Journal of Theoretical and Applied Information Technology
20th January 2014. Vol. 59 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

NTRU ENCRYPTION USING HUFFMAN COMPRESSION

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ABSTRACT

NTRU Labs have proposed a scheme for secure transmission using ring of truncated polynomials in $Z_q(x) / (x^n - 1)$. We have proved in this paper that a pre-processing the data to be transmitted greatly decreases the time of transmission. We have used a matrix version of NTRU Cryptosystems.

Keywords: *Truncated, Transmission, Polynomials, Ring, Secure, Number Theory Research Unit (NTRU)*

1. INTRODUCTION

Secure communication has been the subject of serious research since the discovery of RSA[1] encryption scheme using a public key for encryption and the corresponding private key for decryption. NTRU Labs [2, 3, 4] has come up with a scheme using a ring of truncated polynomials. In this scheme of things, two small polynomials f and g are taken from the ring of polynomials $Z_q(x) / (x^n - 1)$ which are invertible modulo q and modulo p, where q and p as two relatively prime numbers. The security of NTRU was shown to be equivalent to the hardness of some Lattice problems. Although there are many attacks [6, 7, 8, 9] no significant weakness in the NTRU encryption has ever been reported.

The public key is constructed as h = p * fq * g mod q and f, fp are kept as private. Let m be the message to be transmitted, constructed as a polynomial belonging to $Z_q(x) / (x^n - 1)$. The encrypted text is obtained as e = h * r + m where r is a random polynomial chosen to obscure the message. The message can be recovered by decrypting the encrypted message as follows using the private keys f and fp:

a = f * e mod q
= f * (h*r + m) mod q
= f * (p*fq*g mod q + m) mod q ;

a is the intermediate text generated and the original message is obtained as:

b = a mod p
= f * [(p*fq*g mod q + m) mod q] mod p = m

This has been recently extended by Nayak[5] et al., where square matrices are used to generate public and private keys, and the message is also taken in the form of a matrix. The matrix formulation has the advantage that matrix inversions are easier to perform than polynomial inversions in modulo arithmetic.

In this paper we compress the message to be transmitted using Huffman code [11, 12, 13] and surprisingly find that the time taken to zip the message, encrypt the code, decrypt the code and unzip the message is less than the time taken for directly encrypting the message and decrypting the message, when the message size is comparatively larger. We use the matrix formulation of the NTRU cryptosystems.

2. PROPOSED ALGORITHM

We use N x N ordered set of matrices and generate multiple public/private key pairs [10]. The public keys are made available to everyone. Each of these public keys has a unique corresponding private key which will be known only to the receiver of the message. The sender sends the encrypted message along with public key and the receiver chooses the corresponding

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

private key. First the sender chooses the two N X N matrices F and G from {-1, 0, 1} and F should be invertible. The inverse of F modulo p [Fp] and inverse of F modulo q [Fq] are then calculated. The matrices Fp and Fq satisfy F*Fq = I (modulo q) and F*Fp = I(modulo p). Then the public key is constructed as Pu = p*Fq*G (modulo q). The sender also generates the other set of public and private key pairs based on message length.

2.1 Key Generation

a) Randomly generate N x N matrices F and G
b) Compute Fp and Fq
c) Generate Public key Pu = p*Fq*G (modulo q)

2.2 Encryption

a) The text message is then compressed using Huffman algorithm.
Mc = H(m) where Mc is compressed message
b) Encrypt the message as Ec = Pu*R+Mc (modulo q) where R is any N X N random matrix.

The encrypted message can be decrypted through the following steps:

a) Compute A = F * Ec(modulo q) and choose the coefficients in the range –q/2 to q/2
b) Decrypt the message D = Fp*A (modulo p).
c) Then the decrypted message D is uncompressed using Huffman code to generate the original message.

The sender encrypts the block of text, Mc as Ec = Pu * R + Mc (modulo q), where Pu is public key, R is a random matrix. The receiver first computes F*Ec (modulo q) using his private keys F and Fp corresponding to the public key Pu:

A = F*Ec(modulo q)
= F*(Pu*R+Mc)(modulo q)
= F*((p*Fq*G)*R+Mc) (modulo q)
= p*R*G + F*Mc (modulo q) [since F*Fq=I(modulo q) and I is identity matrix]

B = Fp* A (modulo p)
= Fp* [p*R*G+ F*Mc modulo q] (modulo p)
= Mc(modulo p) [since Fp *F (modulo p) = I]
= Mc

3. ILLUSTRATION OF THE PROPOSED ALGORITHM

3.1. Key Generation

The sender generates the public key/private key pairs using the following parameters: p=3, q=128 and N=15x15. Two randomly generated 15x15 matrices F and G consisting of elements from {-1, 0, 1} are chosen as:

F=

0	0	0	-1	1	-1	0	0	1	0	-1	1	1	-1	-1
1	1	1	-1	1	0	0	0	0	-1	1	1	0	1	0
-1	-1	0	1	1	0	-1	1	0	1	0	-1	1	1	-1
1	0	-1	-1	1	-1	0	-1	0	0	0	-1	1	-1	0
0	0	1	0	-1	-1	0	1	-1	-1	-1	1	-1	-1	0
-1	0	1	-1	1	-1	1	1	-1	0	1	0	0	1	1
-1	0	1	0	-1	-1	1	-1	1	0	-1	1	0	0	-1
1	0	-1	0	0	-1	1	0	-1	-1	0	1	1	-1	0
1	0	0	1	0	1	-1	0	-1	1	0	1	1	-1	0
0	0	0	-1	0	0	0	0	0	-1	0	-1	1	1	0
-1	1	0	-1	0	1	-1	0	0	1	0	1	0	-1	0
0	1	1	0	1	1	-1	1	0	0	1	0	1	1	-1
0	-1	-1	0	-1	1	0	1	0	0	0	-1	1	-1	1
0	1	1	-1	1	0	0	-1	-1	0	-1	-1	0	0	1
-1	0	0	0	-1	1	0	1	1	-1	-1	-1	0	-1	0

and G=

-1	0	-1	1	-1	0	-1	0	1	-1	1	1	1	-1	1
-1	-1	1	0	0	-1	1	1	0	0	-1	0	0	1	-1
1	-1	-1	0	-1	-1	1	1	-1	1	1	-1	1	0	-1
1	0	0	-1	0	-1	0	0	-1	1	1	-1	-1	-1	0
1	0	0	-1	0	0	1	-1	1	1	-1	0	0	-1	1
-1	1	-1	0	-1	1	0	0	1	0	-1	1	-1	0	-1
-1	1	1	0	-1	1	-1	0	1	1	1	1	-1	1	1
0	1	1	0	-1	1	-1	1	0	-1	-1	-1	-1	0	0
-1	1	0	1	1	1	1	0	0	0	-1	0	-1	1	1
0	0	-1	0	0	-1	1	0	0	0	0	1	-1	-1	-1
0	0	-1	1	-1	1	1	-1	1	-1	-1	1	0	-1	-1
0	1	0	0	-1	-1	0	0	1	-1	1	0	0	0	1
1	1	-1	-1	0	0	0	0	0	1	1	-1	0	0	0
-1	1	1	0	1	1	0	0	1	0	0	-1	-1	1	1
1	-1	1	1	0	-1	1	0	-1	-1	1	0	-1	-1	-1

Journal of Theoretical and Applied Information Technology
20th January 2014. Vol. 59 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

The sender computes the inverse of F (modulo p) [Fp] and F(modulo q)[Fq].

Fp =

0	1	2	0	2	2	1	1	1	2	0	1	1	1	0
2	2	1	2	1	1	0	0	2	0	2	2	1	0	2
1	1	2	0	2	2	1	0	2	0	0	2	1	0	1
2	0	0	1	1	2	1	2	0	2	1	1	2	0	2
2	2	0	0	1	1	0	2	1	1	0	2	2	1	1
0	0	2	2	1	2	1	2	1	1	2	0	2	2	1
0	0	0	1	1	2	1	1	2	0	2	2	1	0	2
1	1	2	1	1	2	2	0	0	1	0	2	0	2	2
1	2	2	2	2	0	1	1	2	2	2	2	2	1	2
0	1	0	0	0	1	2	2	2	1	1	2	2	1	1
0	2	0	2	0	0	2	1	0	1	2	1	1	2	1
0	2	0	2	0	1	1	0	0	2	0	2	0	2	2
2	2	2	2	0	2	0	1	0	0	1	0	0	2	0
0	1	1	1	1	2	1	0	2	0	1	2	1	1	2
2	2	1	0	0	1	0	2	0	1	0	2	1	1	2

Fq =

14	12	78	18	10	11	43	49	75	13	19	36	78	10	9
	4			5	6								5	
11	80	10	90	92	67	21	95	35	88	99	74	5	11	1
4		3											2	0
14	24	56	36	89	81	10	11	11	12	50	75	66	10	1
						3	4	7	3				1	
8	12	11	12	65	19	11	81	60	71	96	77	84	29	5
	4	4				9								7
11	12	98	51	90	11	73	90	76	30	10	12	20	16	7
2	5				6					8	5			5
37	12	10	39	23	10	78	5	25	95	9	47	54	11	2
	1	5			3								0	3
89	11	50	12	97	35	54	96	12	77	13	12	49	10	5
	7		7					7			2		3	9
3	64	37	93	30	78	4	12	55	45	63	48	12	2	2
							1							3
50	64	45	10	81	94	27	11	11	2	12	87	43	72	1
							6	2		1				5
6	11	11	0	12	10	12	12	14	13	12	12	11	12	7
	4	6		5		1	1			3	7	2	0	
11	66	11	17	12	63	80	85	12	71	45	45	37	20	9
2				1				7						6
63	12	29	10	52	44	22	15	44	11	26	11	79	10	4
	7		6						8		0		1	3
10	32	20	40	89	19	10	79	6	50	11	63	10	44	2
8						8				7		8		1
39	77	11	78	25	54	26	10	11	25	0	12	39	78	8
		1						2			3			6
66	88	10	61	78	34	55	11	42	66	94	93	36	12	2
		7					9						4	0

Then the public key Pu=p*Fq*G (modulo q) and made available to everyone:

Pu =

73	10	36	4	11	3	55	12	10	73	4	15	16	12	57
	5			5			5	3					3	
12	8	38	85	2	80	63	5	10	13	10	80	12	33	3
5								4		3		1		
64	64	11	10	71	11	47	37	10	32	12	12	10	96	10
		5	1		3			8			2	2		8
93	10	10	6	51	10	31	90	4	15	32	61	0	11	97
		0			3								5	
88	14	69	11	30	53	85	89	96	10	10	10	73	11	76
			8						6	3	8		2	
78	7	58	62	21	84	75	85	80	22	35	27	16	68	10
														4
83	56	92	45	81	12	7	75	63	12	67	41	47	73	83
									2					
95	76	56	27	5	39	55	3	97	10	67	40	9	11	8
													6	
93	1	73	10	84	61	10	69	10	91	91	24	93	11	8
			8			1		6					6	
53	12	53	12	66	12	24	53	11	14	74	52	44	29	6
			3					9						
82	84	24	10	14	86	12	11	62	33	57	91	10	5	75
			3				6					0		
10	8	10	73	20	53	12	23	80	93	48	85	77	42	15
8		3				1								
11	38	98	45	16	57	12	31	12	59	12	77	51	63	93
						0		1		2				
11	12	27	29	12	10	59	7	82	63	32	12	67	12	22
5	0			1	8						4		0	
63	96	9	13	74	99	12	42	44	91	77	11	10	28	19
						5					6	8		

3.2 . Encryption

Let us choose the following text message consisting of 55 characters.

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which when express using ASCII code contains 440 bits. The text is then compressed using generated Hoffman Code for the text message and the length will be reduced to 223 bits:

00100101100001111100001111000001001110001000101000101011100100100100000100011000011111110100101010101001100011000010110011111010100001110111000111000110000000011000010010101010101111010111011001000001101101000001111010101010000011000

The sender arranges this compressed message as 15x15 matrix

Mc =

0	0	1	0	0	1	0	1	1	0	0	0	0	1	1
1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
0	1	0	0	1	1	1	0	0	0	1	0	0	0	1
0	1	0	0	0	1	0	1	0	1	1	1	0	0	1
0	0	1	0	0	1	0	0	0	0	1	0	0	0	1

Journal of Theoretical and Applied Information Technology
20th January 2014. Vol. 59 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

1	0	0	0	0	1	1	1	1	1	1	0	1	0	0
1	0	1	0	1	0	1	0	1	0	0	1	1	0	0
0	1	1	0	0	0	1	0	1	1	0	0	1	1	1
1	1	0	1	0	1	0	0	0	0	1	1	1	0	1
1	1	0	0	0	1	1	1	0	0	0	1	1	0	0
0	0	0	0	0	1	1	0	0	0	0	1	0	0	1
0	1	0	1	0	1	0	1	1	1	1	0	1	0	1
1	1	0	1	1	0	0	1	0	0	0	0	1	1	0
1	1	0	1	0	0	0	0	0	1	1	1	1	0	1
0	1	0	1	0	1	0	0	0	0	1	1	0	0	0

Now choose the randomly generated R matrix as

0	0	1	0	0	-1	1	0	1	-1	1	1	0	1	-1
0	0	0	1	0	-1	-1	0	0	0	0	0	-1	1	-1
0	-1	-1	-1	-1	0	1	-1	0	0	0	0	1	0	0
1	1	1	1	-1	-1	0	-1	1	-1	-1	-1	0	0	-1
1	1	-1	1	0	1	1	0	-1	1	1	-1	0	0	0
-1	-1	1	0	-1	0	0	1	1	0	0	0	0	-1	1
1	0	1	0	0	0	-1	0	0	-1	0	-1	0	1	1
0	0	1	0	1	-1	0	0	0	0	1	-1	1	-1	-1
-1	0	0	0	0	-1	1	-1	0	0	0	0	1	-1	0
1	0	-1	0	-1	0	1	1	0	0	-1	1	-1	0	1
1	-1	0	0	0	-1	1	0	1	1	0	-1	-1	1	-1
1	0	0	-1	0	0	0	0	0	0	-1	0	0	-1	1
-1	-1	0	-1	1	1	-1	0	0	1	0	0	1	1	-1
-1	1	-1	1	0	-1	-1	-1	0	0	1	0	0	0	0
0	1	0	1	1	1	1	1	-1	-1	-1	0	0	1	-1

When we encrypt this message matrix Mc, we get the following cipher text Ec:

21	112	42	81	82	36	34	124	41	74	31	99	98	65	19
9	38	17	20	41	47	35	93	5	79	113	8	16	26	42
94	35	48	101	15	56	74	89	111	121	34	84	126	17	83
102	35	42	118	91	55	108	119	86	113	43	27	9	5	11
88	38	117	100	20	72	28	96	0	95	40	25	104	93	48
123	62	87	33	107	111	105	71	7	10	38	78	48	39	77
41	64	111	30	63	5	25	72	44	105	21	59	33	24	110
71	114	33	127	16	53	83	17	88	25	6	76	13	4	116
124	127	68	0	93	114	107	13	5	86	4	116	31	127	71
22	42	103	87	29	38	21	93	62	106	6	112	42	105	121
57	58	67	66	45	65	19	0	111	27	43	70	0	55	118

60	126	120	22	49	115	91	120	120	85	56	44	7	8	1
20	18	28	30	45	113	120	11	126	48	103	120	83	22	50
52	59	115	67	125	89	96	63	13	124	126	59	97	94	91
89	98	12	126	85	95	20	115	31	39	97	80	67	59	13

This matrix is sent to the receiver along with the public key and the Huffman code is sent as a symbol table.

3.3 . Decryption

A= F * Ec (modulo p)
A=

125	125	10	126	10	127	126	0	3	1	112	119	4	126	116
1	5	125	124	1	3	120	117	125	2	102	125	132	120	140
7	124	8	122	6	122	123	3	6	1	6	1	127	133	124
113	121	126	127	0	126	9	8	126	123	127	4	113	133	122
123	120	0	123	0	6	8	7	123	112	128	8	126	6	8
122	2	8	1	124	119	119	125	3	125	125	5	125	110	172
124	126	117	4	129	118	8	125	2	125	113	3	123	117	2
116	128	8	3	125	117	126	125	5	123	3	1	5	125	124
3	170	0	184	122	4	126	6	125	123	124	118	126	127	7
164	2	6	121	1	125	124	126	127	124	124	124	122	6	8
126	126	175	122	125	126	117	125	102	123	125	124	4	117	104
0	4	5	4	104	123	3	125	2	1	1	123	3	117	118
0	124	127	6	3	124	4	9	3	2	3	6	117	147	119
125	5	125	143	125	125	5	125	125	124	4	125	125	125	125
182	128	8	121	125	117	6	117	9	122	2	117	0	6	124

The receiver chooses the elements of A between –q/2 and q/2 (-63 and 64).

-3	-3	10	-2	10	-1	-2	0	3	1	-16	-9	4	-2	-12
1	5	-3	-4	1	3	-8	-11	-3	2	10	-6	13	-8	14
7	-4	8	-6	6	-6	-5	3	6	1	6	1	-1	13	-4
11	-7	-2	-1	0	-2	9	8	-2	-5	-1	4	-15	13	-6
-5	-1	0	-5	0	6	8	7	-5	-9	-8	8	-3	6	8
-6	2	8	1	-4	-9	-9	-3	3	-3	-5	5	-2	-18	17
-2	-2	-11	4	-7	-14	8	-1	2	-1	-12	3	-5	-11	2
-17	-5	8	3	-2	-11	-5	-2	5	-7	3	1	5	-7	-7
3	17	0	18	-6	4	-5	6	-4	-7	-2	-10	-2	-1	7

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

16	2	6	-2	1	-6	-4	-2	-1	-4	-4	-4	-6	-2	8
-2	-2	17	-6	-7	-2	-11	-1	10	-8	-8	-2	4	-10	10
0	4	5	4	10	-6	3	-3	2	1	1	-3	3	11	-10
0	-4	-1	6	3	-7	4	9	3	2	3	6	-11	14	-9
-6	5	-8	14	-5	-4	5	-4	-7	-2	4	-8	-3	-4	-3
18	-4	8	-7	-6	-9	6	-11	9	-6	2	-11	0	6	-6

Now Mc = Fp * A which is given below

The matrix A becomes

0	0	1	0	0	1	0	1	1	0	0	0	0	1	1
1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
0	1	0	0	1	1	1	0	0	0	1	0	0	0	1
0	1	0	0	0	1	0	1	0	1	1	1	0	0	1
0	0	1	0	0	1	0	0	0	0	1	0	0	0	1
1	0	0	0	0	1	1	1	1	1	1	0	1	0	0
1	0	1	0	1	0	1	0	1	0	0	1	1	0	0
0	1	1	0	0	0	1	0	1	1	0	0	1	1	1
1	1	0	1	0	1	0	0	0	0	1	1	1	0	1
1	1	0	0	0	1	1	1	0	0	0	1	1	0	0
0	0	0	0	0	1	1	0	0	0	0	1	0	0	1
0	1	0	1	0	1	0	1	1	1	1	0	1	0	1
1	1	0	1	1	0	0	1	0	0	0	0	1	1	0
1	1	0	1	0	0	0	0	0	1	1	1	1	0	1
0	1	0	1	0	1	0	0	0	0	1	1	0	0	0

When we decompress this matrix then we get the original text message.

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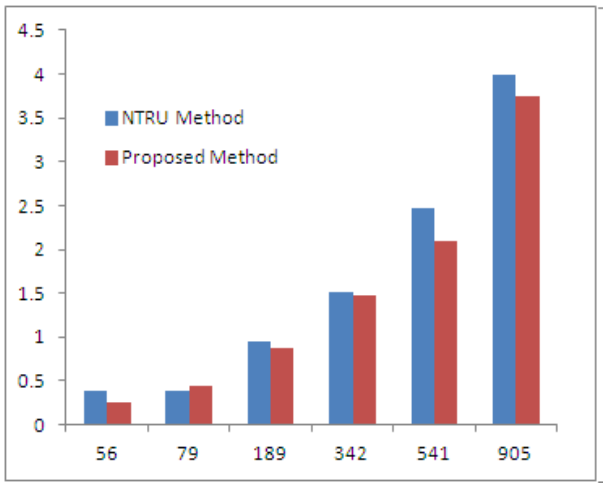
4. EXPERIMENTAL RESULTS

The following table gives the time taken for a direct encryption and decryption and encryption and decryption after a Huffman compression:

Message Length	NTRU Method	Proposed Method
56	0.3	0.2105
79	0.3	0.37518
189	0.75	0.71089
342	1.2	1.19887
541	1.95	1.70452
905	3.15	3.0349



5. CONCLUSIONS

We used Huffman algorithm to compress the message and then used NTRU to encrypt the message and transmit it. It was shown that the compression of the data reduces the time for encryption and decryption. However we observe that when message contain 79 character, proposed scheme takes more time since there was no reduction in the number of blocks to be transmitted. We are presently working on further reduction in time by dynamically compressing the data. We used MATLAB Version 7.6.0(R2008a) for the above calculations.

ACKNOWLEDGEMENTS

We sincerely thank Mr. M S R S Prasad for fruitful discussions.

REFERENCES

[1].R.L.Rivest, A.Shamir, and L.Adleman, "A Method for Obtaining Digital Signatures and Public-Key Cryptosystems ", Communications of the ACM,vol.21, pp.120-126,February 1978

[2].NTRU Cryptosystem, Technical Reports available at http:www.ntru.com

[3].Jofferey Hoffstein, Jill Piper, Joshep H Silverman "NTRU A Ring based public key Cryptosystem" Lecture notes in Computer Science, Springer Verlag, Berlin 1433(1998),267-288.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[4].A Course in Computational Algebraic Number Theory, H. Cohen, GTM 138, Springer Verlag, Berlin, 1993.

[5].Rakesh Nayak, C.V. Sastry and Jayaram Pradhan "A Matrix Formulation for NTRU cryptosystem" Proc. 16th IEEE International conference on Networks(ICON-2008), New Delhi, India 12-14 December,2008.

[6].D. Coppersmith, A. Shamir: Lattice attacks on NTRU, in Proc of EuroCrypt'97 (Lecture Notes in Computer Science),W. Fumy, Ed. Berlin, Germany: Springer, Vol. 1233 pp. 52–61, 1997.

[7].Jintai Ding, Solving LWE problem with bounded errors in polynomial time, Cryptology ePrint Archive, Report 2010/558, 2010.

[8].Jintai Ding, Fast Algorithm to solve a family of SIS problem with l1 norm, Cryptology ePrint Archive, Report 2010/581, 2010.

[9].N. Howgrave-Graham, J.H. Silverman, W. Whyte: A Meet-In-The-Middle Attack on an NTRU Private Key. Technical Report #004, available at http://www.ntru.com/cryptolab/tech notes.shtml

[10]. Vinay Kumar, Mohan Rao Mamdikar, Dr. D. Gosh "Matrix Formulation of NTRU Algorithm using multiple Public keys from Matrix Data Bank for High Degree polynomials" Proc. of the Second Intl. Conf. on Advances in Computer, Electronics and Electrical Engineering -- CEEE 2013, ISBN: 978-981-07-6260-5 doi:10.3850/ 978-981-07-6260-5_40.

[11]. Lecture-15: Huffman Coding (CLRS-16.3) available at www.cse.ust.hk/~dekai/271/ notes/L15/ L15.pdf

[12]. Salomon D. Huffman Coding available at http://www.springer.com/978-1-84800-071-1, ISBN:978-1-84800-071-1,Softcover,2008

[13]. Huffman Coding overview available at http://csnotes.upm.edu.my/kelasmaya/pgkm20910.nsf/de8cc2082fc4d31b4825730e002bd111/e7f85333f149d3414825776f00207cbb/$FILE/Huffman_Coding1.pdf