DOMAIN ENCRYPTION BY SLICE AND SHIFT OPERATION: SAR 256

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Abstract

Symmetric key cryptography is the most commonly used cryptographic primitive in domain encryption that meets the requirement devices which are mostly used today. In the recent past a few such algorithms have been implemented to secure communication channels. In this paper, a domain encryption algorithm SAR 256 (a symmetric key cipher) with probabilistic slice and shift operation has been implemented. Developing a software-based domain encryption algorithm SAR 256 seems to be very beneficial for short length data encryption like node of wireless sensor networks (WSN), SSN, iNode of a file system, password, ATM PIN and other electronic data. The cipher SAR 256 is software-based synchronous ultra-lightweight cryptosystem which mainly design for resource-constrained devices such as Radio Frequency IDentification Devices (RFID) Tags, WSN, iNode, blockchain and other such platform with limited processing capabilities. The cipher SAR 256 inherits the hybrid feature of some well-known cryptographic primitives like Blowfish, Twofish, DES, StegoCrypt3D and IDEA. The cipher SAR 256 uses a variant length keystream ranging from $288 - 560$ bit long which is known to be safe and can withstand against several cryptographic attacks. It also uses a dynamic $(16, 32]$ stage slice and shift operation with an average to worst-case probabilistic vulnerability of ≈ 0.0000125 with the average plaintext length $\lfloor 16.5 \rfloor$. However, in the best and the worst case, the state update function yields a probability of guess and determines attack as ≈ 0.005 and ≈ 0.00000329 respectively. The cryptosystem SAR 256 is implemented in 'C' with GCC Version 10.0.1 and has been tested under Xilinx ISE 14.2 with 1.8 GHz 8-core processor.

Keywords: **e-signing, slice and shift, PRNG, state update, grid permutation, FRAME_3X, intermediate key, initialization vector and boolean gear.**

1. Introduction

Despite an increase in overall security investment over the last two decades, breaches continue to haunt enterprises, academia and corporate sectors. Furthermore, we have seen that many of the cyberattacks that lead to breaches make use of encryption in some way. Unauthorized users may gain access to data without the approval or knowledge of the intender participant. Even though access-level controls should have prevented this, recent experience indicates that human errors happen all the time. With encryption, the situation changes dramatically even if human errors such as phishing, having same password for several accounts, un- conscious share of OTP have taken place. In order to overcome with such serious issues, we have proposed a symmetric key cryptographic algorithm SAR 256. The algorithm SAR 256 is based on the pre-computation slice and shift operation. Despite the fact that precomputation vectors are part of a larger class of designs known as combinatorial designs, which are often difficult to find, a proper match of the original vectors. The encryption function is based on the mix huge precomputation that results an array of fixed length ASCII characters to get a vector of padded hexa. The cipher is identical to the Hill cipher. The cipher mainly designs for domain encryption and is much suitable for resource-

constrained devices. It uses the principle of confusion and diffusion to create an intermediate vector that further goes under padding, swapping and shuffling. At each pass of the encryption, the cipher enters into a state update operation that makes the cipher strong against many cryptographic attacks. The state update function *'doSplitToShuffle'* is based on bounded PRNG, segmentation, rounding a slice and boolean gear that makes the precomputation complex. Reverse engineering of the encryption is also performed in the inverse fashion of the encryption procedure. Section 1 describes basic terminology associated with cryptography and cryptanalysis. Section 3 and 4 represent the associated problems and related work of the proposed model SAR 256. Implementation of the cipher is done in section 5 while the driver function and entry point of the cipher is presented in section 6 and 7 respectively. After implementing and testing the cipher SAR 256 under Xilinx 14.2, the test vector of the simulation is presented in section 8. The conclusion and future work of the model is described in section 9.

2. Basic Terminology

2.1 *Cryptology*

Cryptology is a branch of mathematics which comprise cryptography and the art of cryptanalysis such as numerical theory and application of formulas and algorithm. Since the concept for cryptanalysis is highly specialized and complex, here we only focus on some of the key conceptual mathematics behind cryptography. It encompasses both cryptography and cryptanalysis [1].

2.2 *Plaintext and Ciphertext*

Plaintext $\langle \boldsymbol{P_T} \rangle$ is a term used in cryptography that refers to a message before encryption or after decryption or the information that can be directly read by humans or a machine. Whereas a ciphertext $\langle \boldsymbol{C_T} \rangle$ is the encrypted text transformed from the plaintext by using an encryption algorithm? The term "cipher" is sometimes used as an alternative term for ciphertext. The ciphertext is not understandable until it has been converted into plaintext using a key [1, 2].

2.3 *Key and Cryptographic Systems*

A cryptographic key $'\boldsymbol{Key}$ or $\langle \boldsymbol{K} \rangle'$ is the set of bits that may present in binary, decimal, or hexadecimal is mainly used for the encryption of a message (plaintext) and the decryption of a secret message (ciphertext). Key is generally serving as a transformation parameter of the cryptographic algorithm and makes a cryptosystem public or private. If the key is shared (or common) for both encryption and decryption processes, the cryptosystem is referred to as a symmetric key or private key cryptosystem. **Blowfish**, **AES, RC4, DES, RC5**, and **RC6** are examples of some symmetric key cryptosystems [3, 4, 5, 6]. On the other hand, if the key is not shared in the encryption and decryption process, the cryptosystem is referred to as an asymmetric key or public-key cryptosystem. Some examples of asymmetric key cryptography are **RSA, Diffie-Hellman Key Exchange, Elliptical Key Cryptography (ECC)**. According to **Kerckhoff's Principle**, key complexity is an important part of the algorithm design and reliability of a cryptographic algorithm. The security of a key is mainly depending on [7, 8, 9].

- Key confidentiality or key secrecy
- Key authenticity or verification of key sender identity
- Authorized use of the key or permissible use of the key

2.4 *Encryption* | $\boldsymbol{e(P_T, Key)}$

Encryption is the process of encoding data into an unreadable form. During this process, the original text (or the message is called plaintext) is transformed into an alternative form is known as ciphertext. Only the approved parties are allowed to decode the ciphertext back to get the original plaintext. Mathematically an encryption algorithm is represented as $\boldsymbol{e(P_T, Key)}$ [1].

2.5 *Decryption* | $\boldsymbol{d(C_T, Key)}$

Decryption is the process by which the encrypted data (ciphertext) is converted back into its original form (plaintext). It is noted that encryption without the correct key is very difficult for all practical purposes, and in some cases it's impossible. Mathematically a decryption algorithm is represented as $\boldsymbol{d(C_T, Key)}$ [1].

2.6 *The Cipher*

A cipher is an algorithm mainly design for encryption or decryption. It contains a sequence of well-defined procedure that can be followed. Shift ciphers are one of the earliest cryptosystems and the simplest. There are various types of ciphers are there such as *shift cipher, caesar cipher, substitution ciphers, transposition ciphers, polyalphabetic ciphers, nomenclator ciphers, Permutation Cipher and many more.*

2.7 *Cryptography*

Cryptography can be defined as the art and science of cipher creation. It is the oldest of techniques for secure communication and constructing and analyzing protocols that prevent third parties or the public from reading private messages. The goal of cryptography is to maintain and achieve integrity, authentication, confidentiality and non-repudiation. There are three types of cryptographic techniques that are used, they are [2].

- Public key cryptography (asymmetric)
- Private key cryptography (symmetric)
- The hash functions

2.8 *Cryptanalysis*

Cryptology has classified into two parts: (i) cryptography and (ii) cryptanalysis. Cryptography focuses on the construction of ciphers, secret codes and encryption/decryption functions. Whereas cryptanalysis is the study of ciphers, ciphertexts and a cryptosystem, while cryptanalysts attempt to decode a ciphertext without knowing the actual plaintext, encrypted key and algorithm used to encrypt the plaintext. Cryptanalysis entails a thorough examination of the cryptographic technique and its cracking. Some well-known cryptanalysis techniques and cryptanalytic attacks are Known-Plaintext Analysis, Chosen-Plaintext Analysis, Ciphertext-Only Analysis, Man-In-The-Middle or MITM attack and Adaptive Chosen-Plaintext Analysis or ACPA. CrypTool, EverCrack and Cryptol are some important tools used for Cryptanalysis.

2.9 *Cryptosystem*

A cryptosystem consists of a series of algorithms that converts plaintext into ciphertext and ciphertext to plaintext conversely. A full suite of encryption, decryption and key generation algorithms and protocols are the members of a cryptosystem. Examples of some well-known cryptosystems are Rabin, Cramer-Shoup, the Benaloh, AES and RSA [2, 3].

3. Associated Problems

Many applications store their sensitive information like credentials in a tabular format that contains a username and corresponding password in the database. When a server receives a payload authentication request to authenticate a particular credential, an eavesdropper may take an attempt to break the security of the communication channel (or even the database) and can access that sensitive information [10, 11]. If an attacker broke into the database and stolen the entire credential, then every user's account could be accessed and gets hacked. *To overcome from such serious issue, this paper presents a* ***software-oriented domain encryption algorithm: SAR 256****. The SAR 256 has been developed to protect sensitive data such as bank details, social security numbers, biometric information, credentials, medical data and personally identifiable financial information from the unauthorized access. The proposed algorithm has been designed in such a way that can encrypt data of length varies from 80-256 bit long and is claimed to be cryptographically secure against several cryptographic attacks like Linear Masking Attack, Guess and Determine Attack, Correlation Attack, Key Recovery Attack and Timing Attack. The proposed model SAR 256 is based on the concept of binary precomputation, shift permutation, shadow password and principle of confusion and diffusion* [12, 13].

4. Related Work

4.1 *Data Encryption Standard*

The Data Encryption Standard (DES) is a symmetric-key block cipher that was first published by National Institute of Standards and Technology (NIST) in 1975. It is based on 16 round permutations that use 64-bit block format and based on the Feistel network with a key length is 64-bit [14]. DES has an efficient 56-bit key length as the encryption algorithm (only check bits function) does not use 8 of the 64-bit key. The main problem associated with the DES is that it can break using linear cryptanalysis. This problem gets resolved in 3DES by increasing other performance metrics such as gate equivalent (GE), **ROUND** and key size [15].

4.2 *Triple DES*

Triple DES is a symmetric-key block cipher that applies the DES cipher algorithm three times to each data block by uses using the single keys of DES (of 56 bits length) at each time. It was the most commonly used symmetric algorithm in the industry and recommended standard. Although, the total key length contributes to 168 bits and [16, 17] claim that 112 bits are more similar with key strength. Triple DES can still provide robust hardware encryption [18].

4.3 *Blowfish*

Blowfish is another variant of the DES replacement algorithm. This symmetric cipher divides and encrypts messages into 64-bit blocks. Blowfish is a symmetric block cipher that was first published in 1993 by Bruce Schneier. It uses 32-448 bits key size and 64-bit block size that is permutated in 16 rounds to get a ciphertext [3]. Blowfish provides an optimal rate of encryption and yield secure ciphertext. Till date no cryptanalysis report has been reported against this cipher. It is based on the Feistel network structure and features included key-dependent substitution boxes (S-boxes) and a very high key generation schedule. Sometimes it is also called 16-round Feistel cipher [4, 19]. Use of 64 bits block makes Blowfish vulnerable against birthday attack when it encrypts data in HTTPS protocol and is also known to be susceptible to known-plaintext attacks [20]. In 2016, the SWEET-32 attack has vulgarized the cipher and recover the plaintext successfully.

4.4 *Twofish*

Blowfish and his predecessor Twofish are the key figures of computer security expert Bruce Schneier. The algorithms use a secret key of length up to 256 long and only one key is needed as a symmetric cryptographic system [21]. Twofish is also known to be one of the fastest and ideal for both software and hardware implementation. Due to the unique and complex design, it is considered the best choice among all AES candidates [22].

4.5 *The AES*

The Advanced Encryption Standard (AES) is an algorithm that transforms a fixed-length plaintext string into a new bitstream of the same length through a series of complicated operations was first published in 1998. It uses 192-bit and 256-bit keys for heavy-duty encryption, but it is extremely successful in 128-bit key size [6, 23, 24]. It is known to be completely reliable to any attack except for brute force which is attempting to decode the messages using all possible 128-192 bits or 256-bit cipher combinations. However, due to the simple algebraic structure, similar block encryption and complex counter mode the AES is not suitable for short data encryption [25, 26].

4.6 *Bcrypt*

The Bcrypt function, based on a blowfish cipher presented at USANIX in 1999, is designed by Niels Provos and David Mazières [27]. As well as using salt in the blowfish table, over time the iteration count can be extended to make it slower, thus remaining resistant to brute-force attacks even with the increasing number of computers. Besides Bcrypt, several Java secure hash functions such as MD5, SHA256, SHA512, PBKDF2 and Scrypt are also available for domain and credential encryption [28, 29].

5. Implementation of SAR 256

Pseudo slack low bit(s) PSLB act/serves as a pad for create blocks of fixed length [30].

```
char PSLB_1[] = "0";
char PSLB_2[] = "00";
static int TRUE = 1;
```

5.1 $int\ getLength(int)$

The function ***getLength*** expect a positive integer and return number of digits does it have.

```
int getLength(int N) {
        int i=0;
        while(N) {
                i++;
                N=N/10;
        }
        return i;
}
```

5.2 $char * getHexa(int, int)$

The function ***getHexa*** is implemented to convert a decimal value into hexadecimal. It returns a hexadecimal value **PADDED_hexa** of length 4, if boolean flag is set to 0 else return a 3-digit hexadecimal value when boolean flag is set to 1.

```
char* getHexa(int DEC,int flag) {
        if(DEC==0 && flag==0) return "0000";
```

```
        if(DEC==0 && flag==1) return "000";
        char RAW_Decimal[100];
        static char PADDED_Hexa[100];
        int i=0;
        while(DEC) {
               int temp=DEC%16;
               if(temp<10) {
                      RAW_Decimal[i++] = temp + 48;
               }
               else {
                      RAW_Decimal[i++] = temp + 87;
               }
               DEC/=16;
        }
        int z=0;
        if(flag==0 && i!=4) {
               PADDED_Hexa[0]='0';
               z++;
        }
        if(i==1) {
               PADDED_Hexa[z++]='0';
               PADDED_Hexa[z++]='0';
        }
        if(i==2) {
               PADDED_Hexa[z++]='0';
        }

        for (int j = i - 1; j >= 0 ; j--){
               PADDED_Hexa[z++]=RAW_Decimal[j];
        }
        PADDED_Hexa[z]='\0';
        return PADDED_Hexa;
}
```

5.3 *char* ∗ *getDecimal*(*char* ∗, *int*)

The function ***getDecimal*** expecting two formal parameters, the first is a collection of hexadecimals as **RAW_hexa** and the second is Output Length Flag (OLF) which determines the number of bits in the list **i_Key**. It converts the expected hexadecimal value from the collection **RAW_hexa** and converts each value into its equivalent decimal of length 4 (when OLF set to 0) or of length 3 (when OLF is set to 1) [30].

```
char* getDecimal(char RAW_Hexa[],int OLF) {
        if(RAW_Hexa[0]=='0' && RAW_Hexa[1]=='0' && RAW_Hexa[2]=='0' &&
          RAW_Hexa[3]=='0' && OLF==0)
               return "0000";
        if(RAW_Hexa[0]=='0' && RAW_Hexa[1]=='0' && RAW_Hexa[2]=='0' && OLF!=0)
               return "000";
    int DECIMAL_STORE = 0, BASE = 1, L = strlen(RAW_Hexa);
    static char i_Key[5];

    for (int i = L - 1; i >= 0; i--) {
        if (RAW_Hexa[i]>='0' && RAW_Hexa[i]<='9') {
            DECIMAL_STORE += (RAW_Hexa[i] - 48)*BASE;

            BASE = BASE * 16;
        }

        else if (RAW_Hexa[i] >= 'a' && RAW_Hexa[i] <= 'f') {
            DECIMAL_STORE += (RAW_Hexa[i] - 87)*BASE;
            BASE = BASE * 16;
        }
```

```
    }

    int k=0;
    if(OLF==0 && getLength(DECIMAL_STORE) != 4) {
       i_Key[k++]='0';
    }
       if(getLength(DECIMAL_STORE) == 1) {
              i_Key[k++]='0';
              i_Key[k++]='0';
              i_Key[k++]= (char)(DECIMAL_STORE + 48);
       }
       if ( getLength(DECIMAL_STORE) == 2){
              i_Key[k++]='0';
              i_Key[k++]=(char)(DECIMAL_STORE / 10 + 48);
              i_Key[k++]=(char)(DECIMAL_STORE % 10 + 48);
       }
       if ( getLength(DECIMAL_STORE) == 3){
              i_Key[k++]=(char)(DECIMAL_STORE /100 + 48);
              i_Key[k++]=(char)((DECIMAL_STORE/10)%10 + 48);
              i_Key[k++]=(char)(DECIMAL_STORE % 10 + 48);
       }
       if ( getLength(DECIMAL_STORE) == 4){
              i_Key[k++]=(char)(DECIMAL_STORE/1000 + 48);
              i_Key[k++]=(char)((DECIMAL_STORE%1000)/100 + 48);
              i_Key[k++]=(char)((DECIMAL_STORE%100)/10 + 48);
              i_Key[k++]=(char)(DECIMAL_STORE % 10 + 48);
       }
    i_Key[k]='\0';
    return i_Key;
}
```

5.4 $char * mergeList(char *, char *)$

The function **mergeList** expect two pointers to characters as ***list_a*** and ***list_b***. It appends the content of string ***list_b*** at the end of the string ***list_a*** and return the whole as a collection.

```
char* mergeList(char* List_a, char* List_b) {
char* COLLECTION = (char*)malloc((strlen(List_a)+strlen(List_b)+1)*sizeof(char));
       for(int i = 0; i < strlen(List_a); i++) {
              COLLECTION[i]=List_a[i];
       }
       for(int i = 0; i < strlen(List_b); i++) {
              COLLECTION[i+strlen(List_a)]=List_b[i];
       }
       COLLECTION[strlen(List_a)+strlen(List_b)]='\0';
       return COLLECTION;
}
```

5.5 $int\ getPRNG(int, int, int)$

Function **getPRNG** (Pseudo Random Number Generator) expects three integral parameters '**FROM'**, '**TO'** and '**except'** and returns a random number lie in between these two intervals **(FROM, TO]** excluding **FROM** and including **TO**. The third parameter '**except'** exclude a number if it occurs in between these intervals. It return a random value within the range { **(FROM, TO] – except** } [31, 32].

```
int getPRNG(int FROM, int TO, int except) {
       FROM++;
       int RAND = rand() % (TO - FROM + 1) + FROM;
       if(except == -1) {
              return RAND;
       }
       else {
```

```
            while(TRUE) {
                  if(RAND != except)
                        break;
                  RAND = rand() % (TO - FROM + 1) + FROM;
            }
            return RAND;
      }
}
```

5.6 $char * forwardPAS(char **, char *, int)$

The function **forwardPAS** (Forward Padding and Swapping) expect three formal parameters, they are:

- GRID, a pointer to pointer to char
- PlainText, a pointer to char
- PRNG, a random integer

As function gets called, we pass the value **NULL** value as an actual parameter to **GRID** a message plaintext and a random number **PRNG** as actual parameters. When control enters this method, the length of the plaintext (message to be encrypted) gets computed and is assigned to variable **'*L*'** then determines the '**ASCII**' weight of each character belonging to the instance of plaintext **PlainText** and multiply it with the random integer **PRNG**. The final multiplication is kept on variable **ASCII** (a variable of type int). In this function we have only two possible values of **PRNG** (**2** or **3**), the possible range of **ASCII** of plaintext characters could vary from **0** to **255**. Thus, in the worst case, the variable **ASCII** may contain value **2** (when the weight of **ASCII = 1**) and in the best case, it can contain value **765** (when the weight of **ASCII = 255**). Since the number of digits of **ASCII** is not fixed in this range, so there is a need to pad some slake digits to each of them. After padding some Pseudo Slack Low Bit (**PSLB)** to each **ASCII**, number of bits turn to fix so that the number of digits in **ASCII** can have the same length, so the vector **GRID** may contain elements of length **3** or **24** bits exactly. Next, the algorithm generates a random integer **ROUND** within the range **(10, 20]** such that **|ROUND| = 10** and place the digits of **ROUND** in first two consecutive cell of another vector **MUX**. Now it generates two Mutually Exclusive True Random Number **(MITRN)** $\boldsymbol{Lx\_i}$ and $\boldsymbol{Lx\_f}$ such that $\mathbf{0} \leq \boldsymbol{Lx\_i} < \boldsymbol{L}$ and $\mathbf{0} \leq \boldsymbol{Lx\_f} < \boldsymbol{L} - \{\boldsymbol{Lx\_i}\}$ to swap the block of **GRID** located at index $\boldsymbol{Lx\_i}$ and $\boldsymbol{Lx\_f}$ up to **ROUND** times as shown in Fig. 1.

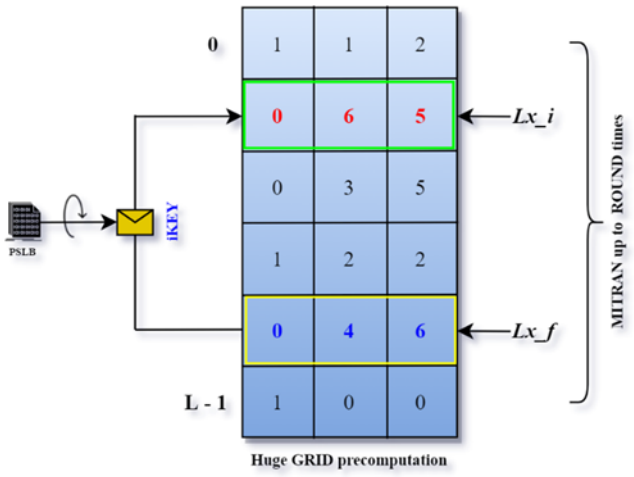


Fig. 1: Huge GRID precomputation of SAR 256

Since the value of **PRNG** is non-deterministic (but bounded) within interval **10** and also the value attends by **ROUND** is **MITRN** in nature and is bounded within the same interval **10**. So, the probability to determine a correct sequence of **PRNG** and **ROUND** becomes $\frac{\mathbf{1}}{\mathbf{10^2}} = \mathbf{0.01}$. At each pass of the **ROUND**, the probability to determine a correct $\boldsymbol{Lx\_i}$ w.r.t. its corresponding $\boldsymbol{Lx\_f}$ is $\frac{\mathbf{1}}{\boldsymbol{L(L-1)}}$. So, the exact probability to determine a correct sequence of **PRNG**, **ROUND** and their associated $\boldsymbol{Lx\_i}$ w.r.t. its corresponding $\boldsymbol{Lx\_f}$ becomes $\frac{\mathbf{0.01}}{\boldsymbol{L(L-1)}}$. Since the average length of the plaintext is **16.5** (because $\frac{\sum_{i=1}^{32} X_i}{\mathbf{32}} \cong \mathbf{16.5}$), thus in average case the probability to determine a correct sequence of **PRNG**, **ROUND** and their associated $\boldsymbol{Lx\_i}$ w.r.t. its corresponding $\boldsymbol{Lx\_f}$ is $\frac{\mathbf{0.01}}{\mathbf{16.5(15.5)}}$ which

is equivalent to $\approx \mathbf{0.0000391}$. In the same way, the best case and the worst-case probability of determining the above sequence is obtained as $\approx \mathbf{0.01}$ and $\approx \mathbf{0.00001085}$. At each pass of the **ROUND**, we have saved the doublet $\boldsymbol{Lx\_i}$ w.r.t. its corresponding $\boldsymbol{Lx\_f}$ to update the secret key for reverse engineering of process $\boldsymbol{forwardPAS}$ and return it as a **MUX**. Here **MUX** act as an intermediate key '**iKEY**' of the whole secret key '**KEY**' such that **iKEY** $\subseteq$ **KEY**.

```
char* forwardPAS(char **GRID, char* PlainText, int PRNG) {
	int L = strlen(PlainText);

	for(int i = 0 ; i < strlen(PlainText); i++) {
		int ASCII = (int)PlainText[i] * PRNG;

		char TEMP[6];
		sprintf(TEMP, "%d", ASCII);

		if(getLength(ASCII) == 1) {
			GRID[i]=mergeList(PSLB_2, TEMP);
		}
		if(getLength(ASCII) == 2) {
			GRID[i]=mergeList(PSLB_1, TEMP);
		}
		if(getLength(ASCII) == 3) {
			GRID[i]=mergeList("", TEMP);
		}
	}

	int ROUND = getPRNG(10, 20, -1);
	static char MUX[82];

	MUX[0] = (char)(ROUND / 10 + 48);
	MUX[1] = (char)(ROUND % 10 + 48);

	for (int i = 0; i < ROUND; ++i){
		int lx_i = getPRNG(0, L-1, -1);
		int lx_f = getPRNG(0, L-1, lx_i);

		char *TEMP = GRID[lx_i];
		GRID[lx_i] = GRID[lx_f];
		GRID[lx_f] = TEMP;

		MUX[4*i + 2] = (char)(lx_i / 10 + 48);
		MUX[4*i + 3] = (char)(lx_i % 10 + 48);
		MUX[4*i + 4] = (char)(lx_f / 10 + 48);
		MUX[4*i + 5] = (char)(lx_f % 10 + 48);
	}
	return MUX;
}
```

5.7 $int * doSplitTriplet(char *, int)$

Function $\boldsymbol{doSplitTriplet}$ expect a pointer to char **VECTOR_imdt** and an integer **PTXt** as length of intermediate plaintext. The algorithm simply split the vector at the mid and join them from rest two extreme. Vector **FRAME_3X** makes a frame of consecutive **3** elements of **VECTOR_imdt** and return it to the caller function.

```
int* doSplitTriplet(char* VECTOR_imdt, int PTXt) {
	int dx = 0;
	char *VECTOR_split = (char*)malloc(PTXt * 3 * sizeof(char));

	for (int i = (PTXt * 3) / 2 - 1; i >= 0 ; i--){
		VECTOR_split[dx++] = VECTOR_imdt[i];
	}

	for (int i = PTXt * 3 - 1; i >= (PTXt * 3) / 2; i--){
```

```
                VECTOR_split[dx++] = VECTOR_imdt[i];
        }
        for (int i = 0; i < PTXt * 3; ++i){
                VECTOR_imdt[i] = VECTOR_split[i];
        }

        int *FRAME_3x = (int*)malloc(PTXt * sizeof(int));
        for (int i = 0; i < PTXt; ++i){
                FRAME_3x[i] =  ((int)VECTOR_split[3 * i] - 48) * 100 +
 ((int)VECTOR_split[3 * i + 1] - 48) * 10 +  ((int)VECTOR_split[3 * i + 2] - 48);
        }
        return FRAME_3x;
 }
```

5.8 $char * listToChar(char **, int)$

The function **listToChar** expects two parameters, a pointer to pointer to char ($** \boldsymbol{char}$) **GRID** and the length of plaintext **PTXt**. Vector **GRID** returned by the function $\boldsymbol{frowardPAS}$ is passed to this function along with the length of the original plaintext. It simply linearizes (row-wise) the elements of **GRID** and returns them as vector **VECTOR_imdt**.

```
 char* listToChar(char **GRID, int L_PTXt) {
        int index = 0;
        char *VECTOR_imdt = (char*)malloc(3 * L_PTXt * sizeof(char));

        for (int i = 0; i < L_PTXt; ++i) {
                for(int j = 0; j < strlen(GRID[i]); j++)
                        VECTOR_imdt[index++] = GRID[i][j];
        }
        return VECTOR_imdt;
 }
```

5.9 $char * doSplitToShuffle(char *, int)$

Function $\boldsymbol{doSplitToShuffler}$ expect **VECTOR_imdt** returned by the function $\boldsymbol{listToChar}$ and length of original plaintext **PTXt**. It generates a random number within the range **(16, 32]** and stores the digits of **segment_ROUND** at the first two consecutive cells of **MUX**. It generates two indices $\boldsymbol{double\_i} \; \forall \; \mathbf{0} \leq \boldsymbol{doublet\_i} < \mathbf{3}\boldsymbol{L}$ and $\boldsymbol{doublet\_k} \; \forall \; \mathbf{0} \leq \boldsymbol{doublet\_k} < \mathbf{3}\boldsymbol{L} - \langle \boldsymbol{doublet\_i} \rangle$ such that $\boldsymbol{doublet\_k} > \boldsymbol{doublet\_i}$, make a slice $\langle \boldsymbol{S} \rangle$ of elements ranging from $\boldsymbol{doublet\_i}$ to $\boldsymbol{doublet\_k}$ inclusive. After cutting a slice $\langle \boldsymbol{S} \rangle$ of length $|\boldsymbol{doublet\_k} - \boldsymbol{doublet\_i} + \mathbf{1}|$ it places the rest two segments (the left sub-segment ranging from **0** to $\langle \boldsymbol{doublet\_i} - \mathbf{1} \rangle$ and the right sub-segment ranging from $\langle \boldsymbol{doublet\_k} + \mathbf{1} \rangle$ to **CTXt-1** of **VECTOR_imdt** in vector **STATE_UPDATE** and attach the segmented slice $\langle \boldsymbol{S} \rangle$ on the vector **STATE_UPDATE** at the beginning (when GEAR = 1) or at the end (when GEAR = 0) as per the value of boolean **GEAR 1** or **0** are shown in Fig. 2 and Fig. 3 respectively.

After shifting a slice into the appropriate position, we have updated the state of vector **VECTOR_imdt** with the current vector **STATE_UPDATE**. Each $\boldsymbol{doublet\_i}$ and $\boldsymbol{doublet\_k}$ assign to **MUX** for further reverse engineering and return to the called function. Since the operation slice and shift (state update) is repeated up to **segment_ROUND** times, so the probability to determine a correct **segment_ROUND** is $\frac{\mathbf{1}}{\mathbf{16}}$ itself.

At each pass of the shift, the only probability to determine the correct sequence of $\boldsymbol{doublet\_k}$ with respect to its corresponding $\boldsymbol{doublet\_i}$ is $\frac{\mathbf{1}}{\mathbf{3}\boldsymbol{L}(\mathbf{3}\boldsymbol{L}-\mathbf{1})}$, so the probability to get a correct sequence of **segment_ROUND** and doublets ($\boldsymbol{doublet\_k}$ w.r.t it corresponding $\boldsymbol{doublet\_i}$) becomes $\frac{\mathbf{0.020}}{\boldsymbol{L}(\mathbf{3}\boldsymbol{L}-\mathbf{1})}$. Since at each pass it attaches the slice $\langle \boldsymbol{S} \rangle$ as per the value of boolean **GEAR**, so the final probability to determine the correct sequence of **segment_ROUND**, **doublets** and **boolean_GEAR** of vector **STATE_UPDATE** become $\frac{\mathbf{0.020}}{\boldsymbol{L}(\mathbf{3}\boldsymbol{L}-\mathbf{1})\boldsymbol{GEAR}} \approx \frac{\mathbf{0.010}}{\boldsymbol{L}(\mathbf{3}\boldsymbol{L}-\mathbf{1})}$. The average length of the plaintext is **16.5**, thus, in the average case the probability to determine the above sequence is $\frac{\mathbf{0.010}}{\mathbf{16.5}(\mathbf{48.5})}$ which is equivalent to $\approx \mathbf{0.0000125}$. In the same way, the best case and the worst-case probability of determining the above-said sequence are found as $\approx \mathbf{0.005}$ and $\approx \mathbf{0.00000329}$ respectively.

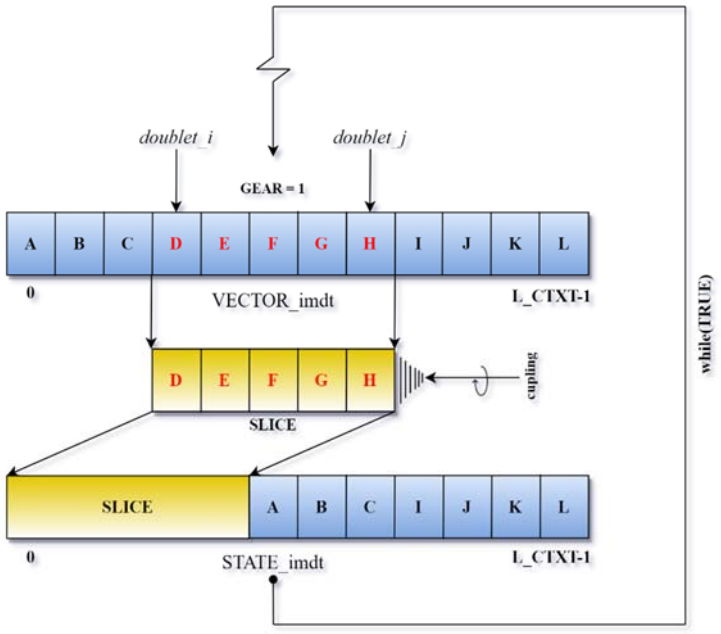


Fig. 2: Slice and shift operation at boolean GEAR = 1

After shifting a slice into the appropriate position, we have updated the state of vector **VECTOR_imdt** with the current vector **STATE_UPDATE**. Each ***doublet_i*** and ***doublet_k*** assign to **MUX** for further reverse engineering and return to the called function. Since the operation slice and shift (state update) is repeated up to **segment_ROUND** times, so the probability to determine a correct **segment_ROUND** is $\frac{1}{16}$ itself.

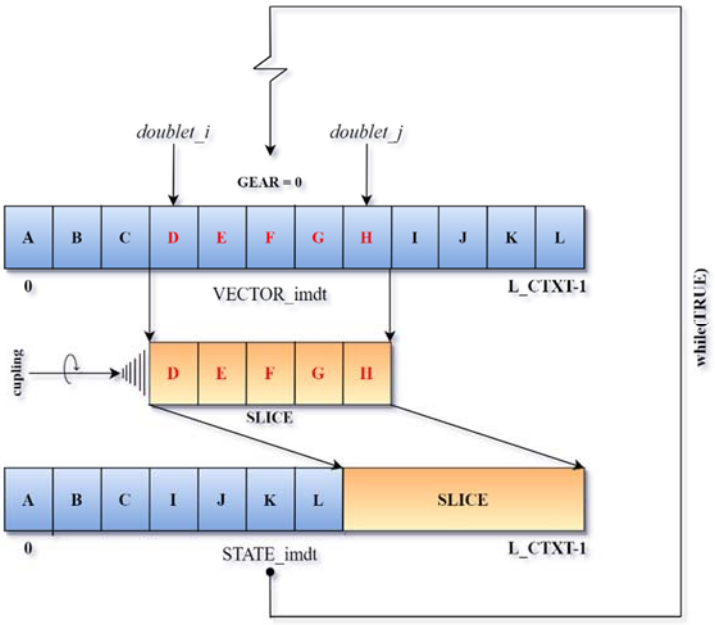


Fig. 3: Slice and shift operation at boolean GEAR = 0

At each pass of the shift, the only probability to determine the correct sequence of ***doublet_k*** with respect to its corresponding ***doublet_i*** is $\frac{1}{3L(3L-1)}$, so the probability to get a correct sequence of **segment_ROUND** and doublets (***doublet_k*** w.r.t it corresponding ***doublet_i***) becomes $\frac{0.020}{L(3L-1)}$. Since at each pass it attaches the slice $\langle S \rangle$ as per the value of boolean **GEAR**, so the final probability to determine the correct sequence of **segment_ROUND**, **doublets** and **boolean_GEAR** of vector **STATE_UPDATE** become $\frac{0.020}{L(3L-1)GEAR} \approx \frac{0.010}{L(3L-1)}$. The average length of the plaintext is **16.5**, thus, in the average case the probability to determine the above

sequence is $\frac{0.010}{16.5(48.5)}$ which is equivalent to $\approx \mathbf{0.0000125}$. In the same way, the best case and the worst-case probability of determining the above-said sequence are found as $\approx \mathbf{0.005}$ and $\approx \mathbf{0.00000329}$ respectively.

```
char* doSplitToShuffle(char* VECTOR_imdt, int L_PTXt) {
	int segment_ROUND = getPRNG(16, 32, -1);

	static char MUX[192];
	MUX[0] = (char)(segment_ROUND / 10 + 48);
	MUX[1] = (char)(segment_ROUND % 10 + 48);

	int index = 0;
	while(index < segment_ROUND) {
		int doublet_i = getPRNG(0, L_PTXt * 3 - 1, -1);
		int doublet_j = getPRNG(0, L_PTXt * 3 - 1, doublet_i);
		if(doublet_i > doublet_j) {
			int TEMP = doublet_i;
			doublet_i = doublet_j;
			doublet_j = TEMP;
		}
		int boolean_GEAR =  getPRNG(0, 1, -1);
		char *STATE_imdt = (char*)malloc(L_PTXt * 3 * sizeof(char));
		char  *SLICE  =  (char*)malloc((doublet_j  -  doublet_i  +  1)  *
sizeof(char));

		int dx = 0;
		for (int i = doublet_i; i <= doublet_j; ++i){
			SLICE[dx++] = VECTOR_imdt[i];
		}

		if(boolean_GEAR == 0){
			int j = 0;
			for (int i = 0; i < L_PTXt * 3; ++i){
				if(i  ==  doublet_i  &&  doublet_j  ==  L_PTXt  *  3  -  1)
	break;
				if(i == doublet_i)  i = doublet_j + 1;
				STATE_imdt[j++] = VECTOR_imdt[i];
			}
			for (int i = 0; i < dx; ++i){
				STATE_imdt[j++] = SLICE[i];
			}
		}
		else {
			for (int i = 0; i < dx; ++i){
				STATE_imdt[i] = SLICE[i];
			}
			for (int i = 0; i < L_PTXt * 3; ++i){
				if(i  ==  doublet_i  &&  doublet_j  ==  L_PTXt  *  3  -  1)
	break;
				if(i == doublet_i)  i = doublet_j + 1;
				STATE_imdt[dx++] = VECTOR_imdt[i];
			}
		}

		for (int i = 0; i < L_PTXt * 3; ++i){
			VECTOR_imdt[i]=STATE_imdt[i];
		}

		MUX[6*index + 2] = (char)(doublet_i / 10 + 48);
```

```
            MUX[6*index + 3] = (char)(doublet_i % 10 + 48);
            MUX[6*index + 4] = (char)(doublet_j / 10 + 48);
            MUX[6*index + 5] = (char)(doublet_j % 10 + 48);
            MUX[6*index + 6] = (char)(boolean_GEAR / 10 + 48);
            MUX[6*index + 7] = (char)(boolean_GEAR % 10 + 48);

            index++;
      }

      return MUX;
}
```

5.10 *void backwardSplitShuffler*(*char* ∗, *int* ∗ [ ], *int*, *int*)

Function ***backwardSplitShuffler*** expect a pointer to char as **VECTOR_imdt, MUX** as a matrix of **KEY**, **segment_ROUND** and length of ciphertext **CTXt** as formal parameters. It performs the reverse engineering of **VECTOR_imdt** to decipher the encrypted ciphertext. In other words, this function performs the inverse of each operation performed by the function ***forwardSplitShuffler***.

```
void backwardSplitShuffle(char* VECTOR_imdt, int MUX[][3], int segment_ROUND, int
L_CTXt) {
      char BUFFER[1024];
      int COUNTER_=segment_ROUND-1;
      while(COUNTER_ >= 0) {
            if(MUX[COUNTER_][2]==0) {
                  int k=0;
                  int d=MUX[COUNTER_][1]-MUX[COUNTER_][0]+1;
                  if(MUX[COUNTER_][1]==L_CTXt-1) {
                        for (int i = 0; i < L_CTXt; ++i){
                              BUFFER[k++]=VECTOR_imdt[i];
                        }
                  }
                  else {
                        int i=0;
                        while(i < MUX[COUNTER_][0]) {
                              BUFFER[k++]=VECTOR_imdt[i];
                              i++;
                        }
                        for (int i = L_CTXt - d; i < L_CTXt; ++i){
                              BUFFER[k++]=VECTOR_imdt[i];
                        }
                        i=MUX[COUNTER_][0];
                        while(i < L_CTXt-d) {
                              BUFFER[k++]=VECTOR_imdt[i];
                              i++;
                        }
                  }
            }
            else {
                  int k=0;
                  int d=MUX[COUNTER_][1]-MUX[COUNTER_][0]+1;
                  if(MUX[COUNTER_][0]==0) {
                        for (int i = 0; i < L_CTXt; ++i){
                              BUFFER[k++]=VECTOR_imdt[i];
                        }
                  }
                  else {
                        for (int i = d; i < d + MUX[COUNTER_][0]; ++i){
                              BUFFER[k++]=VECTOR_imdt[i];
                        }
                        for (int i = 0; i < d; ++i){
```

```
                                BUFFER[k++]=VECTOR_imdt[i];
                        }
                        int i = d+MUX[COUNTER_][0];
                        while(i < L_CTXt) {
                                BUFFER[k++]=VECTOR_imdt[i];
                                i++;
                        }
                }
        }
        for (int i = 0; i < L_CTXt; ++i){
                VECTOR_imdt[i]=BUFFER[i];
        }


        COUNTER_--;
    }
    for (int i = 0; i < L_CTXt; ++i){
        VECTOR_imdt[i]=BUFFER[i];
    }
}
```

5.11 $char * backwardPAS(char *, int, int, int, int)$

The function ***backwardPAS*** (backward Padding and Shuffling) expect a pointer to character ($*char$) as **VECTOR_imdt** updated by the function ***backwardSplitShuffler***, **MUX** as a key matrix, **ROUND**, **PRNG** and length of ciphertext **CTXt** as formal parameters. Basically, it performs the next level reverse engineering of **VECTOR_imdt** to decipher the ciphertext **CipherTEXT**. In general, we can say that, this function is mathematically inverse to the function ***forwardPAS*** and can be written as:

```
char* backwardPAS(char* VECTOR_imdt, int MUX[][2], int ROUND, int PRNG, int
L_CTXt) {
    char** GRID=(char**)malloc((L_CTXt/3)*sizeof(char*));
    int k=0;
    for (int i = 0; i < L_CTXt / 3; ++i) {
        char TEMP[4];
        int j=0;
        for (j = 0; j < 3; j++)
        {
            TEMP[j]=VECTOR_imdt[k++];
        }
        TEMP[j]='\0';
        GRID[i]=mergeList(TEMP,"");
    }

    int _COUNTER=ROUND-1;
    while(_COUNTER >= 0) {
        int lx_i = MUX[_COUNTER][0];
        int lx_f = MUX[_COUNTER][1];

        char *_temP = GRID[lx_i];
        GRID[lx_i] = GRID[lx_f];
        GRID[lx_f] = _temP;
        _COUNTER--;
    }

    int ASCII_pt[32];
    static char PLAINtext[33];

    for (int i = 0; i < L_CTXt / 3; ++i){
        ASCII_pt[i]=atoi(GRID[i]);
        ASCII_pt[i]/=PRNG;
```

```
            PLAINtext[i]=(char)ASCII_pt[i];
        }
        return PLAINtext;
}
```

6. Driver Functions of SAR 256

6.1 char * *encryptPT*(*char* *, *char* *)

The function ***encryptPT*** expect two (* ***char***) as concrete plaintext and secret key **KEY** (KEY initially set to NULL), defines a **GRID** to update the secret key **KEY_Secret** (of size vary from 288-560 bits) and an integer **PRNG**. First, it invokes the function ***forwardPAS*** by passing arguments **GRID** as a **NULL**, a concrete plaintext as **PlainTEXT** and an integer **PRNG** within the range **(1, 3]**. In this process, the intermediate key is generated in **MUX** and is return to the called function that is further saved to **KEY_buffer_1**. At the next phase when function ***gridToList*** gets called by passing the concrete intermediate **GRID** and size of plaintext **PTXt**, it linearizes the elements of **GRID** (into a group of **3** each of **8** bits exactly) into a list and returns to a pointer to char **VECTOR_imdt**. On invoking the function ***forwardSplitShuffler*** by passing the intermediate vector **VECTOR_imdt** (returned by the function call ***gridToList***) and size of plaintext **PTXt** as formal parameters. It split the vector and shuffle the slice up to **ROUND** times and return the next intermediate key as **MUX** and is stored in **KEY_buffer_2**. After that, it performs the intermediate key extraction of **MUX** from **KEY_buffer_1**, **KEY_buffer_2** and arranges them sequentially to design the symmetric key **KEY_Secret** and finally assign it to the variable **KEY** (formal parameter of function ***encryptPT***) [33]. At the end of this encryption process, it calls to function ***getFrame3X*** to frame the **VECTOR_imdt** into a sequence of frames of size **3** and arrange them sequentially into a static char **CipherTEXT**. After placing a null delimiter at the end of the ciphertext, the function returns the encrypted **PlainTEXT** as **CipherTEXT**.

```
char* encryptPT(char* PLAINtext, char *KEY) {
        char** GRID = (char**)malloc(strlen(PLAINtext)  *  sizeof(char*));
        char KEY_Private[512];

        int PRNG = getPRNG(2, 3, -1);
        char* KEY_buffer_1 = forwardPAS(GRID, PLAINtext, PRNG);

        char* VECTOR_imdt = listToChar(GRID, strlen(PLAINtext));

        char* KEY_buffer_2 = doSplitToShuffle(VECTOR_imdt, strlen(PLAINtext));

        KEY_Private[0] = '0';
        KEY_Private[1] = (char)PRNG + 48;

        int index = 2;
        int ROUND = ((int)KEY_buffer_1[0] - 48) * 10 + (int)KEY_buffer_1[1] -48;

        for (int i = 0; i < ROUND * 4 + 2; ++i){
                KEY_Private[index++] = KEY_buffer_1[i];
        }
        int segment_ROUND = ((int)KEY_buffer_2[0] - 48) * 10 +
(int)KEY_buffer_2[1] -48;

        for (int i = 0; i < segment_ROUND * 6 + 2; ++i){
                KEY_Private[index++] = KEY_buffer_2[i];
        }

        if(4-index%4==1) {
                KEY_Private[index]='0';
                index++;
        }
        if(4-index%4==2) {
                KEY_Private[index]=KEY_Private[index+1]='0';
                index=index+2;
        }
```

```
        if(4-index%4==3) {
                KEY_Private[index]=KEY_Private[index+1]=KEY_Private[index+2]='0';
                index=index+3;
        }
        KEY_Private[index]='\0';

        int k=0;
        for (int i = 0; i < index / 4; i++){
                char* test=getHexa(((int)KEY_Private[4 * i] - 48) * 1000 +
                        ((int)KEY_Private[4 * i + 1] - 48) * 100 +
                        ((int)KEY_Private[4 * i + 2] - 48) * 10 +
                        ((int)KEY_Private[4 * i + 3] - 48),0);
                for(int j = 0; j < 4; j++) {
                        KEY[k++]=test[j];
                }
        }
        int* BUFFER = doSplitTriplet(VECTOR_imdt, strlen(PLAINtext));

        static char CIPHERtext[1024];
        k=0;
        for(int i = 0; i < strlen(PLAINtext); i++) {
                char* hex=getHexa(BUFFER[i],1);
                for (int index = 0; index < 3; ++index){
                        CIPHERtext[k++]=hex[index];
                }
        }
        CIPHERtext[k]='\0';
        return CIPHERtext;
}
```

6.2 char * decryptPT(char *, char *)

The function **decryptCT** expecting two formal parameters the ciphertext (the encrypted message of 256 bit long) and the secrete key, in hexadecimal form. Matrix **KEY_BUFFER_1** and **KEY_BUFFER_2** same the intermediate state of the extracted secret key. An array of character "Buffer" (of size 1024) consists the decimal value equivalent to each first three consecutive triplets of the hexadecimal cipher text. All these conversions are done within the scope of a loop with condition index **< L_CTXt**. After converting each three consecutive hexadecimal value of the ciphertext the buffer is terminated by **'\0'**. Similarly, first four consecutive character of the secret key **'KEY'** gets extracted and converted into equivalent decimal in KEY_imdt. The value of **PRNG** and **ROUND** (during encryption phase) are extracted and used to extract **MITRN *Lx_i*** and ***Lx_f*** and is saved into **KEY_buffer_1**. After finding the **SEGMENT_ROUND** and boolean **GEAR** to perform the reverse engineering of operation slice and shift. On invoking function **getFrame3x**, the buffer has splitted into mid, and merge from the two opposite extremes [34]. On calling the function **backwardSplitShuffle** we achieved the reverse action of function **forwardSplitShuffler**, at the end of the decryption phase, **backwardPAS** function gets called that performs the reverse action of the function **forwardPAS** and return the expected plaintext [35].

```
char* decryptCT(char *CIPHERtext, char *KEY) {
        int PRNG, ROUND, segment_ROUND;
        int KEY_buffer_1[100][2], KEY_buffer_2[100][3], L_CTXt=strlen(CIPHERtext);
        char BUFFER[1024];
        int i = 0,index = 0;

        while(index < L_CTXt) {
                char _TEMP[4];
                for (int j = 0; j < 3; ++j){
                        _TEMP[j] = CIPHERtext[j + i];
                }
                _TEMP[3] = '\0';

                char *DECImal = getDecimal(_TEMP,1);
```

```
		for (int j = 0; j < 3; ++j){
			BUFFER[index++] = DECImal[j];
		}
		i=i+3;
	}
	BUFFER[index] = '\0';

	static char KEY_imdt[1024];
	int _COUNTER = 0; i=0,index=0;
	while(_COUNTER < 70) {
		char _TEMP[5];
		for (int j = 0; j < 4; ++j){
			_TEMP[j]=KEY[j+i];
		}
		_TEMP[4] = '\0';

		char *DECImal = getDecimal(_TEMP,0);
		for (int j = 0; j < 4; ++j){
			KEY_imdt[index++] = DECImal[j];
		}
		i=i+4;
		_COUNTER++;
	}

	index = 1;
	PRNG = (int)KEY_imdt[index++] - 48;
	ROUND = (int)KEY_imdt[index++] - 48;
	ROUND = ROUND*10 + (int)KEY_imdt[index++] - 48;

	for (int j = 0; j < ROUND ; j++){
		KEY_buffer_1[j][0] = (int)KEY_imdt[index++] - 48;
		KEY_buffer_1[j][0] = KEY_buffer_1[j][0]*10 + (int)KEY_imdt[index++]
- 48;
		KEY_buffer_1[j][1] = (int)KEY_imdt[index++] - 48;
		KEY_buffer_1[j][1] = KEY_buffer_1[j][1]*10 + (int)KEY_imdt[index++]
- 48;
	}

	segment_ROUND = (int)KEY_imdt[index++] - 48;
	segment_ROUND = segment_ROUND*10 + (int)KEY_imdt[index++] - 48;

	for (int j = 0; j < segment_ROUND ; j++){
		KEY_buffer_2[j][0] = (int)KEY_imdt[index++] - 48;
		KEY_buffer_2[j][0] = KEY_buffer_2[j][0]*10 + (int)KEY_imdt[index++]
- 48;
		KEY_buffer_2[j][1] = (int)KEY_imdt[index++] - 48;
```

```
                KEY_buffer_2[j][1] = KEY_buffer_2[j][1]*10 + (int)KEY_imdt[index++]
 - 48;
                KEY_buffer_2[j][2] = (int)KEY_imdt[index++] - 48;
                KEY_buffer_2[j][2] = KEY_buffer_2[j][2]*10 + (int)KEY_imdt[index++]
 - 48;
        }

        doSplitTriplet(BUFFER,L_CTXt/3);

        backwardSplitShuffle(BUFFER,KEY_buffer_2,segment_ROUND,L_CTXt);

        return backwardPAS(BUFFER, KEY_buffer_1, ROUND,PRNG, L_CTXt);
 }
```

7. Entry Point of SAR 256

An entry point is a place in a programme where the execution of the programme begins and the code has access to command line parameters. This function act as an entry point of two functions **encryptPT** and **decryptCT**. The complete signature of this function is **char** $*$ **getEntryPoint**(**char** $*$, **char**, **char** $*$) that expect a pointer to char as message (either plaintext or ciphertext), an action flag '*e*' for encryption and return ciphertext else decryption and return plaintext, and return (pass by reference) the secret key for the desirable function call.

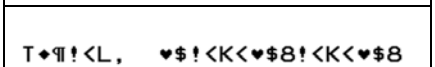
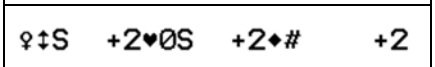
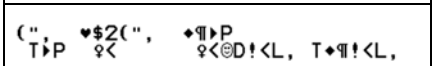
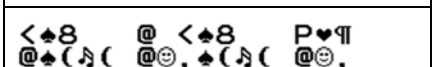
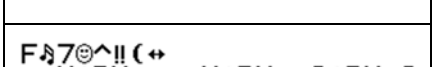
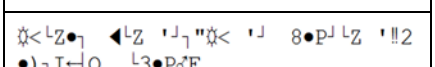
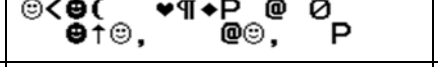
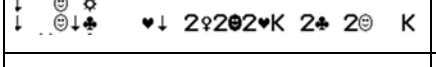
```
char* getEntryPoint(char *message,char action,char *KEY) {
        if(action=='e')
                return encryptPT(message, KEY);
        else
                return decryptCT(message, KEY);
 }
```

8. Test Vectors of SAR 256

Based on the test vector as key and *plaintext*, the model SAR 256 has been tested for encrypting the same message (*plaintext*) several times with different key with the same plaintext, each time different ciphertext has obtained. Both keystream and output ciphertext is represented in Hexadecimal and Unicode characters are given below in Table 1.

Table 1: Test vector's result (in Hexadecimal with Unicode characters) of **SAR 256**

#	P_T	Generated *Ciphertext* (C_T) with Unicodes	Private Key (K)
1	plaintext	13F13419327914D1B119D3540CE	5DFA1F60198026003210080260000202BD0259000201960710070900CF000103210077006703E803FA006F07D105F2007809C403F600110835039400110 76D026A00710641025F0009057900E00000
		♣☺J∢(→♥04¶#C ♦#∢(♂▼☺J+F ♣☺J"P0∢ W♦#"P0∢ ♥0"PN▲♥0S"PN▲♥0S	
		15D0D40DE1400D400227008E016	00D501FB02C2006601910325000700C90258000101970130012D000709D709C4052A0004076C045F006400C90068001608FC0916007507080526006805140590001513 610135006C076C03F9006805DC039D006802BD02D2000D057804BF007D0A280914006A07D0
		(", ♥$2(", ♦¶▸P T▸P ♀< ♀<☺D!<L, T♦¶!<L,	
		1801491AF17C14E15E132146085	013701F60198026003210080260000202BD0259000201960 9DB096002D40002076D03F900000641026B0012076D04C0006E04B102C5007709C4052A0004076C045F006400C90068001608FC0916007507080526006805140590001509610135006C076C
		☺ ☼ ☺↓♣ ♥↓ 2♀2☻2♥K 2♣ 2☺ K -K ↓☺↓ -K ☺ -2☺ ☻↓ -2☺ ☻↓ ♥2☻↓ ♀2☺ ☻↓ ♀2☺↓	

2	**a1b2c3d4 0101 xyz 123 *&^%!@#**	38A01B00007C2942B00A00C937A05C0A9060407C1BF1BC38E37A1CC00461E02B20021AC0A137B0012B301C	04D50C1C09C50A2902590594058C0A3405F1001E03F50A96046100D1070B0191123E0010076C122C002F190100CE006E145001AA002923F01B43009011F8135B0010170D063400941324225B00221DB1135D0000
			
		AA34AE07711216B03D1B91EC0323A38A27715F0BE0810C710D279204388193BE0FA2052710B	AAA009CE00D0097E0139097504B20773090D097405ED0519071D1D4C02C4006C138900E9006705150C6C00AC1E1510F8005522C501E8000217700316000A1AF40E9D008812C1040D0071164409440064
			
		05A2E508F20300C3970D819B1692B21A11AA38B2DA1A611A0951ED29A1FF06A0641310B314F	0BC2309CE00D0097E0139097504B20773090D097405ED051909DF251C09E500010ED912540054232812B1001E1069044300A621350189002E206C03F8009823F00A68006A19641487001A15180DA4008A1EDD117700311519065C007322610ABD000021FD
			
3	**Hello World…**	0210D40B41AC1541A50A213614D3A514C1B116E341	77AA7038A025A0321006A0384025F01FD045003F301F502C409C90F3C014B00250ED907F200120BB8020700120BB908B70076076D039300170FA00D7000780FA0034800700DAC0074000C057801A4006C0C1D0F01000D070901B200850FA1013900150BB9
			
		0CA2BE0DE2680F21241B93861040D301639E052029	00D501FC0130038E0452025A00CC032501FA0192044F032D01F8051D09C90F3C014B00250ED907F200120BB8020700120BB908B70076076D039300170FA00D7000780FA0034800700DAC0074000C057801A4006C0C1D0F01000D070901B200850FA1013900150BB9
			
		1A034214D14D02115613803E0EA11B0B438713926D	0166038A025A0321006A0384025F01FD045003F301F502C406BF0BB809E9000D057802DD00790F3D02CA000508FC0271006908FC08B4000E0BB802E400210ED90079001E0C1C052700790899
			
4	**1111100000**	1BF09019E19B30606F0721A11B91DA1BF	01230006032300C80388026201FC02BD01FD019602BD006806B00A8C0782000B0898039700760961046B001D0C8002CE00750A2808AF000205DD0077006C0C810726000D0C1D05EC000204B1
			
		04505832638C35C3DE2BB3D438D045384	00D5F0CD0006006402C4006401F501F7006E0192025B006C01FD02BF07090BB9052A0007089802D20005089906C2007D0AF0052500080B5403FA00660898006B00110AF1013900700640013D000A09C5007C0000
			
5	**NITCian**	3971451560151430730CA	0FFFF0C5025A006A00C8025801F60193019500640067025A09C907080136001006A5052800090708020700090709006E0076076D03930002076C0527007707D00333007005780074000C057801A4006C03E906B8000D0709019D0070076D013900000385
			
		10307015513112E13F0DE	01000F0CE025A006A00C8025801F6019301950064006 7025A0BBC06400522000704B10012006B057800CD000 4025900CD000102BC03920007076C04C100640064038 E000D076D0001007007D10262006B032106B60067070 9045C000D07D101370064044C058C006704B000D9006 707D000D20000
			

Average encryption time in **GNU C** compiler is ≈ 0.0134 sec. The code is implemented in **macOS** Mojave version **10.14.6 Intel Core i5** with following Run Time Environment (RTE).

Core Technology	:	'C'
Core Framework	:	Xilin ISE 14.2
RTE	:	CodeLite
Compiler	:	GCC Version 15.0.0
Processor Speed	:	1.8

The cipher **SAR 256** has tested on **Xilin ISE 14.2** under **CodeLite** environment in **macOS** Mojave with the above parameters.

9. Conclusion and Future Work

In this paper a domain encryption algorithm SAR 256 is proposed. The algorithm is implemented in 'C' and has tested under Xilinx 14.2 environment and found to be safe & secure against some well-known cryptographic attacks. Since it has a fixed length ciphertext output w.r.t. a plaintext input, thus the implementation of SAR 256 can also be substituted as a hash. It has observed that the ciphertext produced by SAR 256 is cryptographically secure against various cryptographic attacks like timing attack, side channel attack, cube attack, linear masking attack and correlation attack. The cipher has been tested against domain encryption parameters and has found to be unbiased to meet the encryption standard defined by the NIST to encrypt sensitive data such as cookies, e-signing key, login credentials, ATM PIN, iNode, SSN, WSN's node etc. The cipher is mainly suitable for resource-constrained devices due to their less computation time, low hardware requirement and hence it found to be more optimal as compared to other domain encryption algorithms. This cipher SAR 256 can be implemented to encrypt files/data on a server, cloud server, blockchain, wireless sensor networks and other such framework. The only limitation is that it has quite a large key length for each plaintext length which can be resolve in future work.

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