Secure communication via DNA encoding

A COURSE PROJECT REPORT

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ABSTRACT

Secure data communication is the most important and essential issue in message transmission over the networks. Cryptography provides a way of making secure messages for confidential message transfer. Cryptography is the process of transforming the sender's message to a secret format called cipher text that only the intended receiver will understand the meaning of the secret message.

Various cryptographic or DNA based encoding algorithms have been proposedin order to make secret messages for communication. But all these proposed DNA based encryption algorithms are not secure enough to provide better security as compared with today's security requirement. In this paper, we have proposed a technique of encryption that will enhance the message security. In this proposed algorithm, a new method of DNA based encryption with a strong key of 256 bit is used.

Along with this big size key various other encoding tools are used as key inthe encoding process of the message like random series of DNA (Deoxyribonucleic Acid) bases, modified DNA bases coding. Moreover, a new method of round key selection is also given in this paper to provide better security in the message. The cipher text contains the extra bit of information like the DNA strands that willprovide better and enhanced security against intruder's attack.

This paper explores the novel concept of secure communication through DNA encoding, leveraging the distinctive properties of deoxyribonucleic acid (DNA) for information storage and transmission. The method involves encoding messages into DNA sequences, utilizing its vast storage capacity and potential for biometric authentication based on individual genetic codes. We delve into the biochemical operations, such as DNA synthesis and sequencing, required for implementing this approach. While facing challenges such as time-consuming processes and associated costs, the potential benefits in terms of security and information density make DNA-based communication an intriguing avenue for exploration. Ongoing research and development in this field aim to assess the practicality and viability of employing DNA encoding for secure communication in real-world applications.

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PROBLEM STATEMENT

In the realm of secure communication, traditional cryptographic methods face ongoing challenges related to the potential vulnerabilities of existing algorithms and the increasing computational power available to adversaries. The need for innovative and robust encryption techniques has led to the exploration of unconventional approaches. This paper addresses the problem by investigating the feasibility and practicality of secure communication via DNA encoding.

Traditional cryptographic systems rely on mathematical algorithms, and their security is contingent upon the complexity of these algorithms and the secrecy of cryptographic keys. As technology advances, the risk of cryptographic attacks grows, necessitating the exploration of alternative paradigms. DNA-based communication emerges as a potential solution, harnessing the unique properties of DNA for secure information storage and transmission.

However, several challenges and questions must be addressed. The time-intensive nature of DNA operations, including synthesis and sequencing, poses a potential barrier to real-time communication needs. Additionally, the cost associated with biochemical operations and potential error rates in DNA encoding processes raise concerns about the practicality of implementing this approach on a large scale.

Furthermore, the integration of biometric authentication through individual DNA sequences introduces ethical considerations and potential privacy issues. As DNA is inherently tied to an individual's identity, ensuring the secure and responsible use of this information becomes paramount in the development and deployment of DNA-based communication systems.

This problem statement establishes the foundation for investigating the viability of DNA encoding as a secure communication method and highlights the key challenges and considerations that need to be addressed in the pursuit of developing a robust and practical solution.

INTRODUCTION

Security in data communication is required when message transfer between sender and receiver is needed to be kept confidential. Cryptography is the process of achieving confidentiality in message transfer. Cryptography can be thought of as a process of secret writing in order to protect data or messages from various attacks of the intruder. Secret writing is achieved through the process of transforming a message called plaintext into cipher text by means of a cryptographic algorithm. Security is concerned with the protection of message or data while transmitting over the networks. But now-a-days to achieve complete data security is a challenging issue of data or message transfer. In order to get better security in message transfer several DNA based encryption schemes had been proposed. In order to enhance data security and make the data more confidential, effective encryption algorithms are required.

DNA based encryption method is one of the recent techniques embedded into the cryptographic field, a lot of researchers are working on this. Some of them used DNA computing, while some other applied biological properties of DNA strands and DNA sequence after making few modifications. DNA complementary rule substitution, message embedding within a DNA sequence, makes cipher text much larger in size compared to plaintext size. In order to reduce the cipher size a modified DNA substitution has been adopted in this paper using the properties of DNA strands and DNA sequences.

The encryption algorithm proposed here is based on the combination of the concept of DNA based cryptography and conventional cryptography. The algorithm proposed here works on block cipher with a key of 256 bit. The encryption algorithm has four rounds of coding and each round has used the concept of cipher block chaining coding. Moreover the proposed system has a new scheme of key selection for round operation for better security aspects.

LITERATURE SURVEY

1)

TITLE OF PAPER:
"DNA Cryptography: A Review"

YEAR & AUTHOUR:
Abbas et al. | 2016

METHODOLOGY:
Review of existing DNA cryptography methods

RESULT:
Overview of DNA based cryptography

LIMITATIONS OR FURTHER ENHANCEMENT:
Limited depth on specific methodologies

2)

TITLE OF PAPER:
"DNA Key-BasedEncryption"

YEAR & AUTHOUR:
Kundur and Hatzinakos | 2004

METHODOLOGY:
Use of DNA sequences as encryption keys

RESULT:
Improved encryption using DNA keys Failure Cost

LIMITATIONS OR FURTHER ENHANCEMENT:
Limited discussion of practical applications

3)

TITLE OF PAPER:
"Secure Data Transmission Using DNA"

YEAR & AUTHOUR:
Patil and Biradar | 2018

METHODOLOGY:
Encoding data intoDNA for transmission

RESULT:
Secure data transmission via DNA encryption

LIMITATIONS OR FURTHER ENHANCEMENT:
Scalability and error handling not discussed

4)

TITLE OF PAPER:
"Error-Correcting Codes for DNACrypto"

YEAR & AUTHOUR:
Daniella Bar-Lev, Eitan Yaakobi | 2023

METHODOLOGY:
Error correction in DNA based encryption

RESULT:
Improved data integrity with ECC

LIMITATIONS OR FURTHER ENHANCEMENT:
Complexity of ECC implementation

5)

TITLE OF PAPER:

"DNA Computing in Cryptography"

YEAR & AUTHOUR:

Reif | 2007

METHODOLOGY:

Utilizing DNAcomputing in cryptography

RESULT:

Potential for highlysecure systems

LIMITATIONS OR FURTHER ENHANCEMENT:

Practical implementation challenges

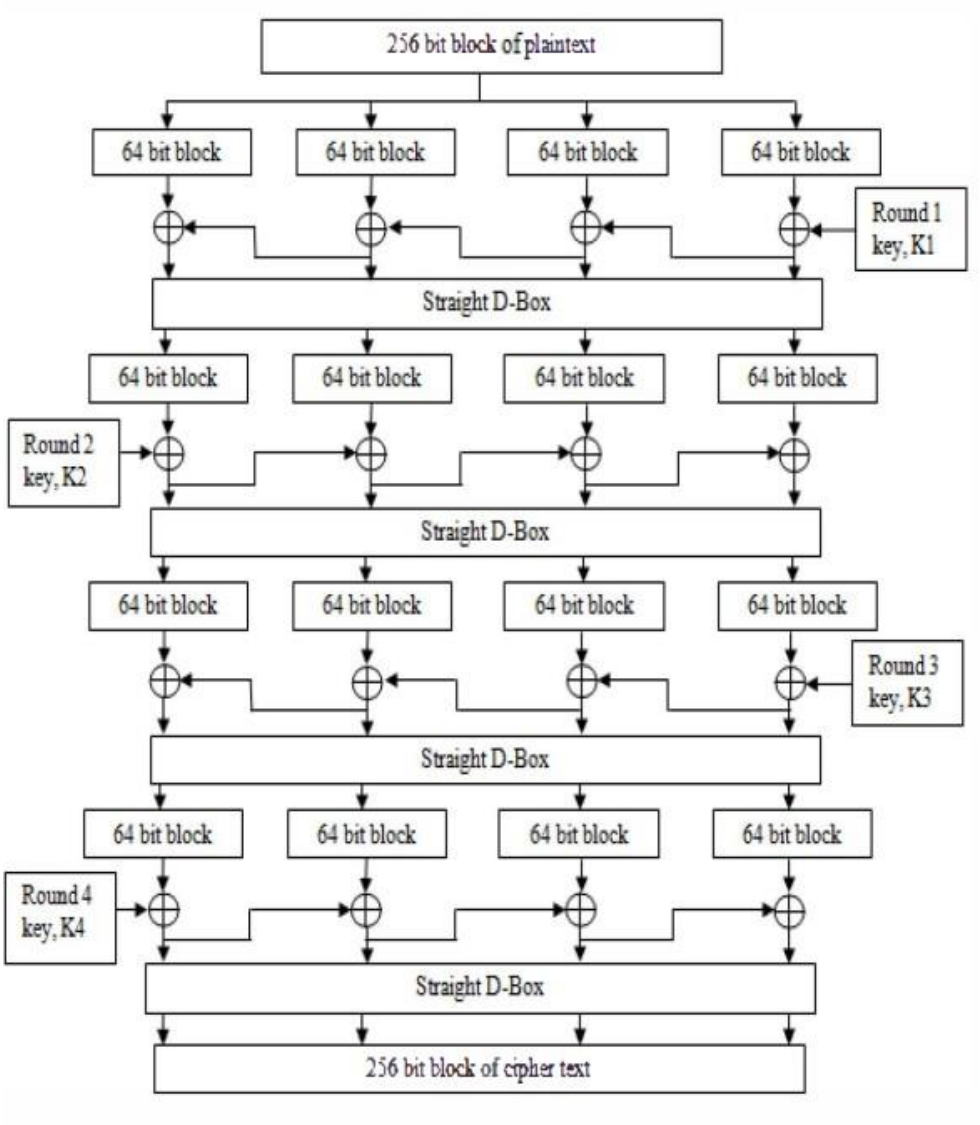
PROPOSED METHOD

In order to provide better security and reliable data transmission an efficient method of DNA based cryptography is proposed here. The algorithm has two phases; these are round key selection and message encryption.

In the round key selection phase, a key of 256-bit is chosen randomly for encryption. This 256-bit key is then transformed into an 8X8 matrix with each cell having 4-bit key value. Transform the 256-bit key into the matrix in row wise.

Then read the key bits in column wise, two columns at a time. Thus every two columns will produce a sub-key of 64-bit that is a total of four blocks of subkeys. Each block of sub-keys is labeled with one of four DNA bases namely A, T, C, G. Select randomly a DNA sequence of length four with no repetition of DNA bases. There are 24 possible combinations like TGCA, AGTC etc., randomly one sequence will be selected for round key selection. At the time of encryption these sub-keys blocks are used in four rounds of encryption operation. The secret key, selected DNA sequences, and position of extra coding are to be shared between the sender and receiver through a secret channel.

In the message encryption phase, the byte values are extracted from the input file or message. The encryption process works on the unsigned byte values of the input file or text called plaintext. Then these byte values will be transformed into 8-bit binary. Plaintext is then divided into 256-bit blocks; each block of plaintext will go through the encryption process. Then in round operation the 256-bit block of plaintext is divided into four 64-bit plaintext blocks. Now perform 64-bit Ex-OR operation between the fourth block of plaintext and the round 1 key, K1. The result is then getting Ex-ORed with the third block of the plaintext. Then this result will go for the second block and so on. Then these four 64-bit results will go through a straight D-Box. The output of the D-Box will be used as input for the second round. In the second round, round key 2, K2 will get Ex-ORed with the first block of plaintext, the result of this will be used as key for the second block as a cipher block chaining method. The four round of encryption operations are shown in following figure:



Schematic diagram of proposed encryption technique

ALGORITHM PRESENTATION

The encryption scheme proposed in this paper has the following phases:

- A. Round Key Selection In this phase, a key of size 256-bit is selected randomly. This selected key is transformed into an 8X8 matrix. Let, K be the key, K='1011 1010 0011 0011 1100 1100 1010 0011 0000 0000 0000 0000 1111 1111 1111 1111 111 0 111 0 1001 0011 0000 10 10 1111 01 00 10 11 11 00 0101 1001 0011 1011 0001 1010 0011 1001 0011 0100 1010 1100 1001 1010 0000 0001 1000 1010 1111 0001 1010 0101 0000 0001 1010 11 00 1000 1111 1000 1111 0001 1111 0011 00 10 1100 0001 1111 1000' Transformation of key values into matrix row wise (in tabular form):

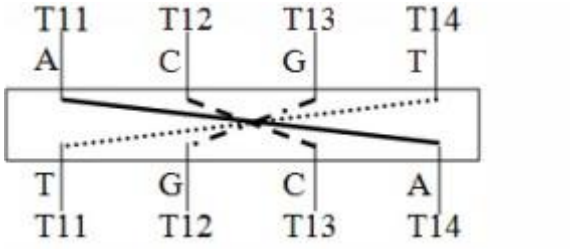
1011	1010	0011	0011	1100	1100	1010	0011
0000	0000	0000	0000	1111	1111	1111	1111
1110	1110	1001	0011	0000	1010	1111	0100
1011	1100	0101	1001	0011	1011	0001	1010
0011	1001	0011	0100	1010	1100	1001	1010
0000	0001	1000	1010	1111	0001	1010	0101
0000	0001	1010	1100	1000	1111	1000	1111
0001	1111	0011	0010	1100	0001	1111	1000

Read the key values column wise (two columns at a time), that generates four sub-keys. Label the sub-keys with DNA bases (A, T, C, G) as follows:
A='1011 0000 1110 1011 0011 0000 0000 0001 1010 0000 1110 1100 1001 0001 0001 1111'
T='OOll 0000 1001 0101 0011 1000 1010 0011 0011 0000 0011 1001 0100 1010 1100 0010'
C='1100 1111 0000 0011 1010 1111 1000 1100 1100 1111 1010 1011 1100 0001 1111 0001'
G='lOlO 1111 1111 0001 1001 1010 1000 1111 0011 1111 0100 1010 1010 0101 1111 1000'

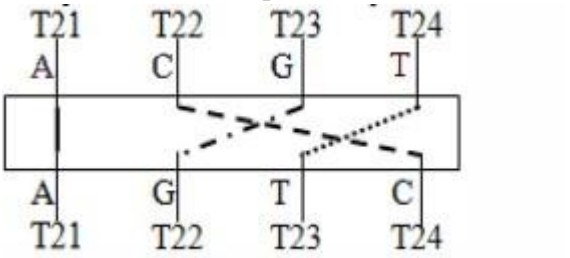
Let, randomly selected DNA sequence with DNA bases be 'TGCA' then,
Round 1 key, Kl =T
Round 2 key, K2=G
Round 3 key, K3=C
Round 4 key, K4=A

- B. Message Encryption Every 256-bit plaintext block will go through the four round of encryption process. After each round coded blocks will go through a straight D-Box. The D-Box has four input and output terminals.The inputs terminals are labeled with DNA bases (A, T, C, and G). The D-Box will works on the randomly selected DNA sequence of length four. The encryption algorithm is given below:
  Step 1: Read the byte values from the input file called plaintext and transform each byte value into 8-bit binary representation.
  Step 2: Make 256-bit plaintext blocks from the binary representation
  Step 3: Repeat step 4 and 5 for each block of plaintext
  Step 4: Split the 256-bit block into four 64-bit blocks, namely PI, P2, P3, P4

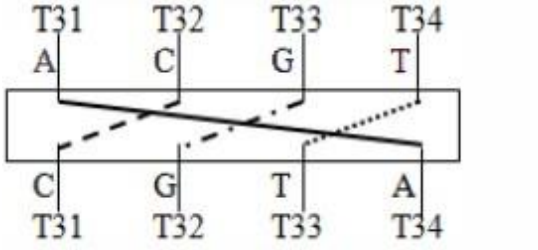
  Round 1: Temporary variables T11, T12, T13, T14 Compute T14= P4 ⊕K1, T13= P3 ⊕ T14, T12= P2 ⊕ T13, TI1=Pl ⊕ T12 Let, randomly selected DNA sequence be 'TGCA'



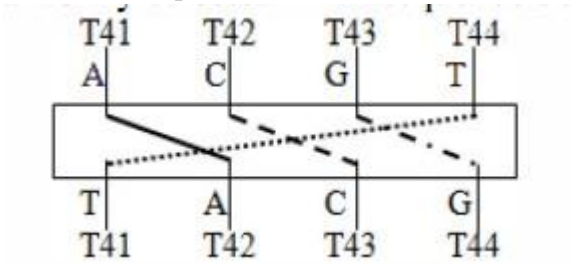
  Round 2: Temporary variables T2l, T22, T23, T24
  Compute T21= T11 ⊕ K2, T22= T12 ⊕ T2l, T23= T13 ⊕ T22, T24= T14 ⊕ T23 Let, randomly selected DNA sequence be 'AGTC'



  Round 3: Temporary variables T31, T32, T33, T34
  Compute T34= T24 ⊕ K3, T33= 23 ⊕ T34, T32= T22 ⊕ T33, T31= T21 ⊕ T32 Let, randomly selected DNA sequence be 'CGTA'



Round 4: Temporary variables T41, T42, T43, T44
Compute T41= T31 ⊕ K4, T42= T32 ⊕ T4l, T43= T33 ⊕ T42, T44= T34 ⊕ T43
Let, randomly selected DNA sequence be 'TACG'



Step 5: Combine all 64-bit cipher blocks to form 256-bit cipher text block
Step 6: Club together all the 256-bit cipher text blocks

After that a fixed number of bits are to be added to both the end of the coded message and two specific positions within the coded message. After embedding extra coding the final form of the cipher text is mapped to a modified DNA sequence. In order to form modified DNA coding, 16 characters are randomly selected for making the modified DNA coding and transform all the 16 characters into 4X4 matrix form as follows:

	00	01	10	11
00	E	L	G	F
01	R	N	P	A
10	T	Q	C	M
11	D	S	B	H

Taking final form of ciphertext as, FnlCT='1 000 110 1 0011 0110'
To make the [mal coded form, Take 4-bit at a time, first 2- bit for selecting column while last two for row. Thus' 1000' is mapped to 'G'
Therefore, after mapping all the bits, final form becomes, FnICT='GADQ'

CODE IMPLEMENTATION

```
import json
{
   "AAA": "a",
   "AAC": "b",
   "AAG": "c",
   "AAT": "d",
   "ACA": "e",
   "ACC": "f",
   "ACG": "g",
   "ACT": "h",
   "AGA": "i",
   "AGC": "j",
   "AGG": "k",
   "AGT": "l",
   "ATA": "m",
   "ATC": "n",
   "ATG": "o",
   "ATT": "p",
   "CAA": "q",
   "CAC": "r",
   "CAG": "s",
   "CAT": "t",
   "CCA": "u",
   "CCC": "v",
   "CCG": "w",
   "CCT": "x",
   "CGA": "y",
   "CGC": "z",
   "CGG": "A",
   "CGT": "B",
   "CTA": "C",
   "CTC": "D",
   "CTG": "E",
   "CTT": "F",
   "GAA": "G",
   "GAC": "H",
   "GAG": "I",
   "GAT": "J",
   "GCA": "K",
   "GCC": "L",
   "GCG": "M",
```

```
    "GCT": "N",
    "GGA": "O",
    "GGC": "P",
    "GGG": "Q",
    "GGT": "R",
    "GTA": "S",
    "GTC": "T",
    "GTG": "U",
    "GTT": "V",
    "TAA": "W",
    "TAC": "X",
    "TAG": "Y",
    "TAT": "Z",
    "TCA": "1",
    "TCC": "2",
    "TCG": "3",
    "TCT": "4",
    "TGA": "5",
    "TGC": "6",
    "TGG": "7",
    "TGT": "8",
    "TTA": "9",
    "TTC": "0"
}
dna = json.load(open("./dna.json", "r"))
keys, values = list(dna.keys()), list(dna.values())
non_enc = [i for i in str(input("Input: "))]
_str = []

for i in non_enc:
  if i in values:
    _str.append(keys[values.index(i)])
  else:
    _str.append(i)

print(f"Encryption: {''.join(str(s) for s in _str)}")
```

OUTPUT:

Input: dna based cryptography is being implemented

Encryption: AATATCAAA AACAAACAGACAAAT
AAGCACCGAATTCATATGACGCACAAAATTACTCGA AGACAG
AACACAAGAATCACG AGAATAATTAGTACAATAACAATCCATACAAAT

```
[10]: import json

dna = json.load(open("./dna.json", "r"))
keys, values = list(dna.keys()), list(dna.values())
non_enc = [i for i in str(input("Input: "))]
_str = []

for i in non_enc:
  if i in values:
    _str.append(keys[values.index(i)])
  else:
    _str.append(i)

print(f"Encryption: {''.join(str(s) for s in _str)}")
```

```
Input:  dna based cryptography is being implemented
Encryption: AATATCAAA AACAAACAGACAAAT AAGCACCGAATTCATATGACGCACAAAATTACTCGA AGACAG AACACAAGAATCACG AGAATAATTAGTACAATAACAATCCATACAAAT
```

- **<u>Result analysis</u>**: This algorithm is applicable for almost all documents, image, audio, video file type such as .doc, .mp3, .avi, .mp4, .txt, .flv and so on. The results of generation of cipher text after encrypting the plaintext on few data sets are given below:

File	File size (KB)	Cipher size(KB)	Encrypt time (ms)	Decrypt time (ms)
.doc	1126.4	2253.4	9531	10672
.jpeg	2304	4609.5	18966	21345
.mp3	5990.4	11981.6	46936	53406
.avi	14950	299002	119281	133500

JUSTIFICATION

- We are going to propose a technique of encryption that will enhance the message security. In this proposed algorithm, a new method of DNA based encryption with a strong key of 256 bit is used.

- Along with this big size key various other encoding tools are used as key in the encoding process of the message like random series of DNA bases, modified DNA bases coding.

- We will be implementing a new method of round key selection to provide better security in the message.

- The cipher text contains the extra bit of information similar to the DNA strands that will provide better and enhanced security against an intruder's attack.

- A new method of round key selection to enhance encryption system security, making it harder for attackers to decipher encrypted messages without knowledge of the key selection process.

- The round key selection method enhances encryption complexity, making it harder for attackers to analyze and break, and adding an extra layer of security.

- Changing the selection of encryption keys can enhance encryption's resistance to specific types of attacks, such as brute force or specific analysis methods.

- Customizing the round key selection method in an encryption algorithm allows for better security features and adaptability to different threat models and security needs.

- Innovation in cryptography is crucial for enhancing encryption systems' security. The round key selection method allows for customization of security features to suit specific purposes.

DIFFERENCES BETWEEN AES AND PROPOSED METHOD

Aspect	Proposed method	AES cryptography
Key Generation	Randomly select a 256-bitkey and transform it into a 8x8 matrix.	Key expansion using key schedule to generate roundkeys.
Sub-Key Generation	Divide the key matrix into64-bit sub-keys based on DNA bases.	Generate subkeys using a key schedule algorithm.
Round Operations	Four rounds of encryption using XOR operations and D-Box.	Multiple rounds (10, 12, or 14rounds depending on key size) with various operations (SubBytes, ShiftRows, MixColumns, AddRoundKey).
Block size	Operates on 256-bit blocks of plaintext.	Operates on 128-bit blocks of plaintext.
Encryption Operations	XOR operations and D-Box transformations based on DNA sequences.	Substitution, permutation, andmixing operations using lookuptables and mathematical operations.
Security level	Security strength depends onthe randomness and uniqueness of DNA sequences used for key and D-Box operations.	Well-established security witha high level of confidence due to extensive analysis and cryptanalysis.
Standardization	Not a standardized cryptographic algorithm; specific to the described approach.	Internationally standardizedby NIST and widely adopted.
Performance	Performance may be slowerdue to DNA sequence operations.	Fast and efficient encryptionand decryption operations, especially in hardware implementations.
Practicality	Limited practical implementation due to the complexity and uniqueness requirement of DNA sequences.	Widely practical and implemented in various applications and systems.
Error handling	Has error handling capabilities	AES has error detection capabilities

ADVANTAGES OF PROPOSED TECHNIQUE

While DNA-based encryption is a novel and exciting area of research, it's importantto note that, as of my last update in January 2022, there is no widely accepted practical implementation of DNA-based encryption that has been proven to be better than the AES (Advanced Encryption Standard) algorithm. DNA-based encryption is still largely theoretical and experimental. However, I can mention a few potential advantages that researchers often discuss when exploring the concept of DNA-based encryption. Keep in mind that these points are theoretical and may not necessarily translate into real-world advantages until practical implementations are established and extensively tested:

Biochemical Complexity: DNA-based encryption utilizes the inherent complexity of biochemical processes, potentially offering unique encoding methods that could be difficult to decrypt using traditional computational approaches.

Massive Parallelism: DNA processes are inherently parallel, allowing for the potential of massively parallel computations, which might lead to faster encryption and decryption processes for specific tasks.

Data Density: DNA molecules can store immense amounts of data in a very small space. This high data density could be advantageous for certain specialized applications where physical storage space is limited.

Biological Security: DNA-based encryption could offer a form of biological security, as the data is stored in biological molecules. This concept raises interesting possibilities, such as secure data storage in biological systems.

Quantum Computing Resistance: Some researchers speculate that DNA-based encryption could potentially resist attacks from future quantum computers due to its fundamentally different nature compared to classical computing. However, this remains a topic of theoretical discussion.

Inherent Redundancy: Biological systems often have redundancy and error-checking mechanisms. Exploiting these mechanisms in DNA-based encryption could potentially enhance the robustness and reliability of encoded data.

New Paradigms: DNA-based encryption challenges traditional cryptographic paradigms and may inspire entirely new approaches to securing information, especially in the context of bioinformatics and biotechnology.

CONCLUSION

In conclusion, the exploration of secure communication via DNA encoding presents an intriguing avenue for addressing the evolving challenges in traditional cryptographic methods. The unique properties of DNA, such as its vast information storage capacity and potential for biometric authentication, offer a promising alternative for ensuring the confidentiality and integrity of sensitive information.

The proposed technique of encoding is far better than the conventional cryptography like DES and DNA based encryption algorithms. The large key size, randomly selected sequence, D-Box, extra coding and modified DNA sequence coding makes the cipher text more secure against an intruder's attack. Intruders will face more difficulty decrypting the cipher text and get the information about the plaintext. The proposed method of DNA based encryption is applicable to text, audio, video rather than almost all type of file. The encryption algorithm proposed here is based on a modified concept of DNA based cryptography methods. The algorithm proposed in this paper is more secure and reliable. It will be able to provide stronger protection against the various intruder's attacks like ciphertext only, chosen ciphertext etc. In this proposed algorithm both confusion and diffusionare embedded while making the cipher text.

The biochemical operations involved in DNA encoding, including synthesis and sequencing, though time-consuming and costly, showcase the potential for a highly secure communication paradigm. The integration of individual DNA sequences for biometric authentication adds an extra layer of personalized security, making it inherently tied to an individual's identity.

However, several challenges, such as the practicality of real-time communication, associated costs, and potential error rates, need to be carefully addressed in the development and implementation of DNA-based communication systems. Ethical considerations surrounding the use of DNA data, especially in the context of individual identification, emphasize the importance of responsible and secure practices.

As research and development in this field progress, the potential benefits of DNA encoding for secure communication cannot be overlooked. While it may not replace traditional cryptographic methods entirely, DNA-based communication has the potential to complement existing approaches, offering enhanced security and paving the way for innovative solutions in the evolving landscape of information protection. Further studies, experiments, and advancements are crucial to realizing the full potential of DNA encoding in secure communication and addressing the challenges associated with its practical implementation.

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