

## DNA Based Cryptography: A Review

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### ABSTRACT

DNA cryptography is a novel field being taken up for research by the researcher community in order to have secure communication on a network. This technique is inspired from biological science, in which DNA is used as an information carrier from one generation to another. DNA cryptography is proposed for a secure end to end communication due to the vast parallelism and extra ordinary information density that are inherent in any DNA molecule. In this paper various trends in DNA cryptographic approaches are surveyed and analyzed, highlighting the merits and demerits of each.

**Keywords** — Security, DNA, DNA computing, DNA cryptography.

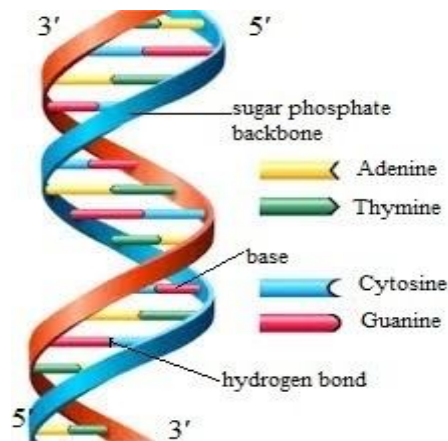
### 1. INTRODUCTION

With the growing pace of Internet and network technology day by day, the security threats are also increasing for the users, due to lot of information flow on the network. There are various adversaries who always try to break into the system in order to steal the crucial information or to destroy the integrity of data. So information security becomes necessity for modern computing systems. There are some sectors like government, banks, military who can't afford any leaks to their secret data. From our past to till date the secret writing techniques are used to protect the data from the adversaries and the techniques such as cryptography and steganography are most common and widely used methods. Cryptography performs the encryption of the data whereas steganography hides the data from the hacker. In cryptography the encryption and decryption of data /plaintext is done with the help of key. The most secure and presently used technique is the modern methods of cryptography which involves much mathematical computations and two types of keys, the public and private keys. Nowadays, there is another newly emerging cryptographic technique in the field of cryptography called DNA cryptography. The main objective of this method is to encrypt the plaintext and hide it in the DNA digital form. DNA cryptography enables the confidentiality of data more high then the modern methods with the use of one-

time pad (OTP) keys and its size. Also it is believed that in DNA cryptography the key can be generated for the huge length of data compared to the modern methods in which key are generated only for smaller length of the data. Also with the breaking up of modern cryptographic algorithm like DES and MD5 the new methods of information security are needed to protect our data [13]. The concept of DNA computing plays an important role in the field of computer security which is assumed to be a more powerful and unbreakable cryptographic algorithm now a days.

## 2. DNA

DNA stands for Deoxyribonucleic acid which store genetic information of the entire living organism ranging from human being to small viruses. It is also called as an information carrier and consists of long polymer of small units called nucleotides. Further nucleotides consist of three components: Nitrogenous base, five Carbon sugar and Phosphate group. Nitrogenous base consists of four bases: Adenine, Thymine, Cytosine and Guanine (A, T, C, G), all the complex information about organism are stored with the combination of these bases. Adenine and Guanine are called purines, whereas Thymine and Cytosine are called pyrimidines. DNA is a double helix structure as shown in the Figure below.



**Figure 1.** Double helical structure of DNA

DNA double helical structure was discovered by the two Nobel laureate Watson and Crick and therefore it is also called a Watson-Crick complementary structure, where A and T form hydrogen bond with each other, whereas C and G forms bond with one another. In this structure of DNA both the strands are antiparallel to each other, means if one strand starts from 3' to 5', then another strand is from 5' to 3'.

## 3. DNA COMPUTING (RELATED WORK)

In 1994, Adleman [1] laid the foundation of DNA computing by giving solutions to the combinatorial problems using molecular computation, one of which is

“Hamiltonian path” problem. He solved the instance of graph containing seven vertices by encoding it into the molecular form by using an algorithm and then computational operations were performed with the help of some standard enzymes. This was solved by brute force method. In 1995, Lipton [2] extended the work of Adleman by solving another NP-complete problem called “satisfaction” by using DNA molecules in a test tube to encode the graph for 2 bit numbers. In 1996, Dan Boneh et al. [3] applied the approaches of DNA computing used by Adleman and Lipton, in order to break one of the symmetric key algorithm used for cryptographic purposes known as DES (Data Encryption Standard). They performed biological operations on the DNA strands in a test tube, such as extraction, polymerization via DNA polymerase, amplification via PCR and perform operations on the DNA strands which have the encoding of binary strings. Then DES attack is planned by generating the  $DES^{-1}$  solution, due to which key can be easily guessed from the ciphertext and further evaluate the DES circuit, lookup table and XOR gates. By using their molecular approach they broke DES in merely 4 months. In 1997, Qi Ouyang et al. [4] applied the approaches of DNA molecular theory in order to generate the solution for maximal clique problem, which is another NP-complete problem. Thus shows the efficiency of DNA: to solve Hard-problems and vast parallelism inherent in it which makes the operations fast.

#### **4. DNA CRYPTOGRAPHY (RELATED WORK)**

In 2003, Jie Chen [5] presented the DNA cryptographic approach based upon molecular theory, one-time pad and performed encryption/decryption of 2-dimensional image. In 2004, Ashish Gehani et al. [6] laid the foundation of DNA cryptography by using molecular approach and the concept of one-time pad- which has perfect secrecy, according to Vernam’s and Shannon: inventor of one-time pad. They have proposed a method of encryption and decryption which is based on DNA chip and one-time pad. So it is very hard for the adversary to guess the encrypted message. In 2005, Kazuo Tanaka et al. [7] proposed the DNA cryptographic approach based on Public Key (one way). In this approach they have clearly explained about the formation of public keys by using solid supports mixture for  $PK_A$  and ODN mixture for  $PK_B$ . After generating the keys, message is encoded in a DNA sequence with the help of one of the public key, which is further synthesized with the DNA synthesizer and then the encoded message sequence is ligated with the another public key. Now the outcome of the previous process is forwarded to the immobilization process and then for PCR amplification, where the amplification is done with the help of secret sequence, in order to decode the encoded DNA sequence. In 2006, Sherif T. Amin et al. [8] proposed the DNA cryptographic approach based on symmetric key, where key sequences are obtained from the genetic database and remain same at both ends (sender and receiver).

In 2008, Anil Verma et al. [9] proposed a novel paradigm for secure routing in Mobile Adhoc Networks (MANETs) that uses Pseudo DNA cryptography approach in order to secure the Adhoc networks. Adhoc network is a wireless network which has no fixed infrastructure and where each node act as a host and router and there is no

centralized authority which makes them vulnerable to the security attacks present in the networks. Pseudo DNA cryptography approach they have used is based on the central dogma of molecular biology. Concept of how messages are stored in DNA and then transfer to the mRNA (transcription), and then to the proteins (translation) which is our ciphertext. Ciphertext is send through the secure channel to the intended receiver and symmetric key with one-time pad is used at both the ends (encryption and decryption). In 2008, Guangzhao Cui et al. [10] proposed the public key encryption technique that uses DNA synthesis, DNA digital coding and PCR amplification to provide the security safeguard during the communication. This encryption scheme has high confidential strength. In 2010, Lai Xuejia et al. [11] proposed a DNA public key cryptosystem which is based on DNA microarray/chip technology in which DNA chip is fabricated with probes. One set of probes are used for encryption process and another set for decryption process. In 2011, Deepak Kumar and Shailendra Singh [12] proposed a new secret data writing techniques based on DNA sequences. They have explained this algorithm by using a simple example of "HELLO" as a plaintext and generate a ssDNA one-time pad key of 350 bits which is 70 times longer than the plaintext and perform encryption and decryption on the plaintext using symmetric key cryptography. So to find the exact key, adversary has to search among  $4^{310}$  different ssDNA string which is impossible for the adversary. In 2012, Sabari Pramanik and Sanjit Kumar Setua [13] proposed a new parallel DNA cryptography technique using DNA molecular structure and hybridization technique which certainly minimize the time requirement. They have explained how message is exchanging safely between sender and receiver with an example. In 2012, Yunpeng Zhang et al. [14] proposed a DNA cryptography based on DNA fragment assembly. In their algorithm they have clearly mentioned how sender converts the plaintext into binary sequence and then into long chain of DNA, which is further fragmented into small DNA chains. Key of short chain implantation takes place in the fragments and forward to the receiver as a ciphertext and then receiver deciphers it and starts fragment reassembly to obtain the plaintext. In 2013, Olga Tornea and Monica E. Borda [15] proposed a DNA based cipher which is based on DNA indexing. They take the random DNA sequence from the genetic database and use as a one-time pad key, which is send to the receiver by a secure communication channel. The encryption mechanisms takes place by converting the plaintext into its ASCII code and then convert it into the binary format which is converted into the DNA sequence (A, C, G, and T). Now DNA sequence formed is search in the key sequence and writes down the index numbers. The array of integer numbers obtained are our ciphertext which is decrypted by the receiver only using the key and index pointer.

**Table 1.** DNA Cryptography (Related Work in Chronicle Order)

Year	Algorithm Title	Cryptographic Approach	Technology Used
2003	A DNA-based, Bimolecular Cryptography Design [5].	Symmetric key	Molecular, one-time pad.
2004	DNA-Based Cryptography [6].	Symmetric key	Molecular, DNA chip, one-time pad.
2005	Public-key system using DNA [7].	Asymmetric key	Molecular, DNA synthesis, PCR amplification.
2006	YAEA DNA Encryption [8].	Symmetric key	Substitution, one-time pad.
2008	DNA Cryptography: secure routing in MANETs [9].	Symmetric key	Central dogma of molecular biology, one-time pad.
2008	Encryption Scheme Using DNA [10].	Asymmetric key	DNA synthesis, DNA digital coding, PCR amplification.
2010	Asymmetric Encryption and Signature with DNA [11].	Asymmetric key	DNA chip technology, Hybridization.
2011	Secret Data Writing Using DNA Sequences [12].	Symmetric key	one-time pad.
2012	DNA Cryptography [13].	Symmetric key	Hybridization, one-time pad.
2012	DNA Cryptography Based on Fragment Assembly [14].	Symmetric key	DNA Fragment assembly.
2013	Security and Complexity of DNA Based Cipher [15].	Symmetric key	DNA Indexing, one-time pad,

## 5. CONCLUSION

DNA cryptography based on DNA hybridization, DNA synthesis, DNA microarray/chip technology, Central dogma, PCR amplification and one-time pad makes it unique from the traditional cryptographic techniques which are unbreakable by the adversaries, due to molecular computation inherent in it. Further with the addition of one-time pad in DNA symmetric key cryptography makes it more strong and secure and protect from brute force attacks. It also offers high confidential strength and large storage density inherent in it, as compare to the traditional storage devices. With the invention of energy efficient DNA computer chip by IBM, opens up the way for the bright inventions by the researchers now days in the field of computing, information security. Though DNA has many positive aspects in different fields which fascinate the researchers, some of the aspects like requirement of bio molecular labs, environment impact, and quantum attacks still an issue for its smooth progress.

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