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IMPLEMENTATION OF ENCRYPTION USING XOR AND MUX IN QCA TECHNOLOGY

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Abstract:
The QCA system employs sophisticated coding technology to attain reduced cell size, minimized power consumption, and enhanced device density with the purpose of establishing an integrated coding system. The text is partitioned into four segments and subsequently encrypted using four distinct keys through the utilization of a multiplexer (MUX). The resultant outcome is a solitary output. Through a comparative analysis, this study examines the current research in relation to earlier studies that utilized an equivalent number of data entries. The tool is utilized for the purpose of simulating cellular automation through the application of a quantitative methodology.

Keywords: MUX ,QCA , Encryption, Comparative analysis

INTRODUCTION

The Quality Control Analysis (QCA) is a widely recognized methodology [1], [2] that serves as a viable alternative to Complementary Metal-Oxide-Semiconductor (CMOS) technology. Conventional CMOS technology encounters certain constraints when attempting to scale down to the Nano-level [3]. Consequently, nanoscale molecular devices exhibit enhanced velocity. Multiple studies have indicated that QCA (Quantum-dot Cellular Automata) has the potential to enhance the switching speeds and reduce power consumption in many systems [4]. The cell serves as a fundamental unit for constructing QCA (Quantum-dot Cellular Automata) logical circuits. Nanometers correspond to the dimensions of a typical cell. The majority gates and inverters serve as the core components of Quantum-dot Cellular Automata (QCA). Various designs and procedures for the implementation of new gates and circuits have been proposed by researchers. Each of these approaches possesses distinct characteristics, advantages, and limitations. The XOR operation is commonly employed by the Majority algorithm. However, in the context of this search, the XOR operation between the text and the key is contingent upon the concept of Polarization.

The multiplexer (mux) is a valuable component within digital circuits. The utilization of an electronic multiplexer obviates the need for individual devices dedicated to each input signal, so enabling numerous signals to be efficiently shared among a singular resource or device, such as an analog-to-digital converter. Multiplexing has been employed in a range of applications, including wideband digital communication [5], on-chip networks [6], multistage interconnection networks [7], cellular networks [8], information security [9], and various other domains. Furthermore, multiplexers have conventionally been utilized as bus controllers and arithmetic logic units (ALU). The most basic form of a multiplexer is a 2:1 multiplexer, wherein the choose line determines which of the two inputs is transmitted to the output. Figure 1 depicts a multiplexer and its corresponding logical circuit. The output is determined by the input line In0 when the select line (Sel = 0) is zero, and by the input line In1 when the choose line (Sel = 1) is one. Furthermore, it is plausible to consider the adoption of a more sophisticated iteration of this study for the purpose of the selection procedure. The equation representing this behavior is denoted as Equation 1. The QCA Designer, a simulation and design tool for Quantum-dot Cellular Automata (QCA), has been developed by the University of Calgary [10].

$$Out = In0.\overline{Sel} + In1.Sel \quad (1)$$

The subsequent sections of this paper are organized in the following manner: The presentation of QCA and its components is provided. In Section 1, following the introductory section. Section 2 of the paper discusses the multiplexer design proposed by many scholars. The subsequent section of this paper provides an exposition on the suggested design of the multiplexer, followed by an analysis of the simulation results. In the fourth section, a comprehensive discussion and comparison of all the obtained results are presented in relation to past studies.

The paper culminates with the presentation of conclusions. To format a specific paragraph, simply position the cursor within the desired paragraph and proceed to select the appropriate style from the styles window or ribbon.

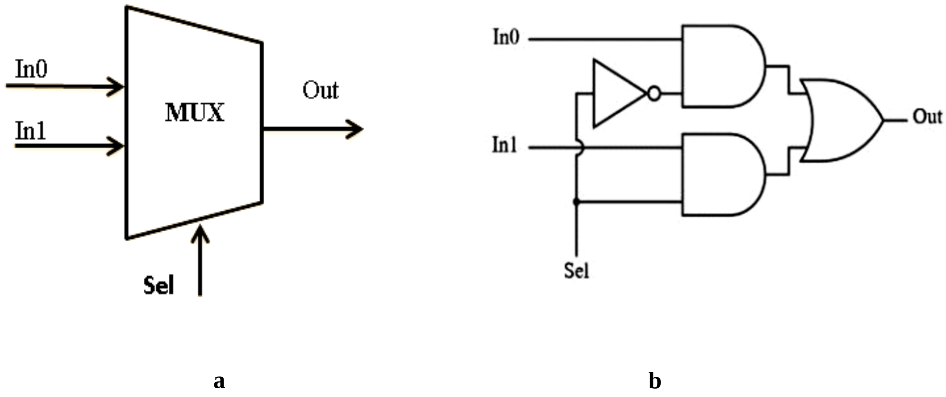


Fig. 1. Block diagram at 2:1 mux and Logic Circuit

1.1 QCA overview (Basic QCA Components)

This section provides a comprehensive analysis of the Quantum-dot Cellular Automaton (QCA) from multiple perspectives. The aforementioned elements encompass wire crossing, clocking in QCA, and the core components of QCA.

Cells serve as the essential constituents of Quantum-dot Cellular Automata (QCA) circuits. The cellular structure contains a total of four quantum dots. Four quantum dots are positioned at the vertices of a square, as depicted in Figure 2. Through the process of tunneling, electrons have the ability to occupy the confined regions known as quantum dots. There exists a potential arrangement of two electrons within four quantum dots that can be achieved in six distinct configurations. However, it is noteworthy that only two of these configurations, characterized by diagonal occupation of the quantum dots by the electrons, are deemed stable. This stability arises from the repulsive forces resulting from the Coulomb interaction between the electrons. This phenomenon leads individuals to be drawn towards a point where the magnitude of their spatial separation is maximized. The polarity is determined by counting the holes in a counterclockwise direction, as per Equation 2. If an electron is present in hole number I within this equation, the value of Pi is assigned as 1. Otherwise, Pi is assigned as 0. The variable P can take on values ranging from -1 to +1, or logical values of 0 and 1, respectively [11].

$$P = \frac{(P1+P3)-(P2+P4)}{P1+P2+P3+P4} \qquad (2)$$

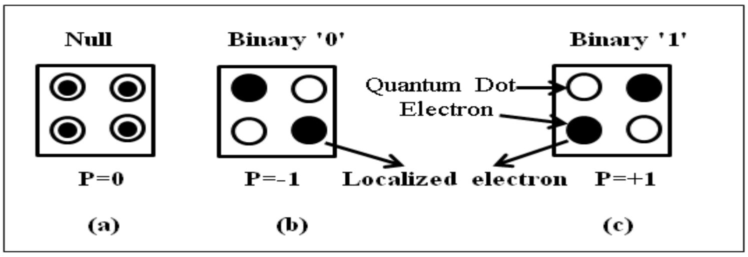
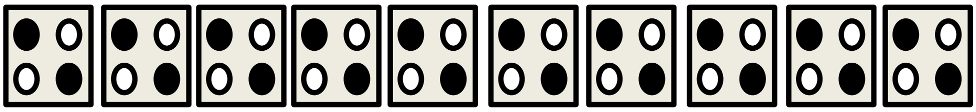
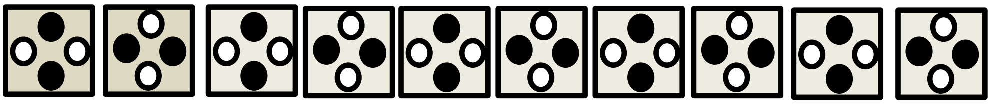


Fig.2. (a) Null (b) -1 Polarity (Logical 0) (c)+1 Polarity (Logical 1)

Electrons exhibit a non-linear flow pattern when they traverse through the pores within a cell. The average distance between holes is 20 nm. Every individual cell exerts an influence on its adjacent cells, in addition to the repulsive force resulting from the Coulomb interaction within the cell. The presence of an intermediate state between adjacent cells mitigates the Coulombic repulsion. Quantum-dot grid configurations demonstrate characteristics that are conducive to computational processes. The arrangement of quantum-dot cells in a sequence, positioned adjacent to each other, is employed to construct a quantum-dot cellular automata (QCA) wire, representing the simplest and most feasible configuration of cells. In the context of Qualitative Comparative Analysis (QCA), the analysis incorporates two distinct wire kinds. Figure 3a depicts a traditional binary wire alongside an inverter chain. The inverter chain is formed by aligning QCA cells at a 45-degree angle, as seen in Figure 3b [12].



Binary Wire(A)



Inverter Chain(B)

Fig.3. Binary Wire (A) Inverter Chain (B)

The fundamental gates in Quantum-dot Cellular Automata (QCA) are the inverter gates (also known as NOT gates) and majority gates [13]. Figure 4a depicts majority gates, while Figure 4b illustrates inverter gates. The representation of the logical action of majority gates is denoted by Equation 3.

$$f(A,B,C) = \mathrm{AB} + AC + BC \quad (3)$$

The output variable is denoted as F, whereas the input variables are represented by A, B, and C. A majority gate functions similarly to an OR gate when one of its inputs is designed to be logical. In this study, we aim to investigate the effects of a particular drug on the growth of The majority gate operates similarly to an AND gate when one of its inputs is held constant at a logical value. The user's text is already academic and does not require any rewriting. Table 1 presents the truth table for the majority gate, which provides evidence for the claim [14].

Table 1. Majorty gate truth table

A	B	C	F	Proof
0	0	0	0	A=0 F=BC
0	0	1	0	
0	1	0	0	
0	1	1	1	
1	0	0	0	A=1 F=B+C
1	0	1	1	
1	1	0	1	
1	1	1	1	

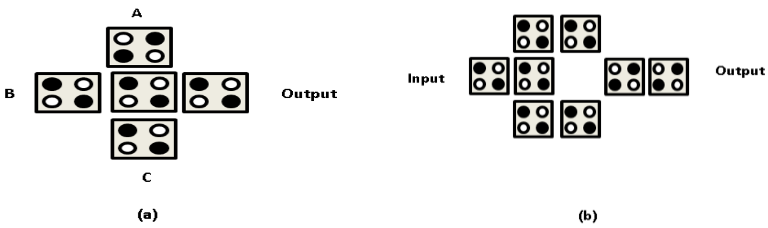


Fig.4. (a) Majority Gate, (b) Inverter Gate

1.2 Wire Crossing

There are two methods available for the purpose of crossing two wires. The in-plane approach is achieved by crossing a wire and an inverter chain. In this particular approach, the transmission signals do not have any influence on each other, even when they are situated within the same plane. The second approach involves arranging each cable in a separate plane. The utilization of intermediary cells is essential for the purpose of facilitating the transportation of a wire to an alternative plane. Figure 5 illustrates two different methods for wiring a crossing. The schematic diagrams illustrating the process of crossing two wires are presented in Figure 5, where the cells are depicted as being traversed by the wires. The presence of crossing cells is denoted by the use of X marks and circles within a square.

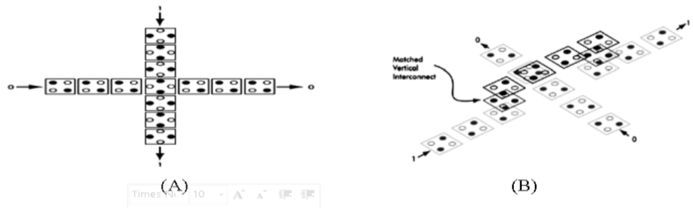


Fig .5. Wires crossing. (A) Crossing in-flight. (B) Cross-Layer Protocol.

1.3 QCA Clocking

QCA clocks inside a system serve the dual purpose of providing electricity for automation and controlling the direction of data transmission. The clock restores signal energy that has dissipated into the surrounding environment. The clock design depicted in Figure 6.a encompasses four distinct stages, namely Switch, Hold, Release, and Relax. During the switch phase, the inter-dot barrier undergoes a steady increase, leading to the establishment of clear polarity in the cell with the assistance of neighboring cells. During the hold phase, barriers exhibit significant strength as they actively maintain cellular polarity and function as input for adjacent cells. During the release phase, barriers are reduced and the cell undergoes depolarization, resulting in a loss of polarity. During the relaxation phase, the cell exhibits a state of non-polarity, allowing electrons to move freely inside the system. The QCA circuit is split into portions known as clocking zones, as depicted in Fig. 6.b. All cells within a specific zone are regulated by an identical clock signal, which coordinates their activities in performing the same computational task. A subarray refers to a collection of cells that are located inside the same temporal zone. The influence of neighboring stable cells in the hold state on the subarray is observed during its operation in the switch state [15].

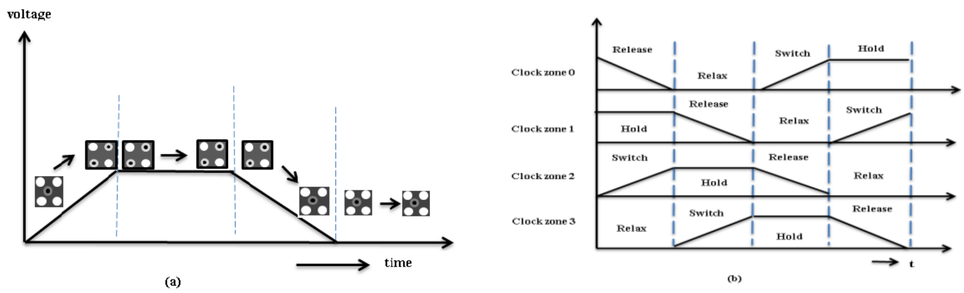


Fig.6. (a) QCA uses four clock phases (b) Signal clock

1.4 The Exclusive-OR(XOR) Gate

When the number of high inputs is odd, the XOR gate, a logic circuit, outputs high. Eq. 4 is an illustration of the XOR Boolean equation.

$$\mathrm{XOR}_{A,B} = A.\bar{B} + \bar{A}.B \qquad (4)$$

In Fig. 7, the XOR logic diagram is displayed.

1.4.1 The XOR Layout used in the search

The XOR gate is a crucial component in various digital circuits, including arithmetic circuits [16] and circuits used for producing parity bits [17]. However, by the process of rearranging the XOR equation, the objective was to minimize the utilization of majority gates or inverters. A number of XOR layouts have been previously documented in the field of QCA technology [18–24]. While other individuals were formed utilizing the inherent capabilities of the Quality Control Algorithm (QCA). Figure 1 depicts an illustration of the conventional XOR structures that were previously mentioned. Figure 7 illustrates an XOR arrangement.

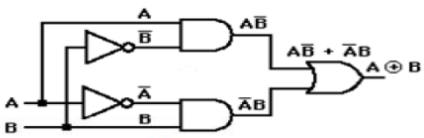


Fig. 7. XOR gate a logic circuit diagram

1.4.2. Physical Verification

This structure was physically confirmed to be what is shown in Fig. 8 and Table 2. Eq. 5 may be used to get the electrostatic energy Ek i,j for the two neighboring cells (i, j).

$$E_{Total} = \sum_{i,j} \frac{q_i q_j}{4\pi\epsilon_0\epsilon_r|r_{i,j}|} \qquad (5)$$

In this context, the symbol εr represents the relative permittivity, while ε0 represents the permittivity of free space. The variable q denotes the charge of an electron located within a dot, and |ri − rj| represents the spatial separation between two dots.

The orientation of the configuration that exhibits the most stability is characterized by a lower energy level for a given input. By maintaining one cell in its original state and altering the polarization states of the other cell to two opposing states, it becomes feasible to ascertain the electrostatic energy, commonly referred to as "kink energy," denoted as Ek, between the two cells. After doing a comparison between the two findings, the value that is smaller is afterwards selected. This procedure was conducted on a considerable number of unidentified polarization cells (c1, c2, c3, and c4) seen in Figure 9, prior to evaluating the polarization of the output cell for the suggested gate. The values of c1, c2, c3, and c4 are determined based on the obtained results. Specifically, c1 and c2 are assigned a value of 1, while c3 and c4 are assigned a value of 0. The calculation of the total electrostatic energy at dot p, denoted as Up, is performed for the input pattern (A, B) = (1, 0), as depicted in the figure provided. $\boldsymbol{Up} = \frac{K}{D1} + \frac{K}{D2} + \frac{K}{D3} + \frac{K}{D4} + \frac{K}{D5} + \frac{K}{D6} + \frac{K}{D7} + \frac{K}{D8} + \frac{K}{D9} + \frac{K}{D10} + \frac{K}{D11} + \frac{K}{D12} + \frac{K}{D13} + \frac{K}{D14} + \frac{K}{D15} + \frac{K}{D16} = \frac{K}{50.61} + \frac{K}{50.61} + \frac{K}{54.78} + \frac{K}{61} + \frac{K}{40} + \frac{K}{32.28} + \frac{K}{36.89} + \frac{K}{41.48} + \frac{K}{22.83} + \frac{K}{22.83} + \frac{K}{21.93} + \frac{K}{11} + \frac{K}{40} + \frac{K}{32.28} + \frac{K}{44.72} + \frac{K}{42.45} = \mathbf{11.7 \times 10^{-20}J}$ (6) Where $K = \frac{q^2}{4\pi\epsilon_0\epsilon_r} = \mathbf{23.04 \times 10^{-20}}$ (7) and D is the distance between

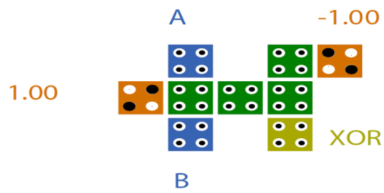


Fig.8. This article uses the input XOR gate provided in [25].

Table 2. Used this validation

Cell polarization)	UP $\times 10^{-20}J$	UP	Ur	Us	Stable position (lower energy required)	Cell
Output +1(Logic 1)	11.7	10.3	9.33	8.5	(q+r) < (p+s)	q+r

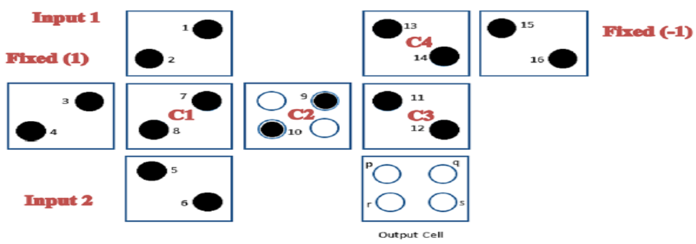


Fig. 9. Configuration to analysis the XOR gate

The QCA Pro software is a tool used for quantitative content analysis in academic research. This tool has the capability to handle large-scale circuits due to its utilization of rapid approximations and ability to anticipate power losses related to non-adiabatic switching. Figure 10 illustrates the power loss diagram of an XOR gate operating at 0.5 times the energy of the threshold voltage (Ek).

Fig.10. The suggested 2-input XOR's power dissipation map at 2-Kelvin temperature and level 0.5 Ek tunneling energy.

2 Related work

Numerous research endeavors have been dedicated to the exploration of Quantum-dot Cellular Automata (QCA) in the field of router circuits, as seen by the existing literature. In a previous study [26], it was proposed to utilize a router circuit that serves the dual purpose of functioning as a data path selection circuit, employing QCA technology for nano communication. The successful transmission of data from a distinct source to the intended destination across a singular route was achieved. Four independent sources were generated with the purpose of directing traffic to four separate destinations, all while making use of a single channel. The user's text does not contain any information to rewrite in an academic manner. The proposal put out was for the implementation of a nano router. The transmission of data packets can be facilitated through the utilization of a router. The proposed Nano router comprises three fundamental components: a crossbar switch, a DEMUX, and a parallel-to-serial converter. The utilization of QCA-based logic circuits for the execution of encryption and decryption operations was documented in reference [27]. The formula for generating cipher text in order to facilitate secure Nano communication using Quantum-dot Cellular Automata (QCA) was presented in the reference [28]. The Nano router circuit depicted in reference [29] enables the consolidation of data from several sources onto a singular pathway for efficient transmission to their respective destinations. Consequently, the suggested circuit can be utilized in the context of distributed computing. Several studies have put forth a viable QCA configuration for multiplexer (MUX) and demultiplexer (DEMUX) circuits (references [29], [30], [31]). This publication exclusively incorporates research pertaining to encryption, and our work is juxtaposed with the outcomes of said research. Based on the findings of the study, the encryption process involves the utilization of three predominant gates to establish an XOR operation. These gates are positioned between the text IP1 and the first key, between the text IP2 and the second key, between the text IP3 and the key, and between the text IP4 and the key. At the onset, a pair of multiplexers are employed with a single selector, as the fourth multiplexer generates a fourth exclusive OR gate. This fourth exclusive OR gate is then fed into the multiplexer every two exclusive OR gates. The process of encoding culminates in the generation of a single output, determined by a secondary selector, subsequent to the selection of two inputs by the primary selector, both of which are then sent through a third multiplexer. The phenomenon described in reference [32] is depicted in Figure 11.

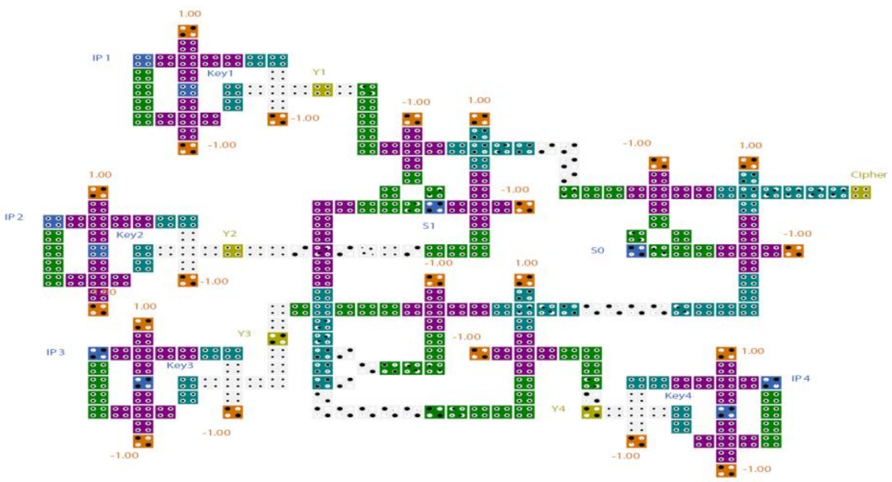


Fig. 11 . Text encryption using four IPs and four

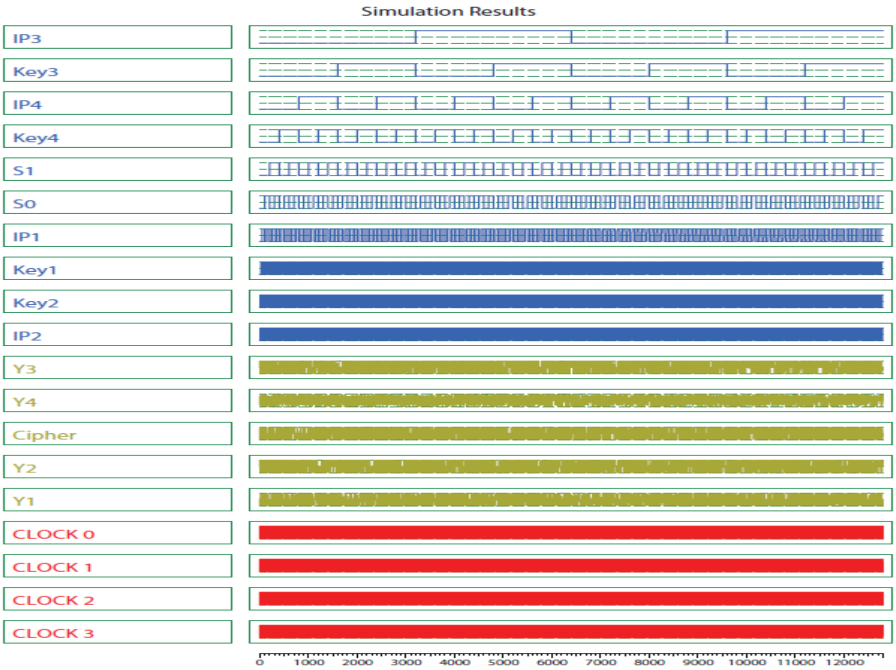


Fig.(12) illustrates simulation results

Features of [30] Shown in table (3).

Table 3. Features of [31]: XOR and MUX-based encryption

Attributes	**Values**
Num. of Cells	282
Area in (µm^2)	0.54
Cost	152.28
Majority	12
Num. AND	7
Num. OR	12
XOR	4
MUX	2
Keys	4
Inverter	10
Selectors	2

3 Proposed Methodology

Using the QCA simulation tool, the proposed QCA was simulated. The planned plan includes a number of XOR and MUX and encoder output

1- XOR Gates ,Fig.(8).
2- 2:1 Multiplexer

The distribution of the scheme is as follows. The text is segmented into four distinct pieces, with each portion being associated with a certain key. Subsequently, each pair comprising a section of text and its corresponding key is processed through an XOR gate. The energy consumption in this case is contingent upon electrostatic energy, resulting in a lower energy consumption compared to the XOR operation that employs Majority gates.

We now proceed to the subsequent section, wherein two XOR gates are incorporated into a multiplexer (MUX). Similarly, an XOR gate is also inserted into another MUX, which is contingent upon the aforementioned selector. Each MUX generates an output, which subsequently enters a second MUX. This second MUX selects one output and is dependent on a novel selector. Consequently, the encoding of the inputs is produced in a manner that is less commonly employed. Cells exhibit reduced energy use and decreased cost.

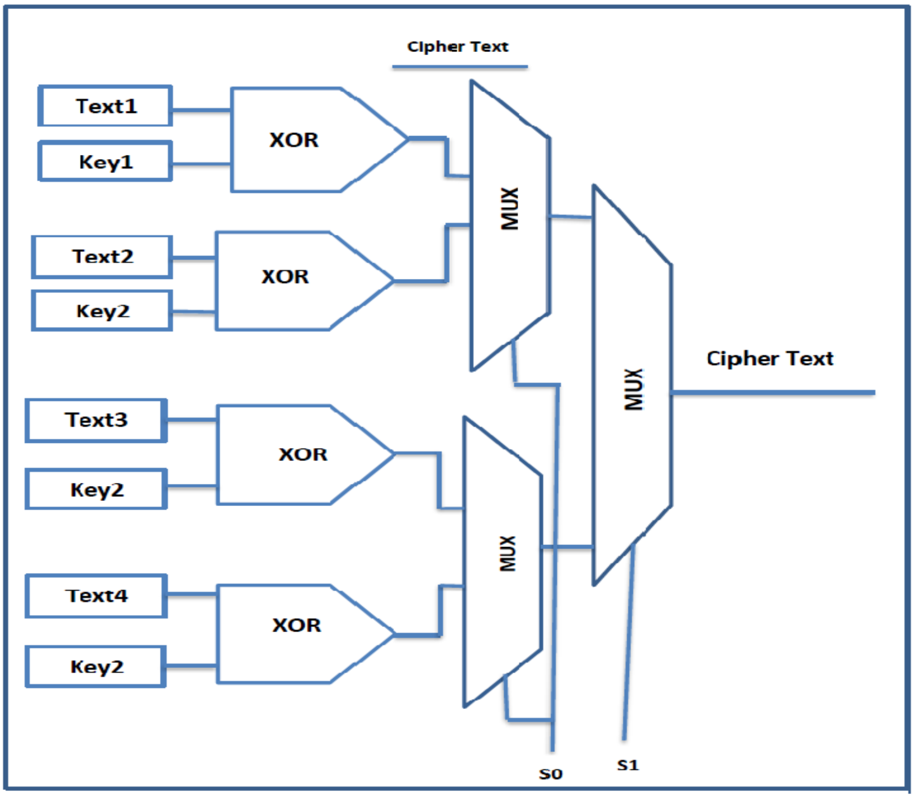


Fig.13. Scheme that shows a multiplexer with two inputs.

Using QCA Designer software, different sides of the circuit are there to produce the output.

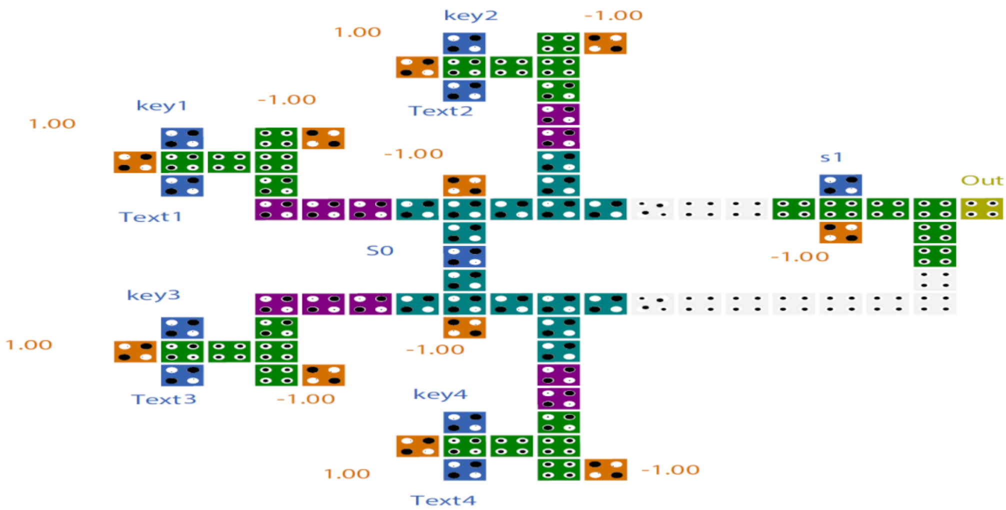


Fig.14. Circuit for proposed Encryption

4 THE FINDINGS AND DISCUSSION

The anticipated QCA structure, area in (µm2), numbers of (cells , majority, AND, OR, XOR , MUX, Key, Selectors and in the end. The output is through the use of XOR and MUX, which combines the text and the key in a way that overlaps each other and makes it difficult to know the text and the key separately.

$$(\textbf{\textit{Cost function}} = \textbf{\textit{Area}} \times \textbf{\textit{Num. of cells}})$$

Table 4. Features of the Proposed XOR and MUX-based Encryption

Attributes	Values
Num. of Cells	85
Area in (µm^2)	0.19
Cost	16.15
Majority	3

Num. AND	4
Num. OR	3
XOR	4
MUX	2
Keys	4
Selectors	2

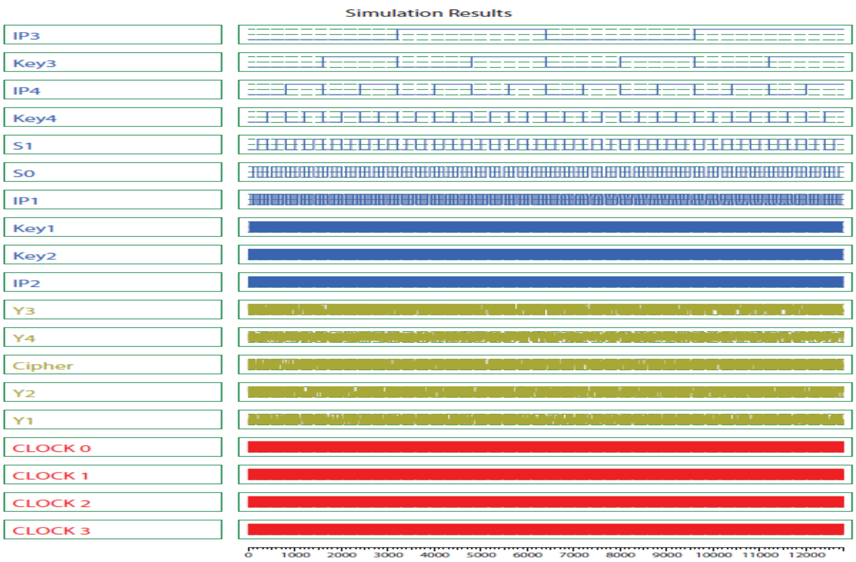


Fig.(15) illustrates simulation results.

Comparison between the proposed encryption and one of the mentioned in previous works (Table4 and Table 3).
First, the comparison begins with the number of cells, as the number of cells in the previous work [31] is 282 cells, and in the proposed work it is 85 cells. And the area in the previous work is 0.54 um, while in the proposed work it is 0.19 um, the cost in the previous work is 152.28 and in the proposed work 16.15. In addition to the number of (Majority, AND,OR , XOR ,MUX, Key , Selector) and finally results in encoding the entered text with the previous work and the proposed work. From the comparisons, we conclude that the proposed work is better than the previous work.

5 CONCLUSION

We concluded in this research that it is possible to make an XOR between the text and the key, and the text is divided into four sections, each section with a different key without using the majority. But we depended in this work on electrostatic energy. After the XOR, we used MUX with the first and second XOR, and MUX is used again with the third and fourth XOR. And using Selector one of them. A third MUX is used with a new Selector that selects one output that represents both the encrypted text and the key so that it is difficult to separate the text alone.

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