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Reversible logic-based image steganography using quantum dot cellular automata for secure nanocommunication

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Abstract: This study introduces a novel architecture for image steganography using reversible logic based on quantum dot cellular automata (QCA). Feynman gate is used to achieve the reversible encoder and decoder for image steganography. A Nanocommunication circuit for image steganography is shown using proposed encoder/decoder circuit. The proposed QCA circuits have lower quantum cost than traditional designs. It shows the cost effectiveness functionality of the proposed designs. The proposed circuit has 28.33% improvement in terms of area over complementary metal–oxide–semiconductor circuit. To perform image steganography LSB technique is used; signal-to-noise ratio (SNR), peak SNR and mean squared error (MSE) are also computed. The proposed QCA encoder/decoder circuit is suitable for reversible computing. To establish this, the heat energy dissipation by the proposed encoder/decoder circuit is estimated. The estimation shows that the encoder/decoder circuit has very low energy dissipation. Single missing/additional cell-based defect analysis is also explored in this study. Reliability of the circuit is tested against different temperatures. Implementation and testing of the circuit are achieved using QCADesigner tool. MATLAB is used to produce the input to the proposed circuit.

1 Introduction

In nanotechnology, quantum dot cellular automata (QCA) is an emerging field which has the capability to function as an alternative to complementary metal–oxide–semiconductor (CMOS) [1–5]. Information is stored in QCA cell in terms of the charge possessed by the electrons, due to their electronic configuration within the QCA cell [6–10]. Mutual electrostatic columbic interaction between cells gives raise to bi-stable activities, required to perform the computation. Without any flow of current between the cells, binary information is encoded. In a CMOS circuit, different components are coupled together which give rise to problem during synchronisation [1–3]. The physical limitations of CMOS will be threatening in future for scalability of CMOS circuit. Thus, transition is essential from transistor circuit to transistor less circuit, where QCA is one of the potential solutions. QCA has low power consumption, high density and high clocking frequency [11–14]. Again, on losing a bit of information in irreversible computations, $K_B T\ln 2$ joules of heat energy is produced, where K_B and T represents Boltzmann's constant and absolute temperature, respectively. In case of reversible computation, energy dissipation would not occur [15]. This shows that the reversible logic is necessary to create low power consumption circuits. In Nanocommunication, the most important issue is to resist data against unauthorised access. Through image steganography data can be secured. The challenging aspect in steganography is the design of steganographic hardware at nanoscale with low power dissipation. Thus, by considering the inherent capabilities of QCA [16–24] and to get ideally zero power dissipation, reversible logic and QCA are combined together to achieve the encoder and decoder circuit for steganographic hardware at nanoscale. In this paper, it has been shown that how a reversible circuit can be designed to perform steganographic operation [21] as well as QCA can be used to implement this reversible steganographic architecture at nanoscale level. This steganographic operation is achieved in QCA based on reversible logic. For simplicity, the basic least significant bit (LSB)-based image steganography is considered in this paper.

The contributions are as follows:

(i) A novel reversible encoder and decoder for image steganography are proposed.
(ii) To achieve nanoscale architecture, the proposed encoder/decoder is realised in QCA.
(iii) A secure Nanocommunication system for steganography is achieved.
(iv) The cost of the proposed encoder/decoder and Nanocommunication circuit is estimated.
(v) Defect analysis of the proposed design is explored.
(vi) Power dissipation by the proposed layouts is estimated.
(vii) Reliability of the proposed circuit is also explored.

2 Image steganography using QCA

2.1 Related work

Recently image steganographic architecture is reported by Das *et al.* [21] based on irreversible logic. In comparison to the irreversible architecture proposed by Das *et al.* [21], the design of reversible QCA architecture for image steganography is achieved in this paper.

2.2 Feynman gate

Feynman gate is a reversible logic circuit [4]. It consists of two inputs and two outputs as shown in Fig. 1*a*. Input and output has one-to-one mapping. Quantum cost of Feynman gate is one. The equivalent QCA layout is shown in Fig. 1*b*.

2.3 Proposed encoder and decoder model for QCA-based image steganography

The procedure is outlined in Section 2.3.1 with an example using the proposed encoding algorithm (Fig. 10) and decoding algorithm (Fig. 11). The overall circuit implementation is performed in Section