Introduction of a Triple Prime Symmetric Key Block Cipher

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ABSTRACT
This paper proposes to put forward an innovative algorithm for symmetric key block cipher named as "Triple Prime Symmetric Key Block Cipher with Variable Key-Spaces (**TPSKBCVK**)" that employs triple prime integers as private key-spaces of varying lengths to encrypt data files. Principles of modular arithmetic have been elegantly used in the proposed idea of the cipher. Depending on observations of the results of implementation of the proposed cipher on a set of real data files of several types, all results are registered and analyzed. The strength of the underlying design of the cipher and the liberty of using a long key-space expectedly makes it reasonably non-susceptible against possible cryptanalytic intrusions. As a future scope of the work, it is intended to formulate and employ an improved scheme that will use a carrier media (image or multimedia data file) for a secure transmission of the private keys.

General Terms
Computer Security, Symmetric Key, Cryptography, Algorithm

Keywords
Data Security, Cryptography, Prime Number, Block Cipher

1. INTRODUCTION
Many symmetric key cipher protocols are developed with application of Modular Arithmetic [1]. Principles of Modular Arithmetic have been applied elegantly to develop the proposed Triple Prime Symmetric Key Block Cipher [2] [3] with the acronym **TPSKBCVK.** The encryption of data using TPSKBCVK results in encrypted data with expanded length, but the strength of the underlying design of the cipher and the liberty of using long varying length key space can make it fairly non- susceptible against probable cryptanalytic intrusions.

Section 2 introduces the scheme of the proposed cipher TPSKBCVK. An account of results observed on implementation of TPSKBCVK on a sample plaintext is demonstrated in section 3. Results obtained from a set of real implementations are exhibited in section 4. Section 5 is an analytical study of TPSKBCVK. A conclusion is drawn in section 6.

2. THE SCHEME
The source data targeted to be encrypted is read as blocks of B-Bits. All such B-bit blocks generated are converted to Base-10 integers. Sufficiently large triple prime integers KEY1, KEY2, KEY3 are taken as private keys satisfying the criteria:

1. Product of KEY1 and KEY2 has to be sufficiently large than the integers to be encrypted.

Sections 2.1 and section 2.2 respectively explains the encryption and the decryption scheme with conventionally *Alice* considered as the sender and *Bob* considered as the receiver.

2.1 Encryption
The steps of computations required to be followed in the encryption end for P being a positive integer to be encrypted are as follows:

1. Set N=(KEY1 x KEY2)^2

2. Set K3 = φ (KEY1 x KEY2) – 1

3. Set B = (P)^{K3} mod N

4. Set C = (B x KEY3)^{K3} mod N

The function φ (KEY1 x KEY2) is known as a totient function. The totient φ (K) of a positive integer K defines the number of integers less than or equal to K that are relatively prime to K. Φ (K) = K – 1, where K is a prime number.

2.2 Decryption
The set of values for KEY1, KEY2 and KEY3 are extracted from the private key, the following steps of operations are carried out in the decryption end.

1. Set N=(KEY1 x KEY2)

2. Set K3 = φ (KEY1 x KEY2) – 1

3. Set B = (C x KEY3)^{K3} mod N

4. Set P = B^{K3} mod N

The function φ (KEY1 x KEY2) is a totient function as illustrated in section 2.1[4].

3. IMPLEMENTATION
This section demonstrates the steps of encryption and decryption using a small test plaintext WORLD considering KEY1 = 17, KEY2 = 19 and KEY3=23.

Table 1 registers different transitional result and the final result of implementation following the encryption algorithm explained in section 2.1. Finally the cipher text þŽ□ ž` Ù¥ "(Áµ is derived for the taken plaintext.

Table 1 : Implementation of Encryption of the Plaintext
"WORLD"

CHARACTER	ASCII VALUE	Value obtained by following step 3 of the Encryption Algorithm	Value obtained by following step 4 of the Encryption Algorithm	Printable Character (including spaces) corresponding to value obtained through step 4 of the Encryption Algorithm
W	87	92404	102142	þŽ
O	79	14396	24734	ž`
R	82	36306	42457	Ù¥
L	76	39710	75810	"(
D	68	4624	46529	Áµ

A reverse process is followed to implement the decryption algorithm stated in section 2.2.

4. RESULTS

A viable implementation of the encryption and decryption algorithm established in section 2.1 and section 2.2 respectively was performed using C language and MIRACL (**M**ulti precision **I**nteger and **R**ational **A**rithmetic **C**/C++ **L**ibrary) [5] for big integer computations. The plaintext was divided and read as blocks of length 8-bits each; a set of triple prime integers KEY1, KEY2 and KEY3 each 8-bit long, was considered as private keys for operation on the plaintext data. Generated Ciphertext was written to file as blocks of 32-bits to get around overflow problem, as in few cases 8-bit data after encryption is to produce values larger than 255. File types .txt, .doc, .docx, .xls, .pdf, .mp4, .ocx, .jpg, .bmp, .dll, .gif, .sys etc were encrypted and effectively decrypted.

A comparative study of file type, source file size, decrypted file size, encryption time and decryption time is illustrated in table 2 and table 3.

TABLE 2:File type, source file size, encryption time, encrypted file size

filename	size (in KB)	encryption time (in sec)	encrypted file size (in KB)
Abc.docx	47	1.625	188
Ap_hawaii.jpg	18	0.688	71
ENG1.docx	47	1.609	104
Cv.doc	60	1.328	238
Effectctrl.ocx	405	11.906	1617
Fishing.bmp	17	0.687	68
Hmmapi.dll	59	1.625	236
Marks.xls	85	1.797	338
Project2.zip	66	2.375	261
Test.txt	2	0.125	7
Tabulator.pdf	434	14.656	1736
TABLE 2 continued: File type, source file size, encryption time, encrypted file size			
Quotes.gif	25	0.953	100

Bee.wav	144	5.172	573
Clock.avi	81	2.516	324
Greenstone.bmp	26	0.828	104
Handsafe.reg	1	0.063	3
Himem.sys	5	0.234	19
IE7Eula.rtf	73	2.687	292
Jview.exe	151	3.281	602
Keyboard.drv	2	0.109	8
Mscomm32.ocx	102	3	406
Normnfd.nls	39	1.094	154
Notepad.exe	68	1.891	270
Preconvertlite.dll	103	3.14	412
Setup.xml	4	0.234	16

TABLE 3: Encrypted File type, encrypted file size, and decryption time

Encrypted File name	Encrypted file size (in KB)	Decryption time (in sec)
Abc.docx.enc	188	1.625
Ap_hawaii.jpg.enc	71	0.703
ENG1.docx.enc	104	1.625
Cv.doc.enc	238	1.265
EffectCtrl.ocx.enc	1617	11.984
Fishing.bmp.enc	68	0.672
Hmmapi.dll.enc	236	1.609
Marks.xls.enc	338	1.781
Project2.zip.enc	261	2.359
Test.txt.enc	7	0.125
Tabulator.pdf.enc	1736	14.734
Quotes.gif.enc	100	0.953
Bee.wav.enc	573	5.172
Clock.avi.enc	324	2.531
Greenstone.bmp.enc	104	0.906
Handsafe.reg.enc	3	0.047
Himem.sys.enc	19	0.234
IE7Eula.rtf.enc	292	2.656
Jview.exe.enc	602	3.25
Keyboard.drv.enc	8	0.11
Mscomm32.ocx.enc	406	2.953
Normnfd.nls.enc	154	1.109
Notepad.exe.enc	270	1.859
PreConvertLite.dll.enc	412	3.141
Setup.xml.enc	16	0.234

TABLE 4: Average Required Time for Exhaustive Key Search

Key Size (Bits)	Number of Alternative Keys	Time Required at 1 Encryption /µs	Time Required at 10^6 encryptions /µs
56	$2^{56} = 7.2 \times 10^{16}$	2^{55} µs =1142 years	10.01 hours
128	$2^{128} = 3.4 \times 10^{38}$	5.4×10^{24} years	5.4×10^{18} years
168	$2^{168} = 3.7 \times 10^{50}$	2^{167} µs = 5.9×10^{36} years	5.9×10^{30} years
26 characters	$26! = 4 \times 10^{26}$	2×10^{26} µs = 6.4×10^{12} years	6.4×10^6 years

It can be observed from data in Table 2 and Table 3 that the relation between encryption time and file size is linear. The average time to encrypt 1 KB of data is calculated to be 0.030825097 seconds. Also, it was found that the average decryption time of 1 KB of encrypted data is 0.007811096 seconds.

Encrypted data produced from 8-bit source data is written as 32-bit data, so the encrypted data file size (in bytes) is observed to be about four times the source data file size (in bytes). Thus it was observed that the proposed cipher accompanies an overhead of data expansion. An operational overhead of being marginally slow in encryption is observed in its practical implementation.

5. ANALYSIS

Small keys were used to exhibit results of encryption and decryption using TPSKBCVK though much larger key-spaces can be used in practice.

The effective length of key is equal to product of length of KEY1 and KEY2. Brute-force attack to the proposed cipher scheme will require searching entire search space of 2 (product of length of KEY1 & KEY2). The projected mean time required for such extensive search is given in table 4[6].

The proposed cipher uses exponentiation hence data expansion in encryption process is expected. Encrypted file size can be reduced significantly by writing encrypted data as bit stream and formulating appropriate padding schemes to mark separate blocks. Faster methods of calculating large integer powers of integers can be adopted to reduce both encryption and decryption time. Encryption process can be optimized to be faster if read block size (in bits) is increased but it should be less than the size of key (in bits). The proposed scheme restricts use of the read block size greater than the product of KEY1 and KEY2.

6. CONCLUSION

The design of proposed cipher TPSKBCVK makes it extensible for implementation with larger keys. Time required for encryption and decryption using TPSKBCVK is almost equal. If brute-force attack is employed to identify the three 128-bit prime integer keys used as keys for encryption then at least all the primes in the range of integers from 1 to 2^{128} are to be tested three times to find all the three probable keys. The approximate number of primes calculated from the relation $\pi (n) \approx n/\ln (n)$, where $1 <= n <= 2^{128}$ is found to be $383534127545935 \times 10^{22}$. It is observed that if one trillion of these numbers per second can be checked then more than $121,617,874,031,562 \times 10^3$ years is needed to test out all such primes. The requirement of time as shown in table 4, to calculate the keys makes it reasonably non- susceptible against cryptanalytic attacks [7]. As a future scope of the work, it is intended to formulate and employ an improved scheme that will use a carrier media (image or multimedia data file) for a secure transmission of the private keys.

7. REFERENCES

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