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The Design A Fuzzy System in Order to Schedule Sleep and Waking Of Sensors in Wireless Sensor Networks

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ABSTRACT
Sensor networks are considered to be a standard technology in wireless communications and they are widely used in military, surveillance, medicine, industry and houses as well. In sensor networks batteries with limited amount of energy provide energy for the whole system. They are not rechargeable and as soon as the batteries die the network life time will expire too. Using computational intelligence to schedule sleep and waking of the sensor nodes is one of the suitable methods which helps the network to have a longer life. In this paper the focus is on a fuzzy method to schedule sleeping and waking of sensor nodes. In this method the Environmental conditions of each sensor (the number of neighbors, the remaining energy, and the distance to the next cluster node) are considered as inputs by the application of a fuzzy system based on which the system creates an output and the sleeping and waking time of each sensor is dynamically determined. The simulated results show that the proposed algorithm is more efficient than other basic methods and consume less energy as well.

Keywords **-** wireless sensor networks, Sleeping and waking, reduction of energy consumption, Fuzzy systems, dynamic Scheduling.

I. INTRODUCTION

Wireless sensor networks include too many sensor nodes which are physically very small and they have some limitations such as processing power, memory capacity, resource etc [1, 2]. The nodes are randomly scattered in surrounding area so as to feel it, collect useful information and send it to the user. Each sensor alone is not capable very much, but a combination of hundreds of them can make a big change. In fact, to be powerful, wireless sensor networks need to use as many small nodes as possible which are able to cooperate and to be organized in order to be used in situations such as navigation, having environmental conditions, structures and a system equipment's under surveillance.

True scheduling of sleeping and waking of sensors in wireless sensor networks helps the sensors to consume less energy and this in turn helps the network to have a longer life. When the nodes are sleeping they consume the least amount of energy and energy is stored and this helps the network to have a longer life. Accordingly, whenever the nodes are free and do not receive any information they had better to sleep and wake when they need to receive and send information to the control center [3].

This paper aims at proposing a method for

scheduling the sensors in a wireless sensor

network by the help of computational intelligence. In this method the Environmental conditions of each sensor (the number of neighbors, the remaining energy, and the distance to the next cluster node) are considered as inputs by the application of a fuzzy system based on which the system creates an output and the sleeping and waking time of each sensor is dynamically determined. Nowadays, as the use of wireless sensor networks is increasing the scheduling of sleeping and waking of nodes in order to reduce energy consumption and increase the lifelong of the networks is significantly important.

In section 2 a review of the previous works is carried out. In section 3 the fuzzy system is explained. The proposed method is explained in section 4 and in section 5 the tests are shown, along with the results. The conclusion appears at the end.

I. HEADINGS

In section 2.1 a review of the previous works is carried out, 2.2 Static Algorithms and 2.3 Dynamic algorithms**.** In section 2.4 the fuzzy system is explained. The proposed method is explained in section 3.1, 3.2 and in section 4.1 the tests are shown, along with the results. The conclusion appears at the section 4.2.

II. INDENTATIONS AND EQUATIONS

2.1 Review

The algorithms used for scheduling the access of nodes to the wireless channel fall under two groups including static and dynamic algorithms for which computational intelligence is used for scheduling sleeping and waking time of the nodes.

2.2 Static Algorithms

In these algorithms the time of sleeping and waking is permanently determined for each sensor and it does not change during the lifelong of the sensor and it depends on the condition of the network.

S-MAC algorithm operates periodically in which each node hears and sleeps according to a fixed schedule and includes: scheduling of hearing and sleeping, avoiding of collisions, preventing of eavesdropping, and message transferring method. Each node's hearing period is divided into three separate parts. S-MAC protocol does not work properly whenever the traffic fluctuates. In order to solve this problem T-MAC introduces some additional time to finish the active period of a node. If a node does not have any hearing in its period additional time, then T-MAC lets it to sleep. T-MAC improves inappropriate results of S-MAC in heavy traffic, but it violate the synchronizing process of hearing periods in virtual clusters and this leads the nodes to sleep soon. This protocol is the plan of the pattern convergence of the most observed frequency communications in sensor networks. The indirect routs from the source to the sink can be shown as collected trees [4]. The main objective of D-MAC achieving very low latency communications convergence plan. D-MAC obtains much better delay than other algorithms based on sleeping/waking and it can be a good choice in networks in which delay plays a crucial role. In D-MAC methods of preventing collisions are not used, so if some of the nodes send data to a specific node at the same time, then collisions will happen [9].

2.3 Dynamic algorithms

They are algorithms which use dynamic methods to schedule the sensor nodes based on computational intelligence. What it means by dynamic scheduling is the way the sensors have access to communication canal based on the network conditions and the way a sensor sleeps when it is free so as to consume less energy.

In [5] a self-learning method, which is one of the computational intelligence, is used for scheduling the sensors nodes. In this method a self-learning planning approach is used in order to reduce energy consumption and reach low delay time in wireless sensor networks. This approach is the development of کیو learning method and it enables the nodes to learn the parameter of sleeping and continuous transfer through cooperating with wireless receiver. In this algorithm SSA mechanism makes the nodes all to wake periodically simultaneously. All nodes learn planning parameters both periodically and simultaneously. In [6] a cluster protocol (LEACH-CS) of adaptive centralized hierarchy of sleeping is proposed for wireless sensor networks. LEACH-CS protocol helps the wireless sensor networks to live longer by proposing a mechanism of an intellectual choice of a node performance which is based on the data felt. If the received data by a specific cluster seems inconsiderable in a period, it makes the clusters that have been set to sleep until the next round. Proposing an algorithm named intelligent smart sleeping (ISM) for choosing a node of state is one of the abilities. LEACH-CS protocol is proposed for applications for which the conditions may stay stable for a period of time. In [7] a method of energy consumption reduction is proposed with a reinforcement learning algorithm. In this method the focus is on the Maximum power of the total consumed energy in a sensor communications package. Consider point-to-point and multistep communications. In both cases, suppose that there is a smart controlling agent in each sender and makes suitable decisions in suitable situations. In this method the reinforcement Learning algorithm is used to solve the problem of optimizing the energy consumption. In point-to-point communication the communication is between a sender and a receiver. Before transferring, the sender observes the existing packages in its buffer and obtains the previous transferring canal. The aim of these factors, intelligent control to find the best level modulation and transmission and maximize the long-term average power in the total energy consumed.

The whole consumed energy in each transfer includes the transfer and buffer energy and the cost of processing.

2.4 FUZZY LOGIC

Fuzzy collections result from the collections classic theories which are useful in fuzzy logic. Fuzzy collections are of those collections whose members have Degree of membership. Fuzzy collection was added to the classic theory of collections as an extension by Dr. Lotfizadeh in 1965 [8] and afterwards, it was widely used [11, 12]. In the classic theory of collections the membership of the members in a collection is determined as binary sentences based on binary conditions i.e. a member belongs to a collection or not. But, in fuzzy theory gradual membership is allowed. Basically, fuzzy inference is a formulized processing of a collection of input data to a collection of output data. Construction fuzzy, fuzzy inference engine and defuzzification, the main functions of each fuzzy system (Figure 1).In the Fuzzfier part variables with real values are changed into a fuzzy collection. Afterwards, the results are transferred to a defuzzificated part by Fuzzy machine interface and basic rules in which a fuzzy collection is changed into a variable with real values. In other words, input information are often complex values and these numbers are changed into fuzzy collections. Model based on fuzzy logic rules IF – THEN they are interpreted. Processing power and optimized time are the most important factors in hardware implementation in fuzzy motors [10].

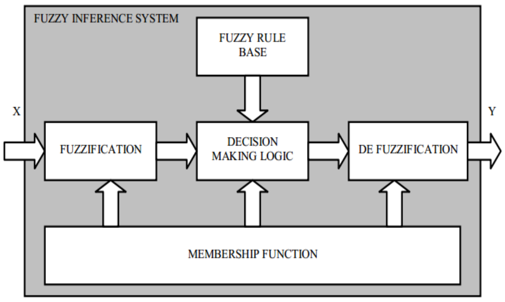

Fig 1. Components of a fuzzy system

III. FIGURES AND TABLES

3.1 The proposed method for scheduling the sensors by the help of fuzzy logic

The proposed method includes the following phases:

3.2 Distributing the sensors in the area, clustering and determining the sink

First, all sensors along with the sink are randomly distributed in the network area. Parameters which are randomly created in the area include 1- information sensors 2- the sent package of each sensor 3- the sink since distance is one of the input parameters in the proposed method and it is calculated with fixed clusters and also other input parameters have to be calculated, the supposed area is divided into the same parts

.

3.3 Normalizing the data and the number of neighbors and their distance from the node

As it was previously mentioned fuzzy system is a system which changes a human concept into a mathematical one. After the calculations are carried out the mathematical values need to be Fuzzfier because they are not readable in fuzzy system. In order to Fuzzfier the classic result the following formula is used. This process is done for each one of the three input parameters which includes some values.

(1)x_i: This variable is the same amount that is calculated in between sets. Between the interval [0, 1]. X_{max} : is the smallest member of the series

$$z_i = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}$$

counted. X_{max} : is the biggest member of the collection. The distance between the sensor nodes and cluster node is necessary. In order to obtain this distance Euclidean relationships used as follows:

(2) $Dn = (X_{cluster\ head} - X_{sensor})^2 + (Y_{cluster\ head} - Y_{sensor})^2$

Where Dn is the obtained distance for nth sensor from the cluster node. $X_{cluster\ head}$ is the Coordinate of X axis which is related to the cluster sensor. $Y_{cluster\ head}$ is the Coordinate of Y axis which is related to the cluster sensor. Y_{sensor} is the coordinate of Y axis and X_{sensor} is the coordinate of X axis. After obtaining the distance of each sensor from the cluster according to formula 2 each result which is not between 0 and 1 is normalized and entered into fuzzy system. The number of each sensor neighbors is as same as the number of sensors belonging to a cluster.

3.4 The implementation of fuzzy system

Fuzzy system is designed as follows:

3.4.1 Creating input and output parameters

After calculations the input variables have to be valued in the fuzzy system. Firs, the fuzzy system need to be implemented. The proposed algorithm includes three fuzzy input functions, four fuzzy membership functions, fuzzy inference motor, defuzzification module, and a fuzzy output function. The proposed algorithm mechanism can be described as follows: first, mathematical obtained results are entered in input parameters, afterwards they are located in [0, 1] interval in the Fuzzfier part. According to some rules and membership degree in fuzzy system, an interference is carried out on the data and an output is created and defuzzificated. The defuzzificated output is shown classically and the percentage of the sleeping time belonging to the sensor node is determined. This process is carried out by fuzzy tools in Matlab software. Three input parameters in fuzzy function are as follows: 1- the remaining energy of the sensor 2- the distance 3- the number of the neighbors.

To define the membership degree of each input parameter triangular and Trapezoidal functions are used. An output is obtained from the inputs by the fuzzy function based on which the time of sleeping for the sensor node is determined. To define the membership degree of each output parameter triangular and Trapezoidal functions are used. The architecture of the proposed model is shown in figure 2.

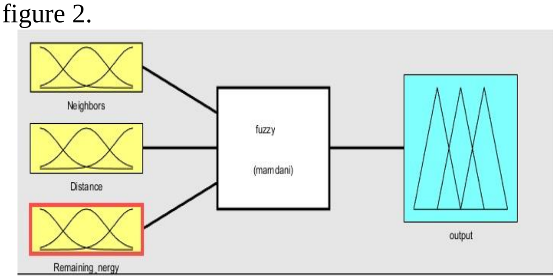

Fig 2. Architectural model fuzzy

3.4.2 The definition of input and output membership degree

Fuzzfier is first carried out on the input data so that the sensors can carried out fuzzy processing on the obtained data. In order to do so all input parameters of the system use three linguistic variables including low, mid, and high. Five variables including very low, low, mid, high, and very high are used for output parameters.

Table1. Fuzzy linguistic variables for Fuzzfier.

Parameters	**Become fuzzy language**	**Type**
remaining energy	Low-Normal-High	input
distance	Low-Normal-High	input
Neighbor	Low-Normal-High	inpout
Sleep time	Very Low-Low-Normal-High-Very High	output

3.4.3 Creating rule base

After having each input and output defined and their membership degree determined, some rules have to be defined according to which the output of the fuzzy system to be determined. The rule base contains a collections of IF-THEN orders which are written and ascertained according to the environmental conditions of the sensors and idea we have in mind. Generally speaking, they are ascertained conceptually and optionally and they do not have any special condition. There are 27 rules in the proposed algorithm that are in accordance with the existing conditions for output and the highest number of rules. The reason is that there the algorithm has got three input and each input has got 3 membership degree.

Table2. Defined rules for fuzzy system

Row	remaining energy	distance	Neighbor	output
1	Low	Low	Low	Mid
2	Mid	Low	Low	Low
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
26	Mid	High	High	High
27	High	High	High	Mid

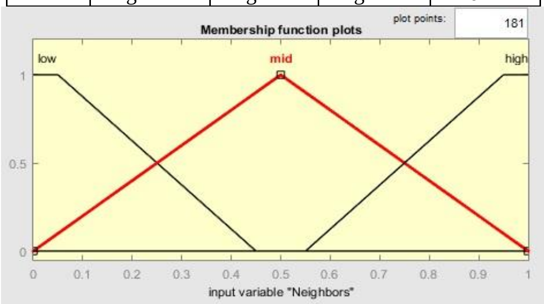

Fig 3. The membership degree of the input parameter of the number of neighbors

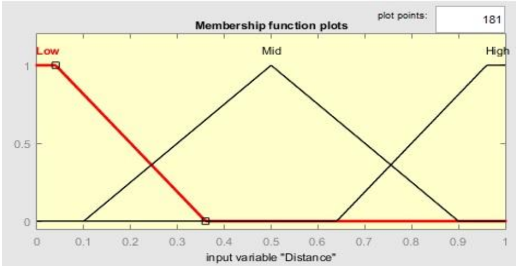

Fig 4. The membership degree of the distance input parameter

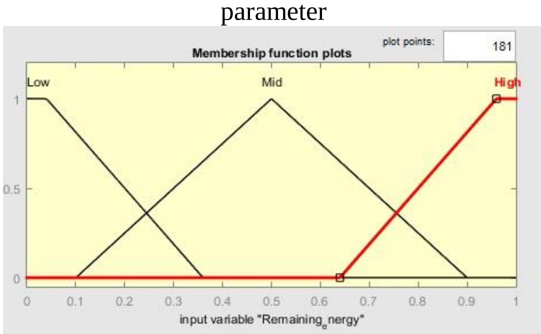

Fig 5. The membership degree of the remaining energy

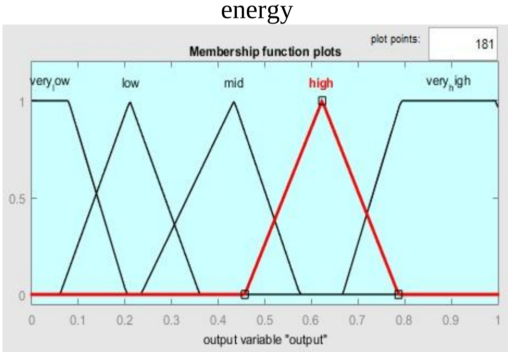

Fig 6. The membership degree of the output parameter

3.5 The semi code of the proposed algorithm

The semi code of the proposed algorithm is as follows: first of all, the sensor area is prepared, afterwards the sensors and the sink are randomly placed in the area, and eventually the cluster belonging to each zone is fixed in the area. After preparing the area of the network each sensor is considered to have three inputs (the number of neighbors, the remaining energy of the sensor, and the distance to the cluster) which are inserted to the fuzzy system and it estimates sleeping time for each sensor node according to input data and the previously defined rules.

1: Setup initial sensor nodes in the network
2: **For** i=1 to iteration time **do**
3: **For** n=1 to number sensor **do**
4: Calculate number of Neighbors, Remaining energy and distance
5: Import data in fuzzy system
6: Determinate sleep time and active time based Output fuzzy system

7: Calculate energy remaining
8: **End**
9: **End**

IV. CONCLUSION

4.1. Experiments and results

In the scenario an area (10002) is supposed to exist in which we want to cover it by a sensor network. The number of sensors is N that N= {1, 2,..m}. each sensor is randomly scattered in the area. The area is divided into some zones and there is a cluster for each which is statically located in the center of the zone and all sensor nodes belonging to that zone can directly communicate with it. The sink is randomly place in the area, too. Figure 1.4 indicates a wireless sensor network and how the location of the sensors and the sink (figure7).

In this paper we carry out the experiments in three ways: 1- results and experiments based on an area with 10 sensors 2- results and experiments based on an area with 100 sensors 3- results and experiments based on an area with 1000 sensors.

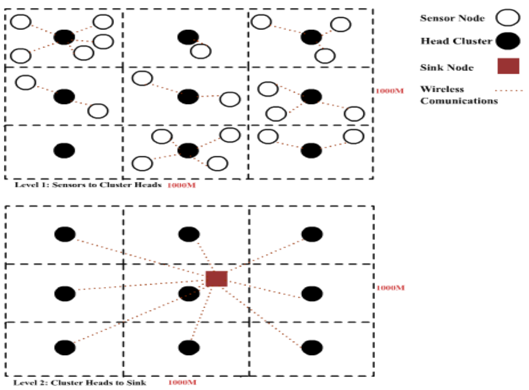

Fig 7. An example of how sensors and the sink are placed

The result indicate that the proposed algorithm consume less energy than S-MAC and the energy has been consumed steadily. In table3 the parameters which have been used for simulation are shown. In figure8 the way the sensors, clusters and sink are scattered is shown.

Table3. The simulation parameters of the network

Parameters	**Value**
The number of sensors of the area	10\100\1000
Time simulation	60 seconds (time unit)
The number of Cluster head	9
Environment	1000m*1000
Primary energy each sensor	10_j

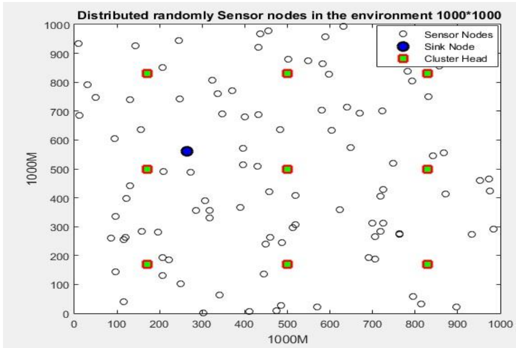

Fig 8. The way 100 sensors are scattered

In (Figure 9) as well as simulation result shows that the proposed algorithm is much more uniform and less energy than S-MAC is consumed.

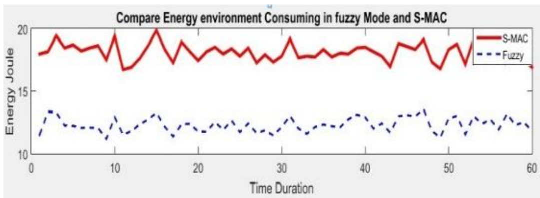

Fig 9. The obtained results based on Jules consumer for 100 sensors.

Figure 10 indicates that the proposed algorithm save much more energy than S-MAC during the operation time.

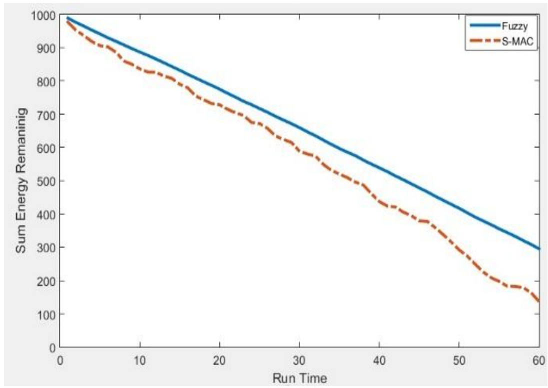

Fig 10. The remaining amount of energy per unit of time for networking with 100 sensor.

Table3. The comparison of the total consumed energy of the network per 60 time unit in fuzzy and S-MAC methods.

Consumed energy after 60 units of time in S-MAC method	Consumed energy after 60 units of time in fuzzy method	The initial energy of the network	The number of sensors of the area
91	84	100_j	10
874	702	1000_j	100
7411	5562	10000_j	1000

4.2 Conclusion and future works

According to the results if fuzzy system is used for dynamically scheduling sleeping and waking time of the sensors nodes the energy consumption will decrease and the remaining energy will also be consumed steadily during the lifelong of the network and help it to live longer. In this paper the proposed algorithm was run in three ways with different number of sensors and the results were obtained. As the results show when the fuzzy scheduling is dynamically carried out for sleeping and waking time the energy is consumed less and the network lifelong is more than S-MAC method.

In future works, in order to decrease energy consumption dynamic clustering can be used instead of static clustering. Another suggestion is to use reinforcement learning algorithm to schedule sleeping and waking time for nodes.

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