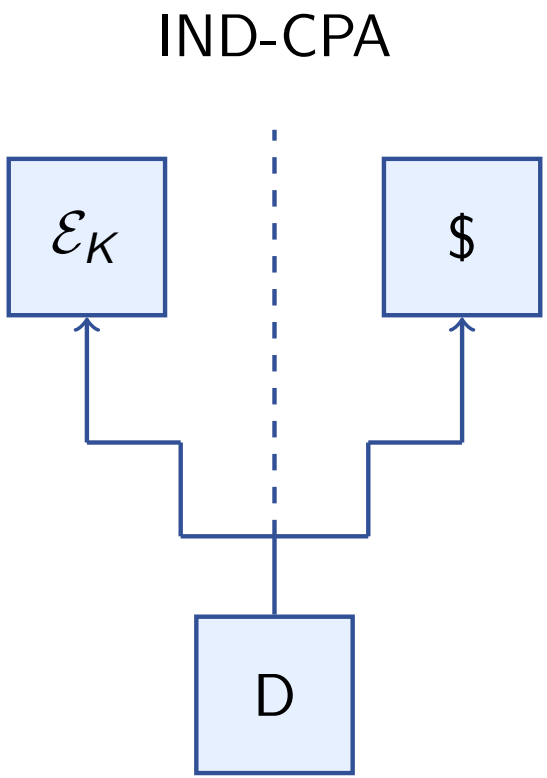
where $Z' = \bigoplus_{i=1}^{\ell} M_i^1 \oplus Z$

4. Submit forgery:

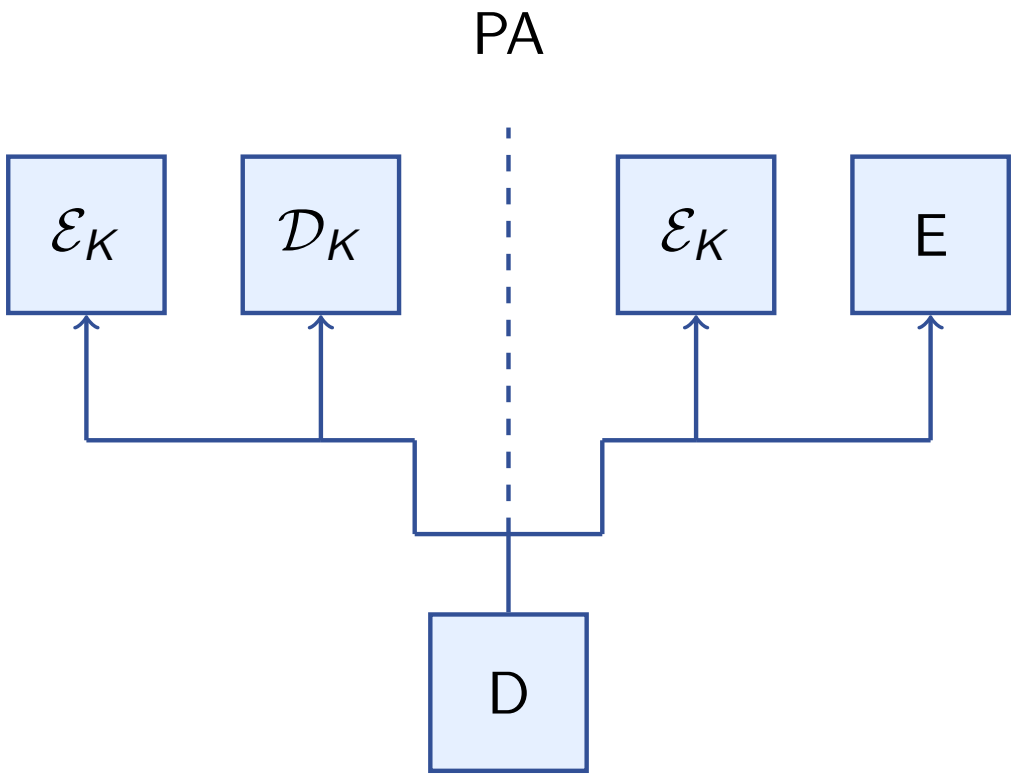
$$C' = C_1^{x_1} C_2^{x_2} \cdots C_\ell^{x_\ell}$$

Probability of success at least $1 - 2^{n-\ell}$

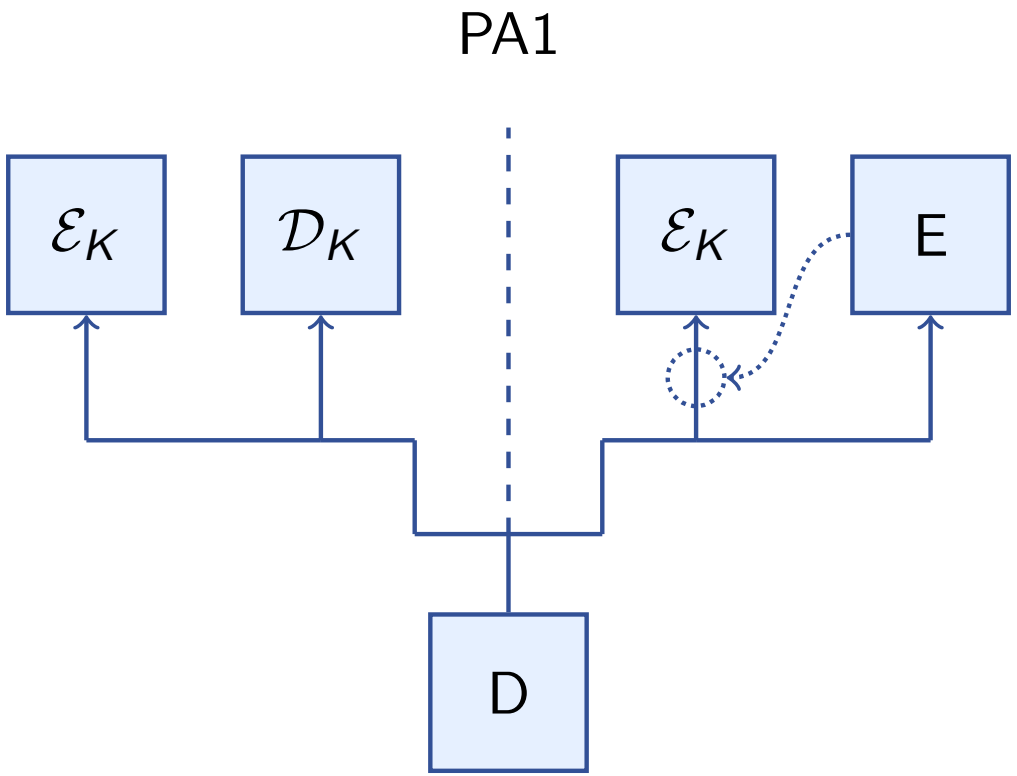
Confidentiality



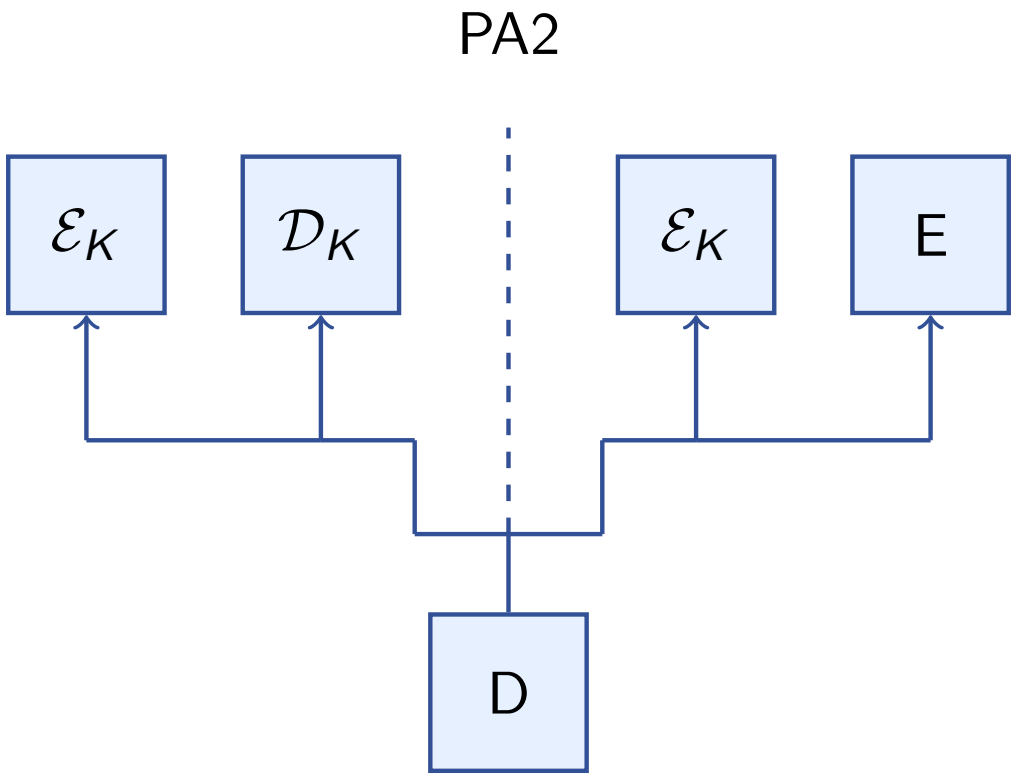
Plaintext Awareness



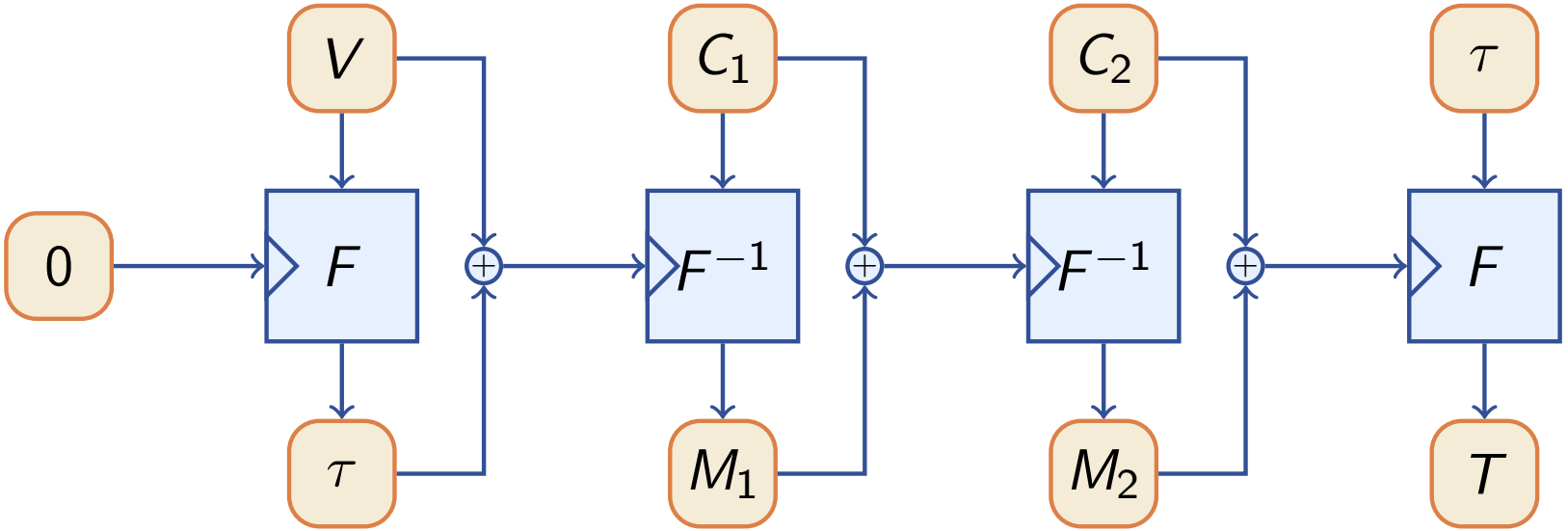
Plaintext Awareness



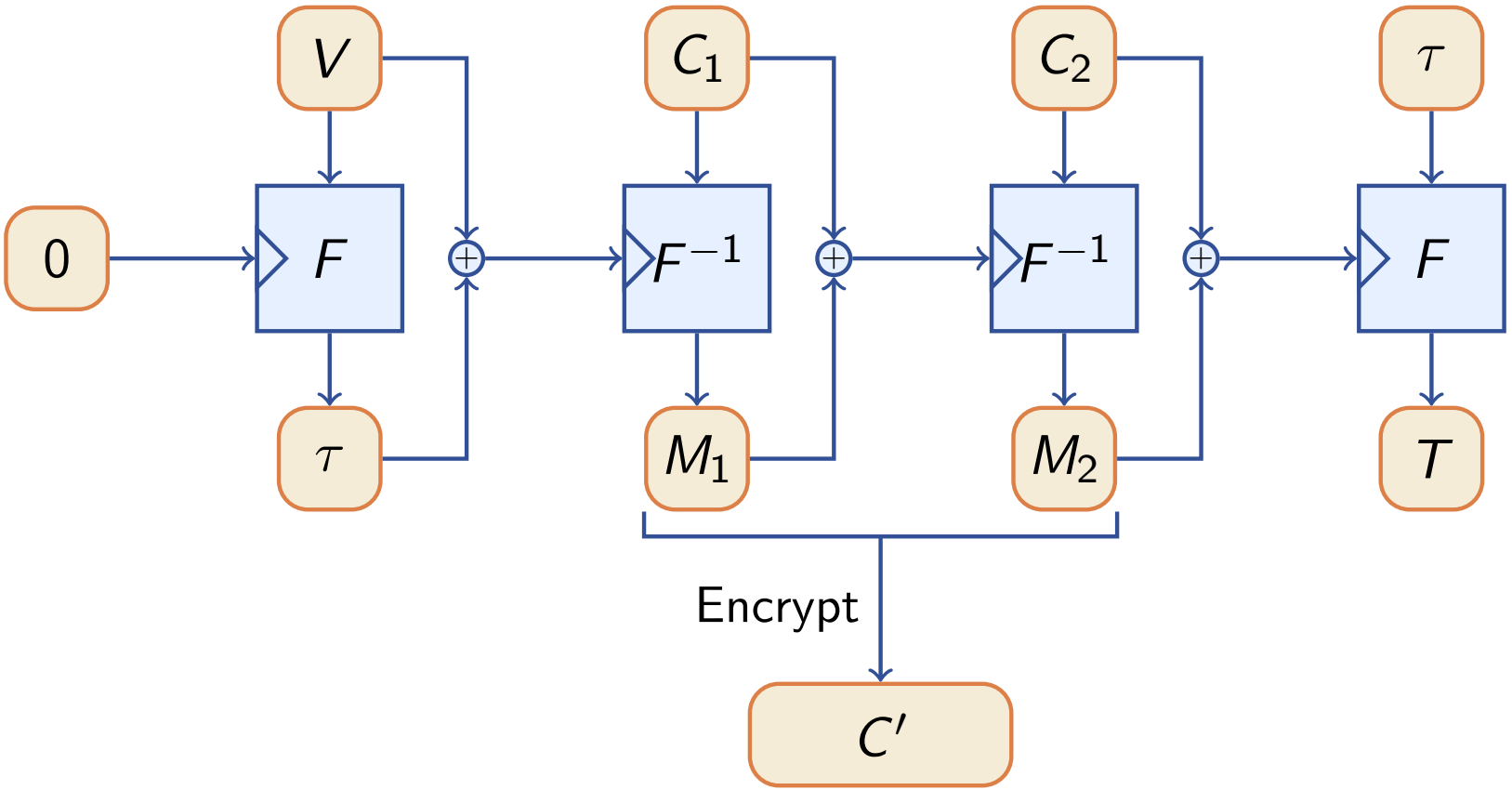
Plaintext Awareness



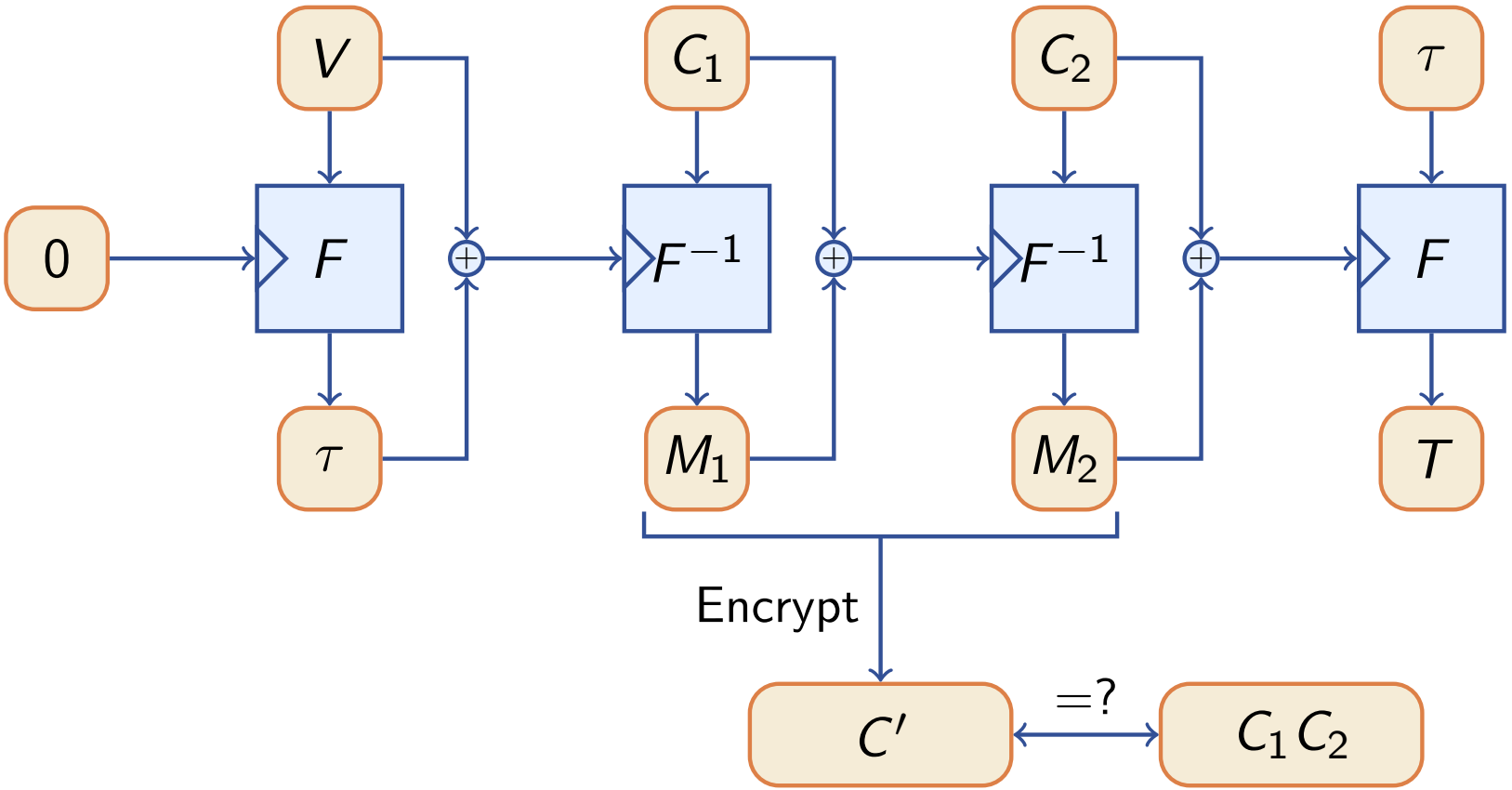
McOE-G Is Not PA1



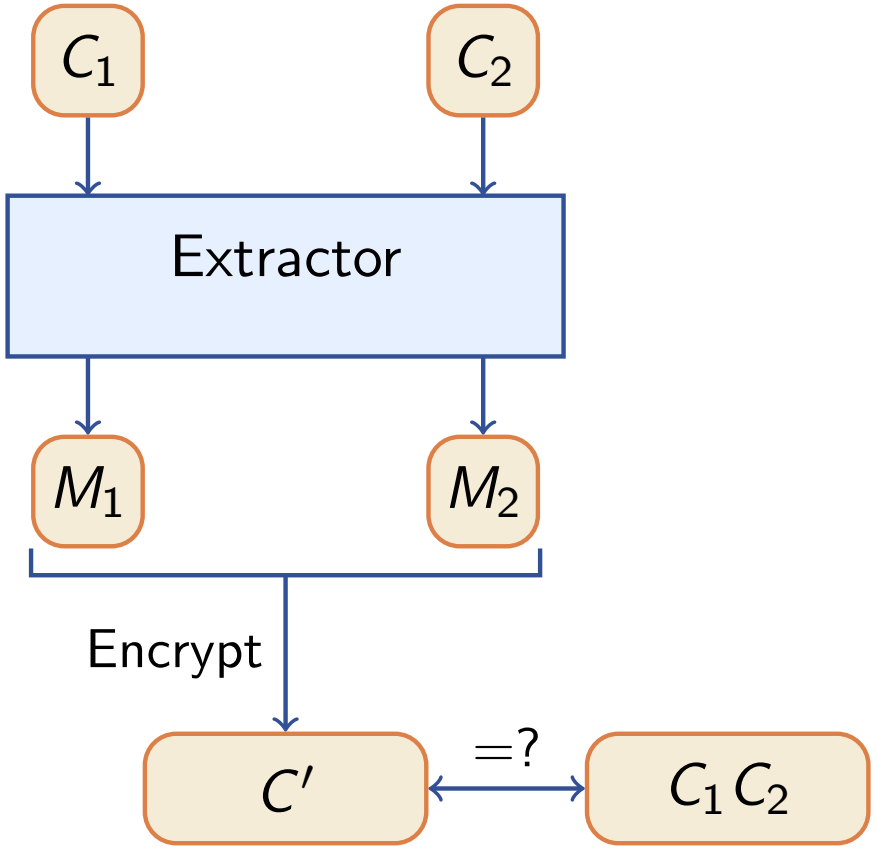
McOE-G Is Not PA1



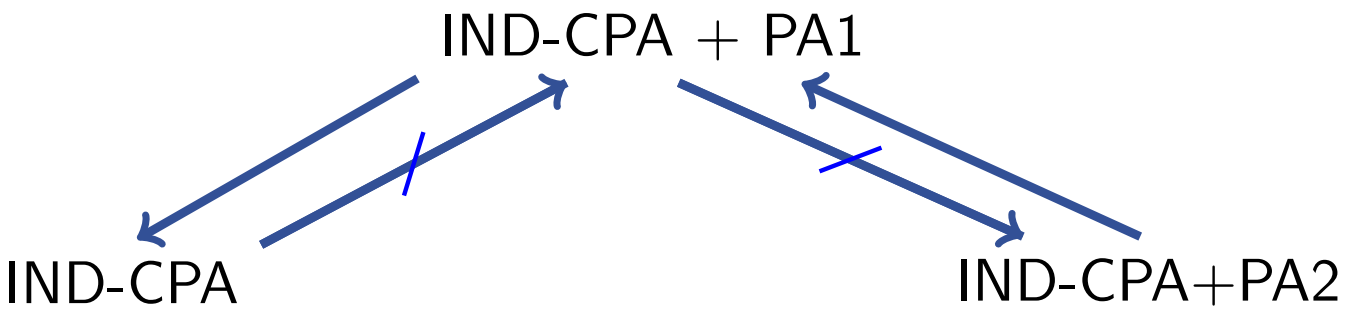
McOE-G Is Not PA1



McOE-G Is Not PA1



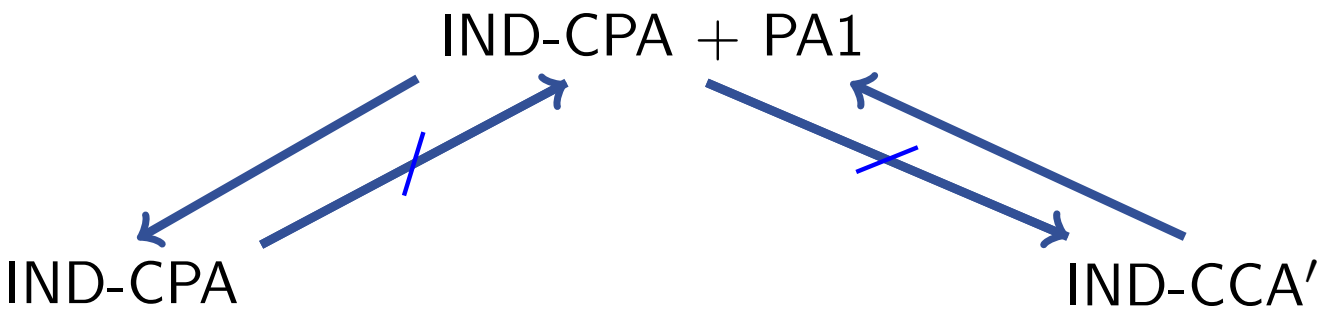
Relations



Nonce + Arbitrary IV

All IVs

Relations



Nonce + Arbitrary IV

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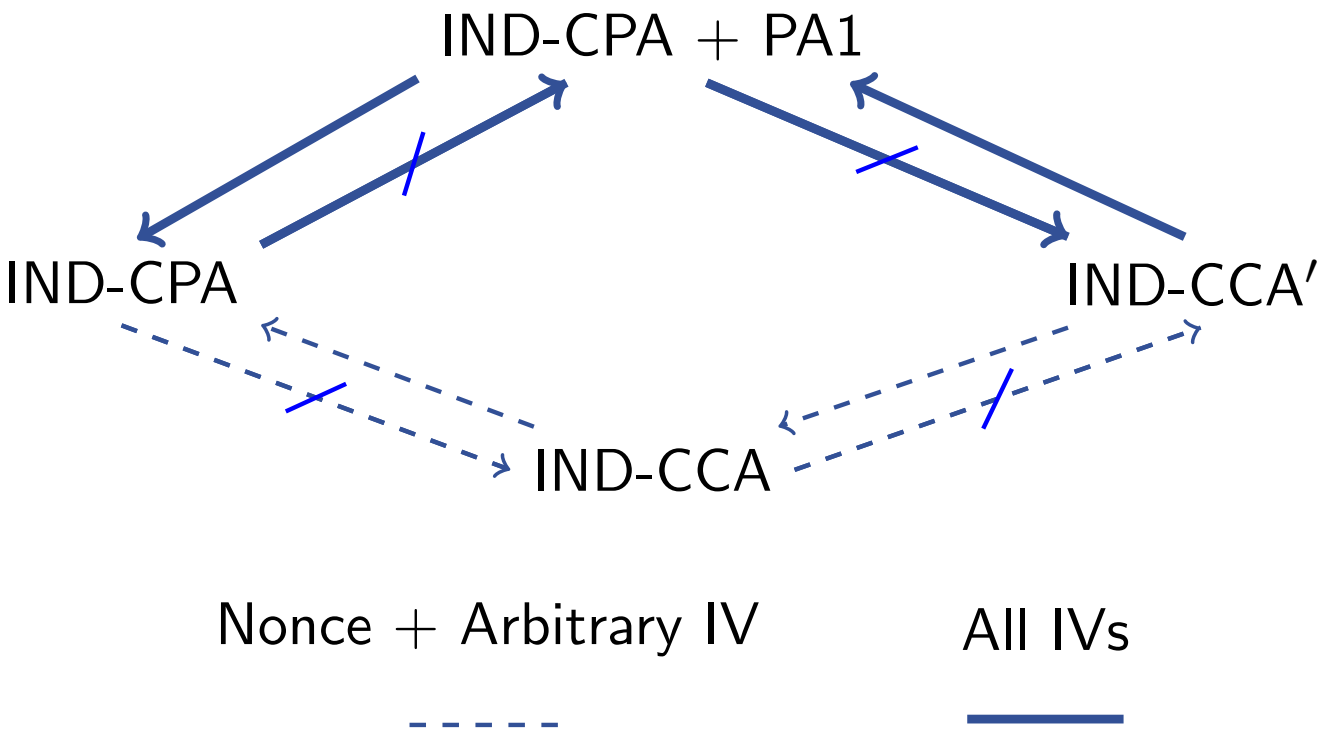
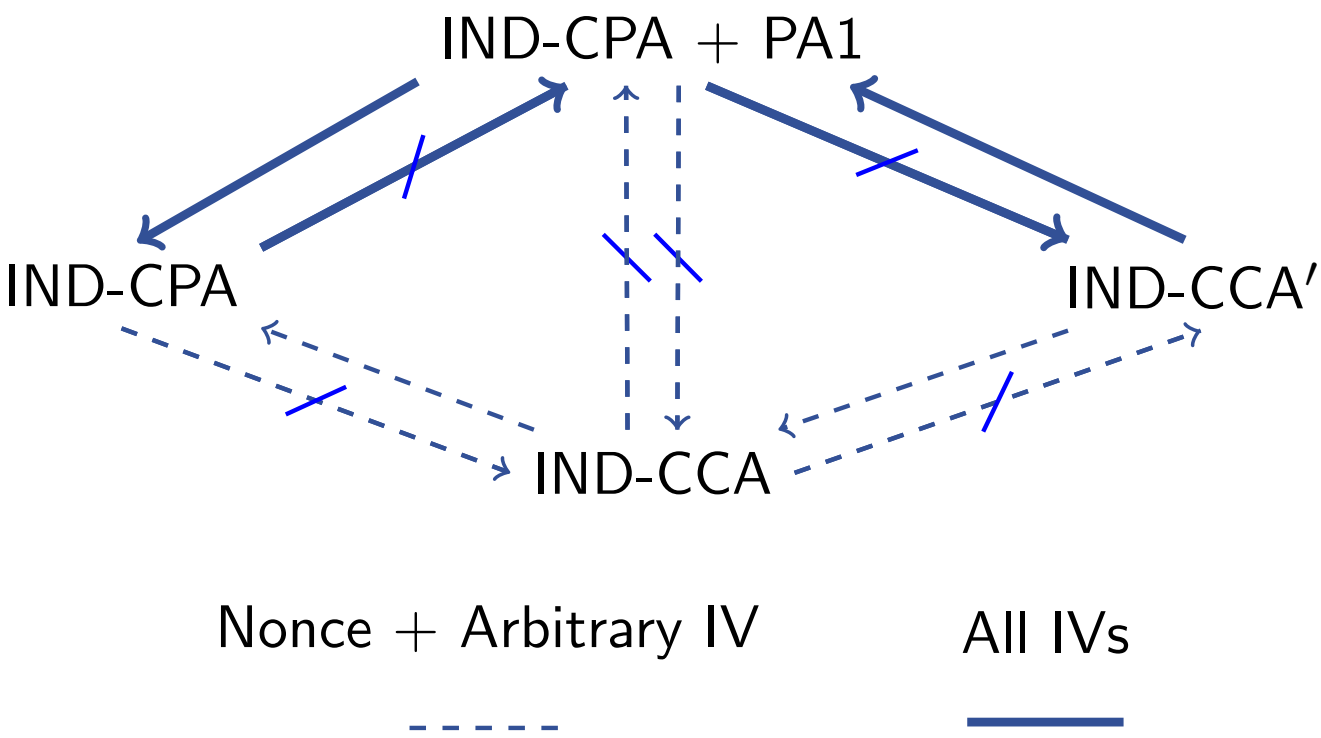


Relations



PA Classification of Schemes

IV type	Online	Scheme	PA1	PA2	Remark
random	✓	CTR, CBC	✓	✗	
nonce	✓	OCB	✗	✗	
	✓	GCM, SpongeWrap	✗	✗	
	✗	CCM	✗	✗	not online
arbitrary	✓	COPA	✗	✗	privacy up to prefix
	✓	McOE-G	✗	✗	//
	✓	APE	✓	✗	//, backwards decryption
	✗	SIV, BTM, HBS	✓	✗	privacy up to repetition
	✗	Encode-then-Encipher	✓	✓	//, VIL SPRP, padding

Conclusions

Formalization

1. Integrity: INT-RUP
2. Confidentiality: IND-CPA + PA1/2

Analysis

1. OCB, COPA INT-RUP attack
2. Relations among PA notions
3. Classification via PA1/2

More can be found in `http://eprint.iacr.org/2014/144`