Performance Analysis on Quantum–Dot Cellular Automata

A Kavitha

Abstract: ***The changes that the Quantum Cellular Automata devices have faced have been evolutionary but still the most advanced chips continue using the same computing paradigm as their old predecessors. There are a lot of expectations that new paradigms will be developed for the processing of information. The CMOS technology uses current switching but the QCA deals with encoding the binary information as it is the array of cells and every cell has quantum dots and its fast-dimensional scaling will in the end be expected to reach the fundamental limit. The interaction of the quantum mechanics with the coulomb in every cell, is the one that determines the cell state. Additionally, the molecular QCA has the ability of operating at a speed of Terahertz (THz) together with a very less power and extremely high gadget density.***

Index Terms: ***Quantum-Dot Cellular Automata, Clocking, Terahertz.***

I. INTRODUCTION

A continued down-scaling of the dimensions of devices in the micro-electronic technology has resulted into much faster gadgets as well as a heavy circumscription. The cellular automata denser circumscriptions have a great impact on the chip performance in the micro-electronic technology devices. The changes these devices have faced have been evolutionary but still the most advanced chips continue using the same computing paradigm as their old predecessors [1]. As much as these computing devices continue using same paradigm, there are a lot of expectations that new paradigms will be developed for the processing of information. Singhal suggested that the CMOS fast dimensional scaling will in the end reach the elementary limit. Notably, among the ever-evolving technologies, the Quantum Dot Cellular Automata is most desirable nanotechnology as it is a transistor less paradigm with an operating system of Terahertz (THz) [2]. QCA is a means of representing the binary information on the cells. The CMOS technology uses current switching but the QCA deals with encoding the binary information as array of cells and each cell has quantum dots.

II. RESEARCH METHODOLOGY

For many years, the quantum structure has been an active area of research.

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Several researchers have suggested the chances of noticing cellular automata which possess frequent arrays of the quantum dots. The interaction of the quantum mechanics with the coulomb in every cell, is the one that determines the cell state [3,4].

On the other hand, interaction of the coulomb within the different cells electrons results to a local inters cellular mechanism An analysis of the quantum-dot cell model which has two electrons is done as an entrant for the quantum cellular automata instrument. These cells have quantum-mechanical states that correspond to the Eigen value of wave equations that has a charge density which is actively lined up in one or two directions [2]? The cell is modeled with a use of a Hubbard-type Hamiltonian with a coulomb repulsion. The model can be shown in figure 1.

$$H_0^{\mathrm{cell}} = \sum_{i,\sigma} E_0 n_{i,\sigma} + \sum_{i,j,\sigma} t_{i,j}(a_{i,\sigma}^{\dagger} a_{j,\sigma} + a_{j,\sigma}^{\dagger} a_{i,\sigma}) + \sum_i E_Q n_{i,\uparrow} n_{i,\downarrow} + \sum_{i>j,\sigma,\sigma'} V_Q \frac{n_{i,\sigma} n_{j,\sigma'}}{|r_i - r_j|},$$

Fig.1. Hubbard-type Hamiltonian

The above formula can be used to calculate the Hamiltonian Eigen states which is directly diagonalized due to the few electron states. A cell to cell response is then analyzed by calculating the above equation. The cell to cell response [9] is shown in figure 2.

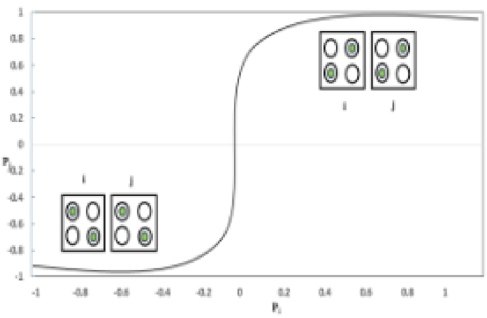

Fig.2. Cell to cell response

If With regards to the materials that are used to get the QCA cell, the kinds of QCA present are the metal island, molecular QCA with a range of, and the magnetic QCA of the range between that and also a semiconductor of values 9&24. Within these findings, the molecular QCA is the only one that is more desirable [2]. This is because it can function at a room temperature. In addition to that, from the development point of view, the molecular QCA is the best viable one.

The molecular QCA has the ability of operating at a speed of Terahertz (THz) together with a very less power and extremely high gadget density.

2.1 Metal based QCA

The Al-AlOx-Al tunnel junction is invented on a corroded Si substance by standard electron beam– lithography and the shadow evaporation [5]. This QCA cell is comprised of four aluminum dots ranging from D1 to D4 which are integrated with the tunnel junctions of aluminum oxide and the capacitors. The dots E1 and E2 are the electrometers for detecting the output [6]. The ballistic point contacts together with the STM method and the electrometer can be used to indicate the outputs. The metal based QCA is executed and revealed in as it had been controlled at a temperature of 70mK. The metal QCA cell is shown in figure 3.

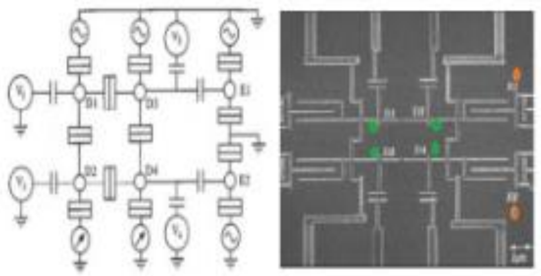

Fig.3. Metal QCA cell

2.2 Molecular based QCA

The molecular QCA is always regarded as the positive implementation for the QCA circuit [7]. The molecular QCA works at a room temperature with higher gadget density, and also operates at a very high speed. The molecular QCA cell is represented in the range of 16-18. The molecular implementation can still be created with a much higher consistency as compared to the ones that are achievable using a semiconductor or metal-island QCA implementation. Every molecule serves as a cell in which the reversible chemical reaction function as dots and tunneling is then given by linking the legends [5]. The binary information is concealed with the charge layouts. Three states of dot molecular QCA representation is shown in figure 4.

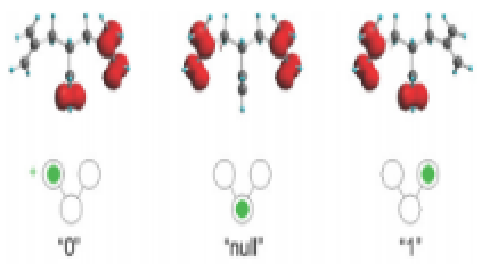

Fig.4. Three states of dot molecular QCA

2.3. Dynamics Simulations

Since the structural changes in time that are related to the intrinsic factors and some of the external pertribution affects the molecular system, related both to intrinsic factors. Pulimeno et al. did various simulations of the bis-ferrocene molecule when different values of electrical field were applied along the x axis [6]. They then did an analysis on the variations witnessed in the molecule structure at various time frames and they realized the key differences were based on the distances in between the two ferrocenes. Fluctuations are remarkable especially when the electrical fields are not on. Hence, these structures are thought to always freeze into a more stable state with an exposure to a higher electric field.

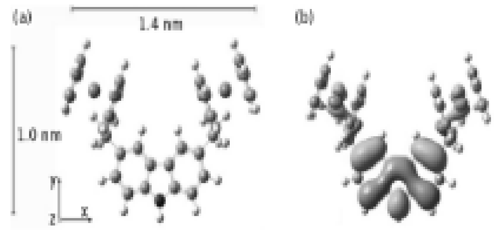

Fig.5. Molecular dynamics simulations

2.4. Magnetic based QCA

Some researchers have developed and proposed a magnetic administration of the QCA ranges between 21 and 22 [8]. This type of QCA is found on the collaboration between the magnetic nano-particles. In the magnetic QCA, the data is disseminated through the magnetic interactions. According to Laajimi, the magnetic QCA is believed to have the ability to get to a speed of around 100 MHz.

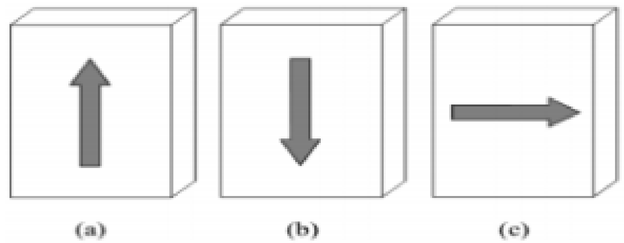

Fig.6. Binary Logic Representation in Magnetic QCA

III. PERFORMANCE OF QCA CLOCKING

The concept of QCA clocking was then introduced by Shin & Jeon. With regards to the CMOS technology, clocking is used to check the timing especially in the sequential circuits [9]. In QCA perspective, the clock facilitates the switching as well as gaining of power to these circuits [10]. Each QCA cell is given a combinational clock signal together with a sequential circuit that will assist in raising or lowering the tunneling barricade that is located within the dots. These clocking signals are initiated by the use of an electric field. They come from the wires that are located under the QCA platform with a use of the CMOS wires. The clocking scheme comprises of 4 clock signals which have four phases(the switch, hold, release and relax) as shown in the figure below. Each clock has the same frequency and a phase shift of 900 each. The reference of one of these clock signals are considered to be (phase = 0) while the rest are 1(phase = $\pi/2$), 2 (phase = π) and 3(phase = $3\pi/2$) quarters of a period as depicted in the figure below. The division of the QCA circuit is divided into several zones and the signals of every clock are placed into its particular zone [11, 4].The assignment of four clock signal will lead to a hold-up in the productivity outcome with regards to the clocks number required for a certain circuit [7].

Notably, a larger circuit might have more delay as compared to a shorter one. Additionally, the assignment of the clock zone is the expositoriest part when laying out a QCA circuit implementation and simulation. Thus, generation of a solid and novel clocking scheme is necessitated [5].

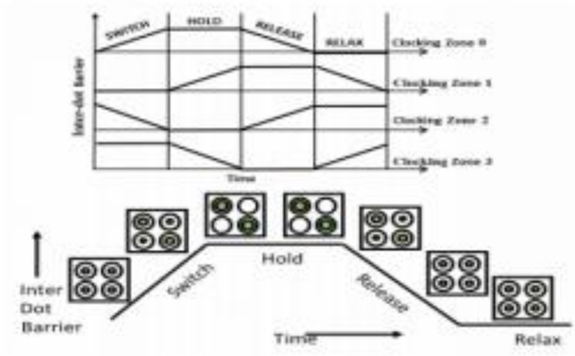

Fig.7. QCA clocking

The majority voter (MV) and the inverter as well as the binary wire are the fundamental composers of QCA [5]. The five cell configurations as depicted in Fig. 8 below is found in 3-input fundamental primitives found in the MV. The input cells are A, B, C respectively, besides, the gadget cell that consists of polarization of most of the inputs is the middle cell. However, the right-hand side cell is the output cell that has got equal polarization as the gadget.

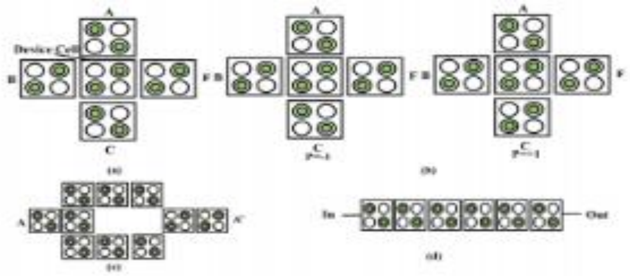

Fig.8. QCA Elements

The crossing of the horizontal and the vertical QCA programmable wires have been invented and also tested for their performances. In the figure below the inputs to the logic gates are A, B, C while there is only one output which is based on the right-hand side of the crossbar circuit. Additionally, the device cell which is also known as the central cell, which is the one that does the calculations and that always remains the same as the output. Figure 9 shows the programmable logic gates for QCA cross bar circuits [12].

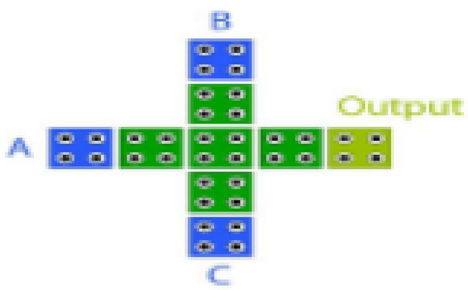

Fig.9. Programmable logic gates for QCA crossbar circuits

IV. CONCLUSION

As highlighted in the above survey, the molecular point of view proves to be of most value as compared to the other QCA values. With regards to the QCA clocking, the clock facilitates the switching as well as gaining of power to these circuits. With reference to the QCA implementation, it is noted that the ranges of different types of QCA vary from one type to the other. The clocking signals in QCA clocking are initiated by the use of an electric field as they originate from the wires which are located under the QCA platform with a use of the CMOS wires. The Quantum Cellular Automata will keep on evolving and it is expected that in the near future outstanding inventions will have been launched and put into use.

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