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Error detection in wireless sensor networks based on Assertion functions

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Abstract— The increasing use of wireless sensor networks in different places, and according to the constraints such as limitation of energy sensors, memory, and that it is distributed in different and unsafe areas, caused to place in a danger and failure situation and it has led to the error management discussion in wireless sensor networks. Several ideas have been proposed in this issue that all of them discover the errors and some reform too. In this paper is used of the error in the normal operation of the system by adding one of the Boolean functions of numbers (Assertion) to notice the error. Simulation results show that our method's utility in energy consumption is better for error detection and amendment so that detect the error by sending some more data with main data to sink node and it is not necessary to use complex and time- consuming algorithms.

Keywords— Wireless sensor networks, Error detection, Assertion

I. INTRODUCTION

The issue of testing and debugging the system, Assertion Based testing is one of the useful methods in test and testable [14, 15, 16, 17] that is online test (in normal operation of the circuit) based on the white-box testing. This method is very similar to the partitioning method by using experimental points [14].

This method has great potential in the systems test, by increasing the visibility and no waiting for the error diffusion to output system and coverage Static and transient error [14].

In this method, an OVL (Open Verification Library) for testing of different points of circuit are used that have a library based on assertion function that allow these functions are used in different parts of the circuit and any assertion inquire a part of the covered circuit and according to assertion function expose desirable output in it's output if the test of circuit is correct.[17,16,14,15].

In this paper we consider the Assertion function for testing of sensor's different parts as for the function of parts that we want to test them, For example Assert-always represents output 1 every time in circuit's normal operation and faultless work of testing area, and thus for testing a part of the circuit such as ATD or other units that several Assertion function is used in them, we can use a combinational circuit (Boolean Function) as a output of circuit that show its correct function and this output be added to transmitted data to sink and the sink is responsible for deciding about how the node does work. As regards in this method complex algorithms for failure detection aren't used so more energy that is used for failure detection, is stored and as a result network's lifetime increase remarkably.

In the second part of the paper related works with the different methods and in the third section proposed method and experimental results are discussed and finally conclusion about proposed method is expressed.

II. RELATED WORKS

So far as regards the complex algorithms for failure detection in wireless sensor networks were used [18, 19, 20] therefore, as related work, we can only mention these algorithms. Although our proposed method is raised for the first time about the sensor but these methods have been tested in other circuits and have optimum results. In this section, we review the methods of experiment.

II.A.1 THE UNITS UNDER TEST

According to the test time, we conducted two sets of test on units under test:1) testing on working time 2)testing out of working time [1,2,3,4,5,7,9,10,13]. In Step 1, the units under test are tested out of system or in the system without affecting other units and in step 2, system is not tested on working time [14].

Methods applicable to the units under test are divided into three categories: Operational, middle circuit, combinational [16].

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In operational test, total performance of units under test is inquired by its main inputs and outputs, means that by giving special input to circuit, the expected output should be produced and if the output seems to be unexpected, In this case, the circuit has errors that it should be corrected if possible. Show that how the operational test does.

In middle circuit test, control and observation capability provided largely for internal components of circuit under test. This is possible with the use of different methods such as flexible metal needles.

II.A.2 DEVELOPED METHODS IN DESIGNING FOR INCREASING OF TESTING ABILITY

In new and efficient developed methods, different and predetermined parts based on standard or special method are added to the circuit in order to facilitate preparation and implementation of the test program. One of the increasing of testing ability methods in a chip or a board providing navigation ability and using it in order to system's testing ability. With the increasing complexity of integrated circuits and the number of their bases, the only way to implement developed testing methods is using of their serial access. One of the most important developed methods is IEEE 1149.1 boundary survey method. The standard is operative in three sectors: piece, board and system. The following is a brief explanation of the standard [1, 6].

II.A.3 ONLINE TEST METHODS

II.A.3.1 PRE-COMPUTED:

Test vectors and test results are stored in a separate hardware and during system's normal operation whenever device inputs is the same with test inputs the results are compared with the expected output that is stored. To determine which circuit is faulty or not [12,13,14].

This method requires additional hardware for storing test patterns and expected outputs and comparing the circuit input with test pattern and it can not be used for sequential circuit which it is the disadvantages of these methods.

II.A.3.2 DUPLICATING:

In this method, the testing process by copying the results of the calculations and the voting on the results will be done [14]. That's a lot of hardware overhead.

2-3-3: invariant-based: In this way, the circuit generates input x based on output f(x) and function g(x) is the relation between diagnostic circuit and under test circuit and the circuit's accuracy is defined by the relationship between f(x) and g(x)[14].

II.A.3.3 ASSERTION:

It is a device for testing that is used in simulation and is very similar to use of experimental points(mechanical) in partitioning method [8, 11, 14, 15, 16, 17]. Error message is not given unless the Assertion is inaccuracy [14]. In Figure 1 is shown how to place assertion in classic case.

Profile of Test Assertion [14, 17]

- White -box testing method (availability of circuit interconnections)
- Increased visibility in designing
- Error detection without waiting error propagation to the system output
- Static and transient fault coverage

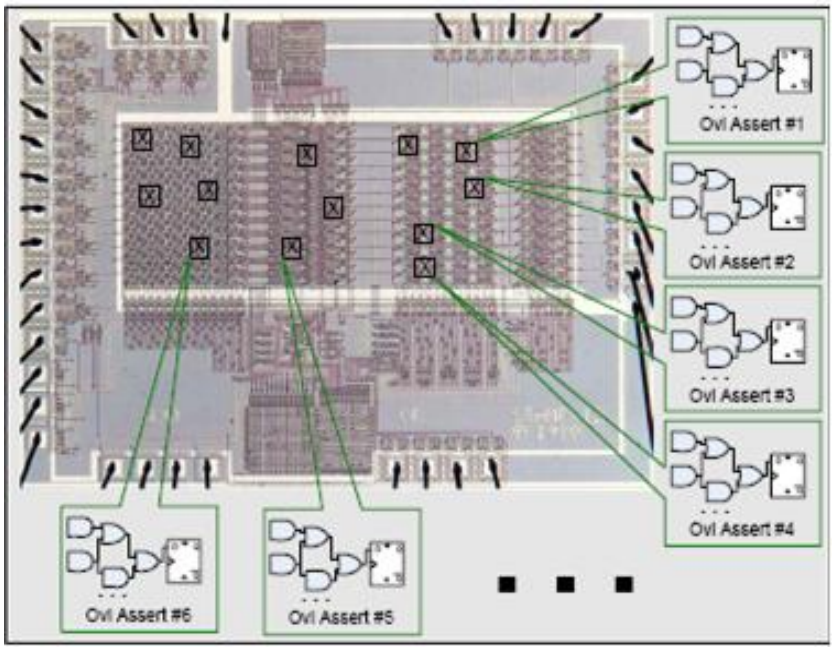

Figure 1: How to Place Assertion [14]

III. THE PROPOSED METHOD

Proportional to designed circuit, the points can be specified to determine the authenticity of hardware circuit so that each time by sending data, determine that the hardware is hale or defective. These points will have constant deals if the

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circuit is intact and one or more points can be selected from different parts of sensor, for instance, from the analog converters, power supply, sensor, etc. Selecting one or more point because that maybe sometimes fail to find a point Whose value is fixed during normal circuit operation, when two or more points will be used And these points are connected by a gateway software will generate a point. For example, if two points of the circuit are variable Zero and the other one at a time and in a moment the picture XOR can convert them to a place that will always have value. (Choice of hardware test hardware discussion is testable, we assume in this section as it did). After the sensor network consisting during sending data, bits be added to data and be sent along it and because all the sensors and the sink node have a program that can separate data and these bits and compare with sensor normal status, means that if these bits are equal to the sensor normal status, recognize the incoming data mid this packet as the correct data and the sensor as intact otherwise data is wrong and sensor is defective and evict from the network. In following this issue is discussed in further detail.

By using assertion functions of each of the components within the sensor select points that their data are essential, for example, suppose points A, B, C, D are sensitive points of the circuit as Figure 2.

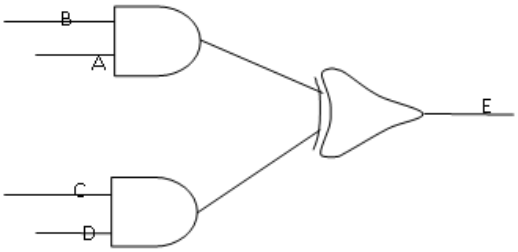

Figure 2: An example of a circuit structure

By compounding they can be converted to a critical point such as E, means that if the points A, B, C, D are points that are selected from the analog converters unit to sensor digital, respectively, assuming 1, 0, 1, 1 in normal operation, they can be converted to a point by XOR and also if points are selected from other components of the sensor such as power supply, Transmitter and receiver, memory and processor and finally, a few points will indicate the safety part of the circuit, Because the volume of transmitted data not be too much (Sometimes even minor damage sensor does not need to know) so they can be converted to one or two bits. If the goal is to identify the precise fault location, the few bits remain that send along data to try to identify healthy or faulty sensor.

IV. RESULTS OF TESTS

At first typical sensor circuit with sensor that assertion functions have been added; be simulated in Verilog in order that the energy difference between conventional sensors and sensors with assertion functions to be determined. Then, two wireless sensor networks with two different sensors (one with Assertion functions and the other without it and ordinary) in different areas with dimensions of 100 * 100 and by uniform distribution of One hundred sensors randomly, were simulated with MATLAB. In this simulation, all the nodes and the central node with the specified coordinates are located in the area. The initial energy of sensors, is considered equal to 0/5 Jules. Duration of simulation is considered for the 1000 period and also the energy consumption is calculated according to Table 1.

TABLE 1: USED RADIO CHARACTERISTICS IN OUR SIMULATIONS

Energy	**operations**
Eelec=27nJ/bit	Send receive data
EDA=5nJ/bit/signal	Data Aggregation
Єfs=10pJ/bit/m2	Send amplifier ifdmaxtoBS ≤ d0
єmp=0.0013pJ/bit/m4	Send amplifier ifdmaxtoBS ≥ d0

Assertion: This method of testing process by copying the results of the calculations and the voting results will be done [14] that have a lot of hardware overhead and the equations must be consistent and also the scale of measures should be adhered.

The simulation results show that the energy consumption of each sensor that was implemented by assertion functions in each period is 0/5 nJ/bit/signal more than conventional sensors that are too small. In the ultimate simulation by MATLAB this number is deduced of the sensor in each period. Again hundred of sensor that implemented by specifications of assertion functions are distributed in a area with dimensions of 100 * 100randomly with a uniform distribution.

According to Figure 6, the simulation results show that the new method detect a variety of permanent and transient errors in comparison with the algorithm of [18.19, 20] at best way and with high accuracy. Simulation results are shown in Figure 3.

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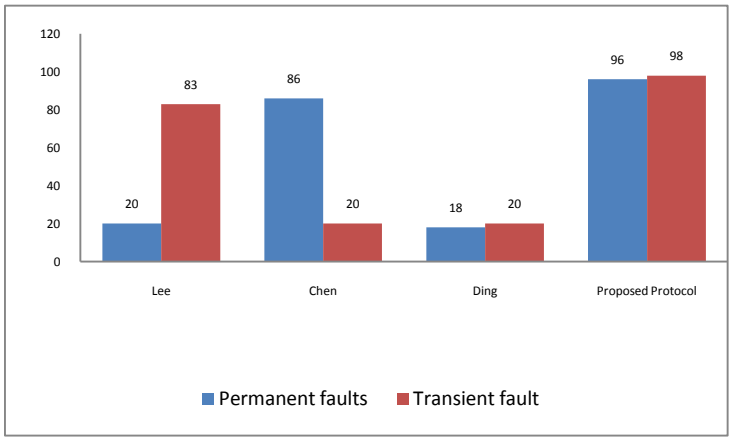

Figure 3: Evaluation of errors with the proposed algorithm and three mentioned algorithms.

As respects in this method a extra bit is sent with data, it's energy consumption compared with other sensors that send own data increase very poor While it can be ignored. Specifications of nodes that implemented by assertion functions are distributed in network ,these nodes consume 0/5 nJ/bit/signal (this number is obtained in the simulation with Verilog) more than other sensors, instead for error detecting don't use complex algorithms like other methods and compared with the most important algorithms for error detection in wireless sensor networks, the Simulation results show that the proposed method has very low power consumption and its lifetime have been compared with some other methods according to Figure 4 that is much better than they are.

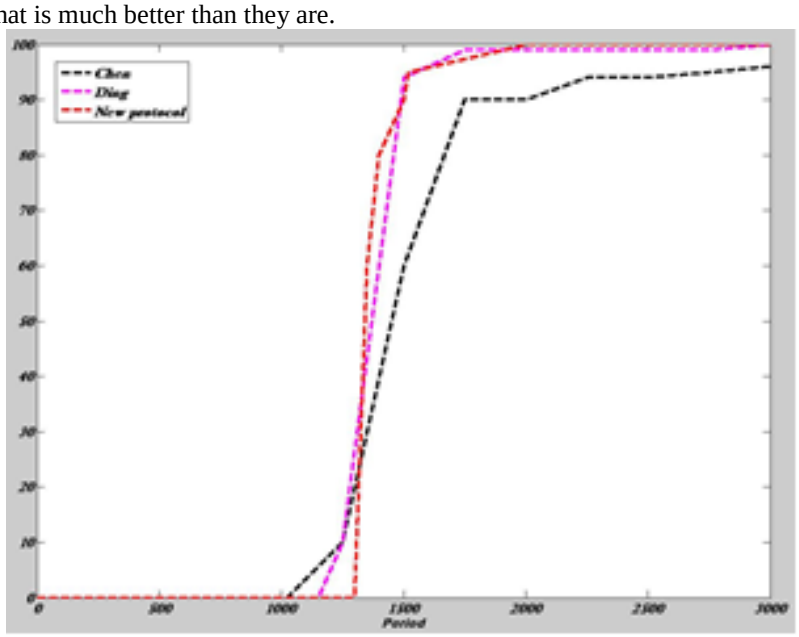

Figure 4: Lifetime comparison of the proposed algorithm with Chen and Dynq algorithms

According to the results of simulation and performed experiments on the proposed approach, instead of using complex algorithms, a few extra submitted bits are used to detect errors. In addition, this method has high accuracy in the detection of permanent and transient failures and longer life than conventional methods.

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