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A new Energy Efficient Connected Target Coverage for WSNs

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ABSTRACT

The lifetime management of sensors is one of the most challenging concepts in targets coverage in order to increase the lifetime of sensor networks. One of the most famous approaches to deal with this situation is to divide the sensor nodes into temporary sets such that sensors of each set are capable of covering all targets independently in each period of time. Therefore, while a set of sensors are activated the other nodes change their status into energy saving. This issue could prevent the number of redundant active sensors which is in turn with energy conservation. In this paper, the problem of connected partial target coverage is analyzed where covering sets are allowed to monitor a subset of targets assuming that it is possible for adjacent targets to have similar information. Hence, when a target is covered, the proposed algorithm doesn't cover any target for a distance of M around the covered target. The introduced algorithm is capable to keep connectivity with the sink node while covers partial targets. This method that is named Improved Partial Coverage Heuristic (IPCH) computes the minimal connected partial K-coverage set. The performance of above method in terms of energy consumption, balance of energy consumption, number of live sensors and network lifetime is evaluated. Extensive experimental results are presented for different numbers of targets, M values and various energy levels. Results show that the network lifetime is largely increased.

KEYWORDS: Wireless sensor network**-** Energy optimization**-** connectivity**-** K coverage**-** Balanced energy consumption**-** Partial coverage

1. INTRODUCTION

Wireless sensor networks are constructed from small, autonomous sensors and are utilized for various measurement purposes. The problem of coverage is known as one of the most critical problems of these networks. The problem that is discussed through either centralized or distributed algorithms, so that each one has its own advantages and disadvantages. On the other hand, this problem could be considered as either of area or targets coverage. This paper focuses on centralized target coverage algorithms, in which most of their processing activities are processed with their Base Stations (BS), that do not have any limitations of energy consumption or processing. So sensors in these types of algorithms do not need any processing energy amount and cheaper sensors could be used. Moreover, targets methods against area coverage approaches cover some desired parts of an environment that are called targets. Therefore, these methods need fewer numbers of covering sensors and as it consequence their energy consumption will be reduced significantly. This issue shows its importance when it is mentioned that individual power capacity of the sensors are so limited (using batteries it may be only some days); however the expected useful lifetime of the network is required to be in the range of weeks or months, depending on the application.

Up to now several approaches have been introduced to decrease the energy consumption of sensors and consequently have a longer life for a wireless sensor network. In one way, it is capable to divide a network's total time into some determined periods, so that in each period a subset of sensors that cover network's targets are being activated while the others are deactivated or slept. Thus, in order to have time efficient networks, low duty cycle (the proportion of activated sensors of a network to its all sensors in each period) operations could be utilized. However up to now numerous works have been done in this regard, several problems are being unsolved yet, such as the problem of K-coverage targets, ignorance about challenges of data collection phase and also results transmission from BS to networks nodes, etc.

Therefore, in this paper an efficient algorithm is introduced in order to improve previous algorithms and solve the above problems. In most of applications it is needed to increase the targets coverage degree of a sensor network in order to increase its information accuracy. In other words, in redundant dense sensor networks various scheduling algorithms are used to control energy conservation. In sensor networks used to austerely monitor an area in space it may also be a requirement that *multiple* sensors be able to provide measurements from each point in space. This property may either be necessary because of the applied measurement technology, safety or performance reasons or to satisfy accuracy requirements with relatively low-quality sensors. High redundancy present in the network is

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necessary to achieve this goal. In general this class of problems can be treated as the k-coverage problem, where coverage means the ability of a sensor to perform measurements over a certain area. On the other hand, lifetime of every wireless sensor network could be maximized by the management of its targets coverage. In order to achieve this issue, with regard to the priority of a network's lifetime and residual energy amounts of its nodes in some applications, it is useful to assume that closed targets have similar information. Then we could just cover one of these closed targets with sensors and let the others uncovered so that as its consequence the number of activated sensors in each period is reduced appropriately. Furthermore, however prior methods do not consider novel facilities of sensor networks such as the capabilities of long transmission and data receiving from BS to the sensors, our presented method appropriately covers them.

To sum up, the problem of partial target coverage for covering sets that retain connectivity with the Base Station (BS) is analyzed in this paper. Furthermore, a greedy heuristic algorithm that computes the covering sets is proposed, by taking into account connectivity requirements as well as the impact of communication costs in order to increase the amount of a network lifetime. In Section II the main previous results are summarized. Section III introduces a centralized algorithm to provide robust k-coverage while minimize the number of awakened sensors at the same time. In Section IV new quality of service metrics are introduced and simulation results are presented to illustrate the capabilities of the proposed algorithms. Finally section V, is assigned for concluding from the presented algorithm.

Related Work

Sensor activity scheduling and having a particular coverage requirement in order to prolong the network lifetime has been studied in the literature [1].

This fact that sensors have two main tasks of sensing and communication are the main focus in sensor networks are considered on [2]. A sensor network should be capable of sensing and gathering information from an observation area and transmitting them to its sink nodes. The k-coverage problem is in association with the information gathering functionality [3]: each target must be covered by at least k sensors (k is determined by the application). There are many issues related to connectivity problem [4].

Recently, a lot of studies about the coverage problem in sensor networks have been performed. Specifically, the authors in [5] could design a centralized heuristic algorithm for a sensor network in order to select mutually exclusive covering sensors that independently cover that network region. The authors in [6] try to investigate linear programming method in order to optimally place a set of sensors on a sensor field for a complete coverage. The authors in [7] consider a different definition of coverage and study the problem of finding maximal paths of lowest and highest observations in a network. Connectivity is also a basic matter in wireless environment, and many solutions have been proposed to deal with the issue of energy efficiency besides of maintaining connectivity in the network topology ([8], [9], and [10]). In many researches it has been considered that connectivity and coverage are in an integrated platform. Authors of [11] consider an unreliable sensor network, and derive necessary and appropriate conditions for the coverage of an area and connectivity of a network with high probability.

The problem of scheduling sensor activities in order to have a complete coverage is discussed in [12, 13, and 14]. Maintaining partial (but high) area coverage is discussed in [15, 16]. Some recent advances on scheduling sensor activity to cover discrete targets are introduced in [17, 18, and 19]. Cardei in [20] models a discrete target coverage problem as a disjoint set covering problem. The problem is proven to be NP-Complete. In [21], the previous work of Cardei et al. in [20] is extended and discussed so that the network lifetime can be more improved without the limitation that the selected set covers are disjoint, i.e., a sensor may appear in different covers. Furthermore, Cardei could continue their work for a discrete target coverage problem with the assumption that sensors have adjustable sensing ranges [22]. It is noteworthy that connectivity is not considered in [20-22]. In [18], Lu schedules a sensor activity by self-configuring sensing range, for an environment where both discrete target coverage and connectivity are satisfied. However, only sensing power is considered in their energy consumption model. Further, the heuristic proposed in [18] maintains a network-wide connectivity, although it is not necessary for target coverage. In fact, only sensors those are required to be active along the routes carrying the sensed data. In [23] the authors assume that each sensor can freely select the target to observe and observe only one target at each time. With such an assumption, the authors propose an optimal solution based on linear programming and combinational matrix theory to find the target observation schedule that achieves the maximum network lifetime. The authors further investigate their work to the situation when each target is required to be covered by at least K sensors (K-target coverage) in [24]. Although, the connectivity problem is not discussed and the observation assumption used in [23, 24] is only a special case of the observation scenario discussed in our work. Maximizing network lifetime is an important subject in wireless sensor networks. In [25], the authors formulate the routing problem as a linear programming problem, where the goal is to maximize the network lifetime.

THE PROPOSED METHOD

3.1 Definitions and Assumptions

In the proposed method, it is assumed that some sensors have been scattered randomly in a field and each sensor knows its position, which can be obtained using either especial hardware such as GPS or localization algorithms. Also, sensing radius is (R_s) and communication range is (R_c) for all sensors. It is also assumed that $R_s < R_c$. Two parameters are introduced called K and M which are network coverage degree and the radius of uncovered area respectively. So considering that, whole targets should be covered with minimum of K sensors; M is a radius that if a target were covered, whole targets that are around the covered target and also are in the radius of M would not be covered. In addition, the coordination of all desired targets is known for each sensor.

It is assumed that n sensing nodes S= {s_1, s_2,...s_n} are scattered randomly with high density and also there are several c targets in a field. Each one of the nodes has an initial energy of E. On the other hand, the energy amount of every node is considered to be e_i for a time period. The energy amount of each sensor is classified into several levels with equivalent values of l_{ji} that are considered for N_i set. Another assumption in this protocol is that sensors are equipped with 3d cubic antennas. Using these antennas, it is possible to have both RFID technology and miniaturized wireless communication equipment simultaneously. The operation frequency lies on the UHF RFID band, 902 MHz–928 MHz (centered at 915 MHz). The ultra-compact cubic antenna has dimensions of 3cm × 3cm × 3cm, which features a dimension length of $\lambda/_{11}$.

The cubic and hallow shape of the antenna allows the sensor equipments to be easily and smartly integrated and packed inside of that. The shape of this antenna is shown in figure 1. Long transmission ranges for BS and safe information receiving for sensors are possible in such a frequency band by using above-mentioned three dimensional antennas. Notice that long range transmissions of BS are one hop.

3.2 Motivation

This method is based on a greedy algorithm working on network connectivity graph and most of processing task of the algorithm is centralized in the sink node. The offered method in this paper is an optimized version of the Partial Coverage Heuristic (PCH) algorithm proposed in [26]. That is because it is named Improved Partial Coverage Heuristic (IPCH) in which tries to mitigate some of its problems like:

- Network heterogeneous coverage
- Differentiating between coverage and relay sensors.
- Lack of implementation for an important part of the algorithm: Collecting information from the network and finally sending the processing results from central node to whole network nodes compose an important part of a centralized algorithm which is ignored in PCH.
- K coverage of targets: PCH doesn't consider covering problem with k ≥ 1.
- Ignoring some abilities of sensor networks. Not all capacities of sensor networks are considered such as the ability of base station to send its data over a far distance and computational ability and memory
- Capacity of base station and new antennas.
- Not eliminating redundant nodes
- Imbalance energies of nodes

3.3 Procedure of the proposed method

The IPCH method includes four phases.

3.3.1 First phase: collecting information

The goal of first phase is collecting information from whole network and forwarding data to sink node in order to select a group of nodes to be activated in that round and rest of them sleep. For this reason, all sensors in each period should send information include number of neighbors, their ID and also their energy to the base station.

To prevent broadcasting and flooding the network, in the first round, sink node broadcast a token in the network so that the received token is forwarded by all nodes. When a token received to a node, that node saves its transmitter's ID, and then rebroadcast that token. Finally, there would be a shortest path from each sensor to the sink node. Figure 2 shows the function of token packet. In figure 2-A all sensors are shown with sink, and figure 2-B shows the created routes by the token packet. After this procedure finished, each node knows its determined path in order to access to the sink node if there would be any information for transmission. So the problem of information broadcasting through all the network's nodes could be prevented dramatically.

Figure 1: The antenna used for sensors

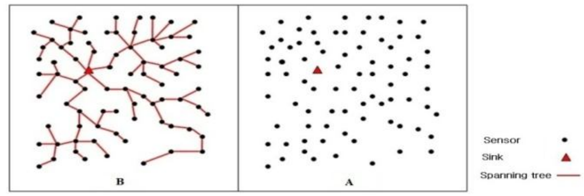

Figure 2: A- Sensors scattering in the field, B- Rotes to the sink

Moreover, an alternative lemma could be considerable in order to decrease energy and transmission information to the sink node consequently. Thus, before sending any information to the sink, each node investigates any change in the list of neighbors and its energy. If there would be any change in the investigated data the node sends the adapted information. Otherwise there would be not any information to send. In this condition, the base station could execute its main algorithm with the information of its previous period.

In this stage, each node sends a Hello Packet with one hop to neighbors and each neighbor node in response this packet return its ID to initial node. In order to decrease transmission numbers of data collection packets to the sink node which are included by the amounts of instant energy of each node and number of its neighbors, it is capable to classify the amount of energy into several levels. While the energy amount of a node has not decreased from one level to lower one, that node assumed that nothing was changed.

Therefore, it is just necessary for each node to compare its present parameters of energy level and the number of its neighbors with their previous amounts. If there would be any change in the amounts of each those parameters, that node is responsible for sending its new data collection packet to the sink node, as demonstrated in figure 3.

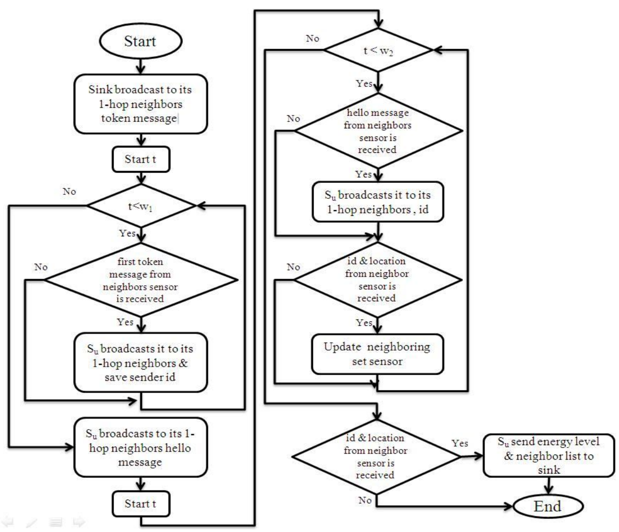

Figure 3: The process of data collection in phase one

3.3.2 Second phase: Information Processing

The purpose of this phase is to select a group of sensors to be active in the next round, which is run on the sink. The main parameters of this phase are the gathered information from all network sensors. If there was no any receiving message from a group of sensors in a cycle, the BS assumes that information of these sensors including their energy level and list of their neighbors has not been changed in relation to their previous stage. Thus, the BS uses the same information to run the algorithm. Also, in addition with the gathered information, two other parameters which are K that shows network coverage degree and M (radius of not covering area) play the role of new inputs for the algorithm. In each cycle, after sending all massages from whole network sensors to the sink, algorithm uses this information to make a graph which is called G. The vertices of this graph are all network nodes and its edges are the possible communication links between them. It means that one edge E_{ab} is between two sensors s_a and s_b which are in their communication that is shown in relation (1).

$$|s_a - s_b| \le R_c \rightarrow E_{ab} \in G \quad (1)$$

Graf G is a weighted graph in which the weight of each edge is computed through relation (2) that is the maximum number of energy degradation among two sides of an edge plus one. If the energy level of a node decrease from a particular threshold this node eliminates from graph and it is not consider in computations of the algorithm.

$$weight_j(E_{ab}) = l_{max} - min\{l_{ja}, l_{jb}\} + 1 \quad (2)$$

In next stage, considering that sink knows all coordination of existing targets in network, sink selects those sensors that have at least one target in their sensor radius. Then dijkstra algorithm implement on graph in order to select lowest cost route to the sink for all sensors, then access cost for each existing node saves in S_s set with its route. These costs are updated by using the relation (3). In this relation two constant coefficients α and β are defined, which are selected based on consuming energy or further ranges of covering targets in network. Using α for old cost and β for the number of under coverage targets the new cost is updated. After updating procedure, existing sensors are arranged from low to high in S_s set based on their access costs. The sensor which has the lowest cost is selected from S_s and is transmitted to S_c. After the selection of each sensor and transmission of that to S_c, the following processes will be done respectively.

$$new\_cost_j(v_i) = \alpha cost_j(v_i) - \beta|Targets_i| \quad (3)$$

I. If this sensor covers more than one target, the one which is the nearest to the sensor is selected as main target and the rest are considered as secondary targets. Then all targets where are existed in a circle with a radius of M around the center of main target are in the uncovered area and then they are eliminated from the list of covered targets.

II. Number of under-covered targets of sensors in S_s set is updated and nodes' costs are recalculated. Eliminated targets from previous stage eliminate from the list of under-covered targets and the sensors which do not have any target in order to cover that are eliminated from S_s set as well.

III. Then k-1 another sensors from S_s are selected so that cover the main target and also have lowest costs. These sensors are omitted from S_s set and are added to S_c.

IV. The above stages continue until the S_s set gets empty.

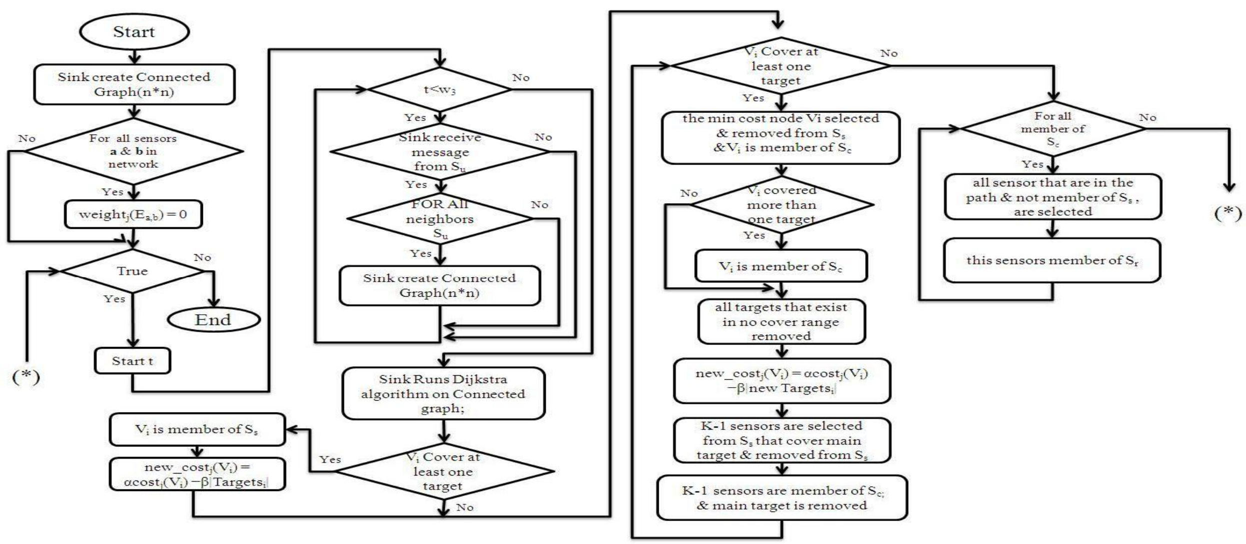

Figure 4: A flowchart for information processing in phase two

After the selection of all the covering sensors, in order to it is needed to determine the forwarding sensors in order to transfer the sensed data to the sink. Each sensor in S_c has a list of sensors along the generated route between itself and the sink which should be added to the set of S_r if they are not in the S_c. Finally, S_c and S_r include all sensors that are needed to be active for the coming round and the rest of sensors should change their mode into sleep until the end of that round. All of this procedure is completely illustrated in figure 4.

3.3.3 Third phase: Redundancy eliminating

Input of this phase is S_c and S_r and the goal of that is to eliminate possible redundant nodes. In fact, we want to make a minimal connected coverage set. The stages of this phase are as follows:

Initially all sensors are unmarked,

I. Select an unmarked sensor with minimum connectivity degree.

II. Investigate whether the elimination of this sensor leads to either disconnect the connected coverage set or not?

III. If elimination of the sensor doesn't disconnect the set, then eliminate it and otherwise mark the sensor.

IV. Repeat the stages of 1 to 3 until all sensors of the set are marked.

3.3.4 Forth phase: Transmitting the results

Now, all sensors should be aware of their status which could be either sleep or active for the coming round. Hence, sink node make a list of those sensors that should remain active and broadcast the list. While each sensor receives this message, it looks for its ID in the list and then forwards it to its neighbors. The whole of this process is shown in the figure 5.

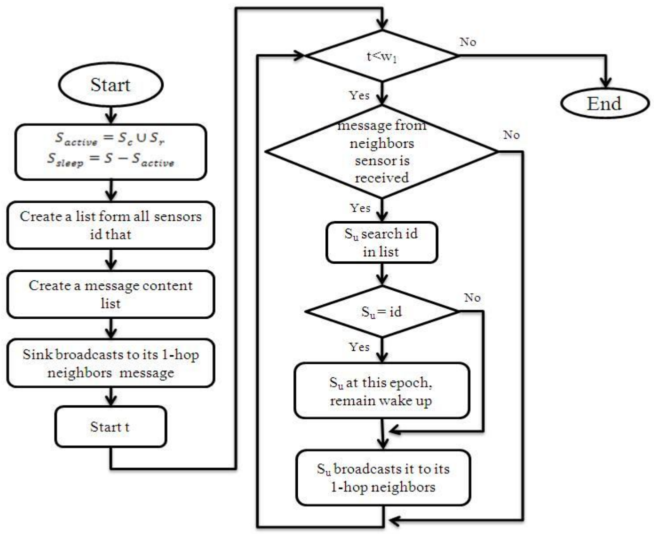

Figure 5: transmitting the results in one view

In this phase, the capability of BS can be exploited so that BS can send the message including a list of active sensors in one hop with a high transmission power in 915 MHz. Also, each sensor is equipped to a 3-D cubic antenna that works in 915 MHz [9] to receive BS's data. When sensors in the field receive the message they decide whether to be sleep or remain active for the coming round. Consequently, in order to save energy, the operation of broadcasting of network's nodes will be prevented.

It should be noted that in proceeding methods, with consideration of each node's information transmission to the base station and base station's obtained results transmission to the network, those nodes that are placed around the sink node use their energy amounts more and die sooner than the other nodes so that we have a useless network. In consequence, the energy usage of network's nodes will be being imbalanced. As it will be demonstrated before in both phases one and four, our proposed method could desirably solve this problem.

2. Evaluating the proposed IPCH method

4.1. Evaluation and simulation

Using C++, we developed our simulation environment that is appropriate to the proposed method. The simulation software have some inputs like communication range, sense range, number of targets and their coverage degree, number of sensors in the field, maximum energy for transferring a data unit, uncovered radius (M), time of a cycle, time of the simulation and etc. A 400*400 environment is considered for the simulation.

4.2. Simulation assumptions

In the following we introduce some assumptions for the simulation process.

It is assumed that 800 sensors are scattered in the field and there is a sink in the centre of the field. Communication and sensing ranges of sensors are 40 and 30 respectively. The initial energy of each sensor is 10000 mw/h and the energy amount of consumption for each sending and sensing operation are 10 mw/h and 5 mw/h respectively. In the relation with waiting time it is assumed $\alpha = 0.5$ and $\beta = 0.5$. Each simulation run is repeated for 1000 times.

4.3 Active sensors in PCH and IPCH methods

In this section, the proposed method is compared with PCH from the point of average number of needed sensors to cover the targets in each period. In this comparison, since PCH doesn't consider M>0 and K>1, it is assumed that M = 0 and K = 1. Moreover, the number of scattered sensors in the field is 400 and the number of targets will be varied from 1 to 30.

Figure 6 shows the influence targets' number which would to be covered on the number of active nodes. The proposed method has been evaluated with different covering degrees. Assuming M=0 and K=1, the both of PCH and proposed method have similar performances. However it would be clear that according to the improvements of the proposed method in several points, it indicates better results. In this paper because of closed output averages of both of proposed and PCH methods for large numbers of entrains, they are not separated from each other.

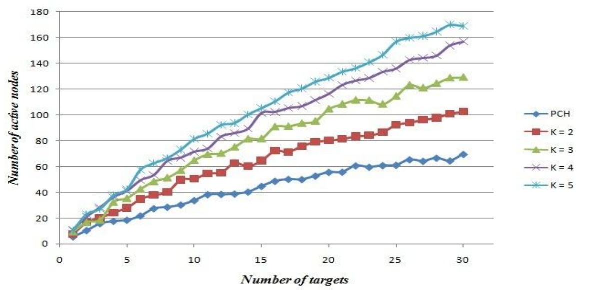

Figure 6: influence of targets' numbers with different K values on active nodes

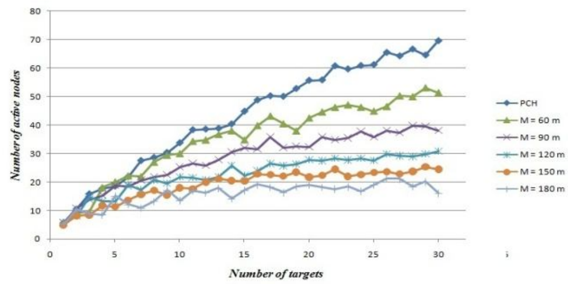

Figure 7: Effect of number of targets on number of active sensors with different values of M

It is obvious from figure 6 that while the number of under-covered targets is increased it is needed to have more sensors to cover targets and forwarding the sensed information to the sink node. On the other hand, the number of active nodes will have an ascendant trend while the coverage degree is increased for an individual under-covered target.

Figure 7 depicts the impact of M (radius of not covering area) on both PCH and proposed methods. Different values of M have been experimented. It is clear that while M increases, fewer number of activated sensors would be needed because a fewer targets are covered, in which that is caused to energy saving and prolong the lifetime of the network. On the other hand, bigger values of M have smaller slopes of increment. For instance, as it is shown in figure 7 when M=60, the slope of the diagram is far more than the case in which M=150. Hence, the expansion of M it not suitable because in proportion with the loose of large pieces of coverage area, lower amounts of energy would be saved.

4.4 Energy consumption in PCH and IPCH methods considering number of targets

One of the important parameters in evaluating different sensor network applications is energy consumption. In this simulation the algorithms run for 15 cycles, in which in each cycle, every target covering node sends a message to the sink and each data forwarding node consume 30 mw/h energy. In this simulation it is considered that K=1 and M=0, and the amounts of Communication and sensing energy for each sensor are 5 and 2 mw/h respectively.

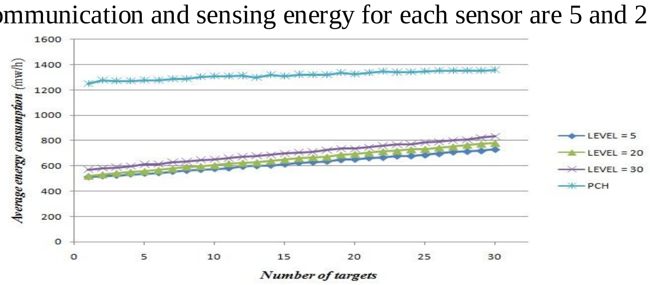

Figure 8: Average energy consumption considering number of targets and energy levels

Considering the results shown in figure 8, it can be understood that having energy levels in the algorithm causes a significant drop in energy consumption. This is due to elimination of redundant communications between sensors and the sink. Notice that while the number of energy levels is less than a threshold amount their influence on energy consumption will be slight and on the other hand that could disarrange the balance of energy consumption.

4.5 Balance of energy consumption in both PCH and IPCH methods

Balanced energy consumption is a desirable parameter in most sensor network applications and it usually has a direct effect on networks' lifetime. It is assumed that number of targets are 30, M=0 and K=1. In this simulation, nodes are categorized in 100 different levels of energy. Each level has a range of 100 (mw/h). For example in 99's category, those sensors that have the energy amount of 9800 to 9900 (m/h) are classified. The balance of energy consumption for IPCH method with 5 levels, 20 levels, and the PCH results are shown in Figures 9, 10 and 11 respectively. When the number of levels is 5 due to limited levels of energy, many fewer data collection messages are sent to the sink and a same group of sensors is selected by the sink for consecutive cycles. This causes that a group of sensors dramatically lose their energy while other sensors still has not used their energy.

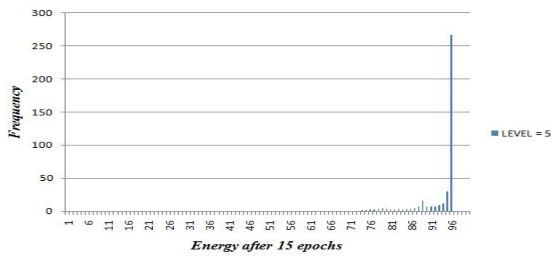

Figure 9: Balance of energy consumption; levels = 5

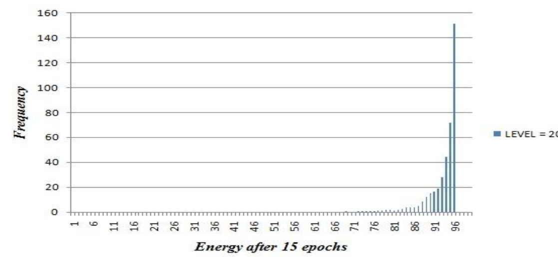

Figure 10: Balance of energy consumption- levels = 20

In figure 10 this issue is demonstrated again for 20 levels. Same event happens again although the intensity of that in comparison with the previous case is lower owing to having more levels that causes frequent updates of nodes' energy. Hence, a same group of sensors are selected for a fewer rounds comparing to the case of energy levels = 5. In other words, it is permitted to more different sensors to participate in the process of covering during continuative cycles. Hence energy consumption is more balanced. In fact if there were more energy levels, the balance of energy consumption is increased. Figure 11 shows the same situation for PCH. Since in this algorithm all sensors send their information to the sink in each round, sink is always updated and it can be inferred that almost in each round a new group of sensors are selected. Figure 11 demonstrate this and most of the categories have some members. And most of the sensors are participated in covering process.

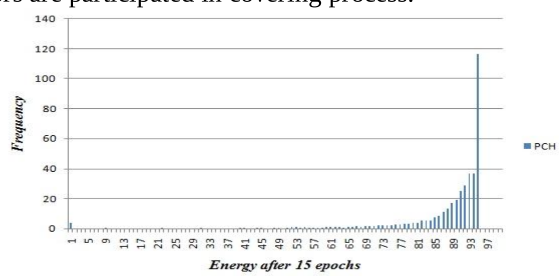

Figure 11: Balance of energy consumption- level PCH

Since the aforementioned figures cannot illustrate the whole situation, in order to gather more information we have computed the average and standard deviation of the categories. Table 1 shows these results.

Table 1: Average and standard deviation of remaining energy in different categories

Method	Levels = 5	Levels = 20	Levels = 50	PCH
Average ***(mw/h)***	9315.572864	9267.957362	9138.108859	8636.860049
Standard deviation	490.1317	449.4950	673.5164	1533.53400

Considering table 1 the average of temporary energy will become less if the number of energy levels become more. Because while the number of energy levels increases, the number of data transmissions to the sink increase.

About the standard deviation it is inferable from the table 1 that increasing the number of levels, at first reduces the amount of standard deviation but later it grows. This is because when the number of levels increases, more sensors' numbers participate in the covering process that leads to more balanced energy consumption and subsequently smaller standard deviation. While the number of energy levels becomes more than a threshold value, it could cause more packet transmission specifically for those sensors that are closer to the sink that in turn causes imbalanced energy consumption and subsequently increases standard deviation. Therefore, the number of energy levels should be carefully determined.

4.6 Effect of uncovered range (M) on the lifetime

The Lifetime of every wireless sensor network is one of its most important parameters of that. In this section it is tried to calculate the lifetime of a network based on different uncovered radiuses (M).

It is intelligible from the figure 12 that the network's lifetime is increased when the amount of M becomes greater. That is because of the avoidance of using more sensors for covering the targets. Thus larger amounts of energy are saved in nodes and finally increase lifetime of the network.

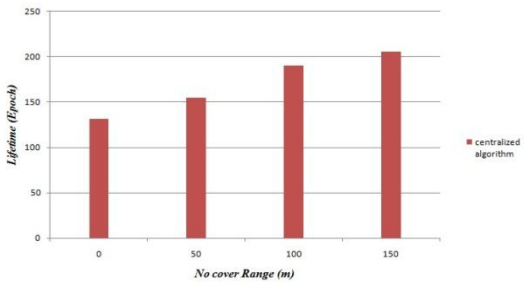

Figure 12: Effect of uncovered range (m) on the lifetime

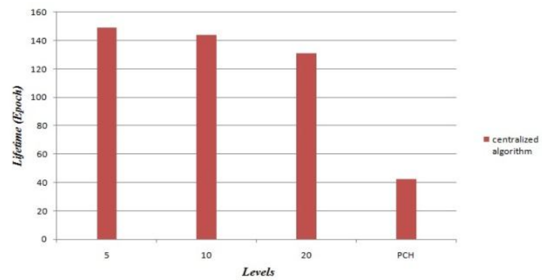

Figure 13: Effect of energy level on the lifetime

4.7 Effect of energy levels on the lifetime

In this paper we introduce the energy level as another parameter of sensor networks which effects their lifetime, in which it could determine the frequency of information updating. While there are fewer levels of energy, the number of energy variations update messages becomes less. This cause more energy conservation and leads to prolonging the lifetime of the network.

Although fewer energy levels has the favor of fewer number of data collection messages, too fewer levels could lead to unawareness of the sink node about the energy levels of sensors in which it could not select appropriate nodes. This in turn causes energy degradation and reducing lifetime of the network. Hence a tradeoff for the choosing of the number of energy level should be performed. The influence of energy levels on the network's lifetime is shown in Figure 13. It is clear from this figure that the classification of energy into 5, 10 and 20 levels could dramatically increased the network's lifetime in comparison with the PCH algorithm. However the differences of network's lifetimes between the categories which involve 5 and 20 energy levels are not perceptible.

5. Conclusion

In this paper the problem of connected partial target coverage is analyzed. We developed an energy efficient greedy heuristic algorithm that could provide the same target coverage as PCH algorithm which is named IPCH. In this way, it was assumed that adjacent targets probably have similar data. Therefore, in order to cover a target, it was avoided to cover those targets that are in the circle around it with radius M. The results of this paper revealed that by using the parameter M in the partial coverage of targets an efficient management algorithm is created. Moreover, K-coverage of targets and connectivity were considered in the proposed algorithm. IPCH could merge both capabilities of covering and relaying in an arbitrary node, so that could minimize the number of its activated nodes per cycle. In this work we categorized the energy amounts of nodes into several levels, and also used the BS as a leading node in order to run our proposed algorithm and transmit its information for long distances just in one hop. Therefore, the number of transmitted packets dramatically reduced. Finally an efficient algorithm that balances and minimizes the energy consumption of a sensor network was defined. The simulation results of our proposed method indicated that the most critical parameters of sensor networks such as energy usage, number of transmitted packets, number active nodes and their lifetime were improved noticeably.

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