

Image Composition Using Data Encryption Standard (DES) Output Result Over the Internet

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Abstract: Data protection is a major concern for information security professionals. Due to the rapid development of the means of exchanging information over the Internet and its large quantities, it is necessary to develop methods to protect the Information from intruders (Hackers or Crackers) by using cryptographic algorithms such as (AES, DES, RSA ...etc.) with fast processing and data protection. There are other ways to protect the data by hiding it in a certain medium, such as using an image or video or audio file.

This search uses Data Encryption Standard (DES) to encrypt the data then convert this data to a picture of a particular pattern used to randomize the distribution of data in the form of different point's colors and sites and send it over the internet. The proposed system has been implemented on the local network between two devices running on (Windows10) as well as applied on the Internet in a continuous manner.

Keywords: Cryptography, DES, TCP/IP, RGB, Winsock.

تشكيل الصورة باستخدام نتائج مخرجات خوارزمية تشفير البيانات المعياري (DES) عبر الإنترنت

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المستخلص

ان حماية البيانات تعد الشغل الشاغل للعاملين في مجال امنية المعلومات وبسبب التطور السريع الحاصل في وسائل تبادل المعلومات عبر شبكة الانترنت وكمياتها الكبيرة أصبح من الضروري وضع طرق لحماية البيانات من المتلصقين او المتطفلين عليها وذلك بكتابة خوارزميات للتشفير تتميز بسرعة المعالجة وحماية البيانات ومن هذه الخوارزميات (AES,DES,RSA...). كذلك توجد طرق اخرى لحماية البيانات وهي بإخفائها داخل وسط معين مثل استخدام صورة او ملف صوتي او ملف فيديو.

تم استخدام خوارزمية الـ (DES) لتشفير البيانات وبعدها تم تحويل هذه البيانات الى صورة ذات نمط معين يتم استخدام العشوائية في توزيع البيانات على شكل نقاط مختلفة الالوان والمواقع وارسالها عبر الانترنت.

تم تطبيق النظام المقترح على الشبكة المحلية بين جهازين يعملان بنظام (Windows 10) كذلك تم تطبيق عمله على شبكة الانترنت بشكل متصل.

TCP\IP, RGB , DES, Winsock, التشفير:

1. Introduction

In data security, the cryptography is the mathematical function used for encryption and decryption. The main goal of cryptography is to secure the sensitive data communication that travel over secure channels such that internet, from adversaries [1].

In the past decades, there has been tremendous growth in the field of digital storage and communication of data, triggered by several substantial breakthroughs like the internet and the vast development communications' wireless. Those recent communication technology and information will require sufficient security. Cryptology is a science aimed to supply the security of information in the digital term. Security of information includes numerous portions and the most significant are authenticity and confidentiality [2].

2. Internet Protocol

The Internet Protocol (IP) is the method or protocol by which is data sent from one computer to another on the Internet. Each computer (known as a host) on the Internet has at least one IP address that uniquely identifies it from all other computers on the Internet. When you send or receive data, the message is dived into little chunks called packets. Each of these packets contains both the sender's Internet address and the receiver's address [3].

TCP/IP is a two layers program. The higher layer, (Transmission Control Protocol), achieves the message's assembling or file into smaller packets, which are transmit via the Internet and received via (TCP) Layer that reassembles the packets into original message. The lower layer, Internet Protocol, manages the address section of every packet so that it gets to the right destination. Every gateway computer on the network examines this address to see where to forward the message. Even though some packets from the same message are routing differently than others, they will reassembled at the destination [4].

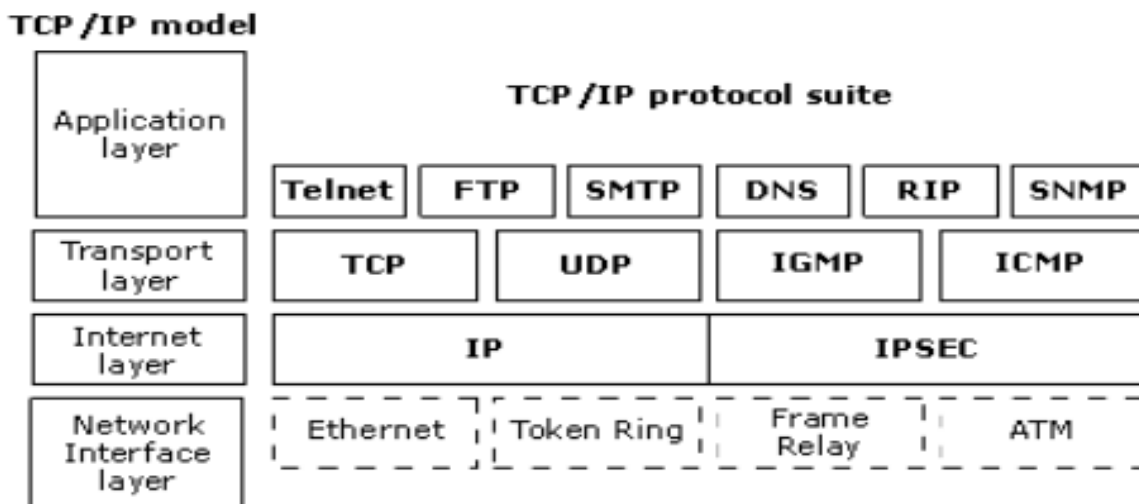


Fig. 1: TCP\IP Protocol Suite.

3. Encapsulation of Data and Protocol of TCP/IP Stack

A packet was the requisite information's unit, which can transfer via a network. A requisite packet includes a header with the receiving and sending systems' addresses and a payload or the body with the data to be transmits. As the packet can travel via (TCP/IP) protocol stack, the protocols at every layer either remove or add fields from a requisite header. When a protocol on the sending system adds data to the packet header, the process will know encapsulation of data [5]. Moreover, every layer has a various term for the changed packet, which is illustrate in (Fig.2).

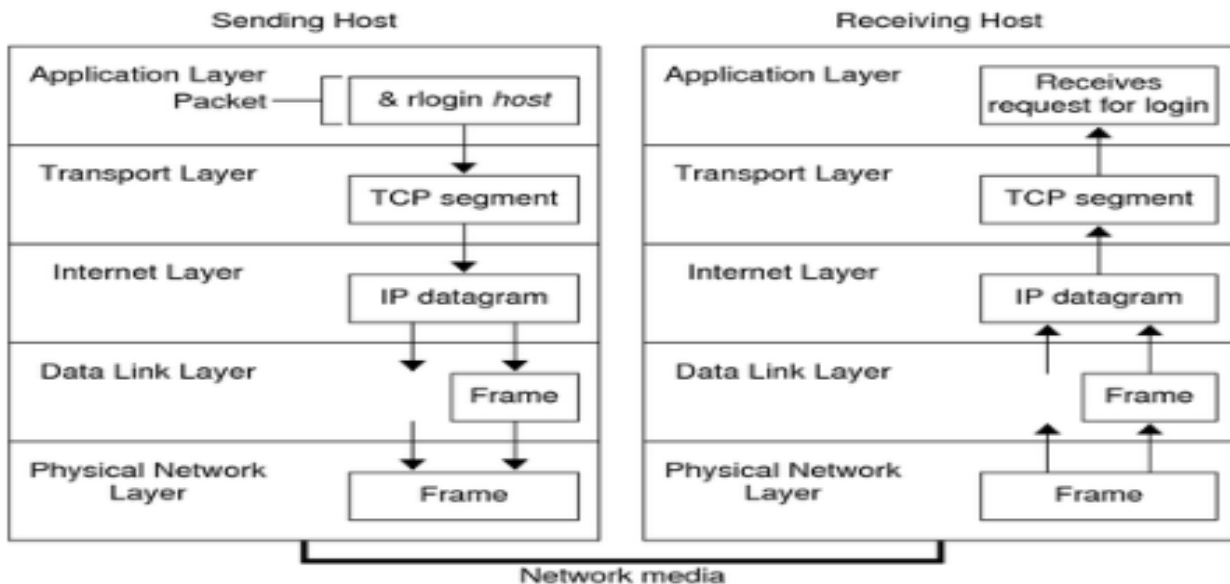


Fig. 2: The Packet Travels through the TCP/IP Stack

4. Winsock

A Windows sockets (Winsock) is an application-programming interface that allows for communication between Windows network software and network services, Windows sockets provides a standard interface between Windows TCP/IP client applications and the underlying TCP/IP protocol suite. Winsock can be divide into the following steps:

- A. Server intercepts network, a connection-oriented agreement in (TCP), to make connection preparation before data transmission. At this time, sever intercepts whether there is information from network at any time through methods like Listen [6].
- B. Client requests connection, Client specifies the host (IP) and port address to send out connection request to remote server through internet.
- C. Server connection request, Server has two choices, one is allow request and the other is reject request. If it allows the request can continue and follow-up, else transmission of data is interrupted [6].
- D. File transfer when the connection is completed, data of both sides can be Transferred. Transmitting end calls Send Data and produces Data Arrival event in server, and the needed file can be gained by calling Get Data in this event. However, since they are transfer files rather than ordinary characters, it has to place files to array and then read file and write file from data [6].
- E. Close connection Close connection aims to release resources (port) that both sides occupy to make sure those resources can be used by other routines [6].

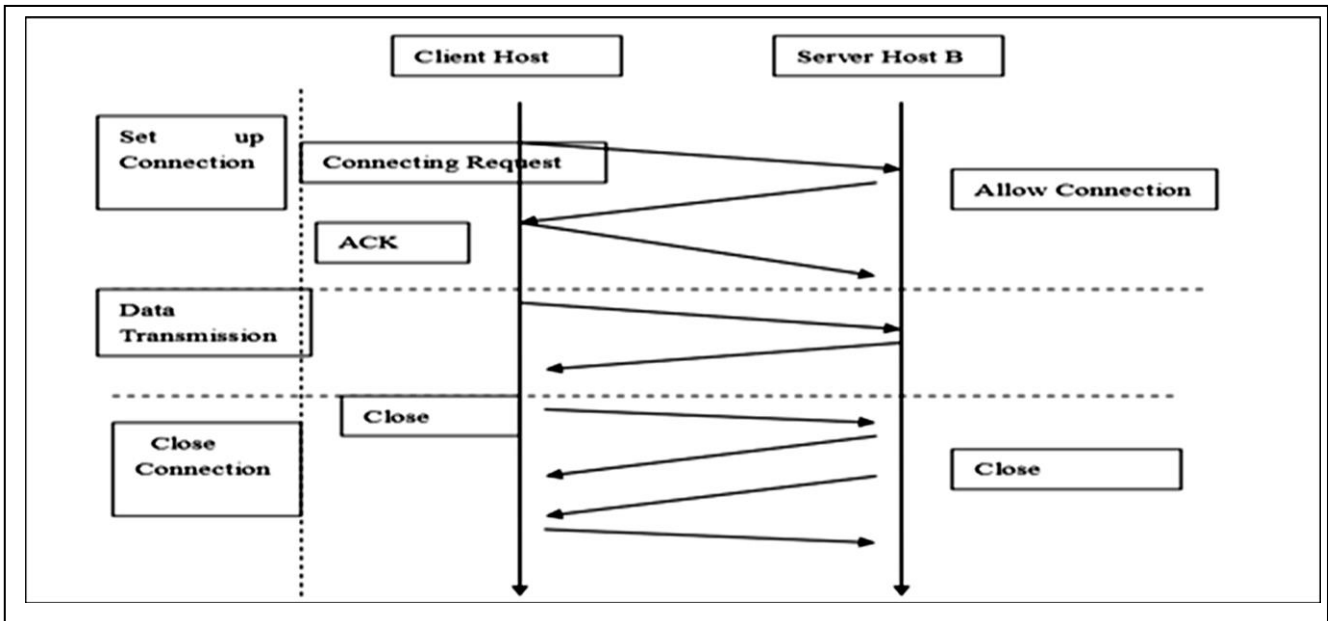


Fig. 3: Winsock Workflow Chart

5. Types of Cryptography Model

The cryptography algorithm used to encrypt data in a (symmetric or asymmetric) algorithm. This encrypts every packet from a data transmission session. Moreover, it can generate keys between the sender and the recipient and can negotiate the cryptographic keys that will be use during the session [7].

5.1. Symmetric Paradigm

Symmetric encryption was a paradigm of cryptosystem in which decryption and encryption can perform via employing the similar key that called a conventional encryption. Symmetric encryption converts plain text into cipher-text via employing a secret key and an algorithm of encryption. Employing the similar key and an algorithm of decryption, a plain text is retrieval from a cipher-text .Symmetric cipher constructs from two broad groups: stream ciphers and block cipher [7].

5.1.1. Data Encryption Standard (DES)

The utmost widely employed encryption "schema of block cipher" is DES (Data Encryption Standard) adopted in 1977 via the National Bureau of Standards, now the National Institute of Standards and Technology (NIST), For DES can encrypt and transform blocks of (64-bits) input employing (56-bits) key in this algorithm a series of stages into (64-bits) output. The similar stages with the similar key employed for reversing the encryption [8].

The encryption transformation relies on (56-bits) secret key and constructs from 16 iterations feistily surrounded via 2 layers of permutation. An initial permutation (IP) bit for input and its inverse (IP-1) for output. The process of decryption is similar like an encryption, except for the round keys' order employed in the iterations of Feistel. The 16 -round feistily network that constructs the core's cryptographic of DES, divides (64-bits) data blocks into two (32-bits) words, (R) Block and (L) Block and (indicated via R0 and L0). In each round or iteration, the second word (RI) was fed to the function (f) and the outcome was added to a first word (LI). Then the words swapped together and an algorithm proceeds be taken to a next iteration [8].

5.1.2. Stream Cipher

In a stream cipher, encryption and decryption process one symbol (such as a character or a bit) at a time. The cipher of stream was one, which can encrypt the digital data stream 1 byte or one bit at a time.

The process of encryption illustrated as:

$$\text{Cipher (t)} = \text{Plain (t)} * \text{Key (t)} \quad (1)$$

Where (*) indicates modulo 2 additions. The process of decryption illustrated as:

$$\text{Plain (t)} = \text{Cipher (t)} * \text{Key (t)} \quad (2)$$

It can note as specified via Eqs. (1) and Eqs. (2), which are both an encryption and decryption require similar key stream sequence Key (t) [7].

It is clear that Stream ciphers' security relies completely on the generator of the key stream, a stream cipher constructs elements successive of the key stream depend on an internal stage. This stage updated for two methods, if the stage alters independently of the cipher-text or plain text messages, then cipher can classify as a synchronous stream cipher. By contrast, self-synchronizing stream ciphers alters their stage depend on previous cipher-text digits [9].

6. Types of Images & Image Processing

There are three kinds of images can be illustrated below:

6.1. Binary image

Logical array can construct only from (1s) interprets as white and (0s) interprets as black[10].

6.2. Gray scale image

Called also an intensity, gray level or gray scale images. Class of Array with uint16, uint8, double or single relies on the values of pixel specify values of intensity. For double or single arrays, range values from [0, 1]. For uint16, the range values from [0, 65535]. For uint8, the range values from [0,255]. For int16, the range values from [-32768, 32767] [10].

6.3. Image of True color

Also called like (RGB) image. An image of true color was an image, which every pixel is construct from 3 values one each for red, green and blue of the pixel scalar's elements. An array of M by-n-by-3 for class uint16, uint8, double or single who is the values of pixel specify the values of intensity. For double or single arrays, the range values from [0, 1]. For uint16, the range values from (0, 6553) for uint8, the range values from (0, 255) [10].



Fig. 4: Binary Image



Fig.5: Gray Scale Image

Fig. 6: True Color Image

7. Mathematics Concepts and Equations

7.1. Permutation Rule

A permutation of (n) objects in a particular order utilizing (r) objects at same time called (n) objects' permutation taken (r) objects at a time it can write like $({}_n P_r)$ and a formula is [11].

$${}_n P_r = \frac{n!}{(n-r)!} \quad (3)$$

Example: How many different arrangements of three boxcars can be selected from eight boxcars for a train? The order is important since each boxcar delivered to a different location [11] .

$${}_8 P_3 = \frac{8!}{(8-3)!} = 336$$

7.2. The Rule of Combination

The combination's number for (r) objects which can be chosen from (n) objects is indicated via $({}_n C_r)$ and is specified via a formula [11]

$${}_n C_r = \frac{n!}{(n-r)!r!} \quad (4)$$

Example: How many combination of four objects are there taken two at a time

$${}_4 P_2 = \frac{4!}{(4-2)!2!} = \frac{4!}{2!2!} = 6$$

7.3. Random number generation & Computational methods

Utmost computer produced numbers randomly employ (pseudorandom number generators) (PRNGs) this algorithms can create automatically long runs of numbers with perfect random features but finally a series repeats or the memory employment grows without bound. These random numbers are penalty in numerous cases but are not as random as numbers produced from electromagnetic atmospheric noise used as a source of entropy. The values series produced via an algorithm are determined generally via a constant number known a seed. One of common PRNG is the linear congruential generator, which employs the recurrence [12] .

$$X_{n+1} = (aX_n + b) \text{ mod } m \quad (5)$$

To produce numbers, the (a, b) and (m) are large integers numbers and the $\{X_{n+1}\}$, (X_{n+1}) is the next (X) as a sequence of pseudo-random numbers. The extreme number of numbers the formula can generate is one less than the modulus (m-1). The recurrence relation can be extended to matrices to have much longer periods and better statistical features [12]. To avoid certain non-random features of a single linear congruential generator, numerous such random number generators with slightly various values of the multiplier coefficient, a, can be employed in parallel, with a "master" random number generator that choice from among the numerous various generators.[13] .

8. Proposed Method.

The aim of this project is to establish powerful secure communication system through the internet (network communication) between two (PC) to protect data during transmission by using two stages.

1. Encryption the text using (DES) Algorithm.
2. Convert the (DES) output result into image.

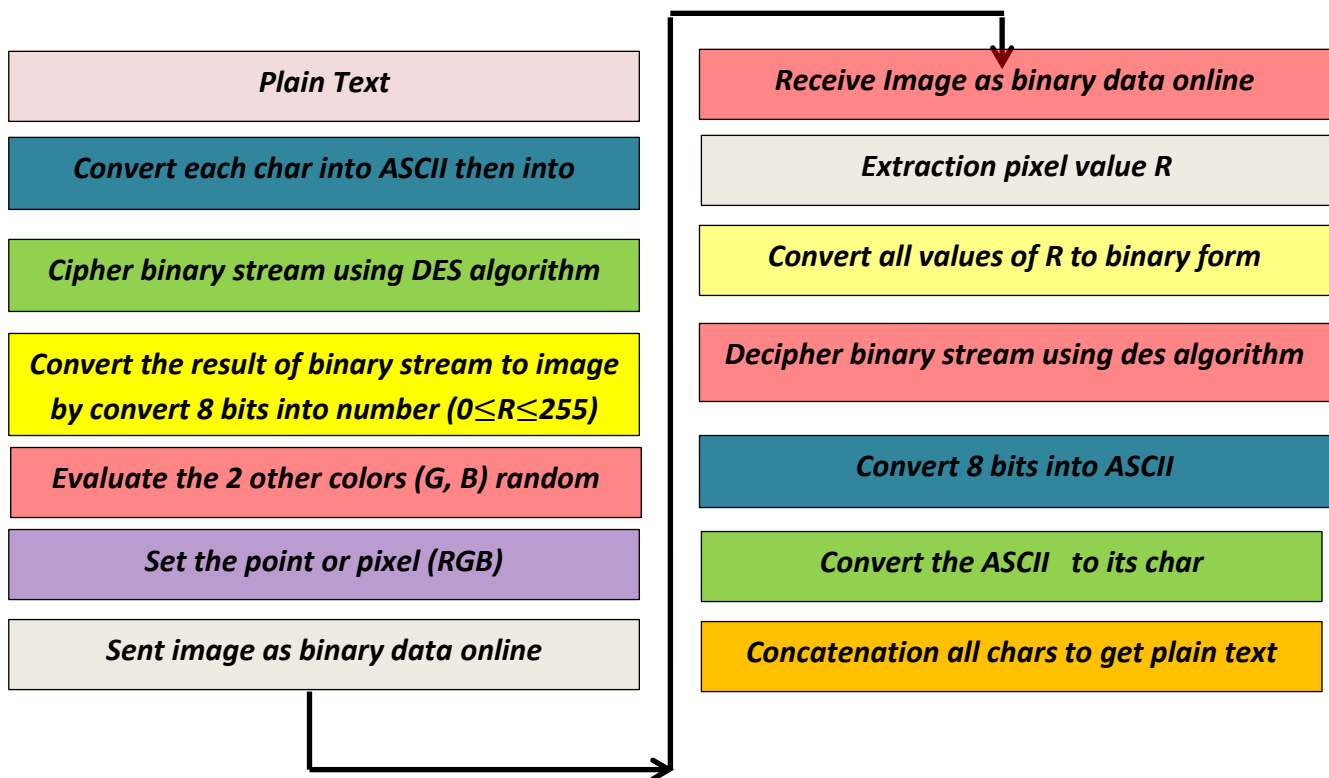


Fig. 7: Proposal Communication Method

A true Color image, also known as an (RGB) image, is an image in which each pixel is specified by three values, each one for the red, blue, and green components of the pixel's color. Each one has 8-bit per channel (RGB) image file containing exactly (16,777,216) possible pixels color values. The image is arranged as 256 slices of the (RGB) color cube. This image may be useful for investigating the effects that image processing. Moreover, this characteristic is used to draw an image by converting the output into a number and then filling the rest of the pixels with random colors [14].

Procedure Complexity (Row, Column, R, G, B)

K as integer

$K = (\text{ROW} * \text{Column}) \bmod 6$

Select case k

Case 0: Pset (ROW,Column)=RGB(R,G,B)

Case 1: Pset (ROW,Column)=RGB(R,B,G)

Case 2: Pset(ROW,Column)=RGB(G,R,B)

Case 3: Pset (ROW,Column)=RGB(B,R,G)

Case 4: Pset (ROW,Column)=RGB(G,B,R)

Case 5: Pset (ROW,Column)=RGB(B,G,R)

End select

End Procedure

Increase complexity

Great Image Algorithm

The steps below shows how to create (draw) the image from DES result

1. Set all the pixels =RGB(0,0,0) ' total number of pixels is 25*25
2. While DES result length $\neq 0$
3. Cut 8 bits then convert it from binary to decimal called R.
4. Generate random number by using the random number generation equation computational method $(X = a_0 + b_0 X_0) \bmod p_0$, p_0 is prime number > 625 and (a_0, b_0, x_0) are random numbers $< p_0$ called seeds
5. If $X > 624$ Then swap X_0, X , Generate a random number
6. Determine the random location of pixel as follow (row= $X \bmod$ picture width) and (column= $X \div$ picture width).
7. Generate a random number by using the random number generation equation computational method $(G = a_1 + b_1 G_0) \bmod p_1$, p_1 is prime number > 256 and (a_1, b_1, x_1) are random numbers $< p_1$
8. If $G \leq 100$ Or $G \geq 200$ Then swap G_0, G , Generate new random number G
9. Generate a random number by using random number generation equation computational method $(B = a_2 + b_2 B_0) \bmod p_2$, p_2 is prime number > 256 and (a_2, b_2, x_0) are random numbers $< p_2$
10. If $B \leq 100$ Or $B \geq 200$ Then swap B_0, B , Generate new random number B
11. Complexity (Row, Column, R, G, B)
12. End of while

Fill the rest of pixels by colors

13. For i = 0 To 24 'picture width - 1
14. For j = 0 To 24 ' picture height - 1
15. If Point Color (i, j) = 0 Then "RGB(0,0,0) no color set
16. $G = (a_1 + b_1 * G_0) \bmod p_1$ 'create green color
17. If $G > 100$ And $G < 200$ Then swap (G0,G) create new green color G
18. $B = (a_2 + b_2 * B_0) \bmod p_2$ 'create blue color
19. If $B > 100$ And $B < 200$ Then swap(B0,B) create new blue color B
20. $R = G * B \bmod 256$ 'create red color
21. Complexity (Row , Column, R , G , B)
22. End if
23. Next j
24. Next i
25. Save picture
26. Send picture as binary form
27. End

Extraction Locations and values Algorithm

To extraction the value of color component we have to determine two things which are.

A. Pixel location

1. To determine pixel location we have to use random number generation equation computational method ($X = a_0 + b_0 X_0$) mod p_0 , p_0 is prime number > 625 .
2. Determine the random location of pixel as follow (row= $X \bmod$ picture width) and (column= $X \div$ picture width).

B. Evaluate R,G,B color for location (row, column)

Select Case (row*column) mod 6

Case 0 or 1:

If ($G > 100$ and $G < 200$) and ($B > 100$ and $B < 200$) Then

Convert (R) from decimal to binary form

End If

Case 2 or 3:

If ($R > 100$ and $R < 200$) and ($B > 100$ and $B < 200$) Then

Convert (G) from decimal to binary form

End If

Case 4 or 5:

If ($R > 100$ and $R < 200$) and ($G > 100$ and $G < 200$) Then

Convert (B) from decimal to binary form

End If

End Select

Example:

Suppose we have the sentence (my name is) want to encrypt and send as a picture. The encrypted result of DES algorithm output is-

**10110110 01100110 11111001 00011111 01001110 01101001 10110001 10110001
01011100 00101000 11010110 00100101 01011110 00001101 00010100 10110101**

[convert each 8 bits into decimal form each value is R component].

182-102-249-31-78-105-177-177-92-40-214-37-94-13-20-181

According to the random number generation equation the locations and the values of the green and blue colors and arrangement of (R, G, and B) will be

$P_1(i,j)=P_1(1,13)=RGB(R,B,G)=RGB(182,134,144)$

$P_2(i,j)=P_2(10,5)=RGB(G,R,B)=RGB(151,102,181)$

$P_3(i,j)=P_3(7,23)=RGB(B,G,R)=RGB(160,197,249)$

$P_{14}(i,j)=P_{14}(24,20)=RGB(R,G,B)=RGB(13,110,118)$

$P_{15}(i,j)=P_{15}(15,15)=RGB(B,R,G)=RGB(164,20,127)$

$P_{16}(i,j)=P_{15}(5,23)=RGB(R,B,G)=RGB(181,185,123)$

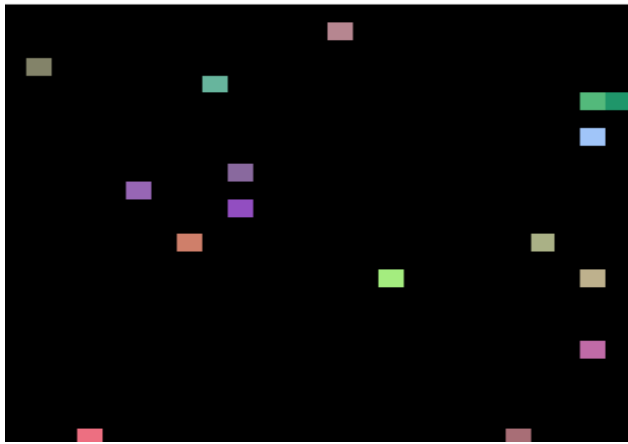


Fig. 8: First Step to Create the Pixels and Distributed Randomly

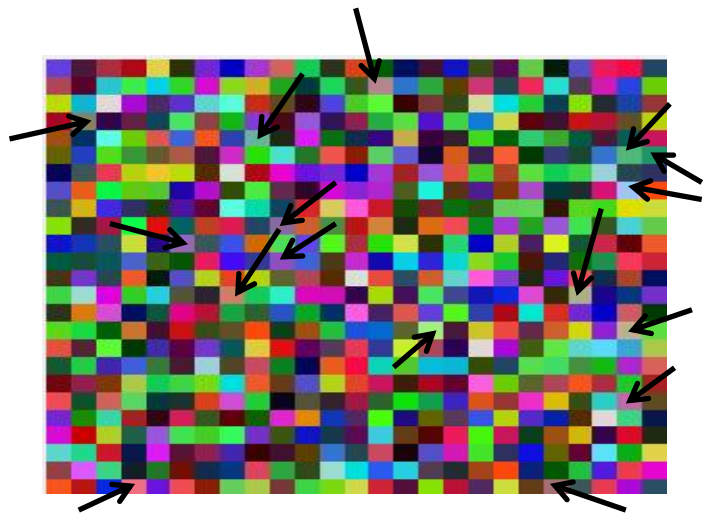


Fig- 9: Second Step to Create the Rest of Pixels Randomly as a Values And Locations

In our example, the image number (1) shows 16 pixels, is represented by 8bits of DES result which comes from cipher the sentence (my name is) with 10 char length after padding it to become 16 char by adding 6 a's (my name is aaaaaa) because DES algorithm working on 64 bits block i.e. 8 chars for each round.

The image number (2) shows the final image after filling the rest of pixels randomly. To find the right location of pixels according to the Permutation Rule is:-the size of image is $25*25=625$ pixels each one with 3 components (R,G,B) then the total number is $3*625=1875$ to find 16 values of 1875 pixel and the order is important.

$$P(n, r) = \frac{n!}{(n-r)!} \quad n \text{ is total number of locations } 1875, r = 16$$

$$P(1875, 16) = \frac{1875!}{(1875-16)!} = \frac{1875*1874*.....*1860*1859!}{1859!} = 218851031611642 \times 10^{38}$$

Table 1: Shows Probability of Different Size of DES Algorithm

<i>DES algorithm</i>	<i>Number of Characters</i>	<i>Number of pixels</i>	$P(n,k)=\frac{n!}{(n-k)!}$	$P(n,k)$
64 bits	8	8	$\frac{1875!}{(1875-8)!}$	1.5×10^{26}
128 bit	16	16	$\frac{1875!}{(1875-16)!}$	2.18×10^{52}
256 bits	32	32	$\frac{1875!}{(1875-32)!}$	2.25×10^{101}
512 bits	64	64	$\frac{1875!}{(1875-64)!}$	5.4×10^{204}
1024 bits	128	128	$\frac{1875!}{(1875-128)!}$	1.79×10^{407}

According to the table above let used a super processor and each trial of probability needs (Attosecond) 10^{-18} second the time to find the right locations is:-

Note: 1 year =365*24*60*60=31536000 second

Table 2: Shows the Time of Each Algorithm to Hack the Right Location of Pixels.

<i>DES algorithm type</i>	$P(n,k)$	<i>Time in year=</i> $10^{-18} * P(n,k) / 31536000$
64 bits	1.5×10^{26}	4.7 years
128 bit	2.18×10^{52}	$6.9 * 10^{26}$ years
256 bits	2.25×10^{101}	$7.1 * 10^{75}$ years
512 bits	5.4×10^{204}	$1.7 * 10^{179}$ years
1024 bits	1.79×10^{407}	$5.6 * 10^{381}$ years

To shrink or decrease the time in table (2), the right method to do that is to use parallel system which is multi-processor (CPU) work at same time (synchronize).

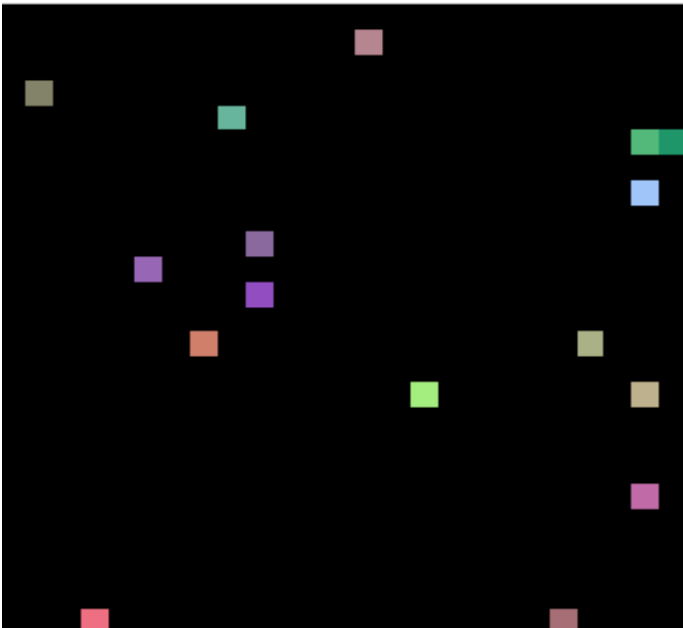


Fig.10: The Result of Sentence "my name is" with Specific Parameters (a0, b0, x0, a1, b1, G0...)

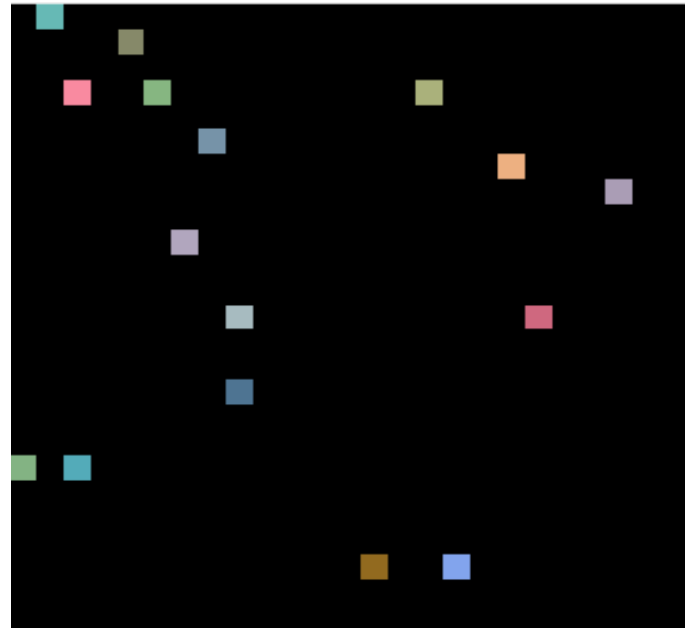


Fig. 11: The Result of Same Sentence "my name is" with Deferent Parameters (a0, b0, x0,a1,b1,G0...)

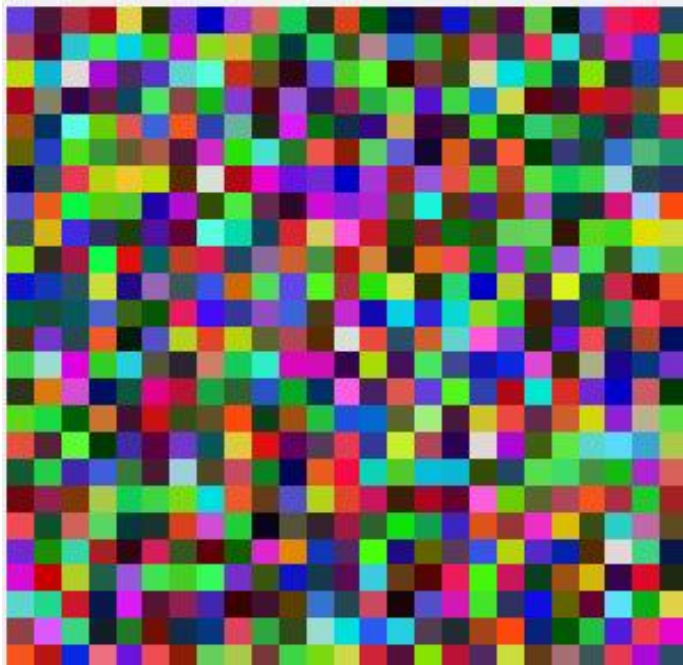


Fig. 12: The Image in Fig. 10 After Fill the Image with Rest of Pixels

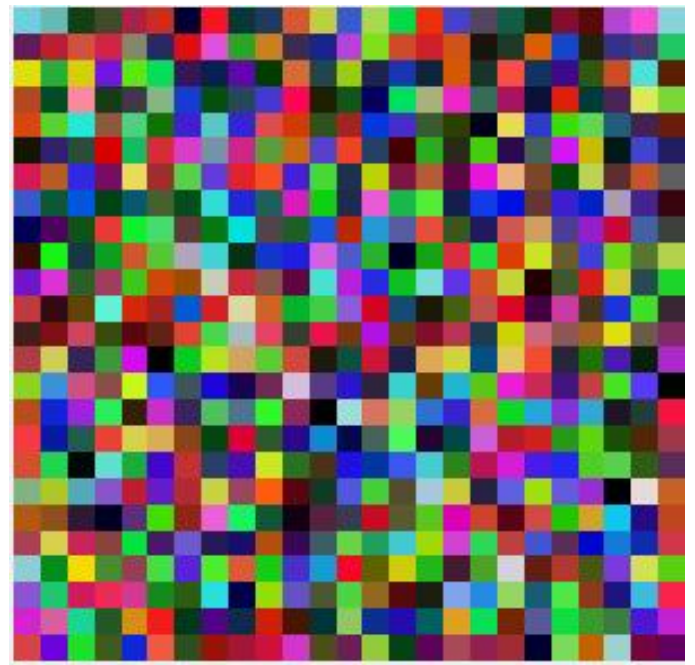


Fig. 13: The Image in Fig. 11 After Fill the Image with Rest of Pixels

The Image in (fig. 12) is totally different from image in (fig-13) i.e. there is no way to find a pattern between them to extract the right locations and values.

Table 3: Shows Time Process

Time in second			
A	B	C	D
Number of char	Time of DES processes	Time to convert the stream of 0,1 into number then to pixel	Time to fill the rest of pixels
8	0.00429	0.00068	0.0145
16	0.0083	0.00119	0.0117
32	0.0165	0.002	0.0094
64	0.0329	0.0042	0.0071
128	0.061	0.0046	0.0065

1. Column (B) shows time of DES process the value increase systematically because the number of char increases.
2. Column (C) shows time to convert the stream of (0, 1) into number then to pixel the value increase step by step because number of (0, 1) depend on number of char.
3. Column (D) show the time to fill the rest of pixels. The value is decrease because the relationship between column (C) and column (D) is reverse because the total number of pixels are constant, when the number of pixels increase to fill with value of DES result that mean the number of the rest of pixels decrease. that lead to decrease the time process to fill them.

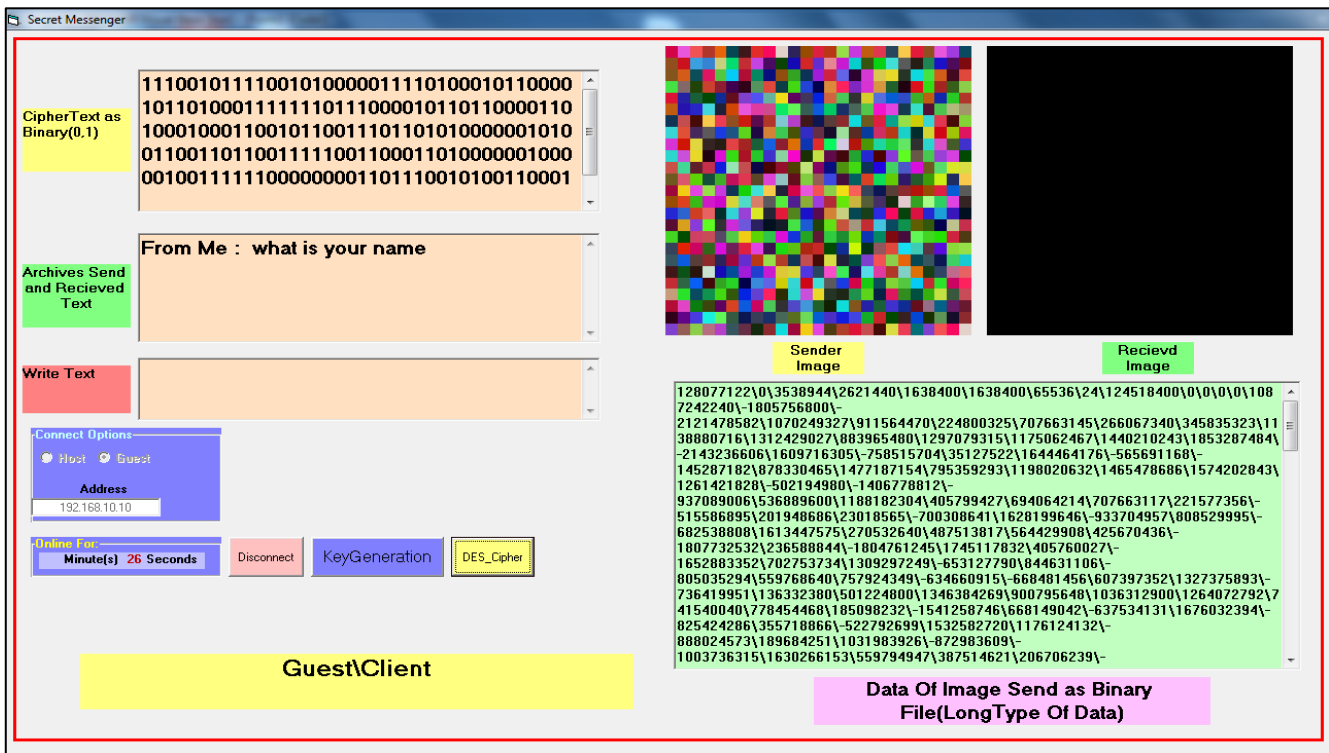


Fig. 14: Graphical User Interface (1) for Client send text as image

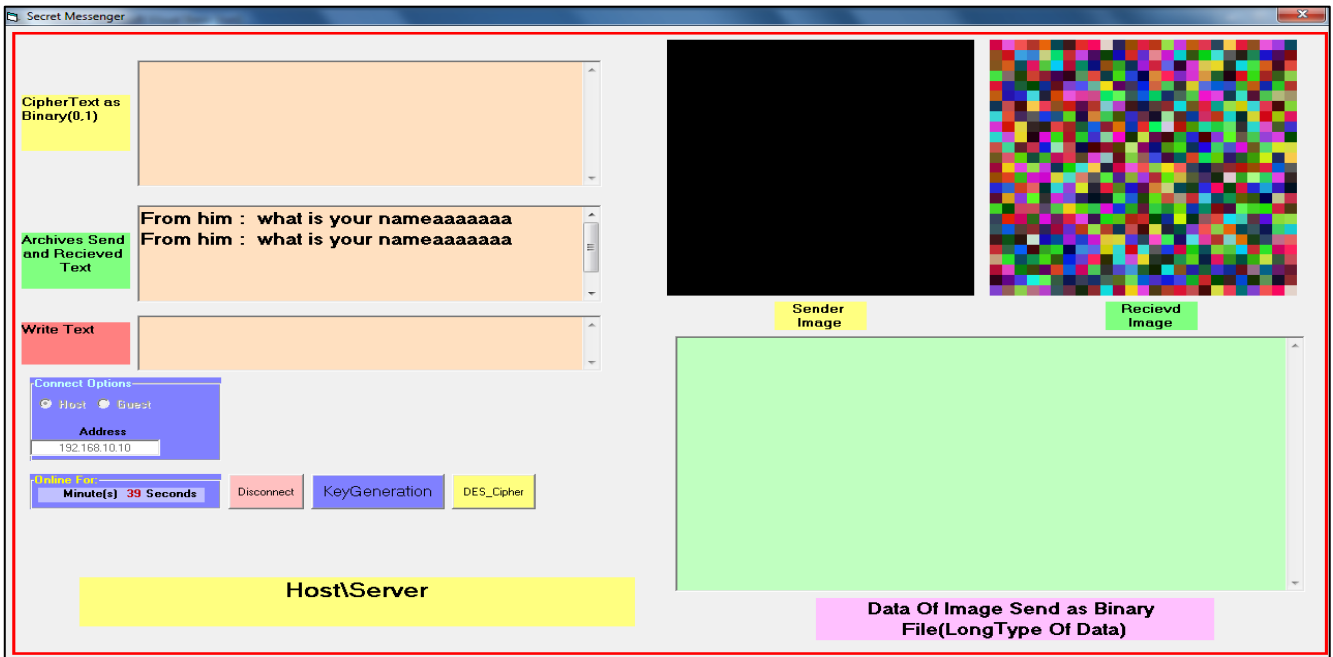


Fig. 15:Graphical User Interface (1) for Server received text as Image

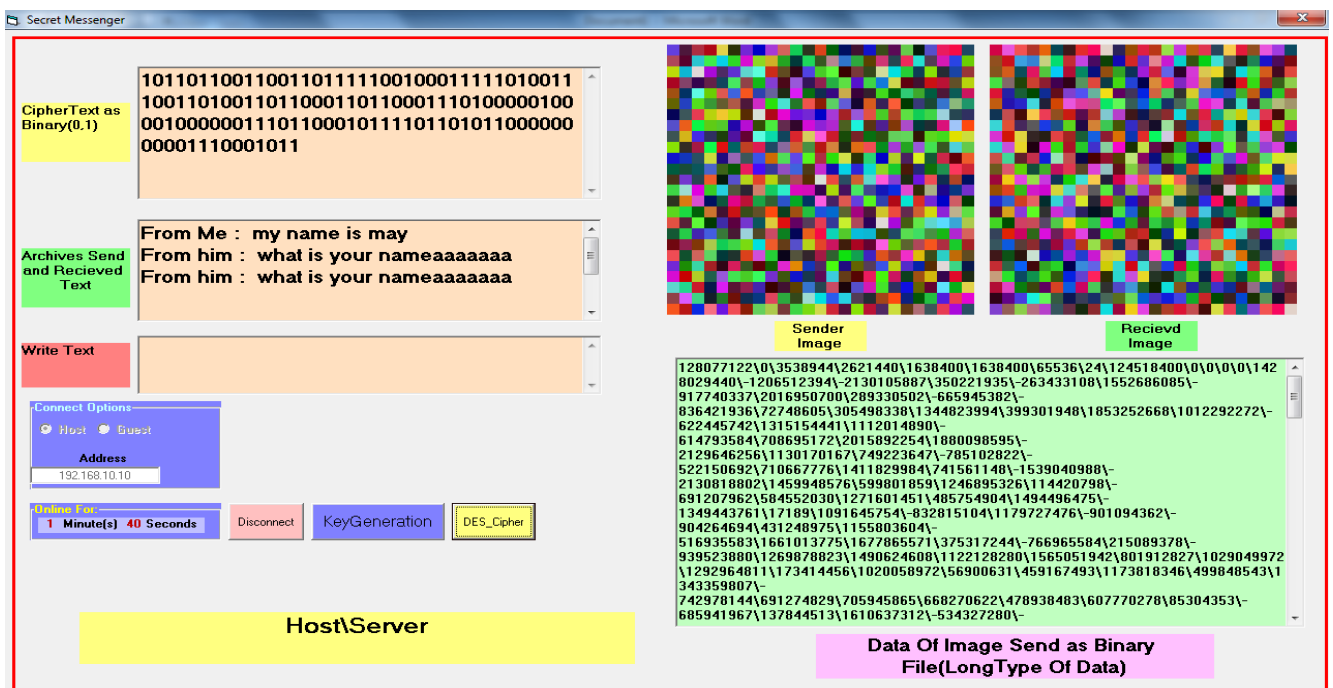


Fig. 16: Graphical user interface (2) for Server send text as Image

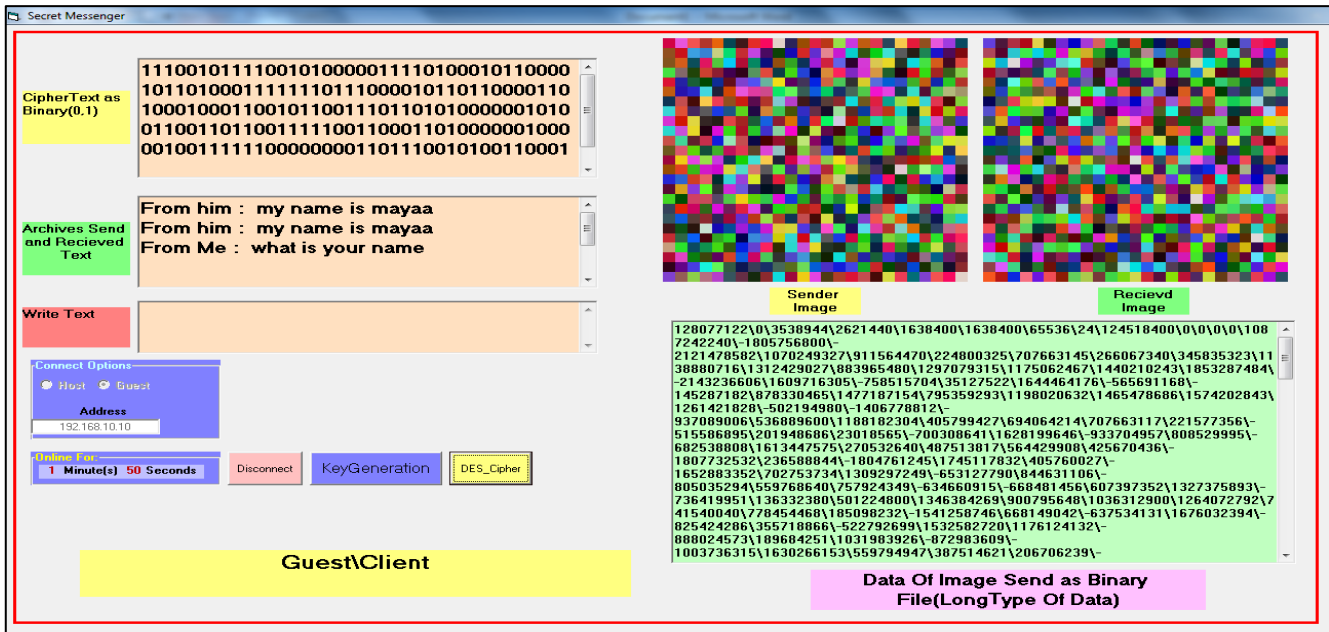


Fig.17: Graphical User interface (2) for Client received text as Image

9. Discussion and Conclusion.

1. This work used Winsock (socket) to send and receive confidential information in the form of image via the Internet and designed by (Visual Basic 6) language in the (Windows System).
2. The image is design by the sender in the form of colored boxes, in agreement with the recipient, after hiding the secret information in these boxes by using (DES) algorithm.
3. The image size (25 * 25) pixels that equal 625 pixels was used in this work because it's the proper size to ensures transmit the data without losing any part during sending it via the Internet to the other side.
4. In case the image larger than (625) pixels is used, it's probable a portion of the data has been lost, due to the fact that the communication devices (router & nano station) used are of low efficiency and quality, high efficiency devices are used to enable the use of images of larger sizes that give more security to the data.
5. The image sent to the other side over the Internet(online)

10. Future work

1. Establish a protocol between pc_1 and pc_2 to change all main parameters like $(a_0, a_1, b_0, b_1, x_0, b_0, g_0, \dots)$ etc.) for each session and subroutine to change the parameter for each single sentence (every sent process).
2. Convert the DES result (0, 1) into Hoffman code then create the image.
3. It is possible using other program languages such as (VB.NET) & (C#) language and in different System like Unix, Linux... etc.
4. Using (AES) algorithm to develop this work.

References

- [1] Rémi Géraud, "Advances in public-key cryptology and computer Exploitation", Security [cs.CR]. PSL Research University,2017.
- [2] Sarita.D, Abhay.S "New Trend in Digital Data Storage for the Internet" Article, International journal of computer sciences and engineering · March 2018.
- [3] Pranab Bandhu "TCPIP Model in Data Communication and Networking" American Journal of Engineering Research (AJER) volume-4, Issue-10, pp-102-107 www.ajer.org 2015.
- [4] Long Hoang. " A Study of Internet Protocols " Oulu University of Applied Sciences of Information Technology . Spring 2019.
- [5] Xie Wendi, Yao Ling and Wang Enliang "Application Research of Ethernet Communication System Based on UIP Protocol Stack" IOP Conf. Series: Journal of Physics: Conf. Series 1237 (2019).
- [6] Mao Zhuolin Jiangxi "Design and Implementation of Computer Rank Examination System based on Winsock" International Conference on Education, Management, Computer and Society College of Foreign Studies (EMCS 2016).
- [7] William, S., Cryptography and Network Security: Principles and Practice Fifth Edition, Prentice Hall, 2011.
- [8] Isnar Sumartono, Andysah Putera and Utama Siahaan " Encryption of DES Algorithm in Information Security", International journal for innovative research in multidisciplinary field Volume - 4, (Oct – 2018)
- [9] Belal Al-Khateeb Sufyan T. Faraj Al-Janabi," Intelligent Techniques in Cryptanalysis: Review and Future Directions" <https://www.researchgate.net>. Article / April 2017
- [10] Fernando. A.Mendoza, Renfu. Lu, "Basics of Image Analysis". Chapter from book (Hyperspectral imaging technology in agriculture (pp.9-56) ResearchGate, January 2015.
- [11] Ramesh Chandra Published by Notion Press, "Permutation and Combinations" ISBN 13: 9789384391478- 2014.
- [12] "RANDOM.ORG - True Random Number Service". Www.random.org. Retrieved (14-1-2016).
- [13] "High Dimensionality Pseudo Random Number Generators". Retrieved (21-11-2018)
- [14] Sanjay saxena, neeraj sharma, "Parallel Image Processing Techniques, Benefits and Limitations", Article in Research Journal of Applied Sciences, Engineering and Technology 12(2):223-238 · January 2016,