Cryptanalysis of mCrypton

<Team Mitnick>

Department of <Computer Science Engineering>
Indian Institute of Technology Bhilai

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Outline

Introduction

Increasing demand of resource-constrained and compact devices

1.Low consumption of power
2.Compact size
3.Security for data exchanges

Introduction to light weight Cryptography

→ As the demand increased, to solve the problems and make things easy lightweight cryptography came into action.
→ There are multiple ciphers in the market are introduced such as SEA, PRESENT, mCrypton, KATAN, etc.
→ mCrypton is one of the best devices overall and its hardware complexity stands at the top of the chain.

Introduction

Short details of mCrypton:

1.It name refers as miniature of Crypton
2.It is a 64-bit block cipher which is also an SPN network with 12 rounds
3.It is available in three key sizes 64, 96, 128 bits for minimal, moderate, standard Securities, respectively.

Some areas in usage of RFID tags

1.Medical
2.logistics
3.Maintenance
4.Railways

Outline

Specs of mCrypton

Properties of Cipher

→ mCrypton is a SPN based block cipher.
→ mCrypton is a 64-bit block cipher.
→ It has three Key sizes 64, 96, 128.
→ The input message for encryption is in the form of 4x4 matrix.

S-box of mCrypton

x	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f
$S_0(x)$	4	f	3	8	d	a	c	0	b	5	7	e	2	6	1	9
$S_1(x)$	1	c	7	a	6	d	5	3	f	b	2	0	8	4	9	e
$S_2(x)$	7	e	c	2	0	9	d	a	3	f	5	8	6	4	b	1
$S_3(x)$	b	0	a	7	d	6	4	2	c	e	3	9	1	5	f	8

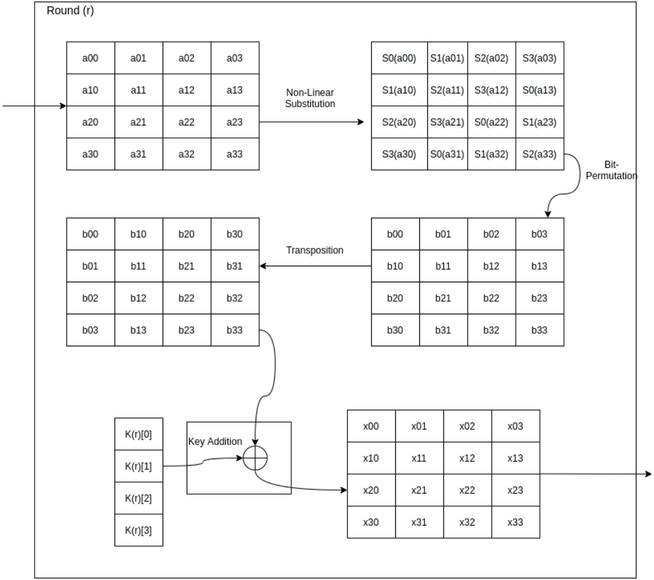
Encryption Algorithm of mCrypton

→ There are 12 rounds in mCrypton

There are four major transformations in each round:

1.Nonlinear substitution γ
2.Bit permutation π
3.Column-to-row transposition τ
4.Key addition σ

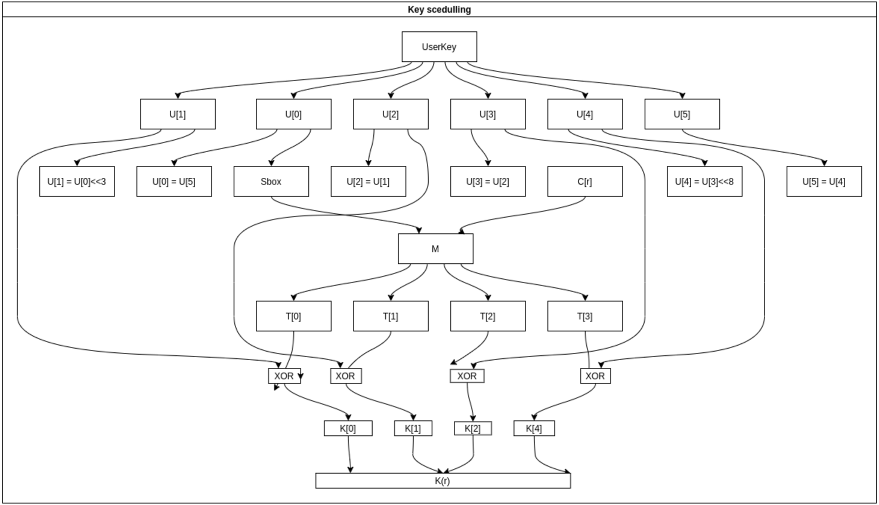
Pictorial representation of a single round



Key-scheduling

- Initially we should give a user key, U.
  U = (U[0], U[1], U[2], U[3], U[4], U[5])
- $T \leftarrow S(U[0]) \oplus C[r]$, $T_i \leftarrow T \bullet M_i$ (S(U[0]) is nibble wise sbox substitution)
  $i = 0, 1, 2, 3$, M_0 =0xf000, M_1 =0x0f00, M_2 =0x00f0, M_3 =0x000f
- $K_r \leftarrow (U[1] \oplus T_0, U[2] \oplus T_1, U[3] \oplus T_2, U[4] \oplus T_3)$,
- $U \leftarrow (U[5], U[0]^{<<3}, U[1], U[2], U[3]^{<<8}, U[4])$ ($^{<<3}$ denotes bits are left rotated by 3 places)

Pictorial representation of Key Scheduling



Outline

Various attacks

Some attacks on mCrypton:

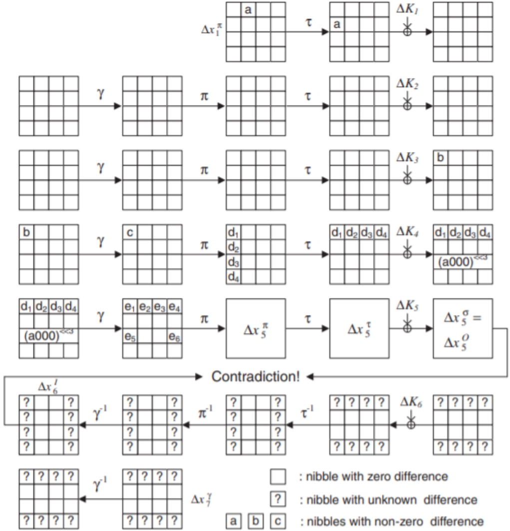
1.Biclique Cryptanalysis
2.Related-key Rectangle attack
3.Related-key impossible differential attack
4.Collision attacks

Various attacks on mcrypton

I mentioned 4 attacks. In which, I will explain more about the related-key impossible differential attack

1.Short note on Related-key impossible differential attack
2.In this attack, we are going to analyse on 6-round and 9-round mCrypton-96.
3.The attack procedure is similar for 6-round and 9-round mCrypton-128

Pictorial representation of 6-round related-key differential on mcrypton-96



6-round related-key differential on mcrypton-96

6-round related-key differential

Assume the two related key differences to be;

Δ K = K $\oplus$ K^1 = (0000|0000|0000|a000|0000|0000)

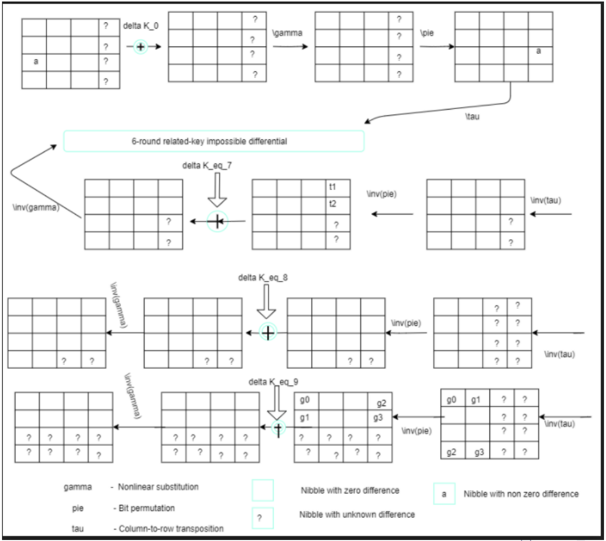
1. A 4.5-round related key differential
2. A 1.5-round related key differential

Table 1:Sub Key Differences of 9 rounds

Round(i)	$\Delta K_(i, row(0))$	$\Delta K_(i, row(1))$	$\Delta K_(i, row(2))$	$\Delta K_(i, row(3))$
0	(0000)	(0000)	$(a000)$	(0000)
1	(0000)	(0000)	(0000)	$(00a\ 0)$
2	(0000)	(0000)	(0000)	(0000)
3	(0000)	(0000)	$(00b0)$	(0000)
4	$(a000^{<<11})$	(0000)	(0000)	(0000)
5	(0000)	$(a000^{<<11})$	(0000)	(0000)
6	(0000)	(0000)	$(a000^{<<11})$	(0000)
7	(0000)	(0000)	(0000)	$(a000^{<<3})$
8	(0000)	(0000)	(0000)	(0000)
9	$(b'000)$	(0000)	(0000)	$(000b'')$

a, b and at least one of b' and b'' are non-zero nibble differences.

Pictorial representation of 9-round related-key impossible differential attack on mcrypton-96



9-round related-key impossible differential attack on mcrypton-128

- Using the 6-round distinguisher from the previous slides, we present a related-key impossible differential attack on 9-round mCrypton-96.
- To reduce Time complexity, in rounds 7-9 we changed the order from σ, τ, π to τ, π, σ.
- Due to change in order, K_i key of ith round changes, as its equivalent key(k_i^{eq}) is $\pi(\tau(k_i))$.
- In this we use 16 related-keys K^0,...,K^{15}, having a relation $K_i \oplus K_j = (0000|0000|0000(i \oplus j)000|0000|0000)$

9-round related-key impossible differential attack on mcrypton-128

- The attacker can choose the value of a, values of b' and b" in round 9 are from s-boxes which are unknown.
- The attack is briefly explained in the term paper

Complexity of the attack

There are a total of 7 steps in calculating the complexity which are explained in the term paper. Following are the complexities involved in the 7 steps:

- step 1: $2^{n+20} = 2^{59.9}$
- step 2: $1/8 \times 2^{n+19} \times (4x64 + 8) \approx 2^{63.9}$
- step 3: $2^{n+11}x2^{8} = 2^{58.9}$
- step 4: $2 \times 1/9 \times 1/4 \times 2^{n+11} \times 2^{8+16} \approx 2^{70.7}$
- step 5: $2 \times 1/9 \times 1/4 \times 2^{n-1} \times 2^{24+16} \approx 2^{74.7}$
- step 6: $2 \times 1/9 \times 1/4 \times 2^{n-13} \times 2^{40+8} \approx 2^{70.7}$
- step 7: $2 \times 2^{n-19.4} \times 2^{48} = 2^{69.5}$

Complexity of the attack

- In the 7 steps, step 4, 5, 6 are dominant part of the time complexity as the total complexity will be the sum of these 3 steps.
  $2^{70.7} + 2^{74.7} + 2^{70.7} \approx 2^{74.9}$ encryptions.
- The memory required for step 2 is dominant over all other steps as it is $2^{74.7}$
- The above attack procedure is similar for mCrypton-128.

Outline

Brownie points

- Visualizations like Encryption algorithm and Key Scheduling were added for better understanding
- Secure against differential and linear cryptanalysis
- Properties like S-box and Bit-permutation are analyzed
- It has a better hardware architecture than most of the other lightweight cryptography

Outline

Conclusion

- Lightweight cryptography
- Advantages of Lightweight Cryptography
- Encryption Algorithm of mCrypton
- Various attacks on mCrypton
- Explained the related-key impossible differentiable attack on 6-round and 9-round mCrypton-96
- Complexities of the related-key impossible differential attack
- Explained Uniqueness of mCrypton over other lightweight cryptographic ciphers

Thanking You

Team Members

- Tumma Manohar Sai, 11841170
- Goolla Abhijith, 11840510
- Anugu Rakesh Reddy, 11840200

Implementation Info

- Github Link: github.com/Manohar-Sai/mCrypton—lightweight-block-cipher