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Using Multi-agent System for Solving Coverage Problem in Wireless Sensor Network

Sherehan aburomman
Department of Computer Science, Jordan University, Amman– Jordan
sh86.emad@yahoo.com
Khalaf khataneh
Department of Computer Science, Al-Balqa applied university, Salt-Jordan
khalafk2002@yahoo.com

Abstract
Wireless sensor network (WSN) is one of the most important paradigms in computer networks because of the widespread applications. Coverage problem is a fundamental issue in sensor networks that reflects how the network is controlled by the sensors, this problem appears when any node becomes failure or out of the range, in this case the area will be disconnected and the data will not send to the destination. We present a new approach which uses a multi-agent system to solve this problem and perform an easy and secure network. In order to do that we implement sensor network by four phases: first construct a virtual network by matlab, second we use k-means clustering to cluster nodes in k-groups, third put the intelligent sensor in each cluster to be as a head for its group, fourth we divide the network to four regions and the closet agent to the sink will be the delegate to send the aggregated data from its region to the destination. Therefore, we tried to minimize the power consumption in WSN, we save the energy by keeping it sleep until it has a task to do , at this case the node changes its status to be in active mode and when it finishes it will be idle.

1.Introduction

Sensor networks gained a lot of interest from academic and industry environment in the last years and it has allowed the development of new low-cost, low-power and multifunctional sensor nodes that are small in size and can communicate with each other over short distances [1].WSN used to measure physical conditions like temperature, wind speed, sound and direction for monitoring application as: health monitoring, weather checking, habitat monitoring and fire detection. A sensor network consists of heterogeneous and homogeneous nodes that work together in cooperative manner to collect data from certain domain and send it to the target point called sink that connect with the internet or satellites as shown in figure 1.

There are many challenges that facing WSN, one of those challenges is the coverage problem that reflect how the network is monitored by the nodes and measure the quality of service [14]. There are two types of sensor coverage problem target coverage and area coverage, in the target coverage a set of nodes are deployment in a certain geographical area to monitor a set of targets but in the area coverage the nodes distributed to monitor a specific area [20]. This study is focused on area coverage problem.

Area coverage problem is caused by limited communication between nodes that each node must deploy in suitable range that can sense and monitor the area. Some reasons can be behind that not enough senor nodes in the area to cover the region of interest, limited sensing range and random nodes deployment [14]. However, the power supply effect on the coverage by the batteries that can't be charged and must to be live for months or years without human intervention, and when the node consume all its energy, the node will be idle and this lead to a disconnected network.

Consider the importance of area coverage in WSN. This paper aims to contribute the improvement of the coverage nodes in WSN by present a new approach which uses a multi-agent system.

In Section 2 we review literature related to our work. In Section 3 we briefly describe the multi-agent system. In Section 4 we present our research method, section 5 presents the results and the discussion .Finally, Section 6 sets out our conclusions.

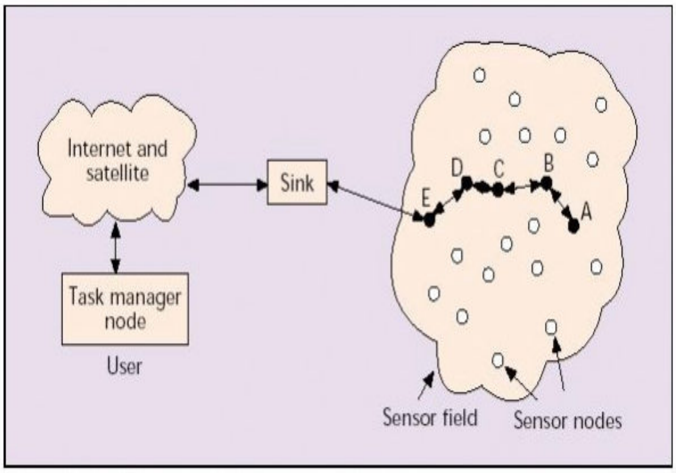

Figure 1. Wireless sensor network architecture [1]

2. Related Work

Coverage in sensor network has received a lot of attention in scientific research, and there are many published papers and reports about this problem.

in their work [8] they used Probing Environment and Adaptive Sleeping (PEAS) protocol that exchanges messages to discover the connected nodes in the environment, this protocol involves two methods the first is probing environment that decides which nodes will be active and when it should be sleep, the second is adaptive sleeping that adjusts the sleeping times of sensor to maintain the wake up rate, any node in PEAS can use probing message if there are any node working in the probing range.

In their work [15] they solve the local minimum problem in geographic routing by finding the weak nodes that are outside the transmission domain then find the holes and try to solve them by using tent rule that tests every node if it is a stuck node and after testing the nodes they used bound hole algorithm to find the effected areas and help packets to eliminate the stuck nodes. In this study [16] they modified the ant colony algorithm to solve the coverage problem by selecting minimum set of nodes to cover all the targets and maximize the network life time. They also compare between the basic ant colony algorithm and modified algorithm to show that they achieve their purpose by reducing the number of wireless networks for specific number of nodes.

They [17] presented the best and the worst-case formulations for sensor coverage properties in wireless ad-hoc sensor networks, in their work they solved coverage problem by generating Voronoi diagram for sensors then they transfer the diagram to a weighted graph and then they find the optimal path by using binary-search and breadth-first search.

The study in [4] worked in SPAN protocol that uses the hello messages between the nodes that each node checks if their a pair of neighbors that can't connect with each other by one or more hops if this case occurs the node will be active otherwise it will be off to save energy. The researchers in [18] used unreliable wireless sensor grid-network to find the conditions to cover the unit square region and ensure that the active nodes are connected; also they derived a sufficient condition for the failure rate of sensors to guarantee that an area is fully covered.

In this research, we try to improve the network efficiency by solving the coverage, minimizing the energy consumption and reducing the long travel to send the data, we used multi-agent technique to invest our goals.

3 . Multi-Agent System

In the sensor networks the nodes are close to each other that the neighbors exchange data about their location so when a node needs to spread a message, the source node knows the location of the destination node Then the message is forwarded to a 1-hop neighbor who is closer to the destination than the current node this procedure is repeated until the message reaches the destination [15]. This process generates a lot of redundancy data, wastes the wireless bandwidth and also consumes the battery energy [13]. Moreover, it is unsuitable for several reasons:

- Delay in receiving the data: in a multi-hop the data transfer from one node to another to reach its destination and any action the base station want to do, it must wait after the data received .also the commands that must send from sink to the nodes take amount of time to reach the target [10].
- The power consumption: the cost of transmission the data depends on the distance between the node and the base station and the number of hops in the path. The transmission and updated the status of

nodes consume a lot of energy [13].

- Data redundancy: sensor nodes are closed to each other that generate a lot of sensory data traffic and redundancy [13].

In our approach we tried to reduce the power consumption issue through sending the aggregated data to the sink. In order to do that, we reduce the transmissions between the nodes and the destination by using an intelligent sensor for collecting data from the target area and saving the processing data in its memory. In this case the node doesn't connect directly to the sink the intelligent agent is a destination for its group. Keeping on mind how to route these data that are collected by intelligent agents to the sink? For this process we used the intelligent agents for finding and aggregation the information from one node to another in the active areas. The intelligent agent sensor is a hybrid agent that can act and react in its environment [11]. It can respond to any changes that may happen. The intelligent agent sensor can be considered as reactive, social and proactive sensor that has social ability to interact with other agent in the system.

In this study the intelligent agent sensor is used in order to do some tasks as following:

- In every cluster there is an intelligent sensor works as cluster head for the nodes, the agent has local information about his cluster and also it can know information about the destination.
- Save the energy in the nodes by keeping them sleep when they are inactive and whenever the agent need information from specific area the status of the node will be active.
- The agent is decreased the number of hops that the node must visited until reach to the destination, in this work the agent will be the cluster head and there is no need to go in along travel to transfer the data and waste a lot of time.
- No data redundancy, the agent aggregated the data from its cluster and eliminated any redundancy that may occur in the closest nodes.
- Discover sensor node failures, if any node become fail or blocked, the agent will find a new links to solve the cutoff and update the node status to be idle.

4. Research Method

A set of assumptions were made for the network design. First the interior nodes keep sleeping until it has an event to do, in this case its status changes from idle to active. Second the node doesn't know any information about its neighbors, it just has data about the cluster head, and we deployed them in complex interactive system. Third an important point is to divide the network to grids because small size of grids helps to discover coverage holes and resolve it which providing a better result. Therefore, we divided the network to four regions and every grid has a delegate to control the coverage in its region.

In this study the research method is divided to four stages as following:

4.1 Sensor nodes deployment

We were generated a virtual network by using MATLAB. The network size is 200*200 meter. We spread 100 sensor nodes and choose a random position for the sink. As shown in figure 2.

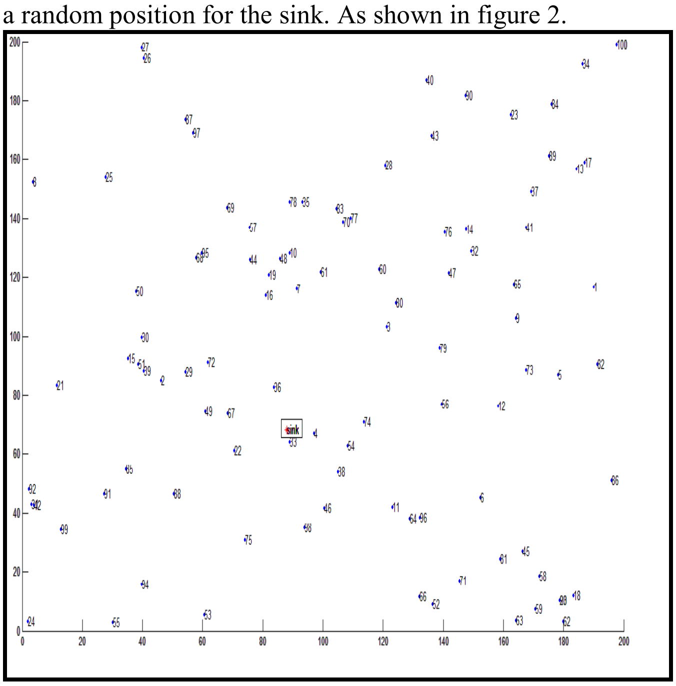

FIGURE.2: SENSOR NODES CONSTRUCTION BY MATLAB

4.2 Clustering the nodes by K-means algorithm.

Figure 3 represents the nodes clustering by using k-means method. It partitions the data into K clusters where K is the number of clusters desired, such that objects within each cluster are as close to each other as possible, and as far from objects in other clusters as possible [12]. K is equal to 10 that they are ten clusters in the network. This technique collects the closest nodes to one group and facilitates the control process

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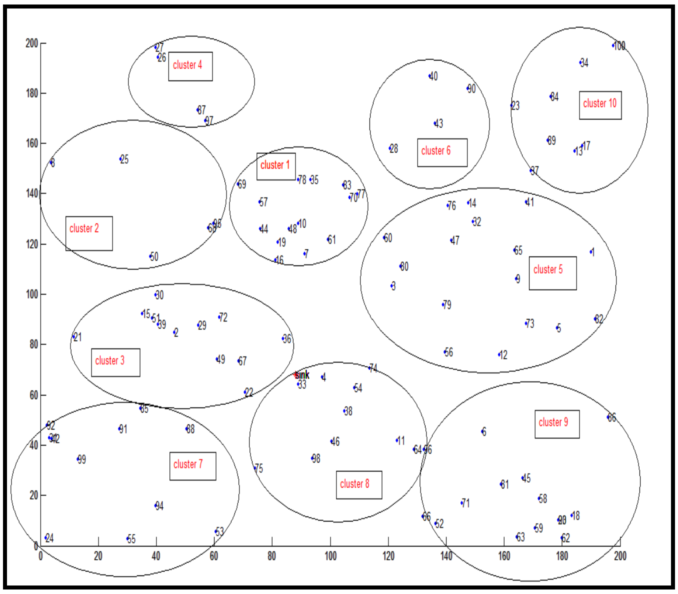

FIGURE 3. CLUSTERING SENSOR NODES BY K-MEANS ALGORITHM

4.3 Generate intelligent agents and spread them

The destination generate ten intelligent sensors equal to the number of clusters and put them in the center point of each cluster as shown in figure 4. The agent is the cluster head for the interior nodes and it is responsible for sending the data to the base station. This technique reduce the communication overhead and save the energy.

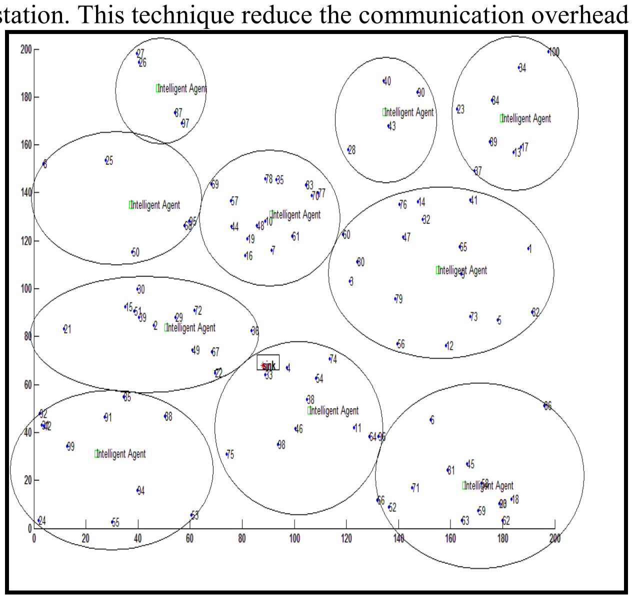

FIGURE 4. GENERATE INTELLIGENT AGENTS IN THE NETWORK.

4.4 Send data from intelligent sensors to the destination

In our method we try to avoid any failures that may occur by hardware or software through putting a smart agent to be responsible if any failure happens it will find alternative path to collect the data and avoid the coverage problem.

- First we divided the network to two sides according to the destination position, take the sink position and divide the area to left and right sides according to x-position as shown in figure 5.
- Second we divided the network to top and down areas also according to the y-position for the sink, The

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down side is for the agents that their (y) position smaller than (y) position for the sink, and the positions for the top side is greater than(y) sink position.

- Third we found the agents that are responsible on each class through calculating the distances between the agents and the sink, and then we take the minimum distance and choose this agent to be as delegate for his class.

Figure.5 shows how the data is routed form the classes to the sink. The dashed green line represents sending data directly to sink and the dotted red line represents sending data to the delegate.

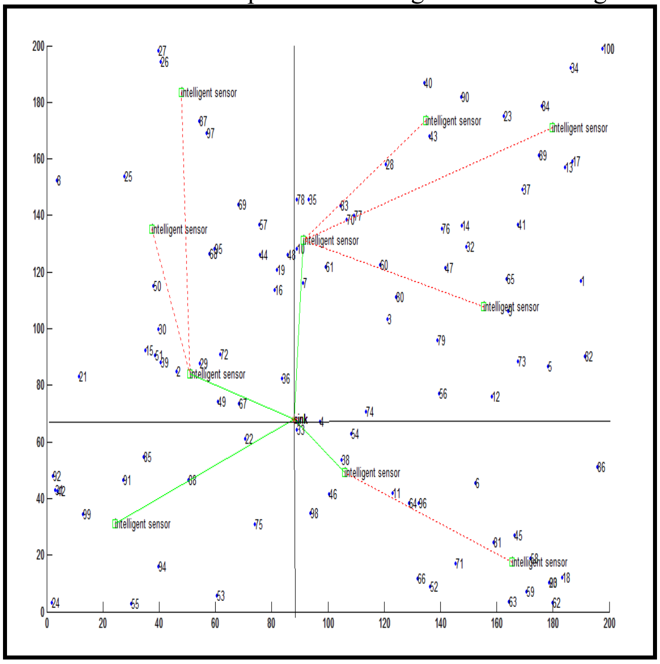

FIGURE .5: SENDING THE COLLECTED DATA TO THE SINK

5. the reults and discussion

We use TRMsim-WSN to simulate our network and compare it with static network, our work achieve the main goal that is the coverage by measure three parameters: accuracy, average path length and energy consumption.

We examine the efficiency of the network according to the appearance of the malicious nodes that provide a bad service, and they may have a negative impact on the performance of the WSN [6].

- The accuracy: represents the selection percentage of trustworthy nodes. It is important in measuring the performance of the network. Figure .6 represents the accuracy in static.

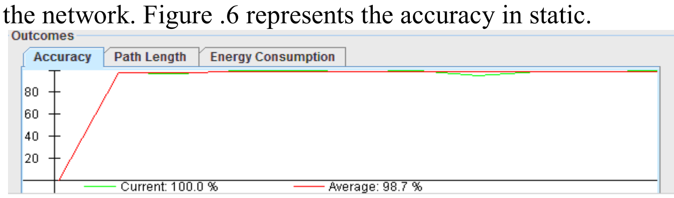

Figure.6: the accuracy value in static network.

And in figure.7 the accuracy value in our work is (99.5) that is better than the static network because the number of malicious node doesn't affect significantly in our network, but the malicious nodes effect in the static network as shown in table.1 .

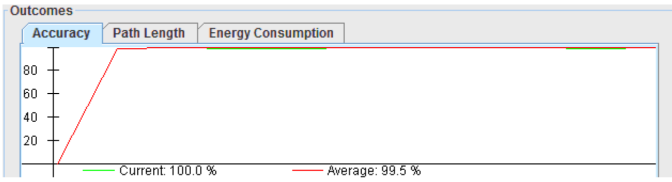

Figure.7: the accuracy value in our network

Table.1: the accuracy results.

	Percentage of malicious nodes			
	10%	**20%**	**30%**	**40%**
in Static network	98.9	86.3	78.4	67.3
in our network	99.6	98.05	97.6	96.2

- AVG path length: use to measure the number of hops in the path. It is assumed that less average path length represents better performance because:

1. ***Lesser number of intermediate nodes means higher security level and less energy consumption.***
2. ***Shorter path length implies that it is easier to find the trusted nodes .however the location of the sensors, distances between these sensors and the type of the topology will effect in the AVG path length.***

In figure.8 the average path length is 6.65 and figure .9 shows the value of the average path length in our network that is 2.06. This means the static network has long way to reach the destination and when we increase the malicious nodes, the average path length will increase.

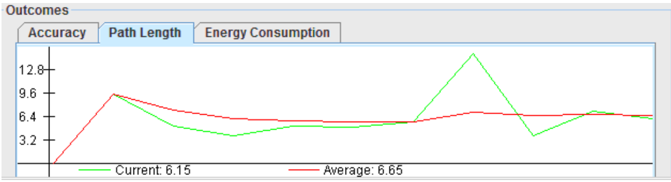

Figure .8: the AVG path length in static network.

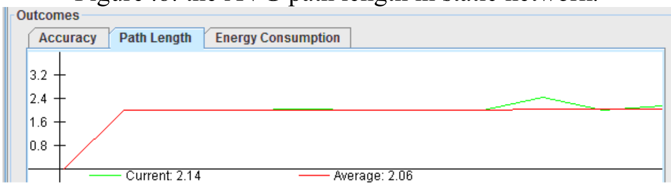

Figure .9: the AVG path length in our network.

Table.2 shows the average path length results according to the malicious nodes appearance.

Table.2: the AVG path length results.

	Percentage of malicious nodes			
	10%	**20%**	**30%**	**40%**
in static network	4.47	9.9	11.5	12.55
in our network	2	2	2.2	2.1

- The energy consumption of the static network is higher than our work because the sensor nods are always in the active mode but in our network the nodes are sleeping until they receive or send packets, in figure.11 we can see how our work reduced the energy consumption over the system. that the energy consumption in static is 25% as shown in figure.10 and in our network it is 10% .An important point that the travel path effects in the energy consumption where if the nodes pass through malicious nodes, the energy will be increase, so if the path contains malicious node or has many hops to reach the destination, the energy increases.

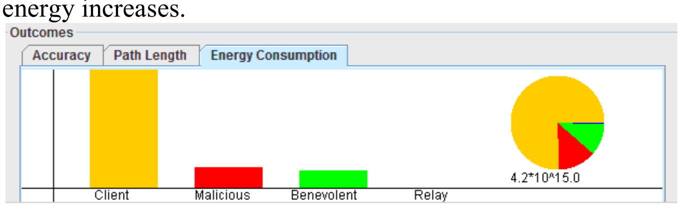

Figure.10: the energy consumption in static network

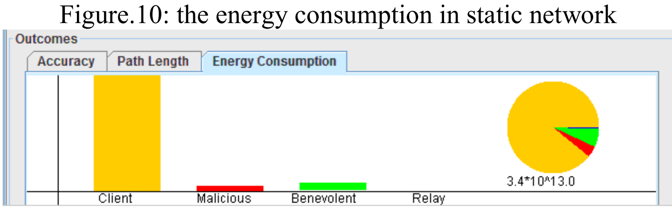

Figure.11: the energy consumption in our network

In table.3 d the energy consumption results as we can see in static network when the malicious nodes increase, the energy of the nodes will increase and in our network the appearance of the malicious nodes doesn't affect significantly in the energy .

Table.3: the energy consumption results.

	Percentage of malicious nodes			
	10%	**20%**	**30%**	**40%**
In static network	20%	30%	35%	40%
In our network	10%	10%	15%	15%

6.CONCLOUSIONS:

This study allows building the sensor network environment as an agent community that can work in distributed WSN. We add a new technique for routing the data in sensor network by using middle intelligent agents between the sensor nodes and the destination. The system also implements a new approach to control the network by dividing the network space into four grids; each of them has a delegate to be responsible on its region .In this work we achieve many goals such as:

- Reduce the energy consumption: by swapping the nodes state from idle to active for awhile if they have an action to do, also by reducing the number of the hops to reach the sink.
- Maximizing the network lifetime: by clustering the nodes into groups, then set the intelligent agent to be as cluster head that reduce the data traffics in its group .in this way there is no need to go in along travel to transfer the data and waste a lot of time.
- Improve search speed and search efficiency: by dividing the network space into four grids, each of them has a delegate to be responsible on its region and the intelligent sensor facilities the search by giving the sink the list of the nodes that are in its group.
- Reduce the data redundancy: just the aggregate data is sent to the sink.
- Coverage: we improved the coverage by controlling all the nodes using intelligent sensors and every intelligent sensor will cover its group also each delegate will cover its region.
- Automatic node failures detection and correction: if any failure happens in the network, our system will solve the failure using intelligent sensor capabilities.

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