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Data Gathering Protocol for Reducing Energy Utilisation in a Wireless Sensor Network

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ABSTRACT

Energy is a main issue in wireless sensor networks (WSN) that function on limited power supplies like batteries. Minimisation of energy utilisation is a promising area of research in WSN. However, energy utilisation of partitioning data still remains a demanding issue. With the objective of reducing the energy utilisation partitioning multi-hop wireless communications, the Energy-Efficient Traffic Renovate Partitioning (EETRP) method is proposed in this paper. The network traffic partitioning method, phantom partitioning, is an efficient technique for practical conditions. The partitioning using double cut methods yields desirable results with significant reduction in energy utilisation. Renovating by the EETRP method provides enhanced data gathering by means of centroid mean point gathering. Crucial sites are recognised and connectivity is reestablished in data aggregation. The results prove that the EETRP method achieves significant improvement in performance over state-of-the-art methods in terms of network-connectivity rate, data-gathering accuracy, network-traffic rate, energy-utilisation rate, node-renovating efficiency and network-partitioning time.

Keywords: Energy-efficient traffic renovate partitioning, partition gaps, phantom partitioning, wireless sensor networks

INTRODUCTION

A wireless sensor network is defined as the group of sensor nodes with one or more base stations. Sensor nodes generate and process through intermediate sensor nodes to base stations. Recent research has developed a capable technique to reduce communication energy utilisation in renovating partitioned nodes. The Connectivity-Based Data Collection (CBDC) algorithm detailed by Abdullah et al. (2014) used the connectivity between sensor nodes to establish the route of the mobile sink to suit its path limit and reduce the number of multi-hop communications. However, it utilised a large volume of energy. Ant Colony Optimisation

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for Data Aggregation (DAACA) as explained by Lin et al. (2012) was used to reduce energy consumption and increase network lifetime. However, the data-gathering efficiency was not at the required level.

Sheetalrani (2014) described an energy-balanced data-gathering routing algorithm that was designed based on the principles of physics. An energy-balanced routing protocol sent data packets to the sink through dense energy areas for preserving the nodes with low residual energy. However, it failed to send the packets by eliminating loops. A cross-layer energy efficient protocol (Munish et al., 2015) decreased the energy utilisation of sensor nodes at the Network, MAC and physical layers of the protocol stack. However, the results for the network and MAC layer were not verified and validated.

Mohamad and Seyed (2014) took an energy-efficient approach based on a genetic evolutionary algorithm for preserving coverage and connectivity where the sensor node had many numbers of sensing ranges and transmission ranges. However, the renovating efficiency remained an unsolved issue. A layer-based topology control scheme for long-term hybrid WSNs (Ikjune et al., 2015) had both battery-powered and energy-harvesting nodes. Each node chose its own layer with the available energy to balance energy levels and preserve network connectivity. However, the scheme took a long time to renovate. The Combine-Skip-Substitute (CSS) scheme used by He et al. (2013) is a good technique with minimum data collection delay in WSN while the Energy-efficient Routing Algorithm to Prolong Lifetime (ERAPL) (Zhu et al., 2010) increased network lifetime when energy utilisation was efficiently managed. In ERAPL, a data-gathering sequence (DGS) was employed to remove mutual transmission and loop transmission between the nodes built, and each node sent out traffic to the links in the DGS. However, an overhead was required to swap the messages among the sink and the nodes.

Our objectives in this research work were threefold. Initially, we introduced the phantom-partitioning method to locate the affected areas to change the range of mobile elements and renovate the network structure derived from inter-partition gaps. Secondly, the method attained high data gathering efficiency by relating the centroid mean point gathering method derived from Euclidean distance. Lastly, double-cut-based partitioning contributed to reduce energy usage in a dynamic sensor environment.

LITERATURE REVIEW

The deterministic model of data collection suffers from many demerits and at the same time, the probabilistic approach of data aggregation improves data collection efficiency. A probabilistic model of data aggregation using path scheduling gives improved performance to the Cell-Based Path Scheduling (CPS) algorithm (Ji et al., 2014). However, CPS does not solve the security issues that could be raised in sensor networks. A hybrid approach of using the centralised heuristic approach with a distributed parallel optimisation (POP) (Liu & Cao, 2011) gives improved data rate against time. However, this hybrid model is not so feasible in the face of practical implementation procedures. Performance improvement in a critical mission with a distributed approach and improved scalability, collision removal etc. were focussed on a conflict-free time slot allocation mechanism (Lin et al., 2011) but this technique did not consider the position of the various sensors involved in data collection.

Ozlem et al. (2011) reported that multi-frequency scheduling could be used to deal with issues related to many interference and channel modes. Even though the problem of data with a static nature was considered, the problem with dynamic data remained unsolved. An efficient data collection scheme by a ferry node was planned by Mariam et al. (2015) with a significant result in the ferry path. The performance of the selecting cluster heads was derived from their residual energy and distance from the ferry path. However, it was not used for a nonlinear route to attain enhanced results. A distributed data compression framework (Lee & Lee, 2013), however, used the broadcasting feature of the wireless medium to increase energy efficiency. However, data compression was not considered.

ENERGY-EFFICIENT TRAFFIC- RENOVATE PARTITIONING

The design and details of the traffic-renovate partitioning method, which offers energy efficiency during data collection in WSN, is discussed here. The key goal of the proposed work was to renovate the structure of the network, and with the help of a renovated network structure, the EETRP method executed an effective data-gathering process with optimised utilisation of energy. Renovation was done based on the position of the mobile node. The process of partitioning the wireless sensor network structure is described in Figure 1.

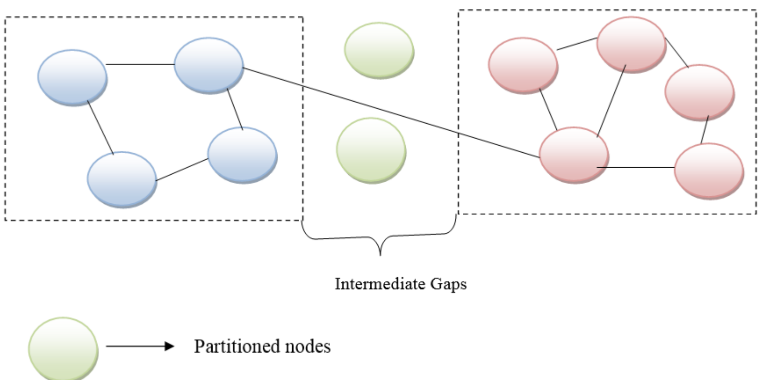

Figure 1. Node partitioned in wireless sensor network structure.

Figure 1 describes node partitioning. The intermediate gaps connecting the partitioned nodes are recognised by means of phantom partitioning. Phantom partitioning in the EETRP method represents spectral-based damaged and partitioned nodes recognised in the wireless sensor network structure. The traffic network structure discovers the route path connectivity with the double cut. The double cut in the EETRP method is employed in order to divide or cut the network structure into two divisions and then balance the partitioned limits with less energy utilisation. The bisected path discovers the safer route in a sensor network with help of the EETRP.

The renovated network structure functions as an efficient data-gathering system using the centroid mean point gathering method. The method is executed after addressing the network traffic problem using the EETRP method. The partitioned nodes are added into the suitable group in the renovated network structure. The data gathering is executed using the centroid mean computation value. The renovated network structure for data gathering executed by the centroid mean point gathering method is explained in Figure 2.

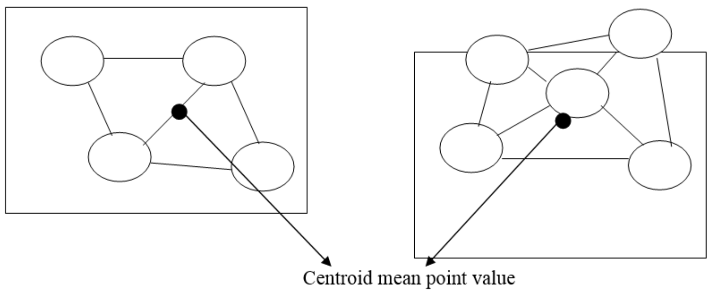

Figure 2. Renovated wireless sensor network structure in EETRP for data gathering.

The centroid mean point in the EETRP method is calculated by Euclidean distance. The centroid-based technique divides the structure into 'n' different zones and the data collection is done at the centre point. The EETRP method makes use of mobile sensor nodes to identify the partitioned nodes. The partitioned node gap inside the traffic network structure is recognised by phantom partitioning. Phantom partitioning utilises the double cut in the EETRP method to balance the limits. The balanced limits eliminate the partitioned node and renovate the sensor network structure. The renovated network structure utilises the centroid mean point gathering method to improve the data-gathering rate. The framework of the Energy Efficient Traffic Renovate Partitioning (EETRP) method is explained in Figure 3.

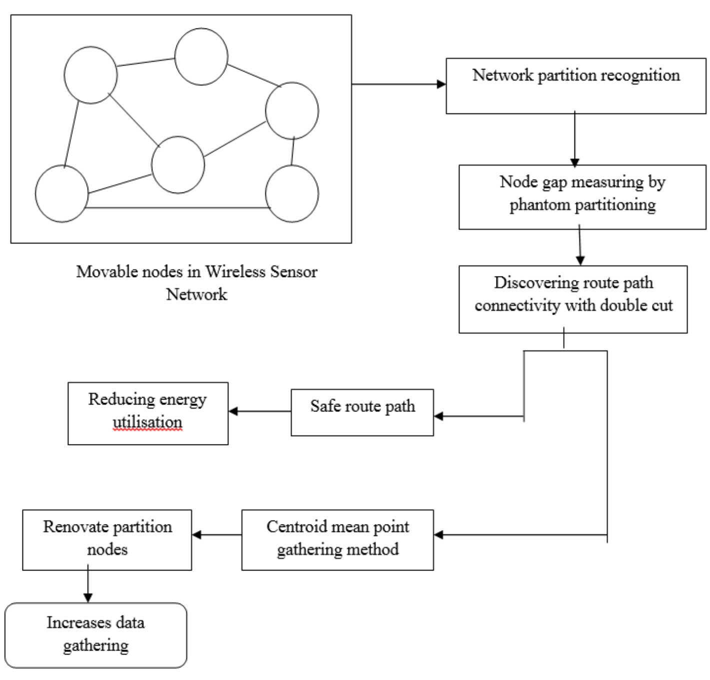

Figure 3. Architecture diagram of EETRP method.

Finally, the renovated network structure, now without any traffic, executes data gathering derived from the estimation of the centroid mean point.

Partitioned Node-Gap Calculation

The gap between the partitioned nodes in the sensor network structure is calculated to renovate the nodes with less energy utilisation. Consider a wireless sensor network with vertex ‘v’ and edges ‘e’ on the two integers ‘p’ and ‘q’. The $v_k \in \mathrm{V}$ is such that:

$$Number\ of\ node\ partitioned = \sum_{k=1}^{p} F_m\,(v_k) \qquad [1]$$

In Eqn (1), F_m denotes the degree of membership function on the vertex ‘v_k’. All the partitioned nodes are added together and form the point ‘1’ to integer ‘p’. The partitioned nodes are represented in Figure 1. Eigen vector value is used to identify the gap between the partitioned nodes. Eigen vector points are a non-zero vector matrix, where the matrix multiplication results in constant multiple points in EETRP method. The vector point is automated as:

$$p * \overrightarrow{v_k} = \lambda * v_k \qquad [2]$$

v_k is the vector point on integer ‘p’ and ‘λ’ represents the constant multiple points. The Eigen vector with the continuous vector space functions computes the distance between the partitioned nodes in the sensor network. The continuous vector space function is explained as:

$$f_c(p, q) = \lambda * e^{\lambda(p,q)} \qquad [3]$$

$f_c(a, b)$ on integer ‘p’ and ‘q’ uses the Eigen value multiple constants for calculation on a larger network zone. The algorithmic step on the partitioned node-gap calculation in the EETRP method is explained as:

Input: vertex ‘v’, edges ‘e’, two integers ‘p’ and ‘q’, Eigen vector 'λ', partitioned nodes ‘n’
Output:
// **Partitioned Node Distance Computation** **Begin** Step 1: Membership function degree on partitioned node is calculated by Eqn (1) on all the vector points Step 2: Recognise distance gap by Eigen vector and calculate vector points using Eqn (2) with constant multiple points Step 3: Calculate continuous vector space function to reduce energy consumption using Eqn (3) **End**

The step-wise explanation is given for the distance-gap calculation on all partitioned nodes in the sensor network structure of changeable mobile range numbers.

Balancing Limits Through Double Cut

The balancing limits (B_L) by the double cut in the EETRP method is given by:

$$B_L = \frac{1}{p}\left|(p * v_k) - |v|\right| \leq q \qquad [4]$$

Eqn (4) uses the vector v_k within the network structure to renovate the network set-up. The balancing limit is less than the integer value 'q' so the partitioned nodes are eliminated and the renovated structure is designed in the EETRP method. The renovated network with a traffic-free mobile element structure recognises the efficient connectivity between the sensor nodes.

Centroid Mean Point Gathering Method

In order to estimate the centroid mean point gathering on all 'n' zones in the sensor network structure by means of the EETRP method, the partitioned nodes are maintained in the corresponding group for the sake of fruitful data collection.

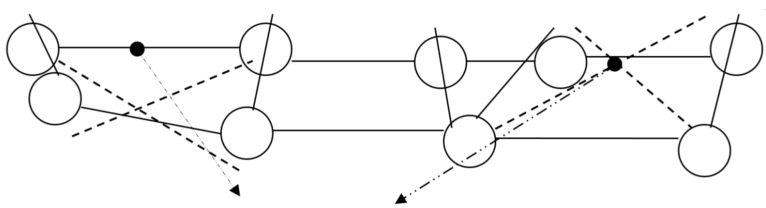

Figure 4. Centroid mean point collection method.

Figure 4 describes the Centroid Mean Point Collection method. The method renovates the partition nodes, which help to increase the data-gathering rate.

RESULTS

The environment was simulated in NS2 with a sensor field size of 900m X 900m. Simulation was done using a configuration of 100 sensor nodes, while the routing protocol initialised was DSR, the speed of the sensor was 30 m/s and random motion was enabled.

The Energy Efficient Traffic Renovate Partitioning (EETRP) method was compared with the existing the Ant Colony Algorithms for Data Aggregation (DAACA) method and the Connectivity-Based Data Collection (CBDC) method with regards to factors such as network-connectivity rate, data-gathering accuracy, network-traffic rate, energy-utilisation rate, node-renovating efficiency and node-partitioning time.

Energy-Utilisation Rate (EUR)

The energy-utilisation rate is defined as the amount of energy consumed for partitioning the nodes by double-cut-based partitioning to create a safe route path. It is measured in terms of percentage (%).

Table 1
Tabulation for Energy-Utilisation Rate

Number of Sensor Nodes	Energy-Utilisation Rate (%)		
	DAACA	CBDC	EETRP
10	35	40	29
20	38	43	33
30	41	47	36
40	45	51	39
50	48	54	44
60	52	57	49
70	55	60	53

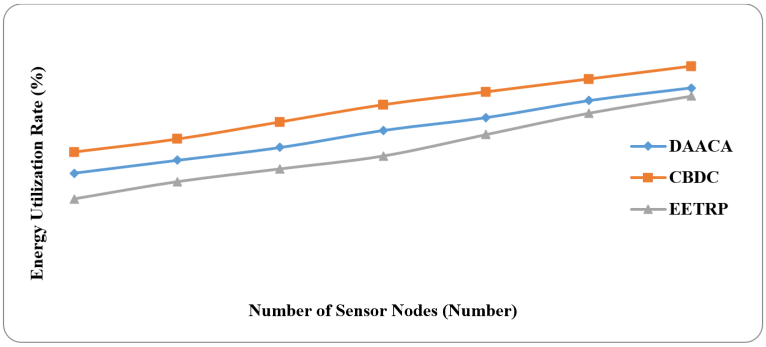

Figure 5. Performance of energy-utilisation rate with respect to sensor nodes.

A performance analysis for energy-utilisation rate with respect to movable sensor nodes was carried out with the existing DAACA and CBDC. The energy-utilisation rate for increasing the number of movable sensor nodes in the range of 10 to 70 was used in a wireless sensor network. The simulation results are shown in Figure 5. It can be seen that when the number of movable sensor nodes increased, the energy-utilisation level also increased; however, this development was achieved using the proposed EETRP method. The Research in Energy Efficient Traffic Renovate Partitioning (EETRP) method utilised 12.01% less energy than the Ant Colony Algorithms for Data Aggregation (DAACA) method and 25.97% less energy than the Connectivity-Based Data Collection (CBDC) method.

Node-Renovating Efficiency

Node-Renovating Efficiency is defined as the rate at which the nodes in the networks get renovated exactly after the partitioning of the nodes. It is measured in terms of percentage (%).

Table 2
Tabulation for Node-Renovating Efficiency

Number of Sensor Nodes	Node-Renovating Efficiency (%)		
	DAACA	CBDC	EETRP
10	70	60	78
20	73	63	81
30	75	67	84
40	78	71	87
50	81	75	89
60	84	78	91
70	86	82	94

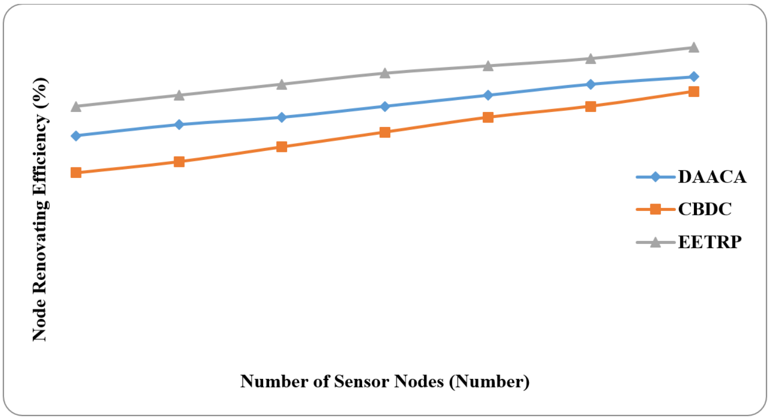

Figure 6. Performance of node-renovating efficiency with respect to sensor nodes.

A performance analysis for node-renovating efficiency with respect to movable sensor nodes was carried out with the existing DAACA and CBDC. Node-renovating efficiency for increasing the number of movable sensor nodes in the range of 10 to 70 was measured in a wireless sensor network. The simulation results are shown in Figure 6. It can be seen that when the number of movable sensor nodes increased, node-renovating efficiency also increased although growth was attained by means of the proposed EETRP method. The Research in Energy Efficient Traffic Renovate Partitioning (EETRP) method had 9.48% greater node-renovating efficiency than the Ant Colony Algorithms for Data Aggregation (DAACA) method and 18.10% greater node-renovating efficiency than the Connectivity-Based Data Collection (CBDC) method.

Data-Gathering Accuracy

Data-gathering accuracy is defined as the degree to which the data are exactly collected. It is measured in terms of percentage (%).

Table 3
Tabulation for Data-Gathering Accuracy

Number of Sensor Nodes	Data-Gathering Accuracy (%)		
	DAACA	CBDC	EETRP
10	75	69	84
20	77	72	86
30	78	73	89
40	80	75	91
50	82	76	93
60	83	79	94
70	86	81	95

A performance analysis for data-gathering accuracy with respect to movable sensor nodes was carried out using the existing DAACA and CBDC methods. The data-gathering accuracy for an increasing number of movable sensor nodes in the range of 10 to 70 was measured in a wireless sensor network. The simulation results are shown in Figure 7.

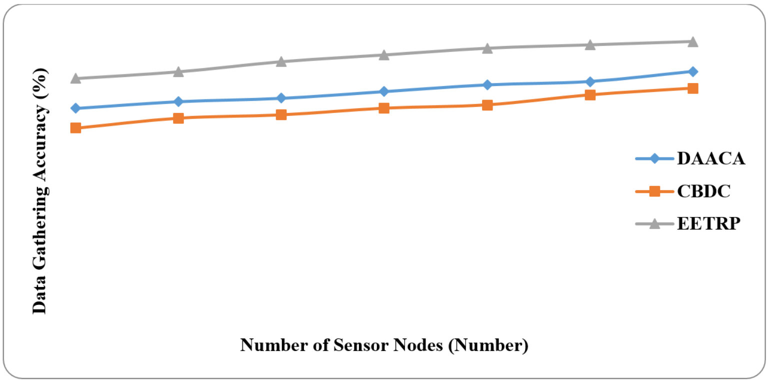

Figure 7. Performance of data-gathering accuracy with respect to sensor nodes.

It can be seen that when the number of movable sensor nodes increased, the data-gathering accuracy also increased, although growth was attained by means of the proposed EETRP method. The Research in Energy Efficient Traffic Renovate Partitioning (EETRP) method had 11.23% greater data-gathering accuracy than the Ant Colony Algorithms for Data Aggregation (DAACA) method and 16.95% greater data-gathering accuracy than the Connectivity-Based Data Collection (CBDC) method.

Node-Partitioning Time

Node-partitioning time is defined as time taken to partition the nodes in an efficient manner. It is measured in terms of milliseconds (ms).

Table 4
Tabulation for Node-Partitioning Time

Number of Sensor Nodes	Node-Partitioning Time (ms)		
	DAACA	CBDC	EETRP
10	20	23	13
20	24	25	16
30	26	29	18
40	27	31	21
50	29	35	24
60	31	37	25
70	33	40	29

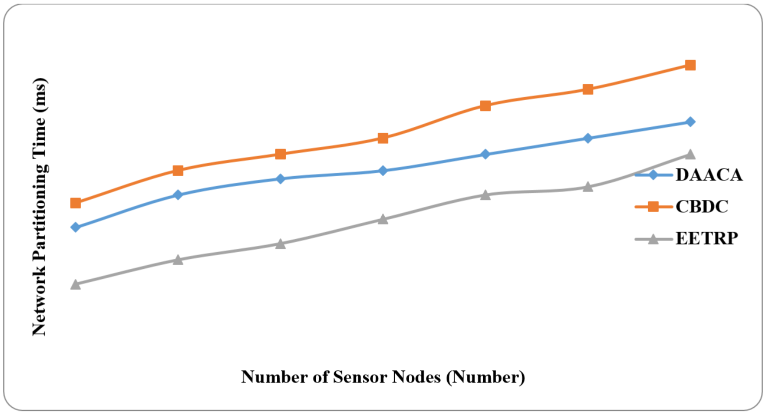

Figure 8. Performance of node-partitioning time with respect to sensor nodes.

A performance analysis for node-partitioning time with respect to movable sensor nodes was carried out using the existing DAACA and CBDC methods. The node-partitioning time for increasing the number of movable sensor nodes in the range of 10 to 70 was measured in a wireless sensor network. The simulation results are shown in Figure 8. It can be seen that when the number of movable sensor nodes increased, the node-partitioning time also increased, although the development was achieved using the proposed EETRP method. The Research in Energy Efficient Traffic Renovate Partitioning (EETRP) method took 33.64% less node-partitioning time than the Ant Colony Algorithms for Data Aggregation (DAACA) method and 55.16% less node-partitioning time than the Connectivity-Based Data Collection (CBDC) method.

CONCLUSION

The issue of data-gathering efficiency in a wireless sensor network was solved using the Energy Efficient Traffic Renovate Partitioning (EETRP) method, which also reduced energy utilisation during renovation of nodes. The mobile nodes were used to reduce energy during transmission in a mobile environment, which also improved data-gathering efficiency. We also examined the process of minimum energy utilisation during renovation into data-gathering efficiency and attained optimality for these contentious ideas. Three important methods were designed; they are termed as phantom partitioning for changing the range of mobile elements in a wireless sensor network structure for recognising the exact positioning of partitioned nodes that use the double-cut structure for efficient energy utilisation, resulting in data gathering by the Centroid Mean Point Collection method for movable sensor nodes. The performances results showed that the proposed EETRP method presented a higher level of data collection efficiency and also reduced energy utilisation compared to state-of-the-art methods.

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