Four Attacks and a Proof for Telegram

RWC 2022

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Martin R. Albrecht, Lenka Mareková, Kenneth G. Paterson, Igors Stepanovs

Royal Holloway, University of London; ETH Zürich

Based on the paper to appear at IEEE S&P 2022.

More information at: https://mtpsym.github.io/

Background

Monthly active users in Jan 2022:

According to Statista 2022.

WhatsApp	$2000 \cdot 10^6$
WeChat	$1263 \cdot 10^6$
FB Messenger	$988 \cdot 10^6$
QQ	$574 \cdot 10^6$
Snapchat	$557 \cdot 10^6$
Telegram	$550 \cdot 10^6$

Collective Information Security in Large-Scale Urban Protests: the Case of Hong Kong

Martin R. Albrecht, Jorge Blasco, Rikke Bjerg Jensen, and Lenka Mareková, *Royal Holloway, University of London*

Telegram was the predominant messaging application used in the Hong Kong protests in 2019-2020.

Telegram was perceived to provide more security than its competitors.

Important advantages of **Telegram**:

- Support of public and private **group chats** for up to 200'000 people (**Signal** up to 1'000; **WhatsApp** up to 256).
- **Pseudonimity**: can use a pseudonym, not revealing phone number to others (not supported in **Signal** and **WhatsApp**).
- **Other features**: anonymous polls; disappearing messages; timed or scheduled messages; ability to delete messages sent by others.

Common use cases: large public groups up to 50'000 members, and small private groups.

Cloud Chats and Secret Chats

	Cloud Chats	Secret Chats
Group communication	✓	✗
1-on-1 communication	✓	✓
Type of encryption	client-server	end-to-end
Enabled by default?	✓	✗

"Q: Why are you not using X? (insert solution)
While other ways of achieving the same cryptographic goals, undoubtedly, exist, we feel that the present solution is both robust and also succeeds at our secondary task of beating unencrypted messengers in terms of delivery time and stability."

Telegram FAQ (https://core.telegram.org/techfaq)

Why not use TLS instead of MTProto?

The **MTProto** protocol – **Telegram**'s equivalent of the **TLS record protocol**.

Cloud Chats encrypt and authenticated messages using **MTProto**.
Secret Chats add another layer of **MTProto** encryption, i.e. messages are double-encrypted.

The **MTProto** protocol is not well-studied:

- **2013: Telegram launched** with MTProto 1.0.
- **2016: Jakobsen** and **Orlandi** showed that MTProto 1.0 is not CCA-secure.
- **2017: Telegram released MTProto 2.0** that addressed the security concerns.
- **2017: Sušánka** and **Kokeš** reported an attack based on improper validation in the Android client.
- **2018: Kobeissi** reported input validation bugs in Telegram's Windows Phone client.
- **2020: Miculan** and **Vitacolonna** proved MTProto 2.0 secure in a symbolic model, assuming ideal building blocks.

The focus in the literature has been on the **Secret Chats**.
We focus on the security of the **Cloud Chats**.

The Design of MTProto 2.0

MAC(mk, p)

msg_key ← SHA-256$(mk \| p)[64 : 192]$
Return msg_key

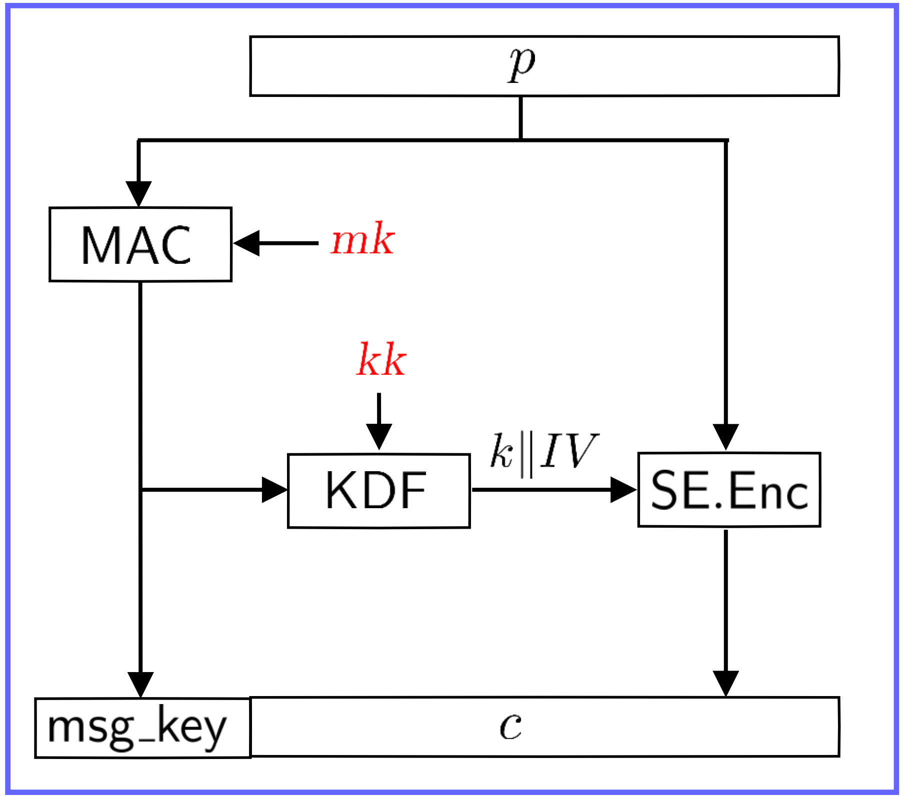
KDF$(kk,$ msg_key$)$

$(kk_0, kk_1) \leftarrow kk$
$k_0 \leftarrow$ SHA-256(msg_key$\|kk_0)$
$k_1 \leftarrow$ SHA-256$(kk_1\|$msg_key$)$
$k \leftarrow k_0 \| k_1$; Return k

payload p:

64 bits	64 bits	96 bits	32 bits	12-1024 bytes
server_salt	session_id	msg_seq_no	msg_length	msg_data padding

MTProto.Encrypt



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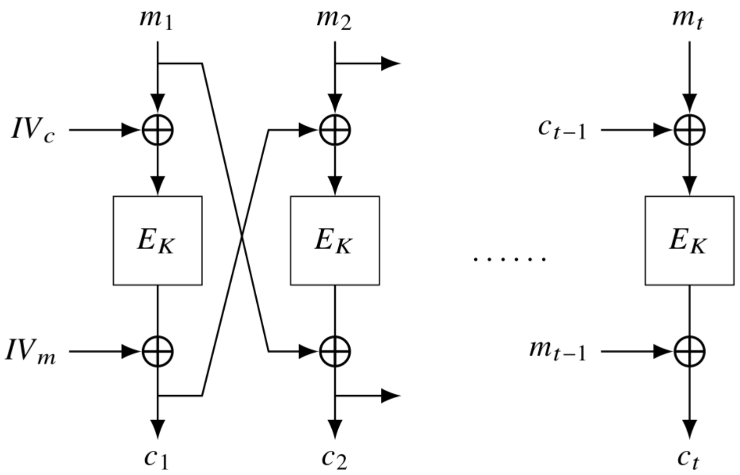

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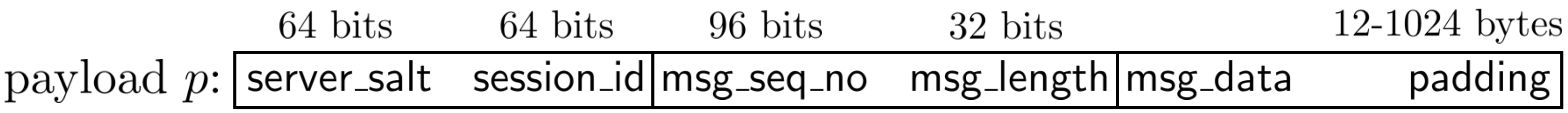

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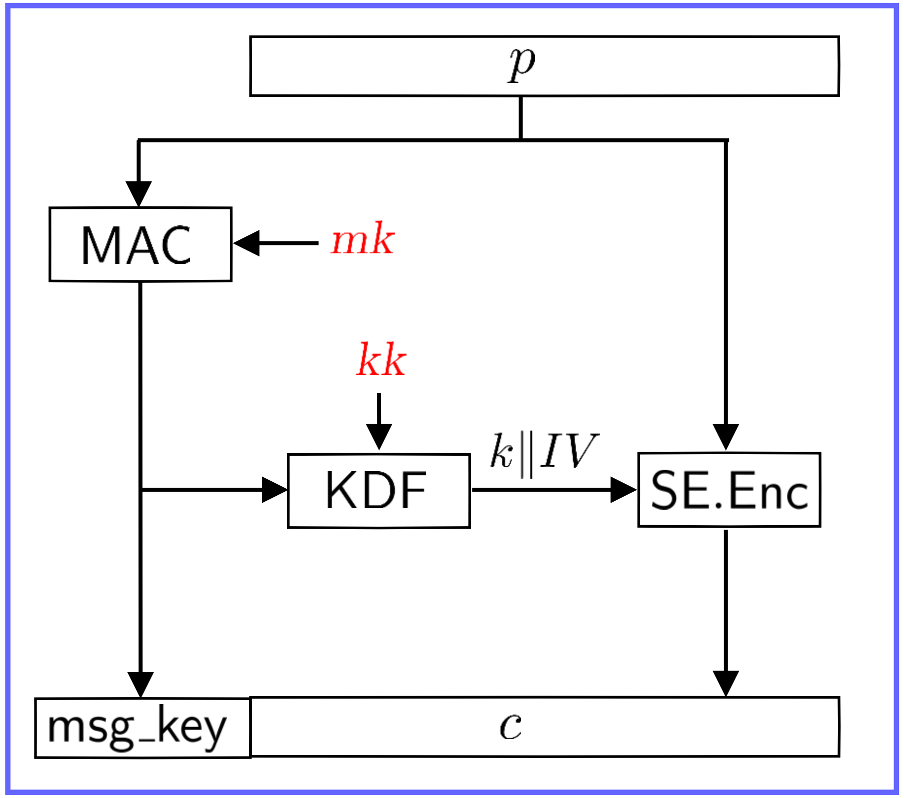

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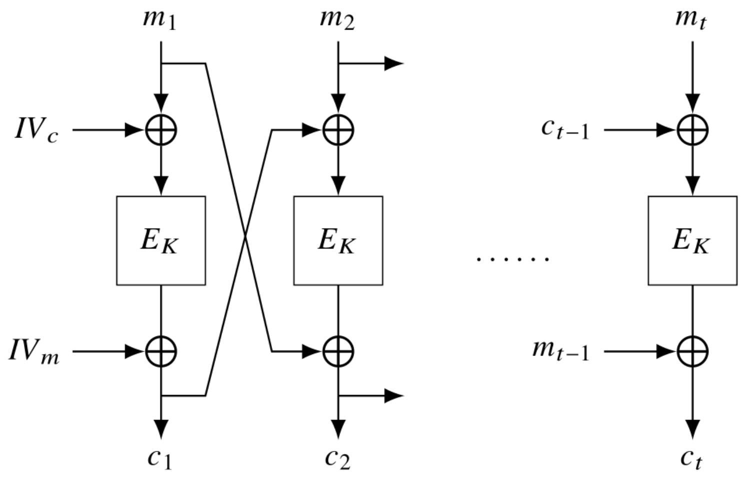

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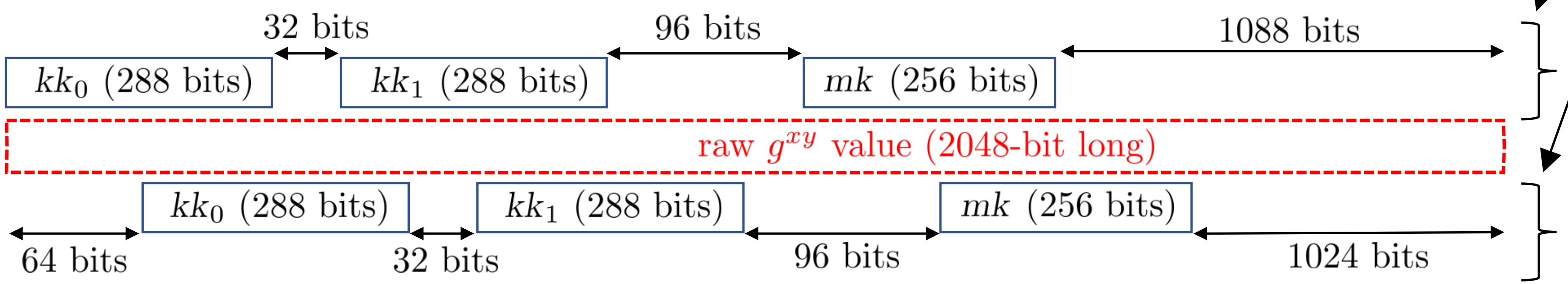

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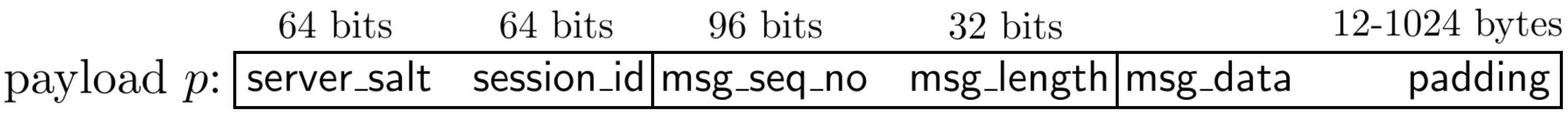

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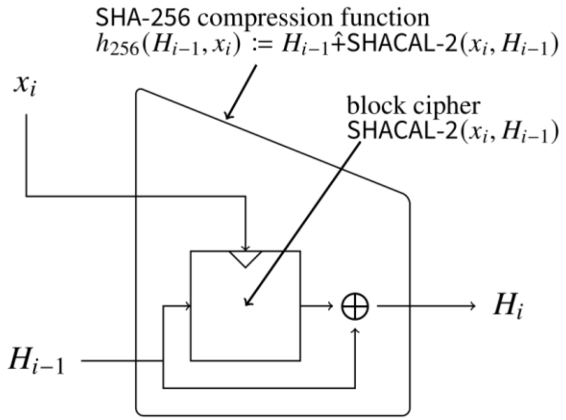

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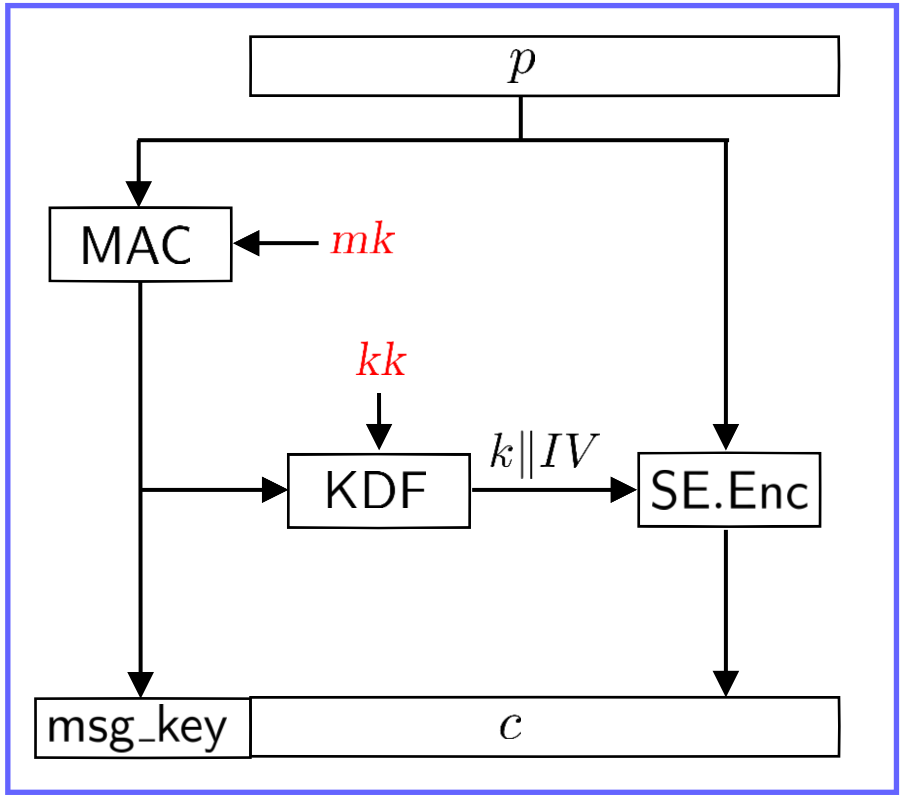

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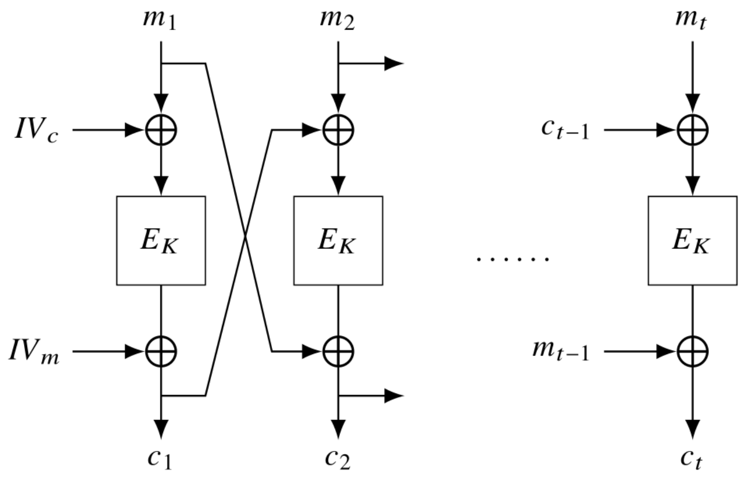

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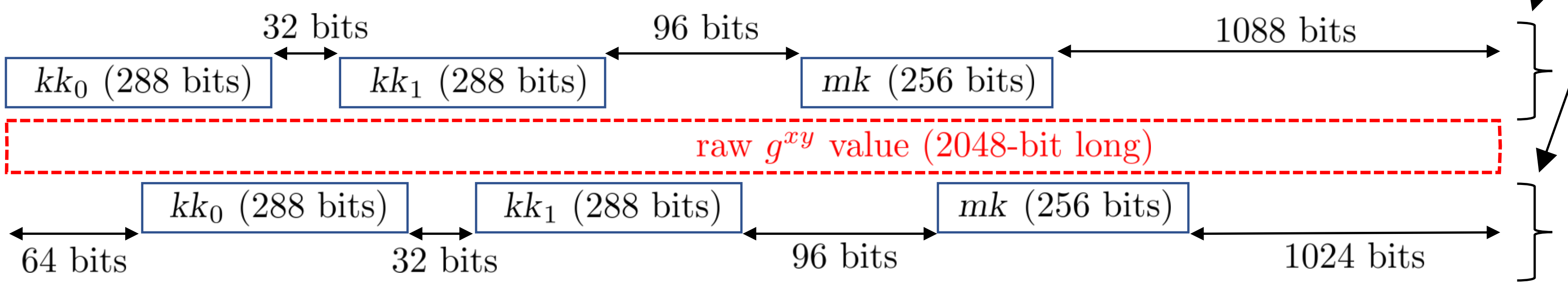

Four Attacks Against Telegram

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We found 4 weaknesses in MTProto.
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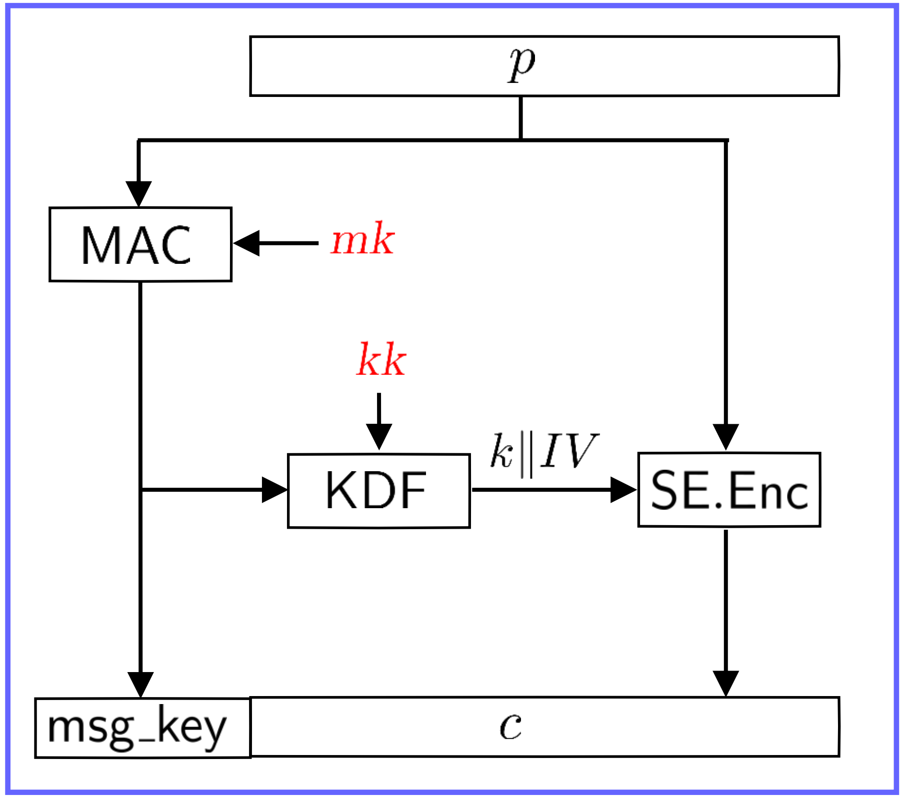

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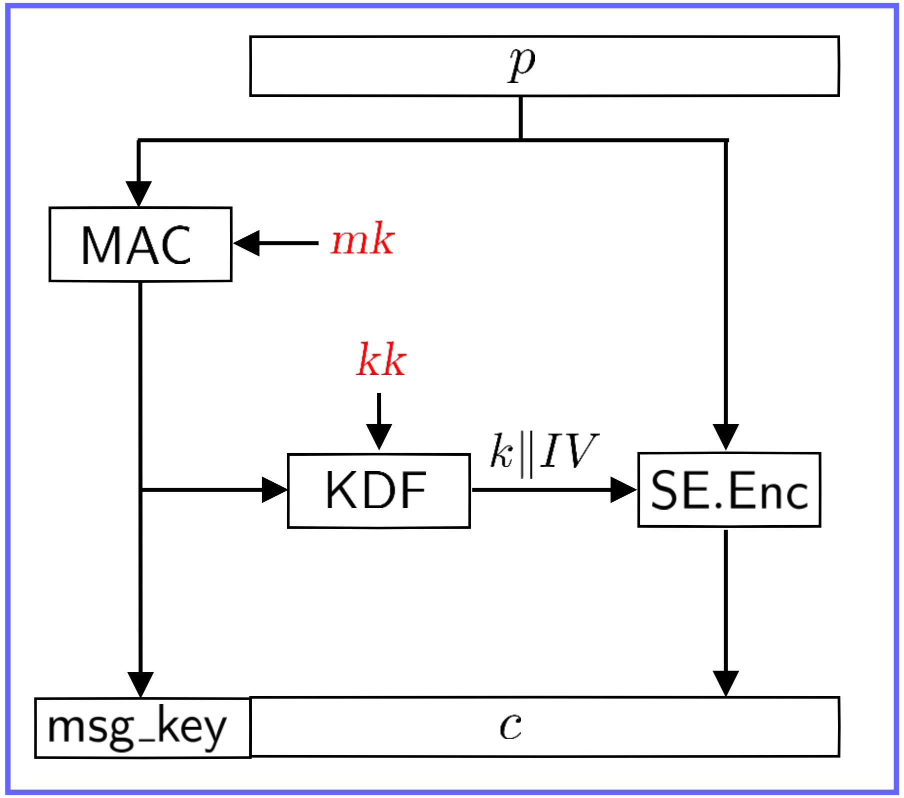

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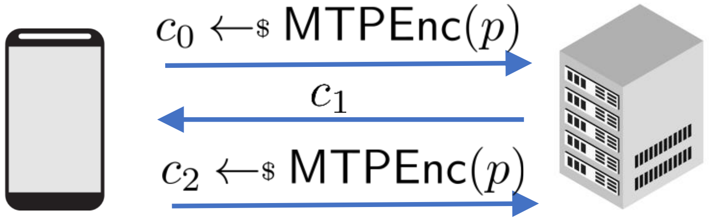

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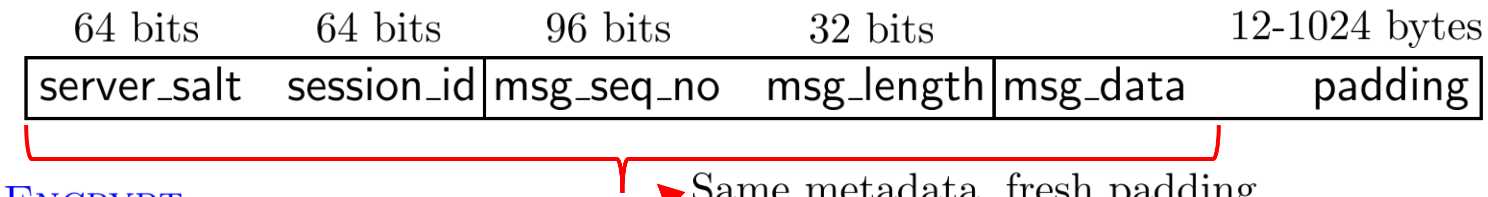

Same metadata, fresh padding.

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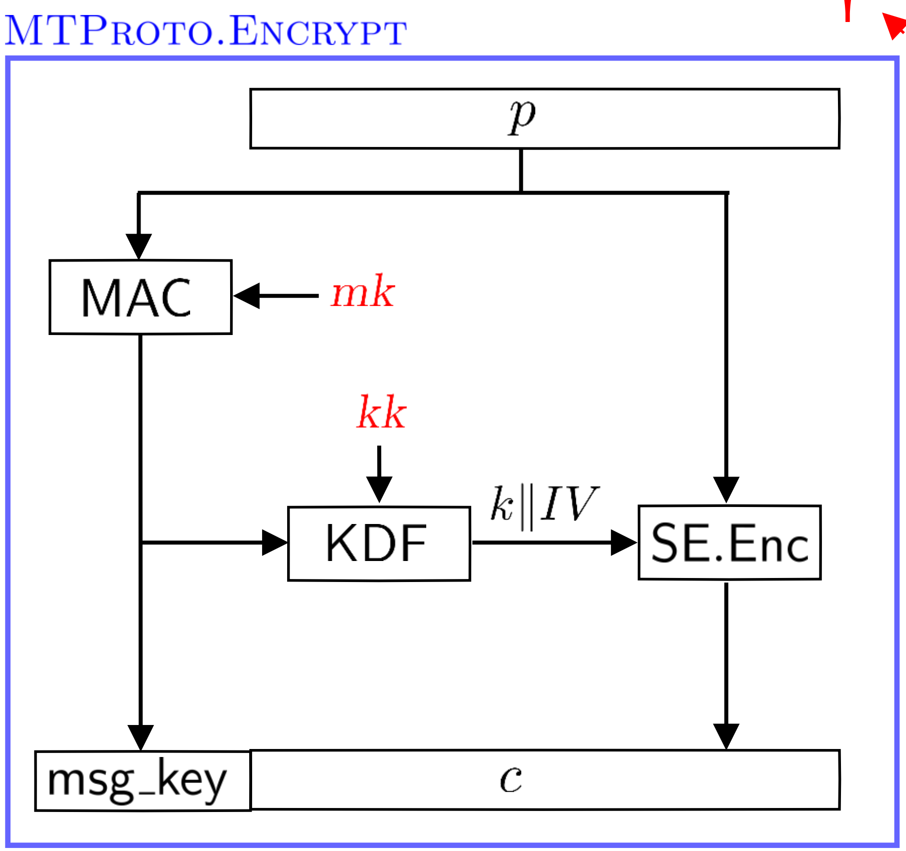

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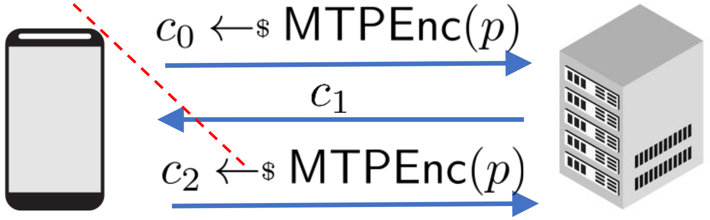

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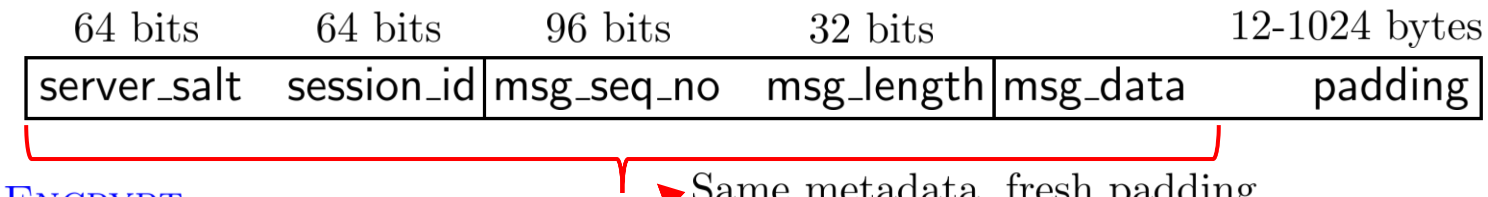

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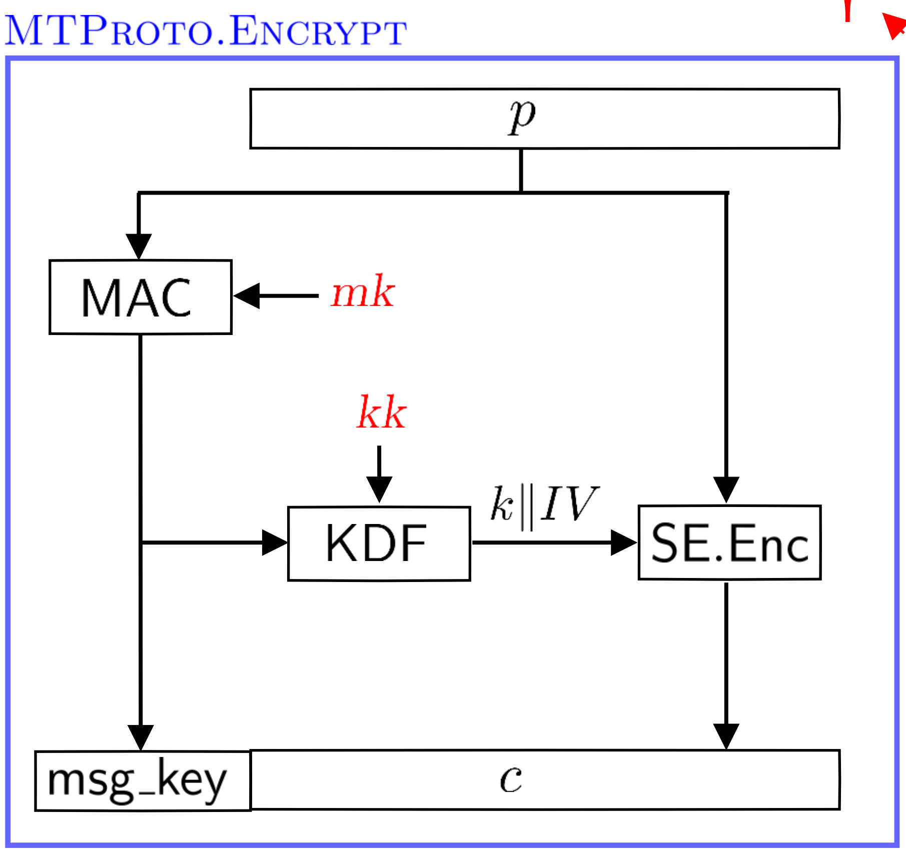

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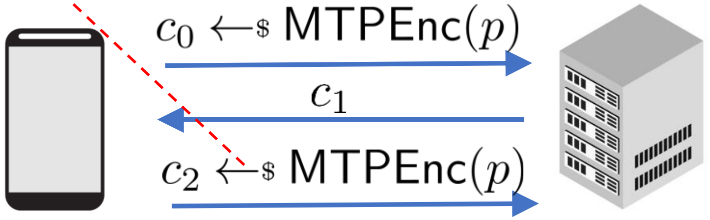

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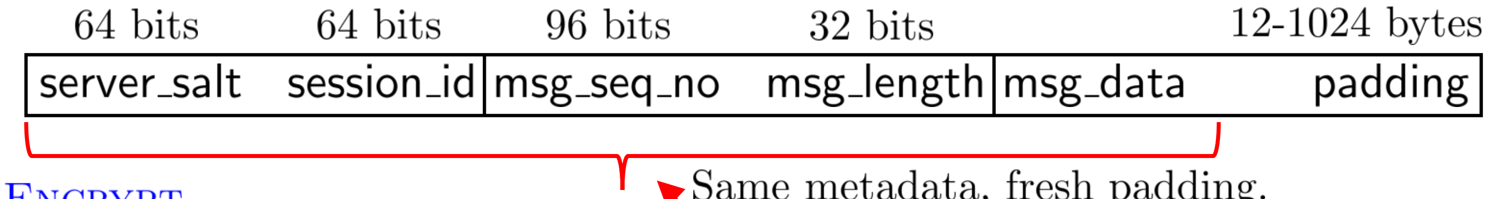

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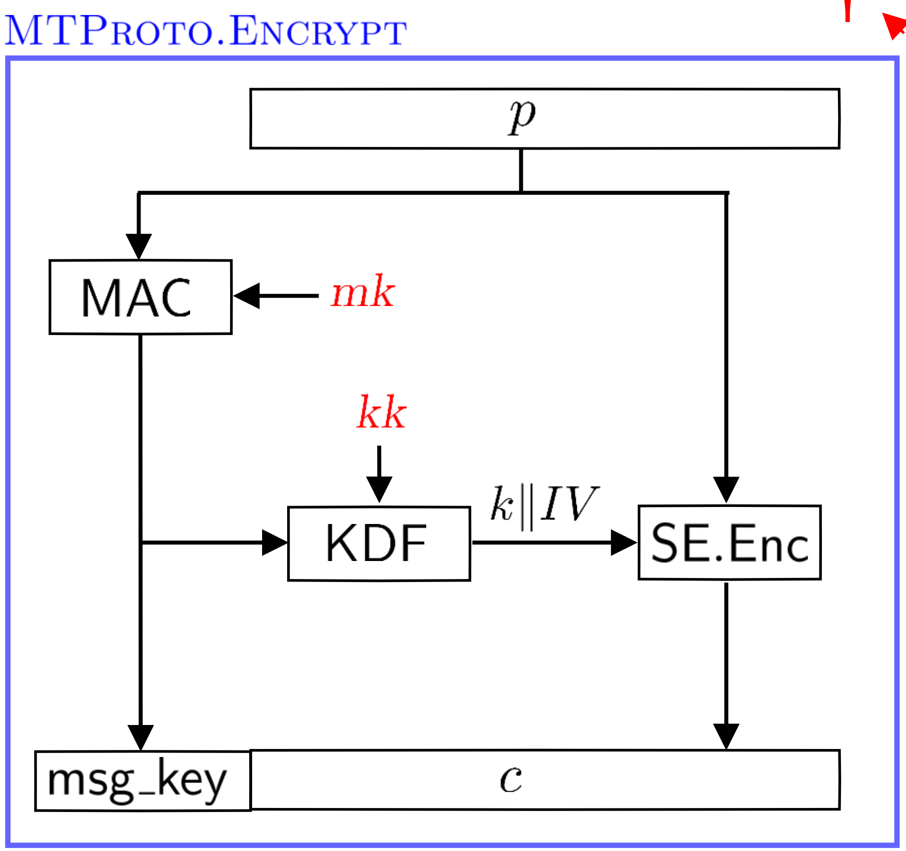

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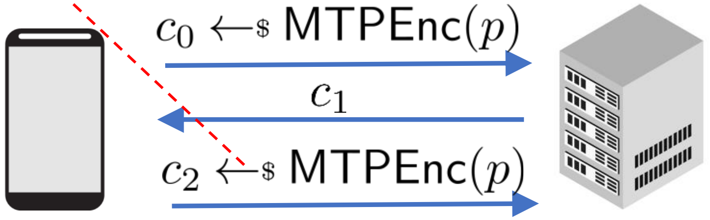

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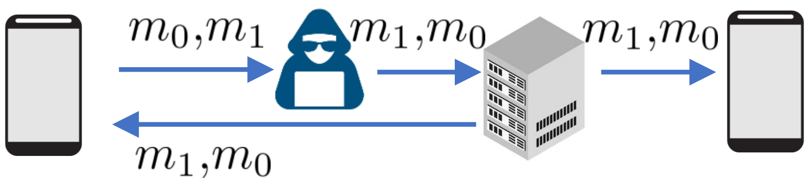

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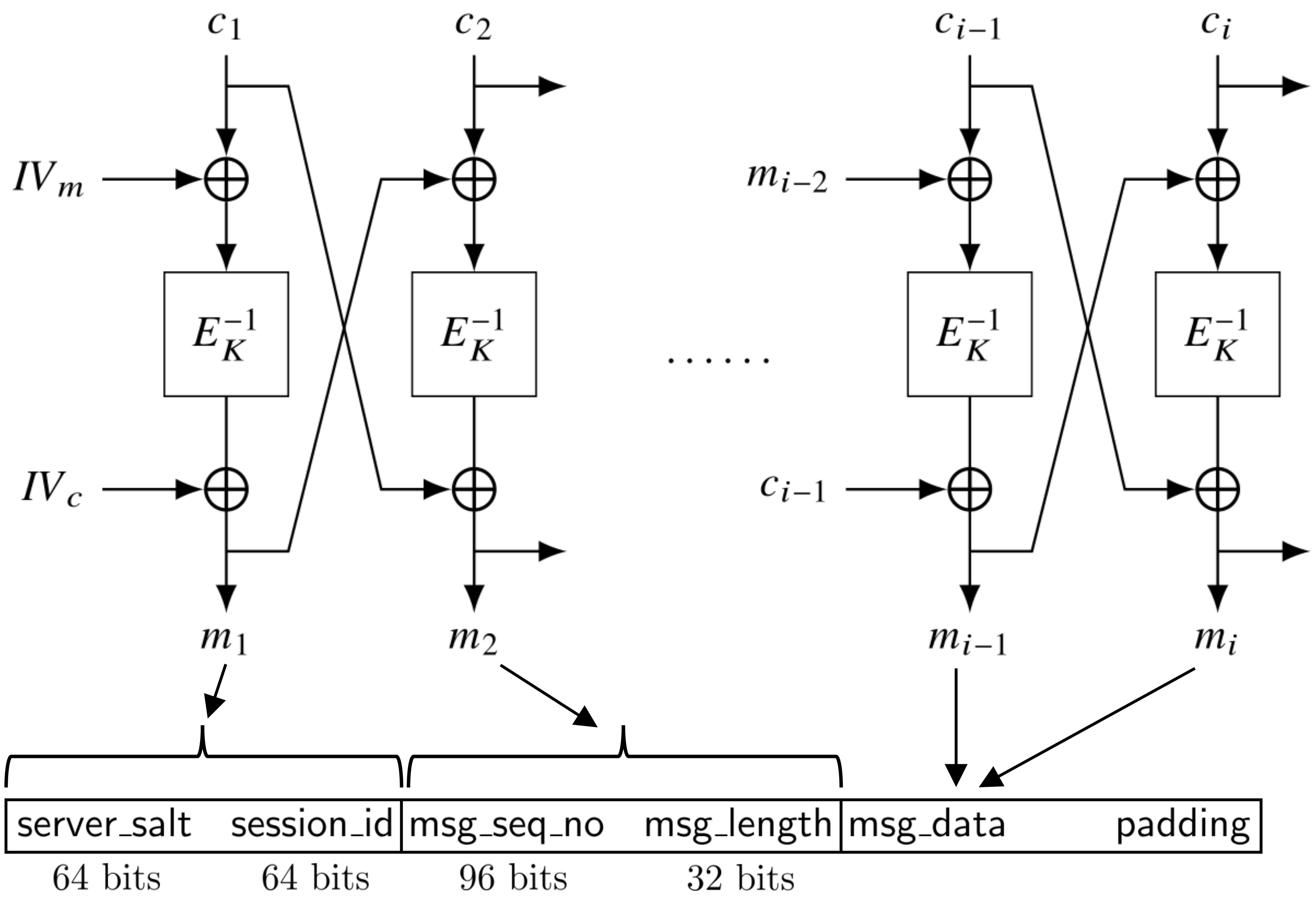

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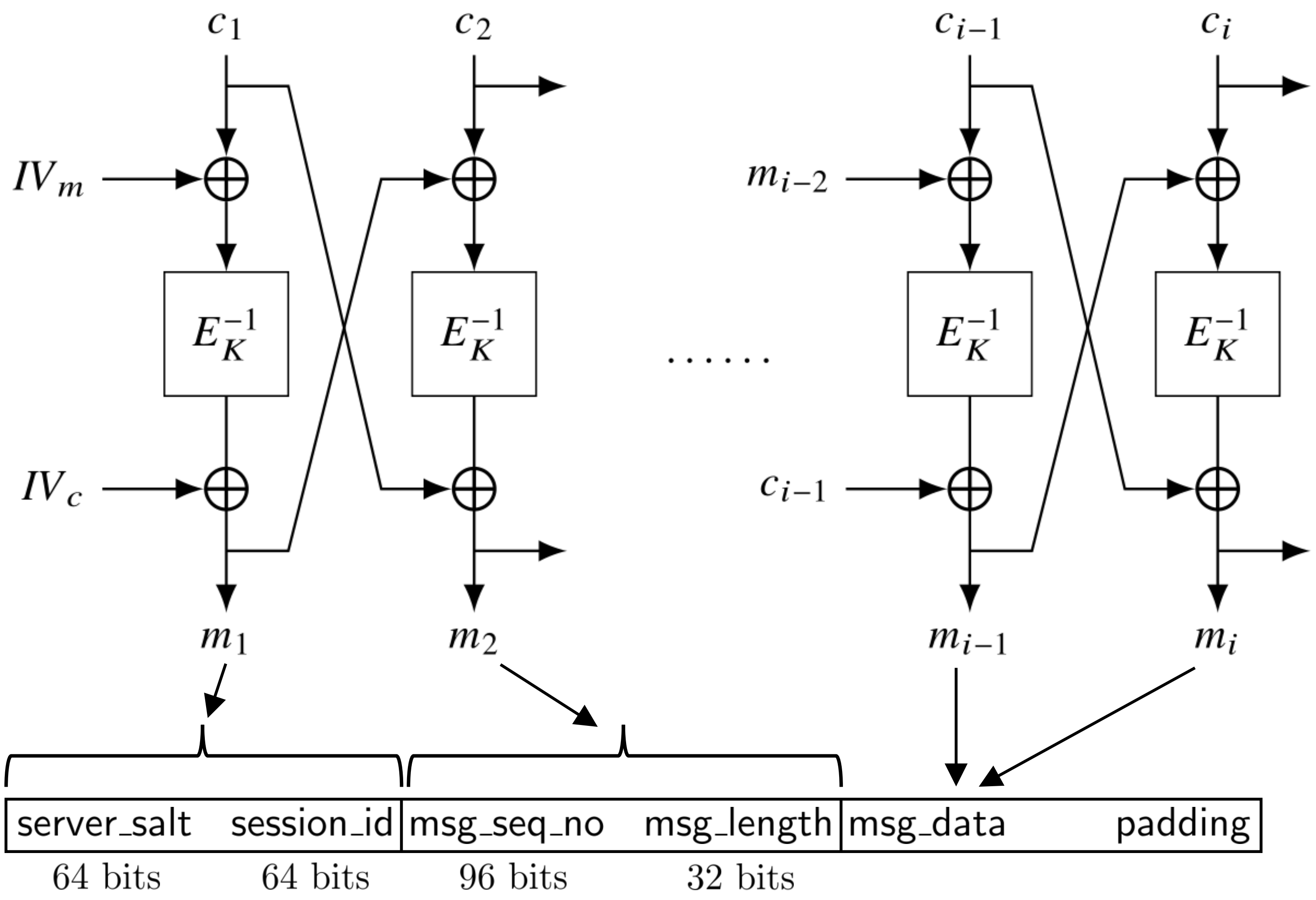

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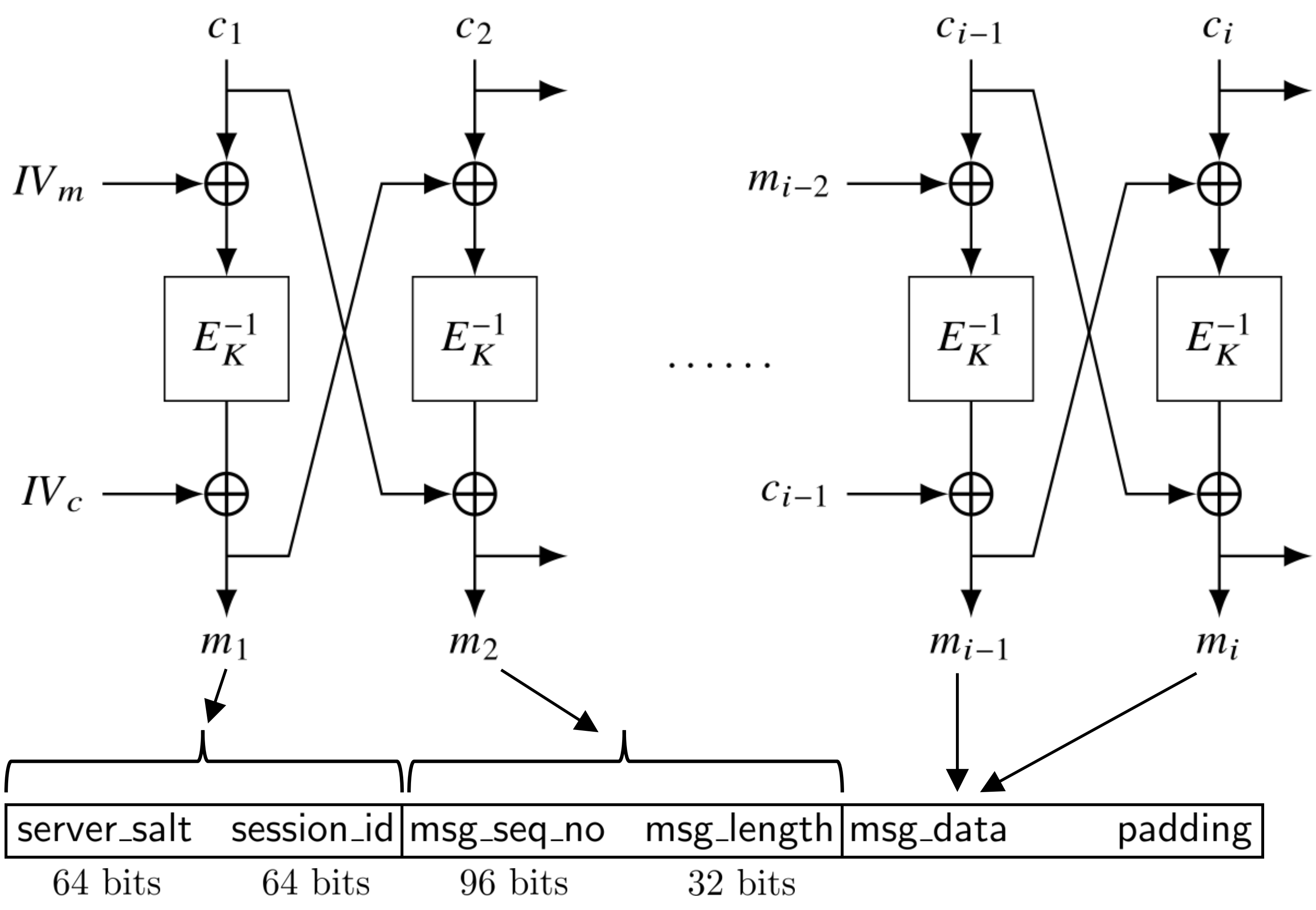

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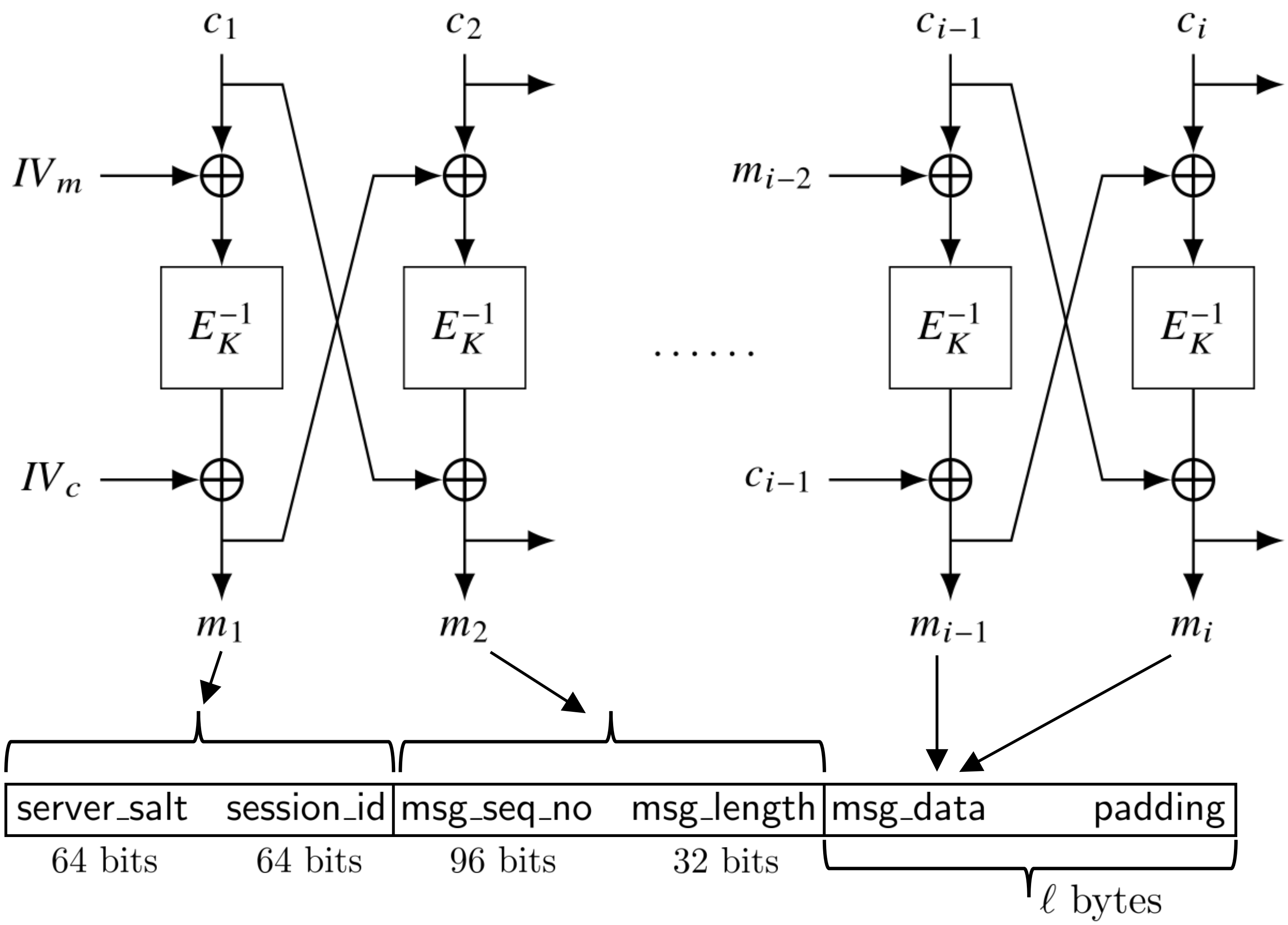

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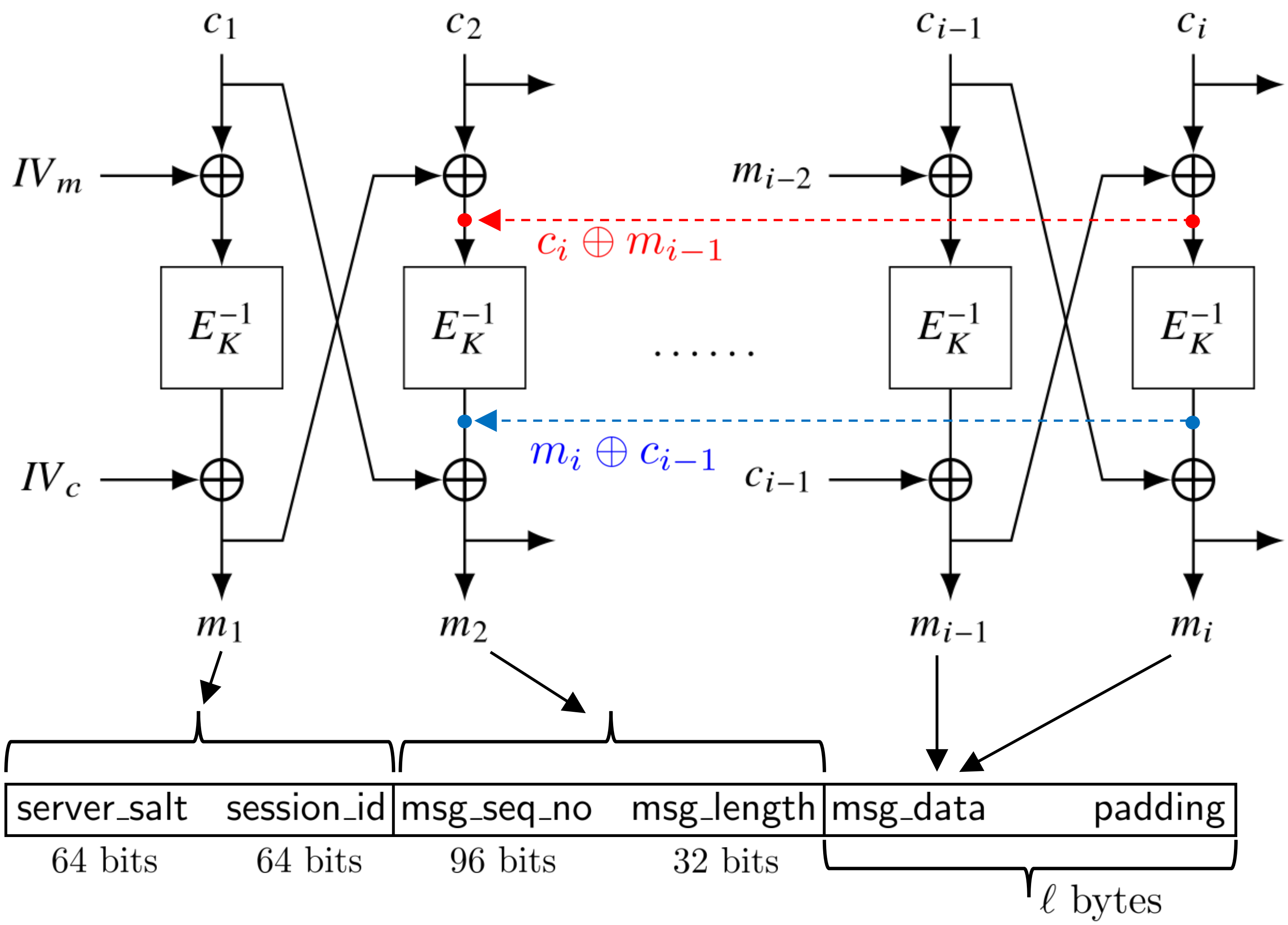

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Martin R. Albrecht, Kenneth G. Paterson and Gaven J. Watson

Assume we know contents of m_1 and m_{i-1}.
Want to learn the contents of m_i.
Set $c_2 := (c_i \oplus m_{i-1}) \oplus m_1$.
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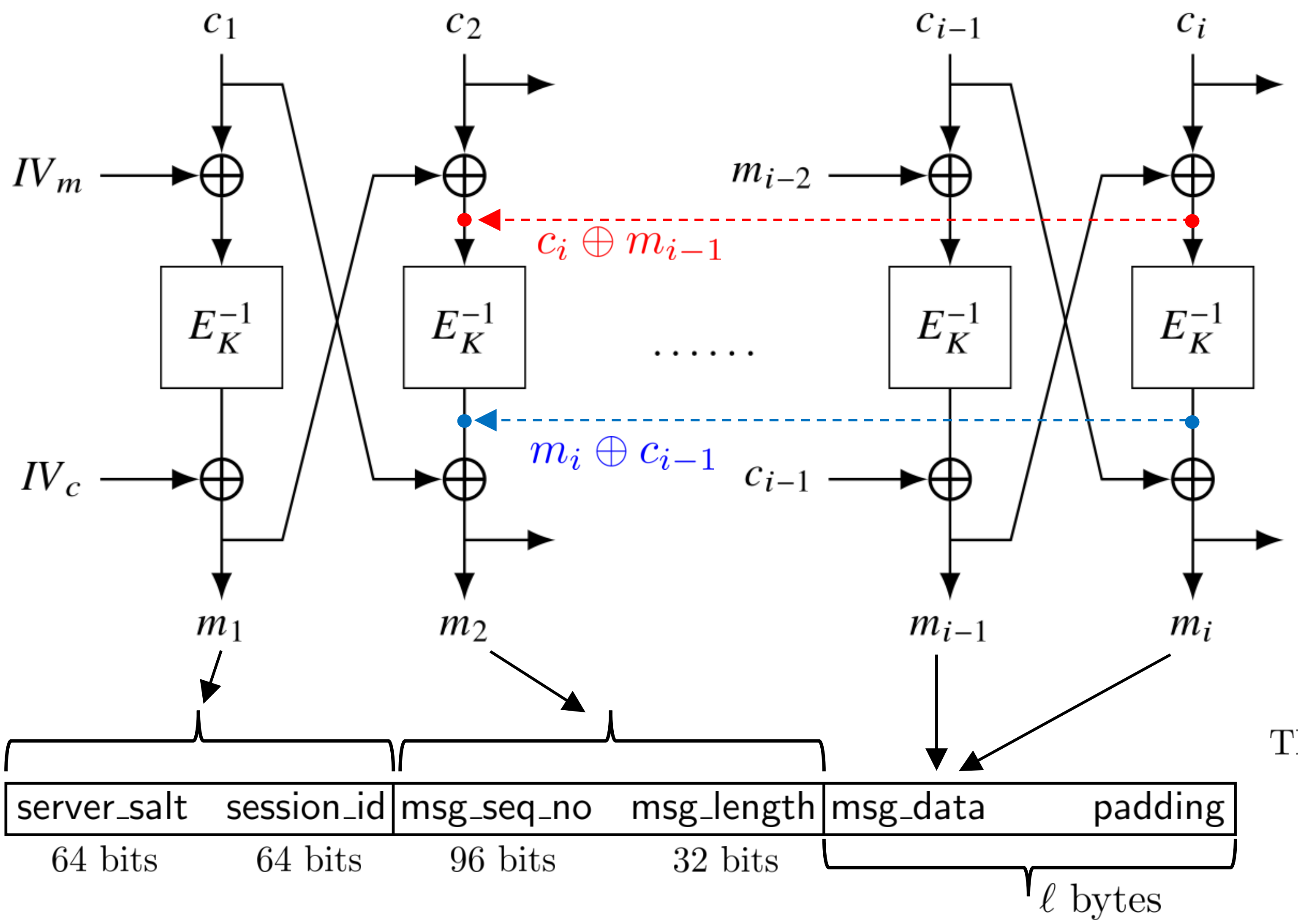

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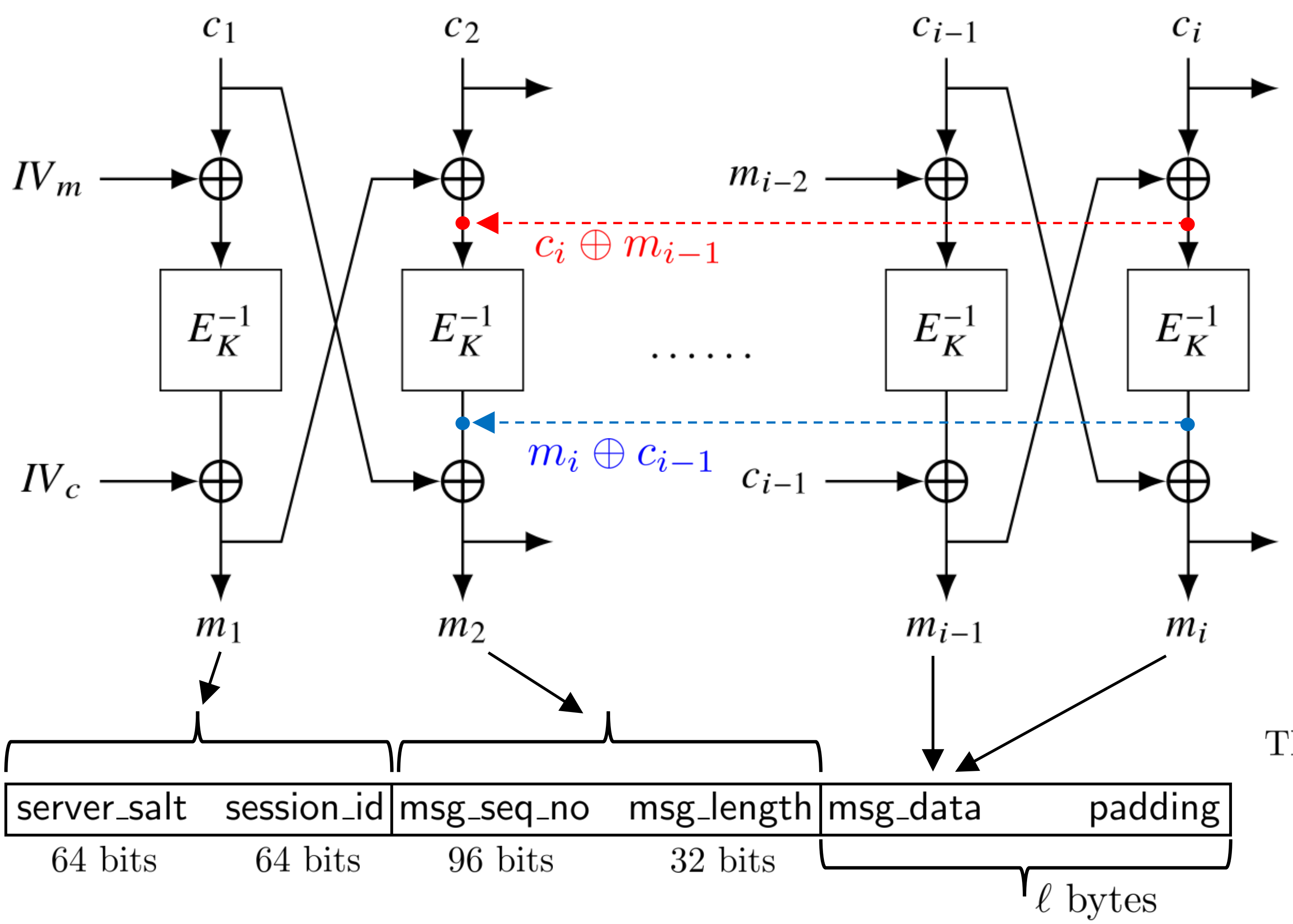

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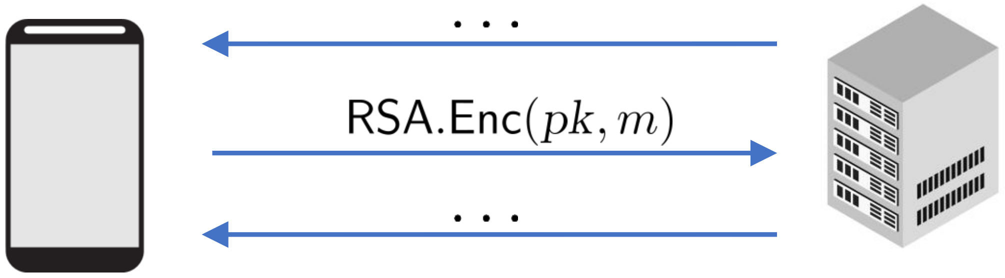
Our attack highlights the **brittle design**.
Stems from using Encrypt-and-MAC.
Operates with a decryption key on untrusted data.
Would be safer to protect integrity of ciphertext.

Timing Side-Channel Attack Against Servers

We attack **Telegram**'s key exchange.



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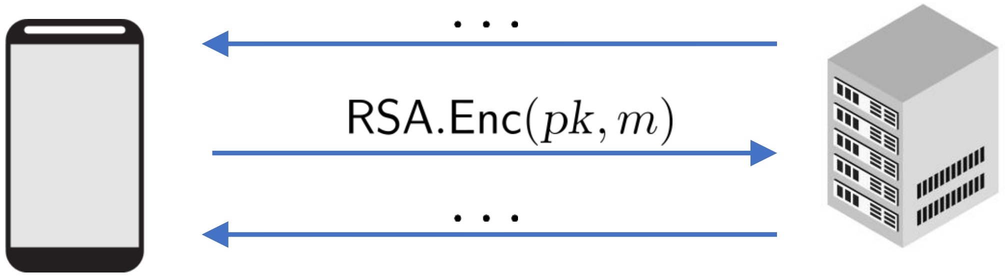

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After RSA decryption but before SHA-1 verification,
Telegram parses m to validate its format
and might omit the computation of SHA-1.

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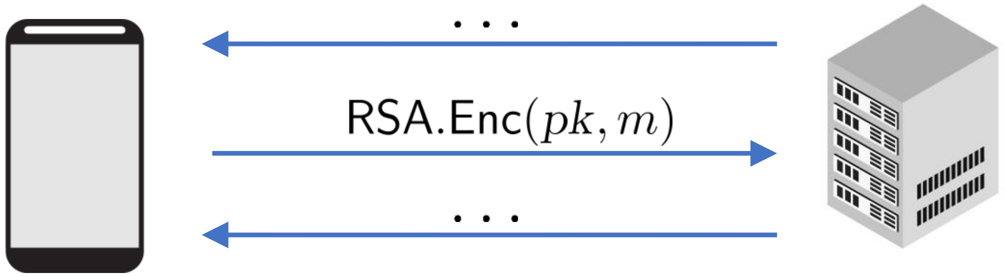

Telegram uses textbook **RSA** encryption.

$m :=$ SHA-1(data)||data||padding

After RSA decryption but before SHA-1 verification, Telegram parses m to validate its format and might omit the computation of SHA-1.

We recover data by solving noisy linear equations via lattice reduction.

Can use data to recover server_salt and session_id.
Can use data to run a **MitM** attack against the (encrypted) **DH** exchange.

The attack is infeasible in practice because:

- The timing side-channel is very small.
- Recovering session_id requires additional 2^{64} computation.
- The key exchange would time out before **MitM** can be completed.

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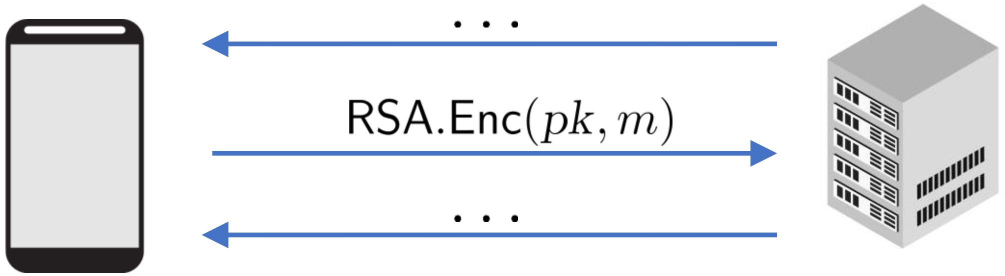

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"Publishing the server code doesn't guarantee privacy, because - unlike with the client-side code - there's no way to verify that the same code is run on the servers. [..]

So why not publish the server code anyway, even if it is only a publicity stunt? 3 years ago I learnt that an authoritarian regime [..] was looking for a way to obtain Telegram's server code. Their plan was to launch their own equally convenient local app and then to shut down all other social media in the country."

Pavel Durov (https://t.me/durovschat/515221)

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Future Work

Large parts of **Telegram**'s design remain unstudied:

Secret chats (including encrypted voice and video calls).
The key exchange.

Multi-user security.
Forward secrecy.

Telegram Passport.
Bot APIs.

The higher-level message processing.
Control messages.

Encrypted CDNs.
Cloud storage.

These are pressing topics for future work.

Thanks!

More information at:
https://mtpsym.github.io/