JACET Journal of Advances in Computer Engineering and Technology, 3(4) 2017

Energy optimization based on compound routing protocol for compactly distributed wireless sensor network

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Received (2017-05-01)
Accepted (2017-09-03)

***Abstract* - Considering the great significant role that routing protocols play in transfer rate and choosing the optimum path for exchange of data packages, and further in the amount of consumed energy in the routing protocol, the present study has focused on developing an efficient compound energy algorithm based on cluster structure which is called active node with cluster structure. The purpose of this algorithm is to distribute the heavy traffic of data and equal load of highly-consumed energy throughout the networks by introducing unequal and unbalanced clusters into the network. In the second stage, the light sensor mechanism which is called active node sensor algorithm has been proposed. The major purpose of this mechanism is to prevent excessive interfering data of sensors through incorporating a set of active nodes in each cluster with a defensive shield near to the incident node. The third stage has aimed at proposing an active node algorithm for complexity of internal and external addressing due to clusters routing in high density distribution based on the values within node range. The obtained results indicate relative success of the design in terms of energy optimization on the basis of routing protocol.**

***Index Terms* - Routing; energy efficiency; dense distribution; clustering.**

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I. INTRODUCTION

Network protocols, particularly those of routing and energy optimization, are among frequently-discussed main challenges in the fields of information technology and communication or computer networks. Thus, specialists in the area of IT and networks are always seeking for optimum techniques in these two fields. The main purpose of wireless sensor networks includes observation and reporting the incidents of physical world. Over recent years, wireless receiving network has gained a widespread popularity in scientific and practical areas dealing with incidents exploration. Most sensor nodes rely on the limited power of batteries and their computational sources. They are usually left unmonitored after installation; recharging or replacement of their batteries is either very difficult or even impossible. Therefore, data traffic should be distributed evenly across the sensor nodes. Otherwise, nodes may confront serious challenges including long delay across two ends, congestion, memory overflow, and unreliability of data. Considering the probability of adverse operational conditions, reliability of data transfer with minimum costs of energy is regarded as one of the significant challenges in practical planning of wireless sensor networks. Clustering is an effective method for organizing a network with interconnected hierarchy, keeping load balance, and extending lifetime of the wireless sensor networks. Clustering technique reduces the energy of each sensor node in a typical wireless sensor network through increasing the cost of communications and loading data traffic on clusters heads. Energy conservation and error tolerability are two critical issues in development of the wireless sensor networks. Design of clustering and routing algorithms in large scale needs to integrate both issues for long-term operation of the network. Therefore, investigation into clustering characteristics in development of large networks seems essential taking into account the main functions of some aspects including collection of effective data, the shortest and the most reliable connecting route as possible, minimum end-to-end delay, and strong adaptability of damaged nodes. In such networks, only routing algorithms and protocols can manage restricting the efficiency of sensor nodes sources and provide a reliable connection for examination of the real world. Consequently, design of a powerful protocol for energy has become a critical challenge in terms of sensor nodes lifetimes, maximizing coverage of the network, and improvement of strength against node failure. The main purpose of the present study is to optimize energy based on routing method which provides a reliable connection taking challenges of routing into account and extends lifetime of the wireless sensor networks.

II. ENERGY OPTIMIZATION ON THE BASIS OF COMPOUND ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS WITH DENSE DISTRIBUTION

The main task is generally divided into three basic phases each of which plays a significant role in this design.

1.Effective Algorithm of Energy on the basis of Cluster Structure

Once the sensor nodes have formed, the effective algorithm of energy on the basis of cluster structure will play a significant role in generating clusters with unequal sizes. The main idea of generating unequal-sized clusters resides in even distribution of total data traffic and consumed energy load throughout the network. In each unique cluster this algorithm is responsible for determining the cluster heads near the sink and measuring the incident, while the remaining cluster heads are assigned to the middle of each cluster. Once the establishment is accomplished, the sensor node BS is responsible for starting the process of cluster forming through transferring start messages (start_msg). NTS represents the number of established sensor nodes, and NTS-S is the number of sensor nodes within the area of Ai. After receiving start_msg from the sink, communication with each other begins with transmission of Hi messages (Hi_msg) within the interactive boundaries CAi taking computational mechanism CSMA into account as illustrated by Figure (1). This algorithm is designated as ABCD.

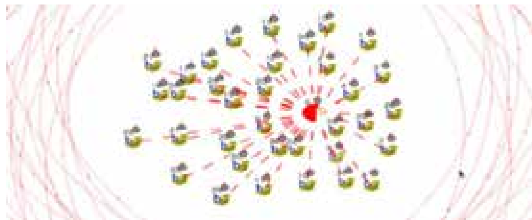

Fig1. Process of cluster forming in ABCD algorithm

Hi_msg contains information about node ID and its remaining energy (REi). After receiving Hi-msgs NTS-S number of sensor nodes in the expanded area Ai calculate their Euclidean Distance (ED) from neighbors based on Equation (1), and update their routing tables.

$$d = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \qquad (1)$$

Then after a certain time interval ti sensor nodes NTS-S in the area Ai following computation of values of their active node obtained from Equation (2), Dec_msg with ID of its node to neighbors is transmitted as the head of cluster.

$$\mathrm{ANCF}_{S_{ni}} = \frac{\mathrm{RE_i}}{\left(\sum_{i=1}^{n} \frac{\mathrm{DN}^{\frac{2}{4}}}{\mathrm{D_{max\,i}}}\right)^2 + \left(\rho - \left(\frac{\mathrm{DN_i}}{100}\right)\right)^2} \; \forall_{SN}: \theta_{S_{ni} \to S_{nj}} \qquad (2)$$

Thus, a set of sensor nodes with higher value of active node is assigned for the current round near to data receivingincident and sink, whereas remaining cluster heads have been assigned in the middle of each cluster. Value of the cluster active node formation depends on the following parameters:

1) Keeping energy (RE_i) at high level: cluster head is continuously subjected to the process and data of the route incident, so the assigned cluster head must have sufficient energy for fulfillment of these duties $CH_{i(REi))} > TH_{threshold}$ in which the threshold distance is $TH_{threshold} \in d_o$.

2) Angle($\theta_{Si \rightarrow Sj}$): the angle between sensor node S_i and its adjacent sensor node S_j.

3) Distance from neighbors (DN2/4):

minimum transfer distance of a node from adjacent nodes within the area of A_i that is covered by the effective region during minimum energy consumption $SN_{active} \alpha 1/DN^n$.

4) Maximum distance (Dmax):

maximum distance between sensor node S_i and its adjacent sensor node S_j in the cluster C_i.

5) Density (ρ): number of sensor nodes within the area of A_i; and density varies from 1 to 2 for high density and low density areas respectively.

After choosing the cluster heads, each head within its range A_i transmits Connect_msg to adjacent sensor nodes. Once the Connect message is received, each sensor node responds to its cluster head with accepting connection request (Connect_acc). After receiving connection request from adjacent nodes each cluster head decides to choose its members according to either minimum transfer distance (e.g. ED) or strength of the received signal (RSS). After a certain time interval $t_i + 1$ each cluster head restricts transmission of Connect_ack message to its adjacent nodes. Connect_ack message contains both unique time slots considering the mechanism of time division multiple access (TDMA) and acknowledgement of the connection message. This approach has been depicted by Figure (2) in the form of a pseudo-code.

Pseudo-code ABCD ( ):
1: Receive(msg,BS) //Recive message from BS;
2: if (msg=start_msg) then
3: $N_{N_{TS-S}} \leftarrow$ Hi_msg //Broadcast Hi_msg;
4: if (Sensor nodes = Hi_msg) Then
5: $N_{TS-S} \epsilon RE_{calculation} \&\& E_{calculation}$ do
//Compute RE and Ed;
6: Compute ABCD values from Eq (2)
7: If ($ABCD_{Si} > ABCD_{Sj}$) Then
8: $Range_i \leftarrow S_{i(CH_i)} Dec\_msg$
//Broadcast declaration message in range;
9: $S_{i \rightarrow n} Range_i \leftarrow S_{i(CH_i)} Connect\_msg$
//Send connecting message to its neighbors in range;
10: If ($S_i \epsilon Min_{Ed}$ to $S_{i(CH_i)}$)Then
11: $S_{i(CH_i)} \leftarrow$ Connect_ack
//send connecting acceptance request;
12: Else
13: $S_{j(CH_i)} \leftarrow$ Connect_ack

Fig2. ABCD Pseuo-code

2. Active Node Sensor Algorithm

The limited energy is regarded as one of the critical challenges of extending the network lifetime. A significant amount of energy is consumed during the process of transportation of dismissed data packages in the network. Furthermore, considering remarkable redundancy of data, cluster heads are inevitably prone to memory overflow which results in a large amount of data loss and excessive message broadcasting within the network. Additional overhead control message, which consumes a large amount of node battery supply, is usually used to overcome the problem of missing data packages. In order to avoid the above-mentioned challenge, the main purpose of active node selection algorithm is to minimize redundancy of interference data through minimizing the overhead cost of control message and to save the high transfer cost of the consumed energy by minimizing the transfer distance. Development plan of assigning a set of active nodes with desirable network coverage near to incident and cluster heads is to measure approaching, provided that all remaining nodes are in sleeping mode. In such algorithm each cluster head, within the cluster to which it belongs, is responsible for determination of a node set as the active node for the purpose of approaching measurement with desirable network coverage. Once an incident is measured, sensor nodes within incident region will inform their cluster heads through transmitting a message containing information about the level of nodes energy conservation, distance from cluster head, and incident data. However, acquiring the exact distance of an incident is of NP-hard type due to various environmental challenges.

Once the value of the chosen active node of each sensor node is calculated, each cluster head, within the cluster to which it belongs, is responsible for choosing a set of sensor nodes with the highest value of the active node for closeness evaluation as illustrated by Figure (3). In order to prevent data packages from collision, each cluster head is responsible for assigning active nodes involved in evaluation incident in a unique time framework for communications taking into account the computational method TDMA ensuring that no two nodes have similar time framework. Certainty of active node selection mechanism applied for maximizing the sum of asleep sensor nodes according to demand of the covered network relies on reducing the number of active nodes in one cluster.

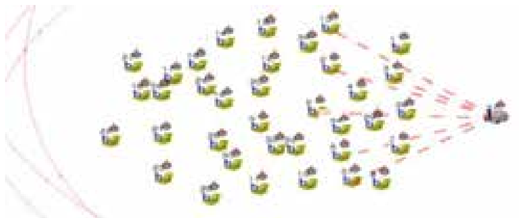

Fig3. Active sensor nodes assignment for monitoring an incident by a cluster head

3. The Active Node Routing Algorithm

The main purpose of this algorithm is consistent distribution of all load of data traffic throughout the network through distributing the task among sensor nodes and cluster heads. In this algorithm total traffic of the network is divided into two main phases: firstly routing from evaluation region to cluster head, and then from cluster head to the sink. In the first phase once the evaluation of each active sensor node is performed, two or more hops which are away from cluster head transfer their evident information to adjacent nodes which are close to cluster head, whereas sensor nodes of a distant hop can engage in a direct communication with the cluster head. Therefore, all traffic of evaluation data in one cluster travels toward cluster head in the form of multi-hop minimum spanning tree.

III. SIMULATION OF THE MODEL

Performance of the present study was evaluated by NCTUNs6.0 that contains 50 set of simulations. All sensor nodes within a cluster involve in evaluation tasks, and are required to transmit the sensed data immediately. Every 39 seconds, each sensor node broadcasts positions of the measured data from one-hop to two-hop neighbors. Moreover, each node transmits the node reporting data to the sink every 33 seconds. The following conditions have been assumed for performing the tests in our real scenario:

--All nodes and sinks are fixed after establishment.

--All nodes and sinks with known positions are obtained by localization program of the calculations discussed in [8].

--All nodes are directly interconnected.

--The connection multi-dimensional model for presenter node to its neighbor has been assumed 360 or R = πr2.

--Contrary to previous simulation studies, the model has been assumed asymmetrical.

At any time, there is at least one route to base station via a sink.

IV. PERFORMANCE ANALYSIS

Results and details of the analysis will be discussed below in terms of different criteria pertaining to the network performance.

1.Consumed Energy and Remote Transmission

Total energy consumption of the network in all routing designs is directly dependent on total number of rounds and sensor nodes of the network. Furthermore, energy consumption rate increases with number of rounds due to introduction of new sensor nodes into the network. Then after a certain time interval, there is an increase in the network energy consumption rate and it's when sensor nodes begin to annihilate. Our design for keeping the chart at a high level between 1550 and 2000 rounds has been more significant than other routing designs regarding to density of the network particles as illustrated by Figure (4). Our proposed design owes its high efficiency to good management and faster adaptation of the dead sensor nodes in this task, while LEACH and PEGASIS are weaker compared with all other routing designs. General performance of this design at starting, median, and final stages of simulation has a more desirable tend towards adaptability and better capability of management for new and dead sensor nodes of the network in comparison with all other designs. Some reasons for high energy consumption in the case of other routing designs include higher consumption of nodes energies in all routing designs and excessively long message transfer distance in dense-distributed networks. As can be seen from Figure (5), capability of routing designs to find next node hop with minimum transfer distance is strictly dependent on the number of sensor nodes that have been deployed throughout the network. At the beginning of the process, between sensor nodes 1 and 100, performances of all routing designs to find next node hop is quickly diminished. When a minimal number of sensor nodes are involved in the network, capability to find next node hop with least transfer distance in the case of CREEC and EEDCP-TB routing designs is slightly better than that of LEACH and PEGASIS. As gradually new sensor nodes are added and their population reaches between 120 and 200, performances of CREEC, EEDCP-TB, and BATR routing designs become better than BATR, PEGASIS, and LEACH.

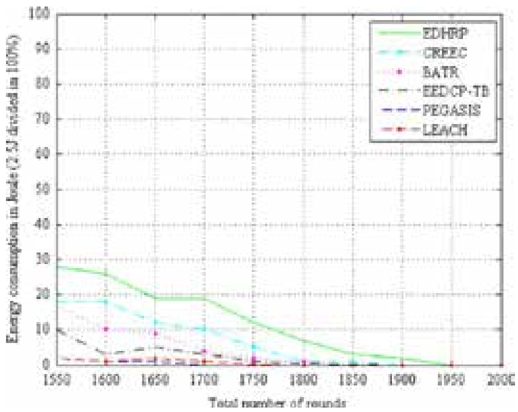

Fig4. Consumed energy at all rounds

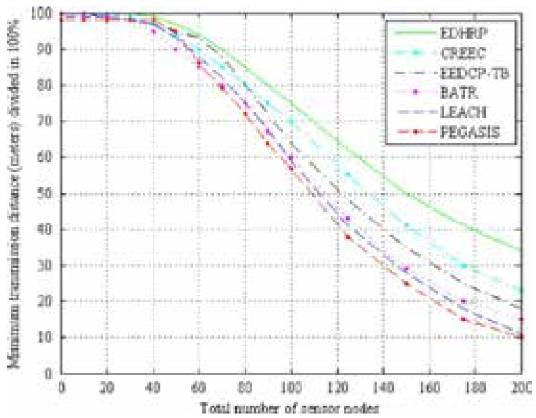

Fig5. Maximum transfer distance in total number of sensor nodes

2.Redundancy of data and density management

Another source of energy consumption in all routing designs is high redundancy of data across the network. Data redundancy is directly proportional to number of interfered sensor nodes including an involved incident in the network with minimum amount of active sensor nodes and desirable coverage which is perceived as a lower data redundancy in comparison with a lot of active nodes due to their overlapping areas. The large amount of redundant (surplus) information influences also the cost of excessive appointments of data during transportation of the information. Since there is one node with limited capacity of buffer storage, we will confront the problem of excessive transfer of repeated data due to buffer overflow because of redundant data, unless the network is effectively operable. Data redundancy in CREEK, BATR, EEDCP-TB, PEGASIS, and LEACH routing designs is a questionable issue due to excessive number of active sensor nodes for evaluation missions in sense distribution. In our proposed design active sensor node plays a significant role in reducing the redundancy of interfered data through appointment of minimum active sensor nodes in each cluster with a desirable coverage for an incident.

Performance of the proposed design for high-dense networks is better compared with other routing designs. The issue of density management in routing algorithm of this design, energy-efficient algorithm based on luster structure, active node sensor algorithm, and active node routing algorithm play a critical role in governing whole network traffic and consistent distribution of consumed energy throughout the network. All network traffic is transferred through multiple data routes taking into account the quality of sensor nodes links within the network which conduct minimum matters in relation to density management in the present design compared with other routing designs.

3. delay and capability in installation

Delay is among effective factors influencing the performance of whole network. Performance of the present design for high or low dense networks is more remarkable than all other routing designs in terms of achieving minimal level of delay. One of the major reasons for higher rate of delay in the case of CREEC, BATR, EEDCPTB, PEGASIS, and LEACH routing designs is due to the cost of their routing table during update process and path finding. Furthermore, reliability of the link plays a significant role in minimizing the network delay which saves an invaluable amount of time for finding the route for new data. Regarding the matter of achieving a minimum level of delay in the present design, the active node routing algorithm has an important requirement for higher reliability of the link between nodes and cluster heads with minimum cost of routing table management in order to provide a powerful transfer from source to destination. Since each sensor in routing algorithm of active node is responsible for protecting the information belonging to two hops of the adjacent node, it helps in finding next hops through increasing the priority. In some cases when one node fails in the path for powerful data delivering, if transmitter doesn't receive any confirmation message from receiver node for a certain time, it sends its information to the next hop that is at second level of priority in routing table. Capability of initiation is directly dependent on certain number of sensor nodes which are involved in the system. Strength of installation for this design in high or low dense networks is more powerful compared with all routing designs. In the present design implementation of low-weight algorithms of energy-efficient algorithm based on cluster structure, sensor algorithm of active node, and active node routing algorithm play a critical role in adopting new sensor nodes into system in most powerful techniques due to flexibility in protection of information in each phase.

4. Network lifetime

It has been recognized, from conducted examinations, that CREEC performance during lifetime of the network is better for minimum energy consumption; however it still suffers from long distance of transferring data packages of unnecessary hops similar to PEGASIS, BATR, and EEDCP-TB. Moreover, in most cases when network is highly dense, CREEC preserves its stability period and selection of the nodes of the next hop with minimum remaining energy. Thus, reliable connection is a significant matter that accounts for performance of network lifetime. Similar to CREEC, one of the major reasons for short lifetime with higher speed is concentrating on the quality of their unreliable link and remote communications across sensor nodes which results mostly in congestion and some issues associated with network delay management. Figures (6), (7), and (8) clearly demonstrate that our proposed design is superior to other routing designs in terms of achieving network lifetime in dense distribution through keeping some sensor nodes alive. In this design the reliability in a stable link across sensor nodes plays a significant role in extending network lifetime along with minimizing total energy consumption within the network. For the purpose of acquiring lifetime characteristics for superior network in this design, sensor algorithm of active node and active node routing algorithm, introducing architecture with reliable and powerful clustering has an effective function. For sensor algorithm of active node and active node routing algorithm, link quality is measured by the mechanism of cost estimation based on minimum distance between each set of node pairs. In the proposed design sensor algorithm of the active node is responsible for extending network lifetime which is accomplished through assigning sensor nodes with minimum values as active nodes meeting requirements of network coverage for closeness evaluation taking into account the node remaining energy and minimum transfer distance between sensor nodes and cluster heads. Moreover, this design incorporates active node routing algorithm for even distribution of energy throughout the network. It has a positive contribution to enhancing the link reliability across cluster ends consuming minimum cost for routing table management for data transfer from evaluation region to target. Figure (9) also illustrates data distribution and their clustering in such a way that after information acquisition from each cluster head, it seems that they have their own routing table, so next node hop chooses the shortest possible transfer distance with higher amount of remaining energy. In the case of route failure, the routing table of active node routing algorithm helps in finding next hop node with higher priority in order to avoid longer delay and energy consumption leading to increase in the network lifetime consequently.

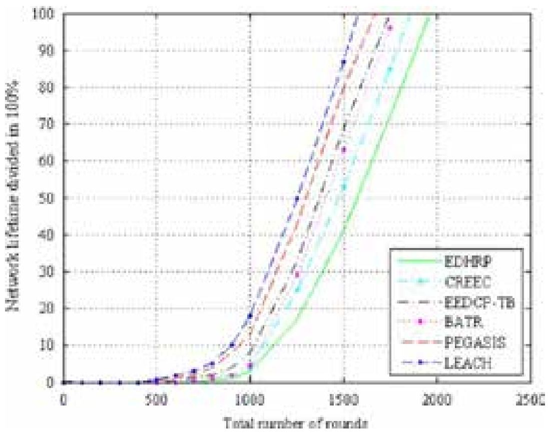

Fig6. Network lifetime in total number of rounds

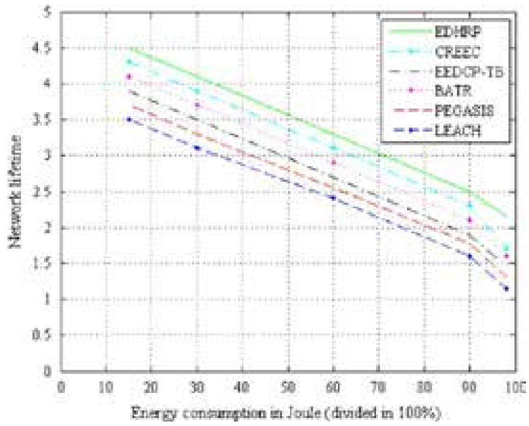

Fig7. Network lifetime in consumed energy in Joule

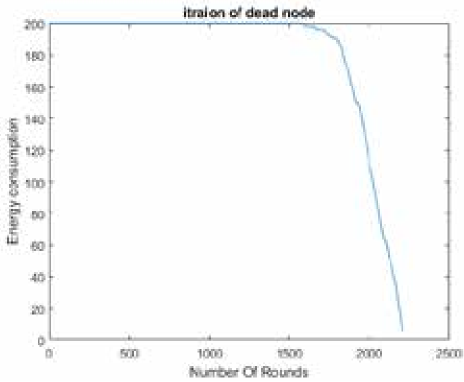

Fig8. Energy optimization process

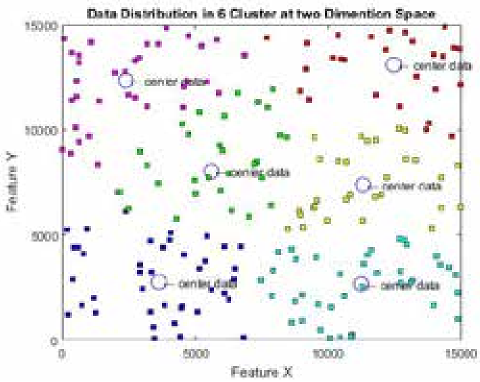

Fig9. Data distribution and clustering during acquisition

V. CONCLUSION

The current study proposes an efficient clustering method for optimization of energy based on routing protocol for data acquisition and analysis, and also routing outcomes within wireless sensor networks with high dense distribution. Furthermore, one algorithm with an efficient energy clustering structure known as active node clustering has been introduced. The main purpose of this algorithm is distributing the heavy traffic of data and equal load of high-consumed energy within networks through introducing unequal and unbalanced cluster heads into the network. The design has been developed in the framework of assigning each cluster head near to sink node and incident measurement while a set of remaining cluster heads within each cluster has been determined to reach the highest level of energy efficiency in dense distribution. In the second stage, one light-weight sensor mechanism known as sensor algorithm of active node has been proposed. It aims at preventing high redundancy of sensors interference data through assigning a set of active nodes within each cluster with a protective shield close to incident node. In the third stage, one active node routing algorithm has been proposed dealing with complexity of internal and external addressing due to clusters routing in high dense distribution based on the values within the node range. The comprehensive experiments conducted for the purposes of this study through network simulations of NCTUNs 6.0 and MATLAB demonstrate that the proposed design has provided some improvements, compared with existing routing techniques, in terms of energy efficiency, end-to-end delay, data redundancy, congestion management, and capabilities of implementation and configuration. As a suggestion for future studies we can focus on potential optimizations in the algorithm through making improvements in various operative criteria, then on investigating the efficiency of the approach in sporadic heterogeneous and more complicated modes including various states of nodes, etc.

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