Energy Efficient Cell Survival and Cell Merging Approaches for Auto-Configurable Wireless Sensor Networks

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Abstract— **In practice, sensor nodes (SN) are battery-powered devices and the variant rate of depletion of power in the devices can hamper the network's efficient operation as the node lifetimes directly affect the network lifetime of wireless sensor network (WSN). There are normally, in practical systems, certain considerations taken at each layer to prolong the network lifetime. This paper focuses on the topology control process. The authors propose a new auto-configurable algorithm to re-organize the network topology efficiently. The proposed algorithm merges both cell merging and cell manager selection process together and is applied in clustered homogeneous cellular architecture. The simulation result proves that the proposed algorithm consumes less power and consequently prolongs the network lifetime than the existing auto-configurable algorithm.**

Index Terms— **wireless sensor network, auto-configuring or self-configuring algorithms, cell merging, clustering**

I. Introduction

A wireless sensor network can be divided into three major segments like sensor components, microelectronic systems and a wireless network. The devices that are used in wireless sensor network contain four fundamental units: power supply unit, central processing unit, data communication unit, and sensor component, altogether form an embedded system. Nowadays, the advancement of the microelectronics makes low-power smaller size inexpensive sensors. Sensors which build the backbone of wireless sensor networks operate at a predetermined set of instructions, the problem becomes very serious when these batteries are not rechargeable and in practice a significant amount of power is spent for processing of transmission and reception of information. The variant rate of depletion of energy in the nodes can seriously hamper the network's efficient operation and therefore its lifetime [1]. For this reason, WSNs have to be self-configuring or self-healing in case of any type of failure and these processes should be optimized so that failure could be recovered by consuming less amount of energy. Therefore, the energy should be maintained and used in a planned way by the sensor networks through efficient survival algorithms. As a result several algorithms and approaches came out with energy efficient solutions for WSN. The purpose of this paper is to demonstrate energy efficient algorithms for self-configuring WSN which will consume less energy than other existing algorithms and prolong the network lifetime. The concentration of this paper is on cell manager selection process and cell merging technique. For simplicity, the proposed algorithm is applied in homogeneous WSNs.

This paper is organized as follows: Section 2 provides a detailed description of the existing algorithms and approaches. The auto-configurable algorithm and its extended version have been described in section 3. Section 4 explains our proposed algorithm. Section 5 presents simulation results and performance evaluations. Finally, section 6 concludes the paper.

II. Related Works

In wireless sensor network, energy efficient communication is the subject of survival of a network. As a result, the researchers are mostly focused towards energy efficient communication, energy management, and extending the network lifetime. The Low-Energy Adaptive Clustering Hierarchy (LEACH) has been proposed in [2] that utilizes a randomized periodical rotation of cluster heads for balancing the energy load among the sensors. This LEACH is further modified in [3] named LEACH-C (Centralized) which uses a centralized controller for selecting cluster heads. The main shortcomings of these algorithms are the selection of non-automatic cluster head and the requirement that the position of all sensors must be known. Another extended version of LEACH's stochastic algorithm is described in [4] with a deterministic cluster head selection technique. Though, this algorithm increases network lifetime compared with original LEACH protocol, it did not solve the previous shortcomings. In [5], the optimal cluster size and the optimal assignment of sensors to cluster heads have determined using the Ad hoc Network Design Algorithm (ANDA). This maximizes the network lifetime but a priori knowledge of the number of cluster heads, number of sensors in the network, and the location of all sensors is required. The Weighted Clustering algorithm (WCA) [6] considers

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Figure 1. Classification of power savings approaches in WSN [24]

some parameters while choosing clusters such as the number of neighbours, transmission power, mobility, and battery usage. The number of sensors is limited in this algorithm for a cluster so that cluster heads can handle the load without degrading the network performance. These clustering algorithms need synchronous clocking for exchanging information among sensors nodes which limits these algorithms to smaller networks [9]. M. Bhardwaj and A. P. Chandrakasan in [10] derived upper bounds on the lifetime of sensor networks, while J. Zhu and S. Papavassiliou in [11] presented an analytical model to estimate and evaluate the network lifetime. In [12], provides a globally optimal solution through graph theoretic approach to the problem of maximizing a static network lifetime. In [7, 8], the authors used a decentralized algorithm for clustering an ad hoc sensor network. Each sensor monitors communication among its neighboring clusters and makes decision (based on the number of neighbors and a randomized timer) either to join a nearby cluster, or else form a new cluster with itself as cluster head. In [13-23], the authors proposed several optimized cluster head or cell manager selection algorithms and approaches. However, these algorithms and approaches used some complex methods for communicating and monitoring neighboring clusters and can be classified as in Fig. 1. Following these existing algorithms and approaches, we come up with a modified algorithm in case of cell manager failure for enhancing the cell survival time and an energy efficient cell or cluster merging algorithm for self-configuring WSNs.

III. Extended Auto-configuring Algorithms

First the existing auto-configuring algorithm has been extended using a new cell manager selection process and later on a new algorithm has been developed in the next section through combining cell merging and cell manager selection process together. When the residual energy of the cell manager is less than or equal to 20%, cell manager will choose the next higher energy (energy greater than or equal to 50% of its residual battery energy) node to assign it as new cell manager from the energy list which is maintained by the cell manager itself and being updated periodically from the messages sent by the member nodes. This is an energy efficient algorithm for self-organizing WSN in case of cell manager failure (Fig. 2).

If there is no such node found whose residual battery energy is greater or equal to 50% to take the responsibility of the cell manager, cell merging activity will take place. The cell merging or cluster merging process is a high energy consuming technique for the survival of the clusters. For understanding cell merging process a scenario has been shown in Fig. 3. There are 9 cells or clusters and the header of cell 5 is no longer available to perform its regular operations. So members need to join a new cell header.

The cell merging process will be done through following steps:

The neighboring cell managers broadcast a “Join_in” message to sensor nodes in the event cell.

To notify the available cell managers, the ”Join_in” message of neighboring cells is delivered to all of the sensor nodes in the event cell.

Sensor nodes in the event cell select the appropriate neighboring cell to join in by checking the minimum hop count and the residual energy of that neighboring cell manager. The nodes then reply acknowledge message to the selected cell manager once they have accepted a cell manager.

Now let’s see how these steps will be applied on our example. The following tasks will happen:

Each node in the event cell (e.g. cell 5) has been aware about the unavailability of the cell manager. They are waiting for the “Join_in” messages from their neighboring cells.

Neighboring cell managers start to broadcast „Join_in‟ messages and wait for the acknowledge messages from the nodes of the event cell.

After receiving “Join_in” messages, a designated node first checks whether it belongs to the event cell. If not, it modifies the hop count of packet and rebroadcasts it.

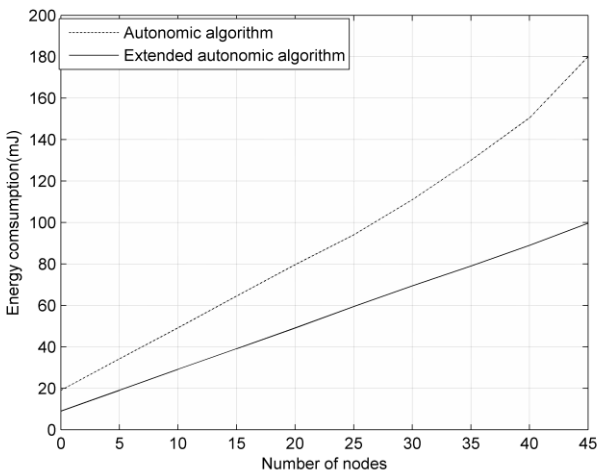

Figure 2. Comparison between the autonomic and existing algorithms of self-configuring WSN

A node in the event cell (e.g. cell 5) records the following information of cell manager upon receiving the "Join_in" message: cell_id, node_id, residual battery energy of the source cell manager and the number of communication hops.

When the node again receives „join_in" message from the same cell manager, it drops the packet for reducing redundant message transmission in the network.

If the node in the event cell receives the „join_in" messages from different cell managers (i.e. from cell 1, cell 2, cell 3, cell 4, cell 6, cell 7, cell 8 and cell 9), it selects the right cell manager by considering maximum residual energy and minimum hop count towards the source cell managers. Thus it selects cell 2 with fewest hops and sufficient residual energy to merge with which is indicated by blue arrows in Fig. 3.

IV. Proposed Algorithm

In this paper, a new algorithm has been proposed for enhancing cell survival time and energy efficient cell merging process. In the extended auto-configuring algorithm, when residual energy of the cell manager is low (less than or equal to 20% of its residual battery energy), cell manager will select the next high energy node and appoint as new cell manager from the energy list which is being periodically updated from the messages sent by the member nodes. A member node should have greater or equal to 50% of its residual battery energy for being appointed as cell manager. If there is no node (residual battery energy is greater or equal to 50%) to take cell manager's responsibility in that cell, cell merging activity will take place which is shown in Fig. 3. In our proposed algorithm, we are considering an additional condition for selecting a new cell manager in case of current cell manager failure which is explained below-

1) Search for a member node having energy greater than or equal to 50%
2) If no such node found, search for a member node having energy greater than or equal to 25%
3) If no such node found, initiate cell merging procedure (modified).

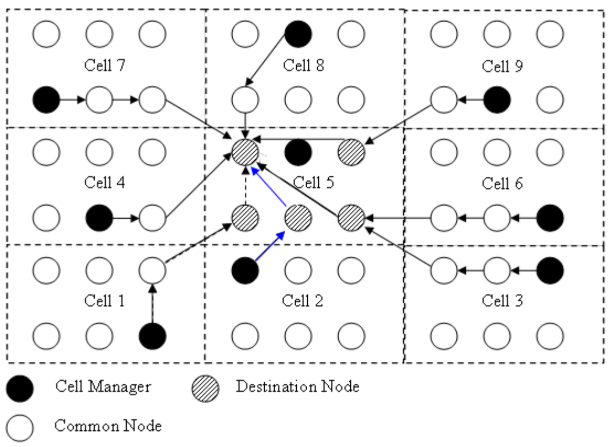

Figure 3. Clustering or cell merging process

The aim of considering the second condition is to extend the operational lifetime of a cell. Other recovery procedures like physical replacement, maintenance etc can be done during this extended survival time. For the third condition, we are proposing a modified cell merging process which will consume less energy. Cell merging is an energy consuming process because it involves all nodes of the event cell and all cell managers in the group for exchanging messages. Cell managers frequently send update message to their group managers consisting of residual energy level of cell members, and the number of available nodes in the cell. Following receiving and aggregating update messages from cell managers, the group manager gets an overview about its group status and constructs a topology map. Thus, the group manager is capable of taking proper actions (e.g. altering the cell formation) according to the events or changes in the group. In case of failure of cell manager,, the border nodes of virtual cells are capable of merging together to produce a large cell. In the proposed algorithm, we are proposing some modifications in cell merging technique which will consume less energy. Proposed steps for cell merging are as follows:

1) Cell manager will inform its group manager that there is no node to take cell manger's responsibility and appoint a border node to communicate with the neighboring cell manager.
2) Group manager will check the energy list which contains energy status of the cell managers of that group. Every cell has a unique id number. Group manager will search the energy list by cell id to find a cell which has minimum hop count i.e. adjacent to the event cell and has a cell manager having higher and sufficient residual energy. Then the group manager will instruct that cell manager to broadcast a "Join_in" message to the event cell.
3) The appointed border node will start communicating with the selected cell as a merged cell.

The detail flow charts of the two proposed algorithms are given Fig. 4 and 5.

V. Peformance Evaluation

The performance of the proposed algorithm is evaluated using the network simulator NS2 [25, 26] which is given in Fig. 6 and 7. Number of sensor nodes is varied from 10 to 300. Each sensor is assumed to have an initial energy of 2000 mJ.

In the existing auto-configuring algorithm, when a cell manager's residual battery energy becomes low, it looks for a node whose energy is greater than or equal to 50% of its residual battery energy. If such node exists, it will be designate as the new cell manager. If no such node found, traditional cell merging process will take place which consumes high energy.

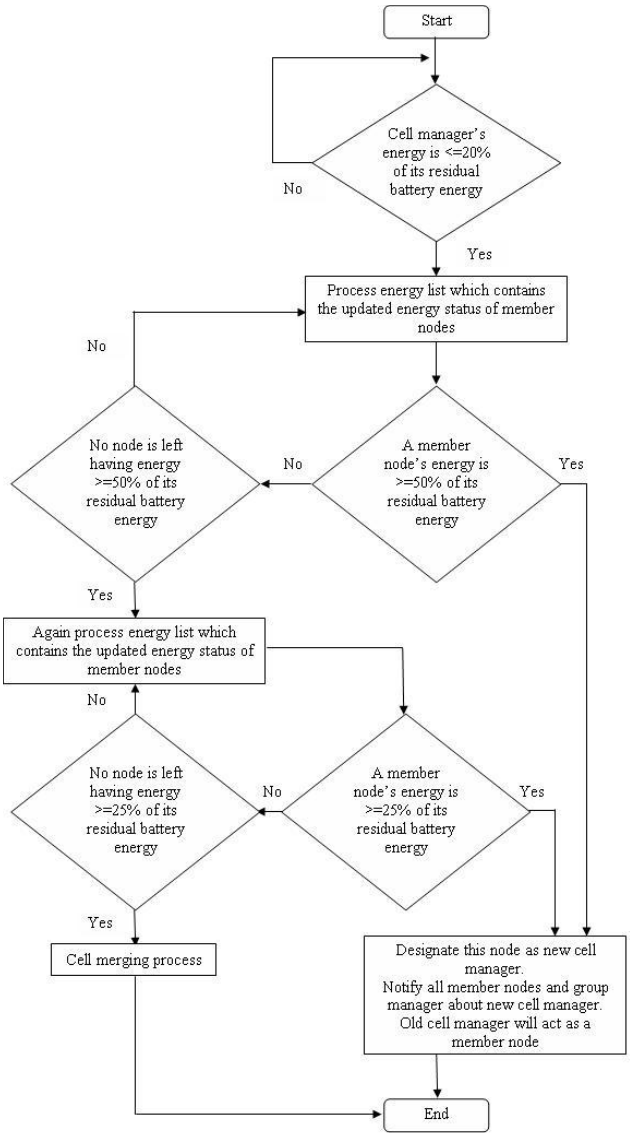

Figure. 4. Flow chart for cell manager selection

In the proposed algorithm, when a cell manager's residual battery energy becomes low, it looks for a node whose energy is greater than or equal to 50% of its residual battery energy. If such node exists, it will be designated as the new cell manager. If no such node found, the cell manager looks for a node whose energy is greater than or equal to 25% of its residual battery energy. If such node exists, it will be designated as the new cell manager. If no such node found, cell merging process will take place in our proposed scheme.

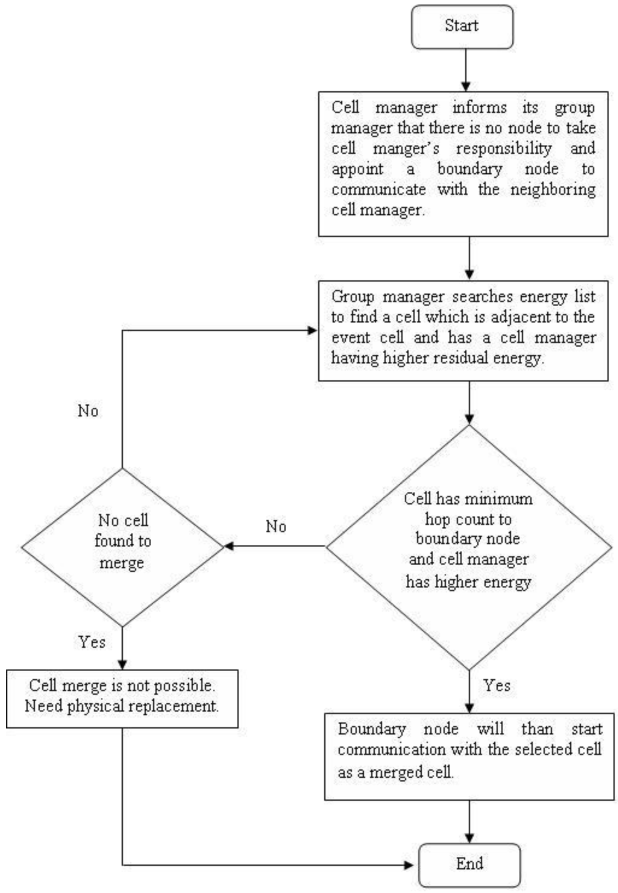

Figure. 5. Flow chart for cell merging procedure

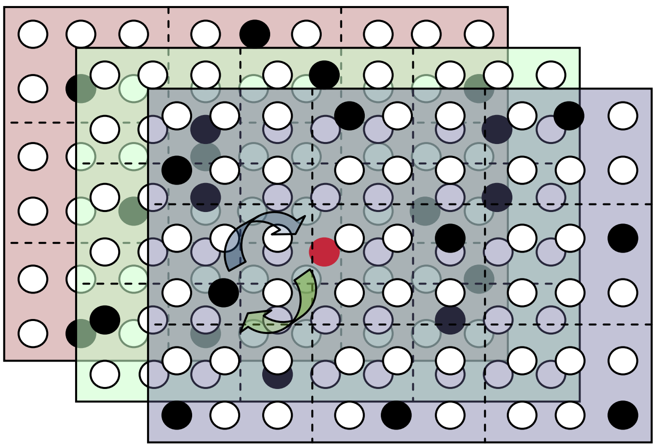

Figure 6. Example of cell merging using proposed scheme. Group manager selects a cell from blue plane to merge with the non-functional cell (red) in the green plane.

The performance graph is being generated based on the energy consumption of the existing and proposed algorithm during cell merging process.

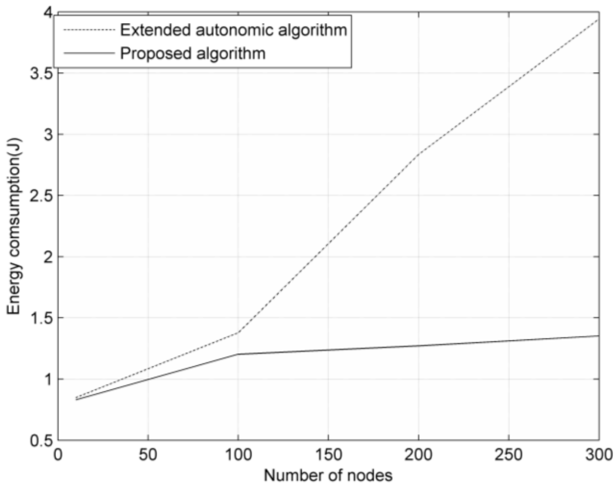

Figure 7. Comparison of existing and the proposed algorithm of self-configuring WSN for cell merging process

VI. Conclusion

The main purpose of cell merging is to increase the number of sensor nodes in a cell to distribute the workload of the cell manager with neighboring cells to form a larger cell. When the remaining residual battery energy of a cell manager or cell head is below the preset threshold, the cell merging process is invoked to combine bordering or neighboring cells. As a result, the network lifetime is extended. In this paper, energy efficient modified algorithms for wireless sensor network have been proposed based on the existing auto-configuring algorithm. The proposed algorithm can extend the cell survival time by selecting a suitable sensor node to be a cell manager and merge cells to reorganize the topology efficiently.

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