DESIGN AND IMPLEMENTATION OF ENERGY EFFICIENT LIGHTWEIGHT ENCRYPTION (EELWE) ALGORITHM FOR MEDICAL APPLICATIONS

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ABSTRACT

Proportional to the growth in the usage of Human Sensor Networks (HSN), the volume of the data exchange between Sensor devices is increasing at a rapid pace. In HSNs, the sensors are either implanted or placed on the human body which are responsible for sensing the health data such as BP, Sugar level, Heart rate, etc. All this collected information is processed by the base station and is sent to the HSN servers via internet. Medical assistants who will have access to servers will analyze the health data of the patient and suggest appropriate medication. This will allow the doctors to have continuous monitoring on patient's health condition. Since the data is related to patient's health, it should be secured and confidential. In this paper, we have proposed an Energy Efficient Lightweight Encryption (EELWE) algorithm for providing the confidentiality of data at sensor level, particularly suitable for resource-constrained environments. Results obtained have proved that an EELWE consumes less energy relative to present lightweight ciphers and it supports multiple block sizes of 32-bit, 48-bit and 64-bit.

Keywords: Human Sensor Network, Security, Lightweight Encryption, Energy Consumption.

1. INTRODUCTION

In HSNs, number of sensor nodes are involved, where communication between the nodes is done within a little distance using wireless links/connections. Conventional encryption algorithms don't fit for these types of environments, because they demand more capacity resources. For all these connected devices, information security is evidently necessary [1]. As the available resources in sensor devices are limited and due to the huge demand of security in resource-constrained environments, the need for lightweight encryption algorithms became essential [2].

Asymmetric and Symmetric are two types of cryptographic security algorithms [3]. Asymmetric type algorithms are the choice for non-repudiation and authentication. In these algorithms, encoding and decoding of data is done using separate keys. Symmetric type algorithms are mostly used for privacy and confidentiality. In these algorithms, same key is utilized for both encoding and decoding. Statistical functions are used in each round for purpose of including confusion and diffusion.
Lightweight cryptography is block cipher-based encoding method [4], used in resource constrained devices. It provides confidentiality in high-speed and lightweight environments such as sensor devices.

Criteria for Lightweight block ciphers include [5,6]:

- Tiny block size of <= 64-bit
- Tiny key size of <= 80-bit
- Round function with simple logic

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- Less complexity in key scheduling.

Though better security is provided by many existing algorithms but are consuming relatively more battery [7]. Thus, causing the tiny sensor devices to exhaust fast. Hence, there is a need for a new algorithm that ensures better or same level of security as the existing algorithms, by consuming less energy.

The organization of the remaining part of the paper is given here: Review of different lightweight encryption algorithms is briefed in section 2. The full narration of the proposed EELWE algorithm is available in section 3. Sections 4 discusses about parameters needed for calculating energy consumption of EELWE. Metric for Security vs Energy consumption is calculated in Section 5. Finally, the results obtained after simulation of EELWE using Xilinx and results of energy consumption are shown in section 6.

2. LITERATURE REVIEW

Regardless of the significant amount of work done in this field of security in HSN, only a few literatures came up with suitable framework for calculating the energy requirements of the existing algorithms.

AES is a popular block cipher developed by Vincent Rijmen and Joan Daemen [8], which is a subcategory of Rijndael block cipher. It follows an SPN structure. It works with three key lengths of size 128-bit, 192-bit, 256-bit and undergoes the iterations of 10,12,14 rounds, respectively.

DESL and DESXL [9] are the two lightweight forms of the standard DES. They follow Feistel structure. DESL which is same as DES, takes a 64-bit block plaintext, a key of size 56-bit and undergoes the iterations of 16 rounds. All the rounds make use of a single S-box. The linear property of S-box is the drawback of DES, which is been reinforced in DESL by utilizing a single non-linear S-box eight times. DESXL takes a key size of 184-bit and it uses a key whitening technique to strengthen the security.

HIGHT is a hardware-oriented lightweight encryption protocol [10]. The operations of HIGHT can be performed using a small 8-bit processor and it follows Feistel structure. It takes a 64-bit block data, a key of size 128-bit and undergoes the iterations of 32 rounds. The round function consists of simple logical and arithmetic operations such as bitwise left rotation, XOR, addition and subtraction with mod28.

IDEA is a traditional symmetric block cipher [11] that is developed by Xuejia Lai and James Massey in 1991. It was proposed as a successor of DES. It takes a 64-bit block data, a key of size 128-bit and undergoes the iterations of 8 similar rounds, which is followed by a half output round. Thus, it undergoes a total of 8.5 rounds.

KLEIN is a lightweight block cipher [12] that was proposed by Gong et al. in 2011 during RFIDSec. It follows SPN structure and has an innovative structure that uses the combination of 4-bit S-boxes and Mix column transformations of AES. It takes a 64-bit block data, a key of variable lengths 64-bit, 80-bit, 96-bit and undergoes the iterations of 12, 16, 20 rounds, respectively.

LBLOCK is a lightweight encryption protocol [13] that follows the Feistel structure. It takes a 64-bit block data, a key of size 80-bit and undergoes the iterations of 32 rounds. Efficient implementation of LBLOCK is possible in both hardware and software.

LED is a lightweight block cipher [14] that was designed keeping hardware compaction in mind. Its main advantage is that the key can be provided by a user rather than using a fixed key. It follows SPN structure. It is also similar to AES and makes use of S-boxes, mix columns and shift rows. It takes a 64-bit block data, a key of size 64-bit, 128-bit and undergoes the iterations of 32, 48 rounds respectively and also re-utilize the S-box of the block cipher PRESENT.

mCrypton falls under the lighter version of Crypton block cipher [15] that is specially designed for devices having limited resources. It follows SPN structure. It takes a 64-bit block data and works with three key lengths of size 128-bit, 96-bit, 64-bit and undergoes the iterations of 32 rounds. Key scheduling is done in two steps: 1) Using S-box for generating round key, 2) Using word wise and bitwise rotations for updating key variable.

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PICCOLO is a lightweight encryption method that follows Feistel structure [16]. It takes a 64-bit block data, and works with two different key lengths of size 80-bit, 128-bit and undergoes the iterations of 25, 31 rounds respectively. The round logic of Piccolo takes three XOR, one XNOR and four NOT gates which is equal to 12 GE and this is the earliest block cipher whose hardware implementation is done with not more than 1000 gates.

PRESENT falls under the ultra-lightweight block cipher [17] that follows the SPN structure. It takes a 64-bit block data and works with two different key lengths of size 80-bit, 128-bit and undergoes the iterations of 31 rounds. The round function of PRESENT contains 3 steps: 1) XOR logic for AddRoundKey, 2) 4-bit S-box is used for 16 times parallelly in S-box layer, 3) Bitwise permutations in P-Layer.

TEA is Tiny Encryption Algorithm [18] developed by D. Wheeler and N. Needham. XTEA is an extension for TEA with 64-bit block size and uses 128-bit key [19]. It follows Feistel structure and uses simple F-function. Since the round function is simple, it undergoes 64 no. of rounds to increase the security.

SEA is relatively cheap encryption protocol [20] designed explicitly for hardware with restricted no of instructions. Likewise, this is an adaptable protocol w.r.t. Size of text, length of key & word size of the processor. It follows Feistel structure, a key of variable lengths and undergoes varying number of rounds.

The comparison of the existing lightweight block ciphers is presented in Table 1.

Table 1. Lightweight block ciphers comparison

Name of Algorithm	Key Size	Block Size	No of Rounds	Structure
AES	128,192,256	128	10,12,14	SPN
DESXL	184	64	16	Feistel
HIGHT	128	64	32	Feistel
IDEA	128	64	8	Lai-Massey
KLEIN	64, 80, 96	64	12,16,20	SPN
LBLOCK	80	64	32	Feistel
LED	64, 128	64	32, 48	SPN
mCrypton	64, 96, 128	64	32	SPN
Piccolo	80, 128	64	25, 31	Feistel
PRESENT	80, 128	64	31	SPN
XTEA	128	64	64	Feistel
SEA	“on-the-fly”	128	variable	Feistel

3. METHODOLOGY

3.1 Structure Used:

The algorithm that is proposed follows Feistel structure [5]. Feistel structure systems offer both encryption and decryption with less expense [21]. The main advantage of using Feistel structure is that the encoding and decoding process use the same form of structure.

3.2 Number of Rounds:

More rounds mean greater security [6]. For a protected block cipher, there ought to be no attack that is faster than an exhaustive key searching like brute force. As a thorough key search takes much longer for a bigger key size, a hypothetical attacker must manage the cost of more work to "break" the cipher. Therefore, one must increment the number of rounds for increasing security of a cipher.

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3.3 Lightweight Algorithm Functionality:

The organization of the lightweight encryption algorithm is presented in Fig.1. It contains two main blocks namely Key scheduling block and round function block with T rounds. Each round takes n-bit data that is generated by the previous round, performs the encoding using the sub-key, and generates an n-bit ciphertext, which in turn is given as an input to the next round. The key schedule function will take the master key as input & expands it into sub-keys, where each sub-key is given to one round.

The implementation of the lightweight block cipher algorithm shown in Fig.2 contains the blocks, namely registers, Overhead logic, and the round's function.

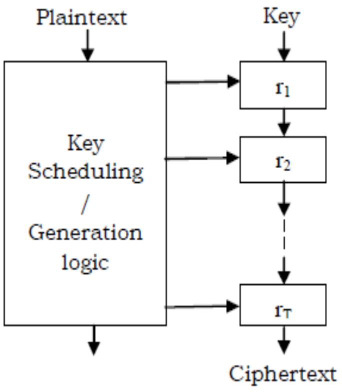


Fig.1 Encoding Algorithm

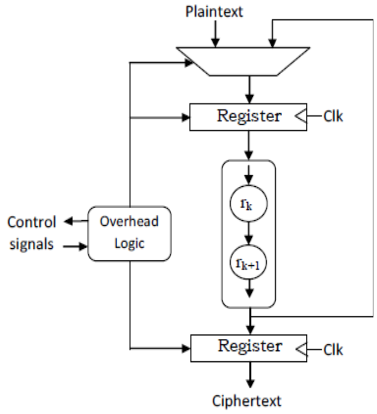
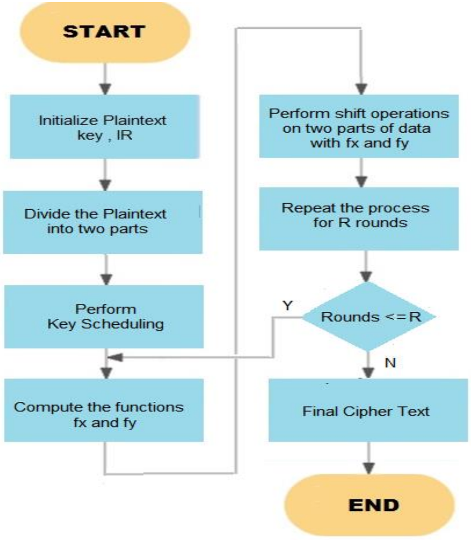


Fig.2 Implementation of Encryption Algorithm

Registers are used to save the initial data, intermediate data, and the final data. Overhead logic is used to generate the sub-keys. Round's function is used to implement ri rounds. Lightweight block ciphers usually have more significant no. of rounds with simple operations & simple key schedule functionality [22].

3.4 Proposed EELWE Algorithm

EELWE algorithm is shown presented in Fig.3.


START
Initialize Plaintext key , IR
Divide the Plaintext into two parts
Perform Key Scheduling
Compute the functions fx and fy
Perform shift operations on two parts of data with fx and fy
Repeat the process for R rounds
Rounds <=R
Y
N
Final Cipher Text
END

The proposed EELWE block cipher is in three variants: EELWE32, EELWE48, and EELWE64 with blocks of sizes 32-bit, 48-bit, and 64-bit. All these ciphers have a fixed key of length 80-bit and go through 254 rounds. They perform key scheduling to provide keys for 254 rounds and make all the variants use the same nonlinear round functions.

The flowchart representing the functionality of the

Fig.3 Flowchart of EELWE

The notations used in the algorithm are given in Table 2.

Table 2. Notations used to explain EELWE Algorithm.

Notation	Description
P1, P2	First part and Second part of Plaintext
Pa, Pb	First part and Second part of P1
Pc, Pd	First and Second part of P2
ai, bi, ci, di	Bit positions of Pa, Pb, Pc, Pd respectively
fx	Round function on 1st part of data using ai and bi values, IR and subkey kx
fy	Round function on 2nd part of data using ci and di values and subkey ky
$\oplus$, &	Logical XOR and AND operation
IR	Irregular Update rule
ki	ith bit of the key
kx	Subkey applied on P1 where kx = k_{2i}
ky	Subkey applied on P2 where ky = k_{2i+1}

EELWE32 is the basic algorithm of the EELWE family with a plaintext of size 32-bit and produces a ciphertext of the size of 32-bit. The given plaintext is split up into two parts of 13-bit & 19-bit. Register P1 is loaded with 13-bit data and register P2 is loaded with 19-bit data. The 12th bit of P1 represents the MSB of the plaintext, and the 0th bit of P2 represents the LSB of plaintext.

Round Function:

P1 data is further split up into 2 parts Pa and Pb, each of 6-bits and 7-bits, respectively. The round function is performed on Pa and Pb using the following nonlinear functions.

$$Ta = (Pa[a1] \oplus Pa[a2]) \oplus kx$$

$$Tb = (Pb[b1] \,\&\, Pb[b2]) \oplus (Pb[b3] \,\&\, IR[i])$$

$$fx = Ta \oplus Tb$$

Ta is computed on Pa data using subkey kx and ai values, and Tb is computed on Pb data using IR (irregular) update rule and bi values. Similarly, Tc and Td are computed based on the below rules.

$$Tc = (Pc[c1] \oplus Pc[c2]) \oplus ky$$

$$Td = (Pd[d1] \,\&\, Pd[d2]) \oplus (Pd[d3] \,\&\, Pd[d4])$$

$$fy = Tc \oplus Td$$

ai, bi, ci, and di represent the random bit positions of Pa, Pb, Pc, and Pd, respectively. Now left shift operation is performed on P1 and P2 by inserting fy and fx into LSBs of P1and P2, respectively.

$$P1 = shl(P1, fy)$$

$$P2 = shl(P2, fx)$$

P1 and P2 are updated with new data in each round. After the completion of 254 rounds, P1 and P2 contents denote the final ciphertext where the 12th bit of P1 represents the MSB of the ciphertext, and the 0th bit of P2 represents the LSB of the ciphertext.

Key Scheduling:

An 80-bit key is expanded using the key scheduling, where two subkeys (kx and ky) are used in each round. kx = k_{2i} and ky = k_{2i+1}, where i denotes the ith round. The subkey kj (which may denote k_{2i} or k_{2i+1}) is given as:

$$kj = kj \qquad \text{for } j = 0 \text{ to } 79$$

$$kj = kj-80 \oplus kj-61 \oplus kj-50 \oplus kj-13 \qquad \text{for } j = 80 \text{ to } 253$$

In EELWE32/48/64, the plaintext is divided into 13 and 19 / 19 and 29 / 25 and 39-bit blocks. P1 of EELWE32/48/64 is further divided into 6 and 7 / 8 and 11 / 10 and 17 bit blocks with a = {5,2} / {7,3} / {9,5} and b = {6,3,1} / {10,6,4} / {16,11,7}. Similarly, P2 of EELWE32/48/64 is further divided into 8 and 11 / 12 and 17 / 14 and 23 bit blocks with c = {7,3} / {11,5} / {13,7} and d = {10,7,5,1} / {16,12,8,3} / {22,17,11,5}. For each iteration, the round function is performed twice in EELWE48 and thrice in EELWE64.

4. ENERGY CONSUMPTION OF PROPOSED ALGORITHM:

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To calculate the energy consumed by an encryption algorithm, the three primary parameters required are Time, Area, and Power [23].

The following equation gives the time required for encrypting one block data:

$$T_B = ((r_T/r_i) + C_0) \times (D_R + r_i \times (t_0 + t_n \times n))$$

(1)

Area required for encrypting one block data is given by the following equation:

$$A_D = r_i^{(g_n \times n + g_0)} \times A_1 + g_b \times n + A_0 \quad (2)$$

Power required for encrypting one block data is given by the following equation:

$$P = ((P_d \times r_i + P_i) \times A_D) / CT \quad (3)$$

Based on the above parameters, the energy consumed for encrypting one block data is given by the following equation:

$$E_B = T_B \times P$$

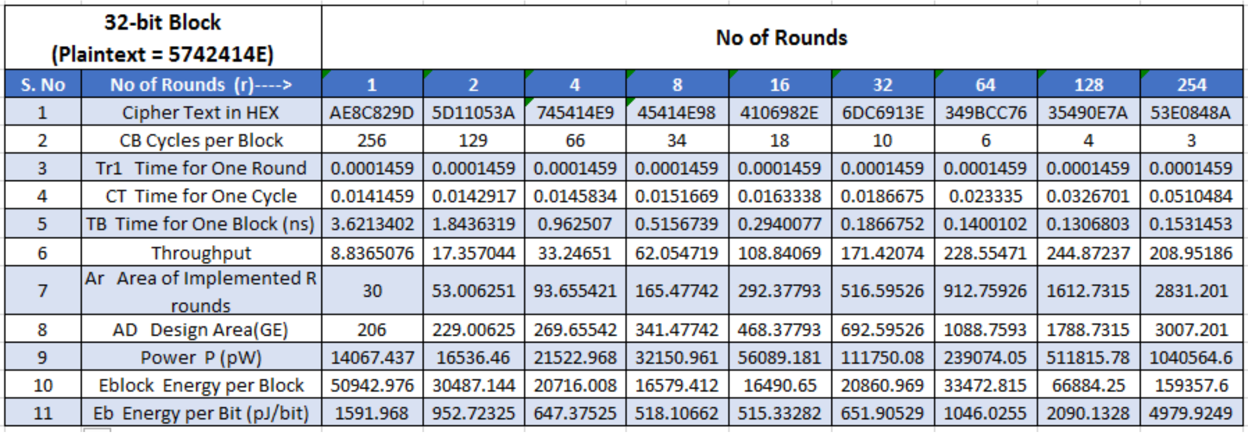
(4)

To have a fair comparison among the block ciphers, it is better to consider the energy per bit rather than energy per block. Energy per bit is calculated using the following equation:

$$E_1 = E_B / n$$

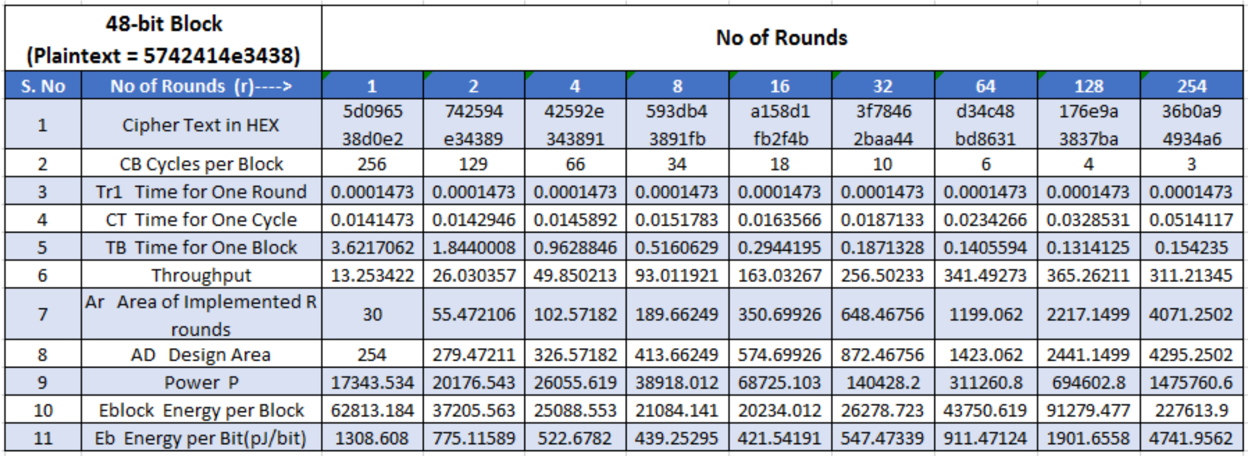
(5)

Different parameter values for energy consumption obtained for EELWE32, EELWE48, and EELWE64 are presented in Fig.4, Fig.5, and Fig.6, respectively.



32-bit Block (Plaintext = 5742414E)		No of Rounds								
S. No	No of Rounds (r)---->	1	2	4	8	16	32	64	128	254
1	Cipher Text in HEX	AE8C829D	5D11053A	745414E9	45414E98	4106982E	6DC6913E	349BCC76	35490E7A	53E0848A
2	CB Cycles per Block	256	129	66	34	18	10	6	4	3
3	Tr1 Time for One Round	0.0001459	0.0001459	0.0001459	0.0001459	0.0001459	0.0001459	0.0001459	0.0001459	0.0001459
4	CT Time for One Cycle	0.0141459	0.0142917	0.0145834	0.0151669	0.0163338	0.0186675	0.023335	0.0326701	0.0510484
5	TB Time for One Block (ns)	3.6213402	1.8436319	0.962507	0.5156739	0.2940077	0.1866752	0.1400102	0.1306803	0.1531453
6	Throughput	8.8365076	17.357044	33.24651	62.054719	108.84069	171.42074	228.55471	244.87237	208.95186
7	Ar Area of Implemented R rounds	30	53.006251	93.655421	165.47742	292.37793	516.59526	912.75926	1612.7315	2831.201
8	AD Design Area(GE)	206	229.00625	269.65542	341.47742	468.37793	692.59526	1088.7593	1788.7315	3007.201
9	Power P (pW)	14067.437	16536.46	21522.968	32150.961	56089.181	111750.08	239074.05	511815.78	1040564.6
10	Eblock Energy per Block	50942.976	30487.144	20716.008	16579.412	16490.65	20860.969	33472.815	66884.25	159357.6
11	Eb Energy per Bit (pJ/bit)	1591.968	952.72325	647.37525	518.10662	515.33282	651.90529	1046.0255	2090.1328	4979.9249

Fig.4 Parameter values obtained for EELWE32



48-bit Block (Plaintext = 5742414e3438)		No of Rounds								
S. No	No of Rounds (r)---->	1	2	4	8	16	32	64	128	254
1	Cipher Text in HEX	5d0965 38d0e2	742594 e34389	42592e 343891	593db4 3891fb	a158d1 fb2f4b	3f7846 2baa44	d34c48 bd8631	176e9a 3837ba	36b0a9 4934a6
2	CB Cycles per Block	256	129	66	34	18	10	6	4	3
3	Tr1 Time for One Round	0.0001473	0.0001473	0.0001473	0.0001473	0.0001473	0.0001473	0.0001473	0.0001473	0.0001473
4	CT Time for One Cycle	0.0141473	0.0142946	0.0145892	0.0151783	0.0163566	0.0187133	0.0234266	0.0328531	0.0514117
5	TB Time for One Block	3.6217062	1.8440008	0.9628846	0.5160629	0.2944195	0.1871328	0.1405594	0.1314125	0.154235
6	Throughput	13.253422	26.030357	49.850213	93.011921	163.03267	256.50233	341.49273	365.26211	311.21345
7	Ar Area of Implemented R rounds	30	55.472106	102.57182	189.66249	350.69926	648.46756	1199.062	2217.1499	4071.2502
8	AD Design Area	254	279.47211	326.57182	413.66249	574.69926	872.46756	1423.062	2441.1499	4295.2502
9	Power P	17343.534	20176.543	26055.619	38918.012	68725.103	140428.2	311260.8	694602.8	1475760.6
10	Eblock Energy per Block	62813.184	37205.563	25088.553	21084.141	20234.012	26278.723	43750.619	91279.477	227613.9
11	Eb Energy per Bit(pJ/bit)	1308.608	775.11589	522.6782	439.25295	421.54191	547.47339	911.47124	1901.6558	4741.9562

Fig.5 Parameter values obtained for EELWE48

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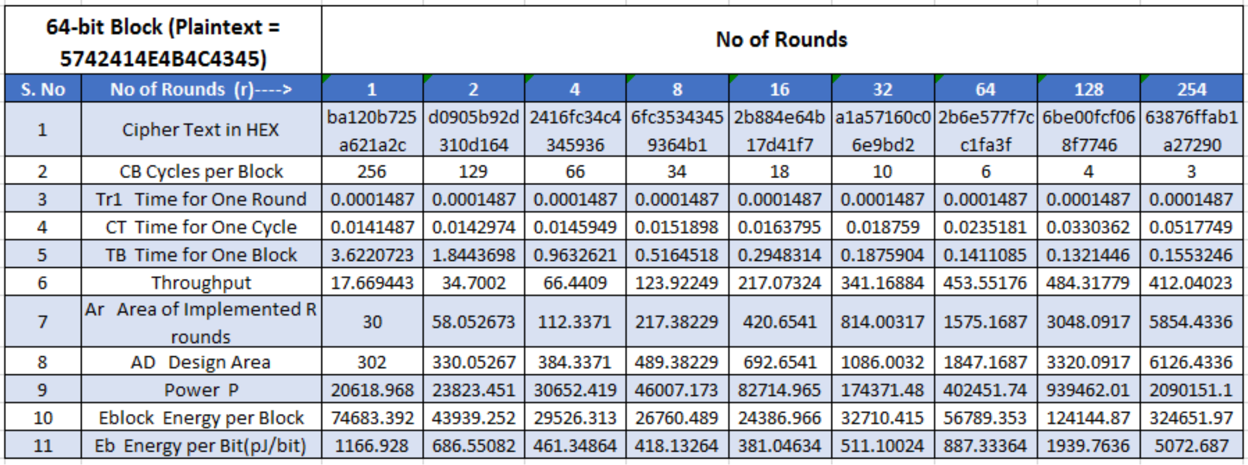

64-bit Block (Plaintext = 5742414E4B4C4345)		No of Rounds								
S. No	No of Rounds (r)---->	1	2	4	8	16	32	64	128	254
1	Cipher Text in HEX	ba120b725 a621a2c	d0905b92d 310d164	2416fc34c4 345936	6fc3534345 9364b1	2b884e64b 17d41f7	a1a57160c0 6e9bd2	2b6e577f7c c1fa3f	6be00fcf06 8f7746	63876ffab1 a27290
2	CB Cycles per Block	256	129	66	34	18	10	6	4	3
3	Tr1 Time for One Round	0.0001487	0.0001487	0.0001487	0.0001487	0.0001487	0.0001487	0.0001487	0.0001487	0.0001487
4	CT Time for One Cycle	0.0141487	0.0142974	0.0145949	0.0151898	0.0163795	0.018759	0.0235181	0.0330362	0.0517749
5	TB Time for One Block	3.6220723	1.8443698	0.9632621	0.5164518	0.2948314	0.1875904	0.1411085	0.1321446	0.1553246
6	Throughput	17.669443	34.7002	66.4409	123.92249	217.07324	341.16884	453.55176	484.31779	412.04023
7	Ar Area of Implemented R rounds	30	58.052673	112.3371	217.38229	420.6541	814.00317	1575.1687	3048.0917	5854.4336
8	AD Design Area	302	330.05267	384.3371	489.38229	692.6541	1086.0032	1847.1687	3320.0917	6126.4336
9	Power P	20618.968	23823.451	30652.419	46007.173	82714.965	174371.48	402451.74	939462.01	2090151.1
10	Eblock Energy per Block	74683.392	43939.252	29526.313	26760.489	24386.966	32710.415	56789.353	124144.87	324651.97
11	Eb Energy per Bit(pJ/bit)	1166.928	686.55082	461.34864	418.13264	381.04634	511.10024	887.33364	1939.7636	5072.687

Fig.6 Parameter values obtained for EELWE64

5. SECURITY Vs. ENERGY CONSUMPTION

Key length plays an important role in defining the security level of an encryption algorithm [24]. If a processor of P Flops encrypts a block of data in C clock cycles, then the number of encryption operations(O) that can be carried out in M years using N systems can be calculated as:

$$O = (P / C) * 60 * 60 * 24 * 365 *$$

(6)

From eq.6, we can obtain the approximate key length that is to be maintained by an encryption algorithm and based on this an 80-bit key is used by an EELWE algorithm. According to the Moore's Law [25], the year Y(γ) till which the cipher will provide adequate protection is calculated as:

$$Y(\gamma) = \text{Proposed Year} + 3(\gamma -56$$

(7)

From eq.7, it is proved that EELWE is secured till the 2317 with security level(γ) of 254.

To measure the security vs energy consumption, a metric called MSEC is used which is calculated as:

$$\text{MSEC} = (\text{No. of Secured years left}) / (\text{Normalized energy})$$

(8)

It is shown that an EELWE has exhibited better MSEC value than the existing algorithm.

6. RESULTS

The proposed EELWE algorithm is implemented in Xilinx. Xilinx is an s/w tool that enables you to synthesize and simulate the HDL (Hardware Description Language) design [26]. The encryption and decryption results of EELWE32, EELWE48 and EELWE64 are presented in Fig.7, Fig.8 and Fig.9, respectively

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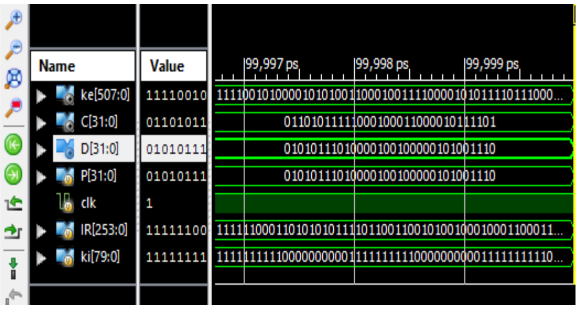
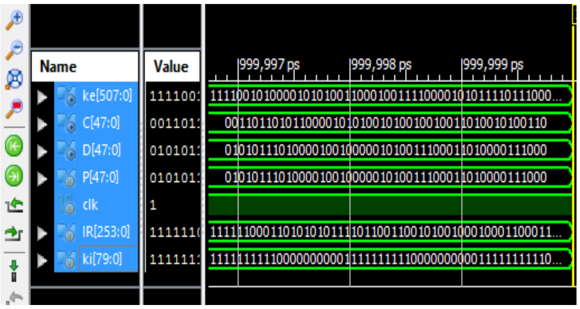


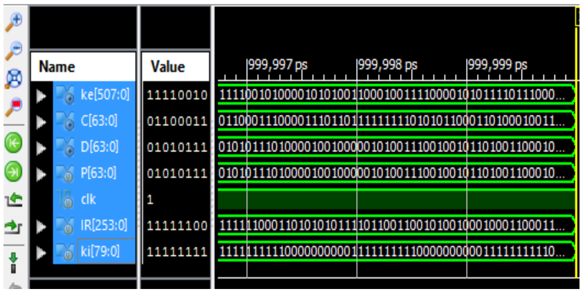
```
Name          Value      |99,997 ps        |99,998 ps        |99,999 ps
ke[507:0]     11110010   111100101000010101001100010011110000101011110111000...
C[31:0]       01101011   01101011111000100011000010111101
D[31:0]       01010111   01010111010000100100000101001110
P[31:0]       01010111   01010111010000100100000101001110
clk           1
IR[253:0]     11111100   11111000110101010101111101100110010100100010001100011...
ki[79:0]      11111111   1111111111000000000011111111110000000000011111111110...
```

Fig.7 Implementation results for EELWE32



```
Name          Value      |999,997 ps       |999,998 ps       |999,999 ps
ke[507:0]     111100:    111100101000010101001100010011110000101011110111000...
C[47:0]       001101:    001101101011000010101001010010010011010010100110
D[47:0]       010101:    010101110100001001000001010011100011010000111000
P[47:0]       010101:    010101110100001001000001010011100011010000111000
clk           1
IR[253:0]     111111(    11111000110101010101111101100110010100100010001100011...
ki[79:0]      111111:    1111111111000000000011111111110000000000011111111110...
```

Fig.8 Implementation results for EELWE48



```
Name          Value      |999,997 ps       |999,998 ps       |999,999 ps
ke[507:0]     11110010   111100101000010101001100010011110000101011110111000...
C[63:0]       01100011   0110001110000111011011111111101010110001101000100 11...
D[63:0]       01010111   0101011101000010010000001010011100100101101001100010...
P[63:0]       01010111   0101011101000010010000001010011100100101101001100010...
clk           1
IR[253:0]     11111100   11111000110101010101111101100110010100100010001100011...
ki[79:0]      11111111   1111111111000000000011111111110000000000011111111110...
```

Fig.9 Implementation results for EELWE64

The energy consumption of different existing lightweight encryption algorithms and the proposed algorithm is shown in the below Table 3. When compared to the existing algorithms, EELWE is consuming less energy.

r	1	2	4	8	16	32	64	128	254
Eb (pJ/bit)	1591.97	952.72	647.38	518.11	515.33	651.91	1046.03	2090.13	4979.92

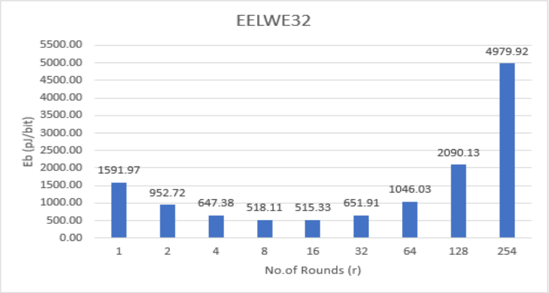


Fig.10 Energy consumption for EELWE32

r	1	2	4	8	16	32	64	128	254
Eb (pJ/bit)	1308.61	775.12	522.68	439.25	421.54	547.47	911.47	1901.66	4741.96

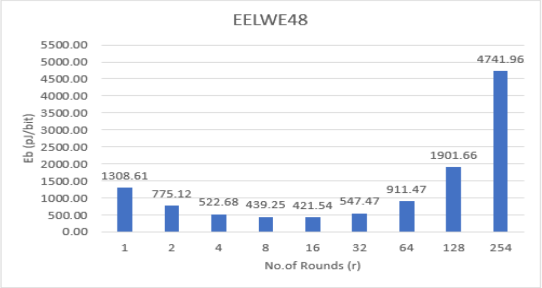


Fig.11 Energy consumption for EELWE48

r	1	2	4	8	16	32	64	128	254
Eb (pJ/bit)	1166.93	686.55	461.35	418.13	381.05	511.10	887.33	1939.76	5072.69

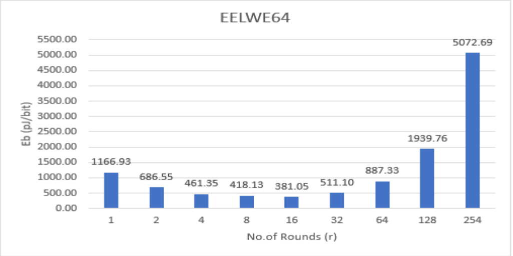


Fig.12 Energy consumption for EELWE64

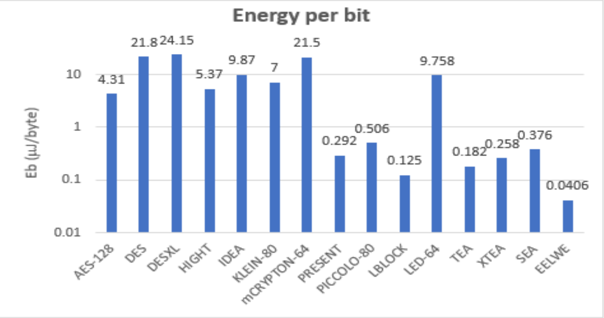


Fig.13 Energy consumption of various LEW algorithms

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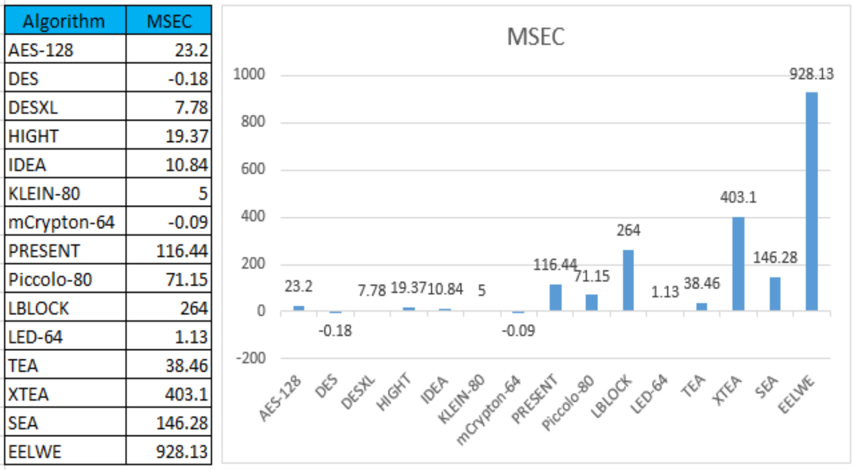
The graphs show that the minimum energy is consumed at 16 rounds in all the three versions. The comparison of energy consumed by various algorithms w.r.t to their block sizes is shown in Table 3 and the graph representation is shown in Fig.13.

Table 3. Comparison of Energy consumed by various algorithms.

Algorithm	Block Size(bits)	Energy consumption for Encryption (µJ/byte)
AES-128	128	4.31
DES	64	21.8
DESXL	64	24.15
HIGHT	64	5.37
IDEA	64	9.87
KLEIN-80	64	7.0
mCrypton-64	64	21.5
PRESENT	64	0.292
Piccolo-80	64	0.506
LBLOCK	64	0.125
LED-64	64	9.758
TEA	64	0.182
XTEA	64	0.258
SEA	96	0.376
EELWE	64	0.0406

MSEC value of EELWE and different existing algorithms are shown in Fig.14.



Algorithm	MSEC
AES-128	23.2
DES	-0.18
DESXL	7.78
HIGHT	19.37
IDEA	10.84
KLEIN-80	5
mCrypton-64	-0.09
PRESENT	116.44
Piccolo-80	71.15
LBLOCK	264
LED-64	1.13
TEA	38.46
XTEA	403.1
SEA	146.28
EELWE	928.13

Fig.14 MSEC value of different algorithms

7. CONCLUSION

A new Lightweight encryption algorithm EELWE is presented in this paper. When simulated in the Xilinx environment, EELWE has consumed comparably less energy than several existing lightweight ciphers. It has supported three different block sizes that are suitable for resource constraint environments such as HSNs. From the observations, it is concluded that EELWE64 obtains the optimized energy consumption with an 80-bit key and for 16 rounds i.e., 0.00305 µJ/byte. But, to have better security, it is suggested to undergo 254 rounds which consumes an energy of 0.0406 µJ/byte. Even this value is far less than energy consumed by other algorithms. Also, EELWE has exhibited better MSEC value compared to existing algorithms.

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