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REVIEW OF DNA AND PSEUDO DNA CRYPTOGRAPHY

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ABSTRACT

The broad development of technology recently, has led to an increase in the ability of attackers and a major challenge to information security, which necessitates the use of untraditional principles and unconventional means, such as focusing on new aspects to achieve security like Biology, DNA and Quantum. This paper covers the various DNA and pseudo DNA techniques that used for cryptography algorithms.

KEYWORDS: Cryptography, DNA, Pseudo DNA, DNA Computing Central Dogma

INTRODUCTION

Cryptography, which is considered a science and an art has been and is still undoubtedly the most efficient means used to attain secrecy. All security concepts can be achieved via cryptographic algorithms, including confidentiality, integrity and authentication, besides other concerns such as availability, privacy and access control. Since 2000 B.C., cryptography has been documented as a tool used by the Egyptian scrivener when he made unusual hieroglyphs in his engraving [44]. It has since continued to be used from that early era to the present day with different and varied applications in all aspects of life and in both peace and war time. The extensive growth and expansion of using computers in all aspects of life, especially in communications has led to the emergence of various new forms of cryptography, the wide and daily increase in the use of wireless network low-end equipment such as wireless sensor nodes, and RFID cards which would be considered useless if they were not secured as it would duplicate the attention and effort needed to deal with the works that are focused on cryptography since this security technique is the standard approach used to achieve security for wireless network equipment. The rise in frequency of attacks against the modern cryptography algorithms has not been matched by the level of development in the capabilities of these algorithms to withstand these challenges and make them secure and immune to all risks. The extensive expansion of technology, has led to an increase in the skill and strength of the attackers and a vital challenge to information security, which necessitates the use of untraditional principles and unconventional means, such as focusing on new aspects to perform security like Biology, DNA and Quantum .This paper is focusing on biological DNA techniques.

Since the establishment of DNA computing by Adleman in 1944 with his work [1], many other studies have been done on DNA cryptography. From these many studies, a number have become more familiar with the application of techniques, attributes and characteristics of the DNA system in the design and development of security algorithms or model applications [5, 16, 40, 41, 48]. The literature suggests that there should be further work done to investigate and better understand the involvement of the DNA system in its application to the block ciphers. Despite the many features, properties and attributes which characterize biological DNA.

DNA Background

DNA (Deoxyribo Nucleic Acid). DNA considers as the genetic drawing of living or existing creatures. All individual body cells have a complete set of DNA, which is exceptional for every being. It is a polymer made out monomers named deoxyribo nucleotides. This nucleotide is comprised of three fundamental components as shown in Figure 1.

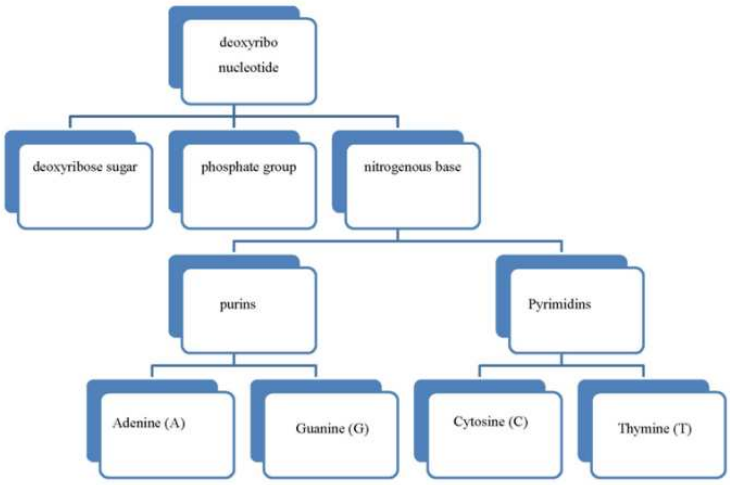

Figure 1: The Structure of Deoxyribo Nucleic DNA

A DNA‘s single-stranded is composed of a sequence of molecules named bases, which stick out from a sugar-phosphate backbone, the bases are defined as four characters {A, C, G, and T} [52]. One of the most basic features of the DNA’ strand sequence is that it’s oriented; accordingly, TTCA is distinct from ACTT.

As shown in Figure 2. and Figure 3. Typically the DNA strands exist as paired, reverse complementary words or strands: The Watson-Crick Double helix, with its four letters, A, C, G and T paired via A^{-} = T and C^{-}= G. Corresponding DNA codes could involve the insertion-deletion metric — with bounded similarity between two strands: The length of the longest sub word common either to the strands or common to one strand and the reverse complements of the other [9].

Figure 2: DNA Sequence Bases

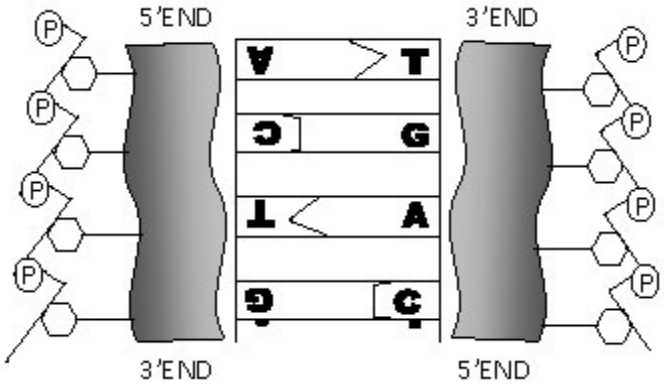

Figure 3: The Structure of DNA Strands and Bases the Watson-Crick Double Helix as Reverse-Complement

Central Dogma

One of the most important methods for biological molecules is central dogma, which includes some processes of DNA and RNA (Ribonucleic acid), such as replication, transcription, and translation, as shown in Figure 4. In which the genes' information glides into proteins [14].

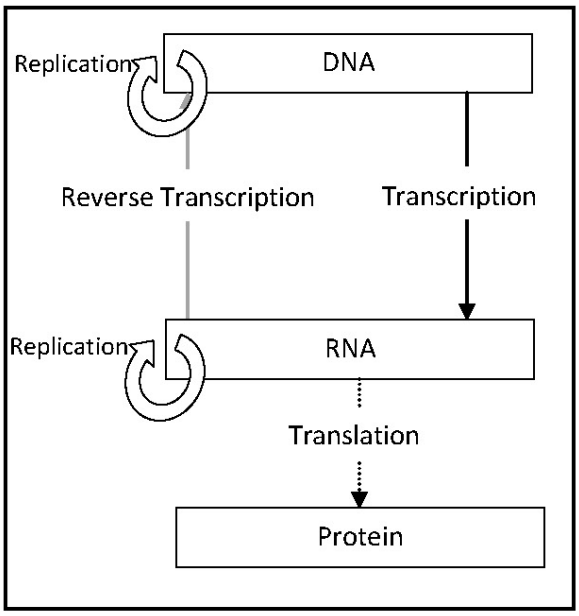

Figure 4: The Processes of DNA Central Dogma

DNA replication and transcription occurs from the 3' end to the 5' end, and the 3' end of one strand is opposite to the 5' end of the complementary strand above. Hence, if it should get the complements, then it should read the second strand in the opposite direction. Figure 5. Describes in detail the central dogma for the DNA segment that forms the genes. The segment consists of three main parts.

- Promoter (starting point)
- Non-coding parts (introns).
- Coding parts (exons).

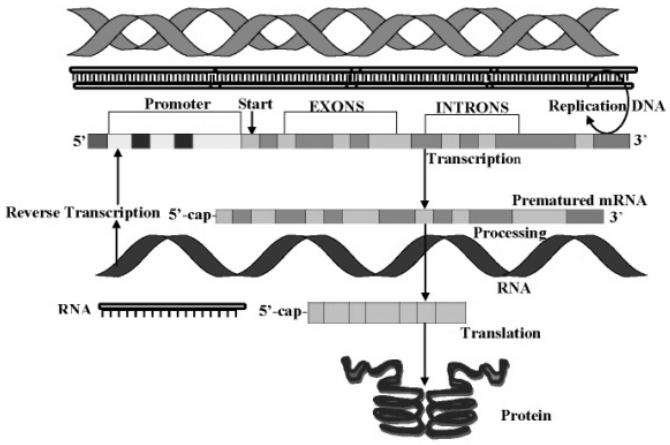

Figure 5: Complete Central Dogma Process

Referring to Figure 5. it can be seen that there are two processes within the central dogma:

- Transcription and slice are performed in four stages:

  First: A DNA segment that forms a gene is read, initiated by the promoter (beginning) of the DNA segment.

  Second: Remove the non-coding parts (introns) depending on the determined tags.

  Third: The coding parts (extrons) are reunited then capped.

  Fourth: Then the resulting chain sequence is transcribed into a single-stranded chain of RNA by creating the message RNA mRNA; mRNA turns from the nucleus into the cytoplasm.

- Translation: Convert the RNA as mRNA into Proteins.

DNA Computing

DNA (Deoxyribonucleic acid) computing has the great ability to solve a class of insurmountable computational problems in which the computing time can rise exponentially with problem size the `NP-complete' or non-deterministic polynomial time complete problems.

Consistent with the wonderful properties of biological system, where it became an ideal area can be hired or draw inspiration from it such as the DNA processes. Recently, a lot of researchers made significant contributions in this space, where DNA and immune system were the most interested issues. In1994 Adleman revealed the ability to use DNA biological molecules in solving the NP problem, that work which is starting what is called DNA computing by solving a small-scale case of the directed Hamiltonian path problem [1]. The success of his work opened the door wide for researchers and baits immense deal of attention. In 1995, Lipton uses the DNA computing to solve a new NP-complete problem which known as satisfaction problem (SAT), the impressive characters of DNA such as vast parallelism, computing and storage abilities beside the using of DNA computing in solving the problems [30].

The Natural DNA Properties

The DNA has several proprieties which lead to its emergence in computers and encryption as below:

- The vast parallelism.
- Exceptional energy efficiency.
- Extraordinary information density inherent in DNA molecular is being explored for computing, data storage and cryptography. A single gram of DNA can be used to store 10^8 Tera-bytes, which exceeds the storage capacity of any known storage medium [8, 13].
- Infinite and rule less DNA sequence could be regarded as a randomized database [15].
- There is almost no difference between a real DNA sequence and a faked one.
- There are a large number of DNA sequences publicly available to be around 55 million [21].
- These features make biology, DNA system one of the most important resources for computing due to the high degree of similarity to the binary system, but with more elements than 0 and 1.

Limitation of DNA Cryptography

- Actual implementations do not exceed the laboratory level in terms of time and cost.
- Constrains high tech lab requirements
- Researchers in DNA cryptography still looking more at theoretical aspects than the practical.
- Biological errors like mutation and difficulty of implementation of real DNA system. [47]

DNA and Cryptography

The breadth of the need for information security push towards the using of DNA for the information security and the emergence of the so-called DNA cryptography [18, 55]. The DNA cryptography is a novel and a very talented route in cryptography research, where is the fast expansion of DNA computing, DNA cryptography has penetrated into the field of cryptography. It is a novel field depends on the researches in DNA computation and new technologies like: PCR (Polymerase Chain Reaction), Microarray, Central dogma [46]. DNA could be employed in cryptography for a number of usages like computing and computation storing, in addition to transmitting the information. Its includes encoding the information by using the techniques of DNA computing in which scientists can amalgam, augment, separate, assimilate and chain DNA strands extremely without difficulty, according to this many works have been done. Boneh et al. used DNA computing methods to crack or break the Data Encryption Standard (DES) [29]. A few years before the 21 century start, Gehani et al, deliberate DNA-based cryptography and proposed DNA One-Time Pad in as well as hiding information in DNA strands as a steganography [18].

Pseudo DNA Cryptography

The utilizing of the DNA as a way of cryptography requires a very high lab specifications; this led the researchers not to use the real DNA to carry out the cryptographic process; but rather use methods to simulate and inspired some real DNA significant processes. In spite the large amount of researches which accomplished in the area of DNA cryptography, the employ of the DNA as a way of cryptography is remains in the preliminary phase since; there are many problems and challenges. A number of reasons have been caused these challenges; one of the most important reasons lies in the requirements for high tech lab in addition to the work serious induction means, so these led to the skillful employ of DNA cryptography not easy in the world of security at the current time. Consequently, an extra hypothetical examination should be carried out previous to its true use.

However, these challenges led the researchers to find an alternate process in utilizing the DNA cryptography and that has been represented by using the digital DNA cryptography or what is called the pseudo DNA cryptography. This kind of cryptography makes use or inspired the techniques from real DNA processes.

Despite the presence of a large amount of works and researches carried out by DNA security the focus will be only on review of works present encryption algorithms (ciphers) inspired or based on DNA techniques are depending on this principle in order to use these works for the security of the digital computers rather than DNA computers which are still in its primitive phase.

DNA Binary Coding

As the DNA strand has four bases which they are (A, C, G, and T) so:

F(X): X → Y, where X = {A, C, G, T} and Y = {00, 01, 10, 11}. This can be express as in Table 1.

Table 1: DNA Binary Coding

DNA base	*Binary code*
A	00
C	01
G	10
T	11

All the logical operation can be performed over the DNA bases as XOR, AND, OR, and NOT, (XOR operation in Table 2), also the coding for each base could be changed also, as A ⇔ 01, C ⇔ 00, G⇔ 11 and T ⇔ 11, this coding in addition to the randomness properties give the DNA a good chance to be used for both computing and cryptography.

Table 2: XOR Operation for DNA Bases

XOR	A	C	G	T
A	A	C	G	T
C	C	A	T	G
G	G	T	A	C
T	T	G	C	A

WORKS ON DNA CRYPTOGRAPHY

A lot of work has been completed within this context, many of these searchers focused on designing DNA cryptography systems based on real life DNA operations or inspired from DNA structures and coding. Sherif T. Amin, et al. have been proposed a virtual DNA cryptographic method by not utilize the genuine biological DNA strands, but only by employing the principle initiatives of the central dogma of molecular biology[5]. Kang Ning has been launched a new cryptographic technique depend on the central dogma of molecular biology by simulates a number of significant procedures of central dogma [36]. Cui, Guangzhao, et al. employing DNA technology to propose an encryption algorithm exploratory process [16]. X. Geng, L. Pan, and J. Xu designed the DNA Symmetric Cryptosystem (DNASC), the DNA crossbreeding is employed for key generation and decryption processes. The encryption and decryption process for this algorithm is a biological exploratory process rather than a mathematical computation [19]. Z. Yunpeng, et al. have been proposed a symmetric-key cryptosystem by using both DNA symmetric cryptosystem with adding index [50].

S. Sadeg, et al. proposed a new symmetric encryption algorithm inspired from DNA by simulating ideas from transcription method (get mRNA from DNA), in this work, the researchers tried to combine DNA computing with an existing encryption algorithm which is Rijndeal to create a new encryption algorithm as in the work of X. Wang, et al. where they process the plaintext by mapping its contents into DNA coding, then encrypted it through a Rijndeal algorithm after handling it with genetic DNA biotechnology [40, 48]. D. Prabhu and M. Adimoolam proposed a new encryption algorithm called Bi-serial DNA encryption algorithm, including the traditional cryptography, an XOR operation in addition to DNA digital coding and technologies of DNA synthesis, PCR amplification [37]. U. N. Hussain, et al. proposed a high-speed secured hybrid algorithm through the utilizing of both DES (Data Encryption Standard) and biological connotation CDMB (Central Dogma of Molecular biology) [24]. S. Chavan designed a DNA cryptography scheme utilizing a mixture of hybridization of DNA oligonucleotides and the generic binary one time pad procedure [12]. O. Bonham-Carter, et al. proposed a model named as sEncrypt (sequence Encrypt),inspired by biology central dogma, through employing a publicly-available sequence data from Bioinformatics research, in order to encode, encrypt, decrypt and decode message

[10]. M. Sabry, M. Hashem, and T. Nazmy, introduced three methods of encoding inspired by real DNA/ RNA structure and it's relative to the amino acids within the standard genetic code table. They described three processes for changing the data in amino acid form from binary form after converting it to DNA form first, and verify the correctness of the reverse of these steps [39].

In addition to this, many other researchers have been adopted the design of new cryptographic techniques that are inspired by real DNA, some of these work specialized in the creation of specific components for the encryption algorithms as a permutation or substitution transformations. A. H. Al-Wattar, et al. designed a new DNA-based ShiftRows, MixColumns Transformations and DNA-based S-Box [2-4]. Furthermore, as mentioned above; there are groups of researchers who designed algorithms inspired by the real DNA for the purpose of achieving specific targets in the field of encryption. One of these groups has paid attention to providing security for networks, for example, S. V. Kartalopoulos proposed a new modern optical communication networks, identified as Wavelength Division Multiplexing (WDM) connection security method that make use of confident notions of the double DNA helix which known as DNA-inspired [28]. In the same general direction Singh at, el. designed a DNA algorithm for mobile network security by proposing a method to guarantee and provide an extremely protected and safe domain for information transmission over the portable networks [43]. Harry C. Shaw and Sayed Hussein designed a novel encryption process inspired by DNA in order to contribute the security of mobile, ad-hoc networks without the need of using the public key [41].

Another group of works, specialized in designing DNA based algorithms which provide security for images and videos. Zhou, S, et al. summarized a significant survey about DNA image encryption and the most important algorithms of image encryption and categorized those algorithms according to their mechanisms and means [60]. Anyhow, it can be listed a number of research that was completed within this group as follows, in 2009 Zhang, Qiang, et al. designed a novel image encryption algorithm using the addition of DNA sequence [55], Zhang, Qiang, Ling Guo and Xiaopeng Wei made a new scheme by combining this algorithm with chaotic map [53]. Zhou, et al. designed an encryption system inspired by DNA used for the encryption of the big images [59]. Zhou, X. Wei, Q. Zhang and R. Liu, present a combined image encryption system which comprises of the logistic chaotic map and the formal model of DNA computing-splicing system [58]. By continuing listing the DNA image encryptions researches and with regards to the researches of image encryption, a number of researches could be mentioned here, Shima Ramesh Maniyath and Supriya have been proposed an image/video encryption algorithm to reduce the encryption time, relying on DNA sequences [35].L. Liu, et al. designed, an original algorithm for image encryption depending on the chaotic modulation of Arnold dual scrambling combining in addition to DNA computing [33]. In addition to this there were many researches that are dealing with image encryption based on or, inspired from DNA have been done as in [6, 22, 31, 32, 38, 42, 45, 49, 57]. Recently a lot of DNA image encryption work has been accomplished [7, 11, 17, 20, 23, 25-27, 34, 51, 54, 56] same as previous, these works depends on some different real DNA techniques to achieve an image cryptographic system.

CONCLUSIONS

The rise of DNA computing opens the door wide for DNA using within computer applications. The biology, DNA system with its properties can be considered as a good factor in computer security, especially in cryptography. It's used as inspiration for many encryption systems for many purposes, including network security, image encryption, hiding information as well as design specific components of encryption algorithms as permutation and substitution units. Pseudo DNA cryptography is used to overcome the limits of using the real DNA cryptography.

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