Securing Data in Low-Resource Systems: Lightweight Block Cryptography Strategies

Presentación examen parcial

Proyecto de Final de Carrera I

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May 16, 2024

Lightweight Block Ciphers

Algorithm	Key size	Block size	N. of rounds	Structure
DULBC (Yang et al., 2022) [1]	80/128	64	25/30	SPN
GIFT (Yasmin and Gupta, 2023) [2] [3]	128	64/128	28/40	SPN
IVLBC (Huang et al., 2023) [4]	80/128	64	29	SPN
LBC-IoT (Ramadan et al., 2021) [5]	80	32	32	Feistel
SAND (Chen et al., 2021) [6]	128	64/128	48/54	Feistel
LBCCS (Zhu et al., 2022) [7]	128	128	20	Feistel
SCENERY (Feng and Li et al., 2022) [8]	80	64	28	Feistel

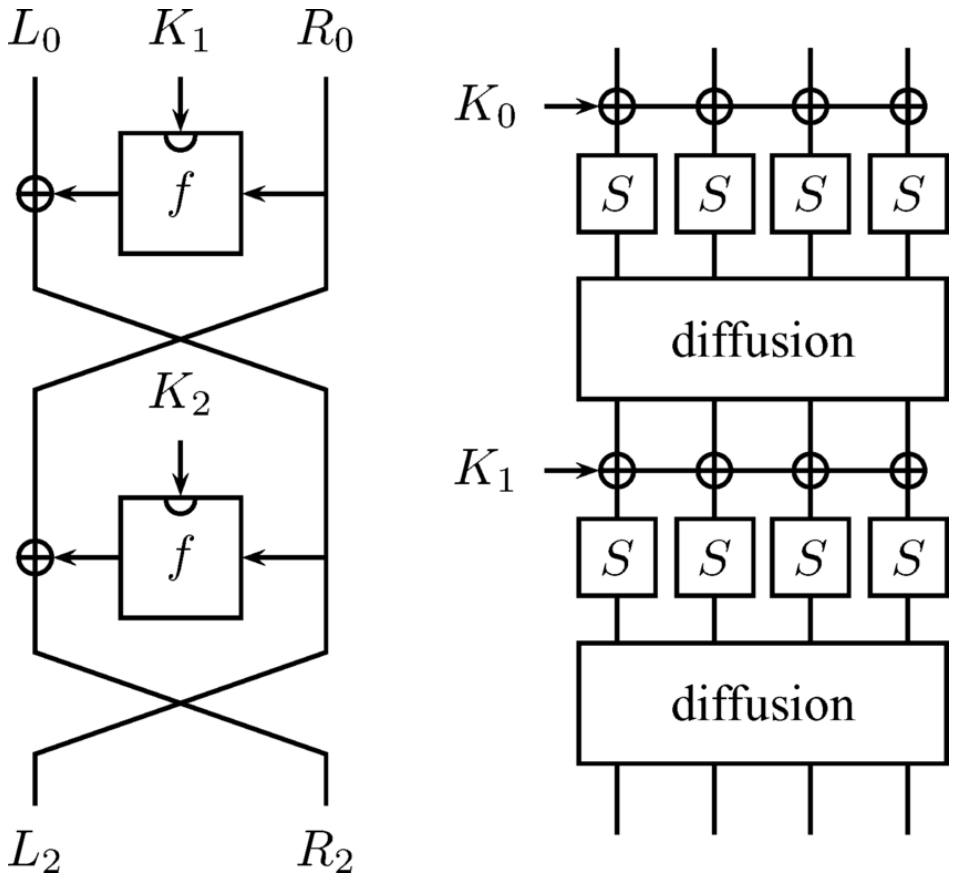


Figure: Generalization of a Feistel network [9] and a Substitution-permutation network [10].

SAND

SAND

SAND-64 and SAND-128

- AND-RX operations = lightweight.
- Synthetic s-box = secure.
- 128-bit key, 64/128-bit block, 48/54 rounds.

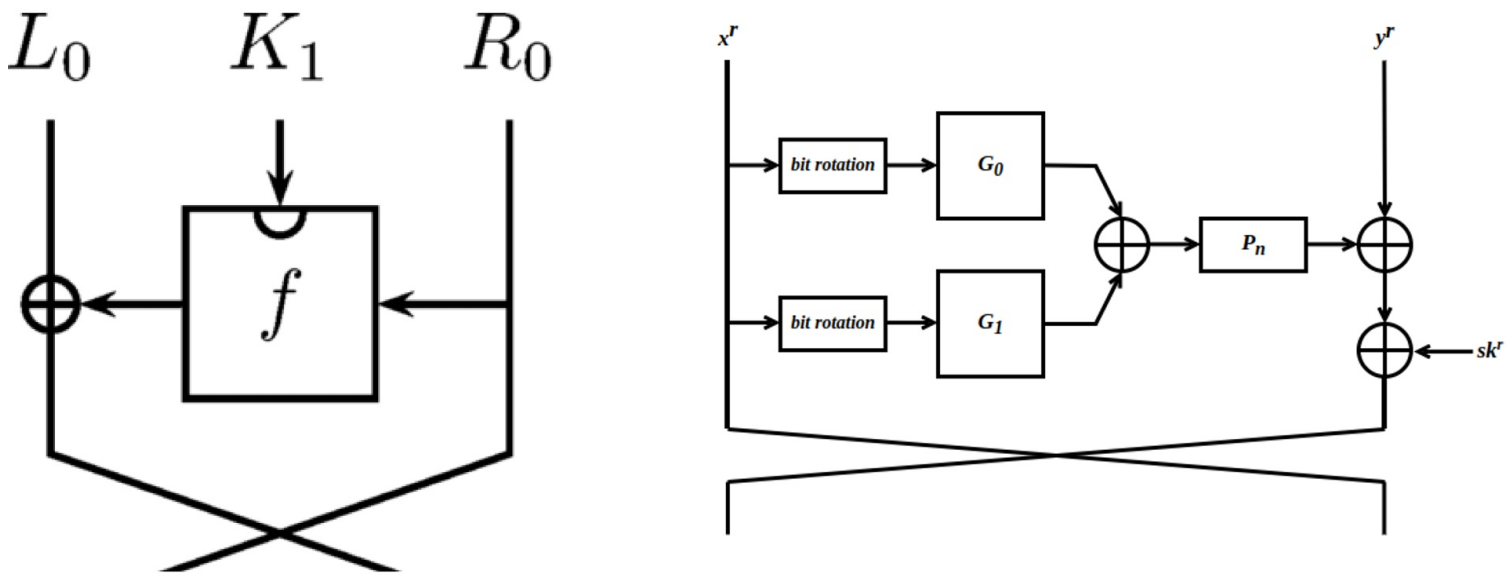


Figure: Comparation between round functions, generic Feistel network and SAND [6].

(3) Non-linear Functions G_0 and G_1

Let the n-bit variable x be the input value of G_0 and G_1, which is regarded as the concatenation of four $\frac{n}{4}$-bit words $x\{3\}\|x\{2\}\|x\{1\}\|x\{0\}$. Let $y = y\{3\}\|y\{2\}\|y\{1\}\|y\{0\}$ denote the output value. For G_0, we have

$$
\begin{aligned}
y\{0\} &= x\{3\} \odot x\{2\} \oplus x\{0\}, \\
y\{3\} &= y\{0\} \odot x\{1\} \oplus x\{3\}, \\
y\{2\} &= x\{2\}, \\
y\{1\} &= x\{1\}.
\end{aligned}
$$

As to the function G_1, the output is calculated as

$$
\begin{aligned}
y\{2\} &= x\{3\} \odot x\{1\} \oplus x\{2\}, \\
y\{1\} &= y\{2\} \odot x\{0\} \oplus x\{1\}, \\
y\{3\} &= x\{3\}, \\
y\{0\} &= x\{0\}.
\end{aligned}
$$

Figure: Definición formal de las funciones G de SAND [6].

SAND

x	0	1	2	3	4	5	6	7	8	9	A	B	C
$N_0(x)$	0	1	2	B	4	5	6	F	8	9	A	3	D
$N_1(x)$	0	1	2	3	4	7	6	5	8	9	E	D	C
Ssb(x)	00	11	22	B3	44	57	66	F5	88	99	AE	3D	DC

Table: Synthetic S-box of SAND-128

SAND

x	0	1	2	3	4	5	6	7
P(x)	7	4	1	6	3	0	5	2

Table: P-box of SAND-64

x	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
P(x)	E	F	8	9	2	3	C	D	6	7	0	1	A	B	4	5

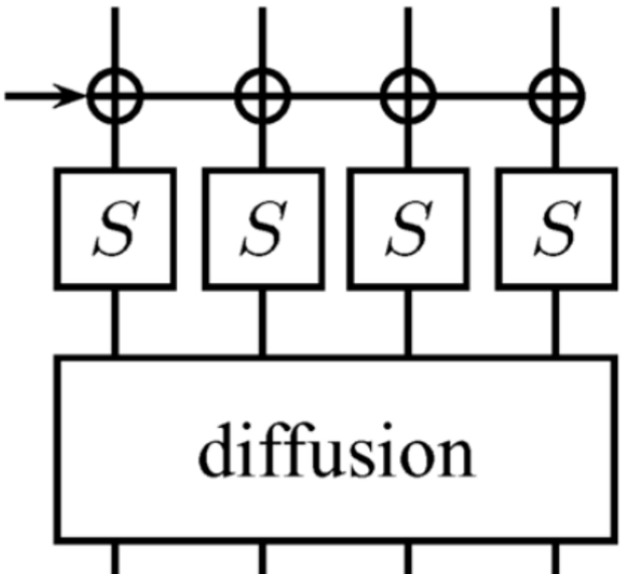
Table: P-box of SAND-128

GIFT

GIFT

GIFT-64 and GIFT-128

- Feistel = lightweight.
- Bitslice substitution = secure.
- Involutive permutation = more secure!
- 128-bit key, 64/128-bit block, 28/40 rounds.



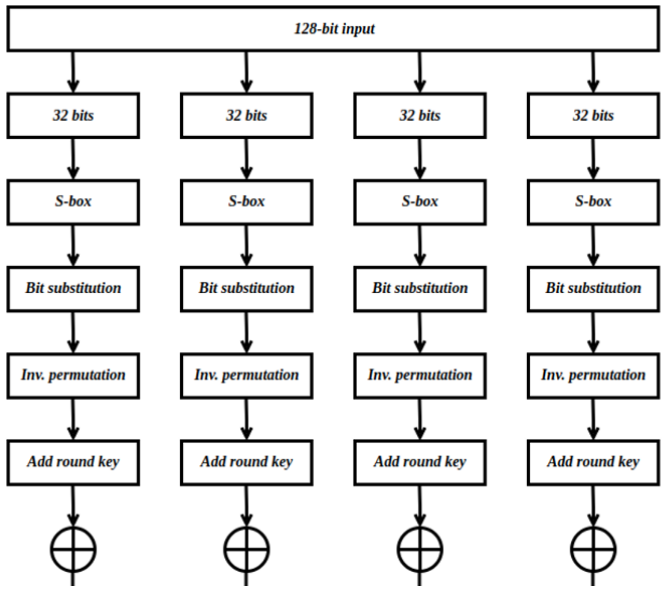


Figure: Comparation between round functions, generic Substitution-permutation network and GIFT [3].

GIFT

Each bit of plain text is placed in a block.

0	4	8	12
16	20	24	28
32	36	40	44
48	52	56	60

1	5	9	13
17	21	25	29
33	37	41	45
49	53	57	61

2	6	10	14
18	22	26	30
34	38	42	46
50	54	58	62

3	7	11	15
19	23	27	31
35	39	43	47
51	55	59	63

Figure: Position of the bits. Sectors 0,1,2,3 are in red, yellow, green and blue respectively. [2].

GIFT

The bit-slice substitution function is defined:

$$T_1 = X_1; T_2 = X_0 \wedge T_1; T_3 = X_2 \oplus X_3;$$
$$Y_0 = T_2 \oplus T_3; T_5 = X_3 \vee T_1; T_6 = X_0 \oplus T_5;$$
$$Y_1 = X_2 \wedge T_6; T_8 = X_1 \oplus X_2; T_9 = T_3 \wedge T_6;$$
$$Y_3 = T_8 \wedge T_9; T_{11} = Y_0 \vee T_8; Y_2 = T_6 \wedge T_{11}.$$

where T_i indicates a temporary 32-bit variable. The input block is X and the output block is Y [3].

GIFT

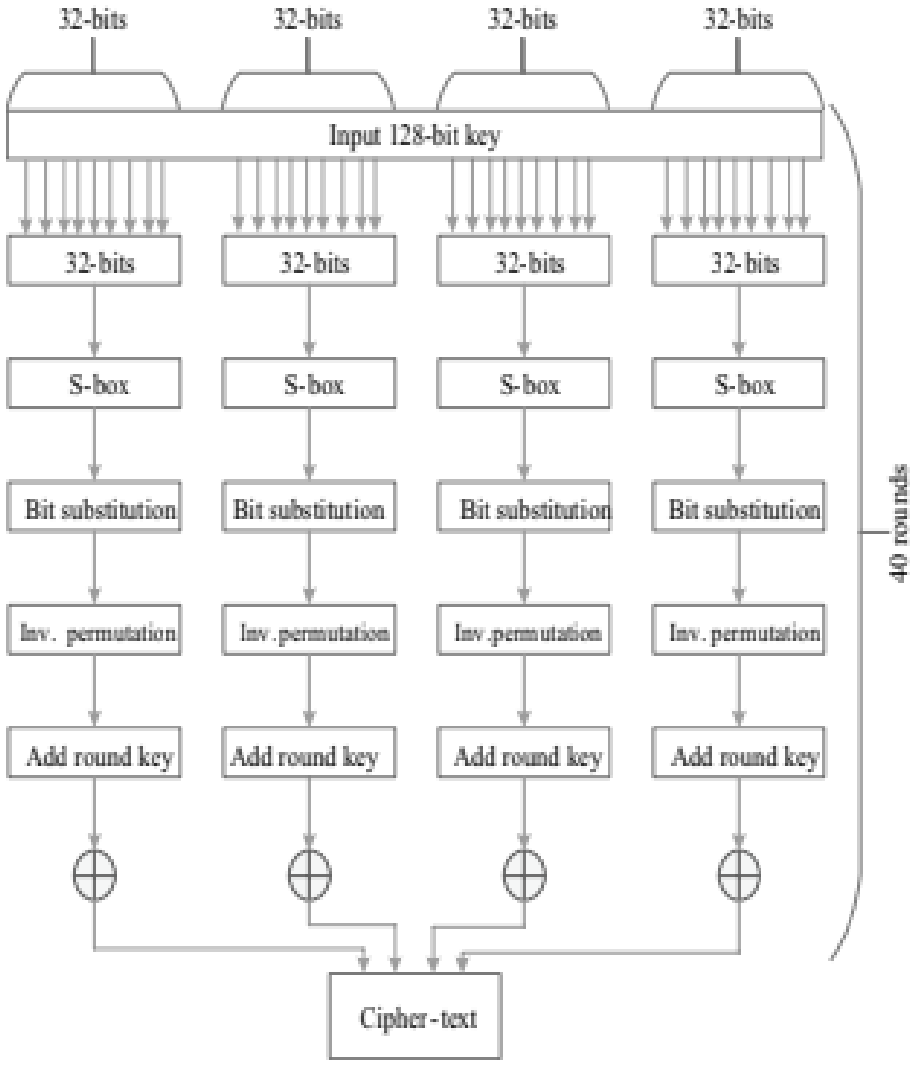


Figure: Sequential representation of GIFT [3].

Conclusions

Conclusions

Feistel Network

- Simplicity.
- Simple decryption.
- Security.
- Too much simplicity!

Substitution-Permutation Network

- Freedom.
  - Design.
  - Implementation: paralelism, hardware/software.
- Too much freedom!

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