Enhanced RSA Algorithm using Four Primes with CRT

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ABSTRACT

Protecting the privacy and the confidentiality of sensitive data of users has become an urgent problem to be solved in the cloud storage environment. This is also the biggest obstacle facing the popularity of the cloud storage services. RSA is one of the well-known public key cryptosystem being used to secure any system like smart cards and e-commerce applications. The purpose of this paper is to design and implement faster RSA variant compare to other variants found in the literature

Keywords: RSA, Security, Cryptography, Encryption, Decryption

I. INTRODUCTION

The main purpose of cryptography is to deliver data or information safely to the intended user without alteration of data or information by any unauthorized person. Cryptography had been used then mainly in the military affairs, when rulers had been transferred encrypted messages with their military commanders. appearance of the modern communication and transfer of secret and private information made cryptography irreplaceable.

RSA is one of the well-known public key cryptosystem being used to secure any system like smart cards and e-commerce applications. The purpose of this dissertation is to design and implement faster RSA variant compare to other variants found in the literature. Through this dissertation, we achieve following objectives:-

- The objective of this work is to analyze existing variants of RSA cryptosystem found in the literature.
- This work shows the comparison of speed up factor between various variants of RSA cryptosystem i.e. Original RSA [1], Takagi RSA [3], Krishnamurthy et al. RSA [5], Abdeldaym et al. RSA [16] and proposed RSA algorithms.
- Compared to conventional algorithms, the proposed RSA provides higher operational speed for message sizes 640 bits, 1040 bits and 1136 bits.
- It is shown that our proposed RSA algorithm is better than Original RSA [1], Takagi RSA [3], Krishnamurthy et al. RSA [5], Abdeldaym et al. RSA [16] algorithms in terms of computational speed for message sizes 640 bits, 1040 bits and 1136 bits.

II. LITERATURE REVIEW

In order to increase the execution speed of traditional RSA decryption, numerous authors have given their valuable contribution in the field. In order to speed up RSA decryption, one interesting approach is given using the Chinese Remainder Theorem (CRT) [1-2]. One can further speed up RSA decryption using moduli of the form $N = p^{b-1}q$ where q and q are n/b bits each [3]. A different approach is provided by [4-5]. In these articles, they are using three-prime RSA or multi -prime RSA to speed up the decryption of the RSA cryptosystem.

Enhanced RSA is based on the RSA algorithm. In order to generate the value of N, the enhanced RSA uses an additional third prime number. Due to this, the encryption and the decryption process become faster. Moreover, it generates the public and private keys faster than the traditional RSA [6]. Taher has proposed an asymmetric key algorithm using Diffie-Hellman key exchange algorithm and it is named as "Elgamal" [7]. Its working is over finite fields [8].

The security of Elgamal cryptosystem relies on the hardness of breaking famous Discrete Logarithm Problem (DLP). Another efficient method has been proposed and the authors proved that their method is faster than the original RSA and Elgamal cryptosystems [9]. In order to generate the public and private keys, a new encryption scheme proposed by Malhotra [10] uses three large prime numbers. The method is an integration of the Enhanced RSA and Elgamal cryptosystem.

Strong encryption technology is required to encrypt user data to ensure storage and backup security in the cloud. Currently, research work is being carried out in the following areas: confidentiality of data for storage, the security audit, and the ciphertext accesses control [11]. Common data encryption algorithms, based on the different key types, can be divided into symmetric encryption algorithms and asymmetric encryption algorithms (public-key encryption algorithms). The Data Encryption Standard (DES) is a classic symmetric encryption algorithm, which is characterized by its high encryption and decryption efficiency, but its key length is too short [12]. To overcome this shortcoming of the DES, a triple DES (3DES) encryption method is proposed ill [13]. This method extends the key length from the original 56 bits to 112 bits; however the software implementation of the algorithm is inefficient. With the rapid development of encryption technology, DES has gradually been replaced by the Advanced Encryption Standard (AES), which is highly efficient, safe and reliable.

The RSA algorithm [14] is a typical asymmetric encryption algorithm, which is widely used not only for user data encryption, but also as a digital signature. However, considering that the encryption and decryption efficiency of the algorithm is low, it is not suitable for encryption of large amounts of data. To enhance the level of security, Jaju and Chowhan [15] proposed modified RSA algorithm. Its efficiency relies on key generation speed and security level.

In network security, the branch of cryptography is which one can save and transmit data in format particular so that only the user intended can read and process it, the text encrypted is the cipher text which is then decoded on the receiver side. The algorithm of RSA is an asymmetric cryptography technique, this is working on two keys i.e. public key and private key. The proposed model [16] takes four prime numbers in RSA. Instead of sending one public key directly, send two public keys to the receiver. But there is problem of the speed, so that in RSA decryption used Chinese remainder theorem to enhancement the speed of RSA decryption.

III. PROPOSED ALGORITHM

This section shows the algorithm for the above working procedure.

Steps for proposed fast RSA algorithm using CRT are as under:-

(1) Initially p, q, r and s four prime numbers are taken .

(2) N is calculated by multiplying p, q, r and s as $N = p * q * r * s$.

(3) Then, $(N)$is calculated by using formula $\varphi(N) = (p-1)(q-1)(r-1)(s-1)$.

(4) Select a random integer "e" $such\ that$, $1 < e < \varphi$ and $gcd\ (e, \varphi) = 1$.

(5) Then "d" is calculated by using formula $e * d \equiv 1\ (mod\ \varphi(N))$.

(6) d_p, d_q, d_r and d_s are calculated respectively , by using formulas as : − $d_p = d\ mod\ (p-1)$, $d_q = d\ mod\ (q-1)$, $d_r = d\ mod\ (r-1)$ and $d_s = d\ mod\ (s-1)$.

(7) Take the plaintext message M and calculate ciphertext C as $C = M^e\ mod\ n$.

(8) cd_p, cd_q, cd_r and cd_s are computed respectively by using formulas as : − $cd_p = C^{d_p}\ mod\ p$, $cd_q = C^{d_q}\ mod\ q$, $cd_r = C^{d_r}\ mod\ r$ and $cd_s = C^{d_s}\ mod\ s$.

(9) Similarly, we find the value of $c_1, c_2,\ c_3\ and\ c_4$ respectively by using formulas as:-

$c_1 = (q * r * s)^{-1}\ mod\ p$, $c_2 = (p * r * s)^{-1}\ mod\ q$, $c_3 = (p * q * s)^{-1}\ mod\ r$ and $c_4 = (p * q * r)^{-1}\ mod\ s$.

(10) Finally, we get the original plaintext message after putting each value in the following formula as:-

$$M = CRT\ (cd_p, cd_q, cd_r, cd_s)$$
$$= (cd_p * c_1 * q * r * s) + (cd_q * c_2 * p * r * s) + (cd_r * c_3 * p * q * s) + (cd_s * c_4 * p * q * r).$$

IV. RESULT ANALYSIS

This section brings detailed result analysis of our work. Experiments are carried out using the following hardware and software specifications: Windows7 64-bit operating system, Core i3 CPU with 2.1 GHz, 4 GB RAM, and 500 GB hard disk.

Plaintext files of 640 bits, 1040 bits and 1136 bits are used as experimental data. The Original RSA [1], Takagi RSA [3], Krishnamurthy et al. RSA [5], Abdeldaym et al. RSA [16] and our proposed RSA algorithm are used to encrypt and decrypt the plain text files of different sizes a 100 times and the average time is noted.

The key length of the modulus of the RSA algorithm is 2048-bit. Here, we use BigInteger class of java [17]. Figure 1 shows comparison of the total time taken with different message sizes 640 bits, 1040 bits and 1136 bits.

Table 1: Comparison of the Total Time Taken (in ms) with Different Message Sizes

Message Size	Original RSA [1]	Takagi RSA [3]	Krishnamurthy et al. RSA [5]	Abdeldaym et al. RSA [16]	Proposed RSA
640 bits	265	62	78	52	32
1040 bits	266	63	93	53	16
1136 bits	270	62	94	56	31

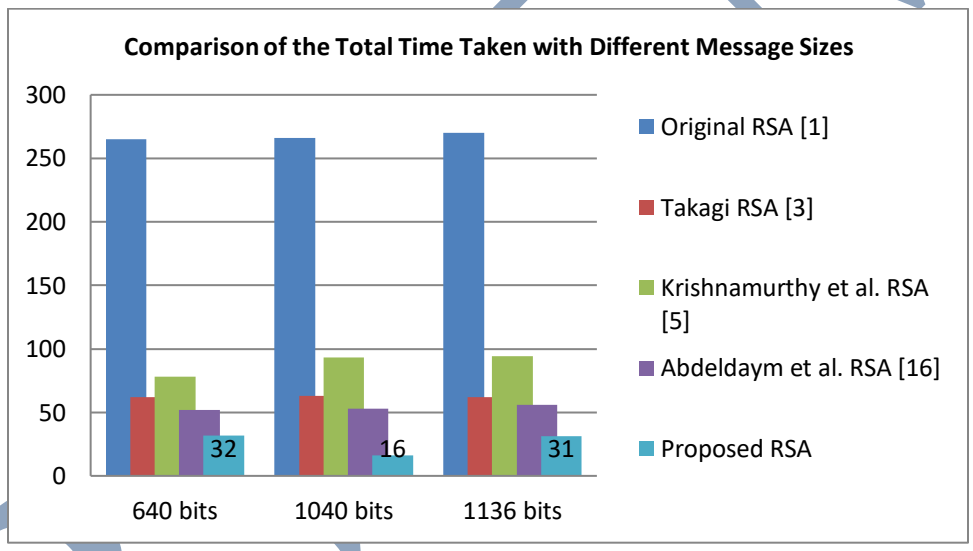

Figure 1: Comparison of the Total Time Taken with Different Message Sizes

V. CONCLUSION

Cryptography plays a vital role as far as security of lightweight data is concerned. RSA is one of the well-known public key cryptosystem being used to secure any system like smart cards and e-commerce applications. The purpose of this paper is to design and implement faster RSA variant compare to other variants found in the literature. Through this work, we can conclude following points:-

- This work shows the comparison of speed up factor between various variants of RSA cryptosystem i.e. Original RSA [1], Takagi RSA [3], Krishnamurthy et al. RSA [5], Abdeldaym et al. RSA [16] and proposed RSA algorithms.
- Compared to conventional algorithms, the proposed RSA provides higher operational speed for message sizes 640 bits, 1040 bits and 1136 bits.

The total time (in millisecond) for encryption and decryption of lightweight data is calculated and shown with the help of bar graph. The total time for all the variants of RSA along with proposed RSA is also compared with each other. It was observed that our proposed algorithm is efficient as compared to all the variants of RSA.

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