EEROSN Technique with Linear Integrated Program an Improved Study on Intermittently Connected Networks

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Abstract

Wireless sensor networks (WSN) consist of several sensor nodes which are used for transmitting the data with limited capacity. In WSN, it is necessary to optimize the resource for better transmission of data from source node to destination and maximize the coverage area of the network to augment the lifetime of the network. In optimizing the resource in WSN, energy plays a major role to sustain the sensor nodes active status in the network. For maximizing the sensor nodes coverage area, several paths are followed by the previous researchers in different set of methods. Among all the previous works, Changlei Liu et. Al., presented a centralized heuristic protocol for scheduling the activities of the sensors for maximizing the spatial temporal coverage. To resolve the optimization problem, parallel optimization protocol (POP) is presented. Even though the sensor nodes are energy constrained by POP, only the limited numbers of sensor nodes are made active simultaneously for better coverage by consuming more energy. To resolve the above said issue, in this work, we plan to resolve the energy-efficient wireless sensor network coverage using node constrained linear integer programming technique. With the technique, a node constrained energy efficient connected coverage algorithm is developed for enhancing the lifetime of the network by increasing the coverage area of the sensor nodes. For the better coverage area phase, an energy drain rate of each sensor node is determined and formulates the sensing structure of the information. Experimental evaluation is done with the sensor nodes for better coverage in network environment and its performance is evaluated with varied set of sensor nodes with measuring metrics such as energy efficiency, network lifetime, and coverage area. The study based on the experiments is analyzed and the problem is improved effectively.

Keywords: Wireless sensor networks, intermittently connections, resource optimization, energy efficient, linear programming technique, greedy approach

1. Introduction

Wireless Sensor Networks (WSNs) have been organized in numerous data-gathering requests for instance health scrutinizing and ecological observing in factories, farms and inhabited areas. The WSN organization comprises of sensor nodes (SNs) and a drop node habitually termed as a base station (BS). SNs are positioned in the intelligence field and BS is typically positioned more away to gather and examine the sensing data. Naturally, SNs could forward data to BS openly or not directly by means of other middle SN(s). Since SNs regularly work by using restricted energy sources for instance batteries, it is detrimental to restore or renew SNs owing to high maintenance cost.

In this situation, Relay Stations (RSs) provide a necessary role to obtain and send data from SNs to BS such that the energy restricted SNs can work for a preferred time of the network lifetime. Since RSs could be prepared with more complicated energy basis for instance solar cells and the energy storage space, the network exploitation cost and lifetime could mostly depend on the number of complicated RSs utilized in the network and how the intellect data is sent to BS.

In wireless sensor networks, there is a transaction among network lifetime and sensor exposure. To attain a better coverage, more sensors have to be vigorous at the identical time, then more energy would be devoted and the network life span is condensed. Conversely, if more sensors are giving to sleep to enlarge the network lifetime, the coverage will be harmfully exaggerated. The transaction among network life span and sensor reporting cannot be merely resolved at the operation stage, since it is hard to expect the network lifetime condition, which depends on the request and might modify as the mission changes.

As well as the fact that stimulating all the sensor nodes concurrently tends to unnecessary energy utilization in the system restraining the network lifetime, such an establishment schedule is also not enviable owing to the subsequent reasons. If numerous active sensors are casing any distinct *target point*, this would effect in unnecessary data been composed at the sink. Furthermore, in such a situation numerous sensor nodes would intellect a distinct occasion in the region and would attempt to broadcast at the similar time, causing avoidable packet collisions owing to unnecessary disputation for the wireless channel. As a result get going a negligible set of sensor nodes at any time leads to enhanced resource consumption in the network and also extends the network lifetime.

Given a suitably high density operation of sensors in the section, the primary decision making charge is to recognize a *possible* set, which is a position of sensors (a separation of the accessible set of sensors), which wants to be triggered so as to make sure the coverage constraint in the network. To discover a possible set which holds the smallest amount of sensors is referred to as the *energy consumption* crisis in this paper.

In this paper, the objective is to make best use of the *Network Lifetime* by implementing the node constrained linear integer program, where the goal of the approach is that both coverage and connectivity necessities are gathered in the network, and away from which associated coverage cannot be assured.

2. Literature Review

Mission-driven sensor networks regularly contain particular lifetime necessities. On the other hand, the mass of the sensors might not be huge sufficient to please the coverage condition even as gathering the lifetime restriction at the identical time. At times, coverage has to be dealt it for network lifetime. In [1], the procedure of setting up the sensors to capitalize on their coverage through specified network lifetime. Not like sensor consumption, where the objective is to capitalize on the spatial coverage, the objective is to take advantage of the spatial sequential coverage by setting up sensors' activity behind they have been organized.

The significant subject measured in the extensive operation of Wireless Sensor Networks (WSNs) is a competence of the energy consumption. In [2], the author presented a revise of the best relay station setting up problems utilizing Binary Integer Linear Programming (BILP) model to reduce the energy consumption in WSNs. The author in [3] presented the representation of network design crisis as an integer linear programming. A key involvement is that the proposed models not only guarantee the network lifetime but also make certain the radio transmission among the energy-limited sensor nodes so that the network can promise packet deliverance from sensor nodes to the base station.

Numerous studies have dedicated on the relay node assignment troubles in which measured no energy restriction at SNs while measured energy constraints [4]. In [5], the authors measured the particular hop communication among sensor nodes and relay stations. The author assumed that the relay stations could regulate the transmit power stage where as considered the connectivity constraints. In [6], the purpose was to exploit the number of packets established at BS. The authors examined descriptions of network lifetime and projected one that is suitable for WSNs in forestry applications.

In [7], the authors lectured to the sensing exposure subject by maintaining the smallest amount of active sensor nodes to put aside node energy. As the offerings of the earlier works are considerable, the existing revises did not believe the things of noise and bit error rate uniqueness of the wireless transceivers and did not supply radio connectivity certification. In addition, the network cost restriction and the energy effectiveness were not measured jointly. For this motive, more sensible and efficient techniques for the WSN plan with the utilization of relay stations are desired [8].

To achieve routing in wireless sensor network with this restriction of short power, force and storage capacities is the foremost problem. Routing procedures are utilized for determining and upholding the routing in sensor networks. The most significant deliberation in scheming procedures for WSN is the energy restriction of nodes owing to partial power [9]. TEEN is practical for requests where the users can manage a trade-off among energy effectiveness, data accuracy, and response time energetically [10]. On the other hand, TEEN is not appropriate for sensing applications where intermittent reports are desired as the user might not obtain any data at all if the thresholds are not attained [11]. But the TEEN protocol does not attain the better energy level of the sensor nodes in the network.

Even though several researches are developed for enhancing the transmission of signals in the sensor network, the accuracy in achieving the energy level of the sensor nodes does not meet the maximum point. This leads to decrease in the lifespan of the network. So, we plan to improve the energy efficiency and coverage of the sensor nodes in the wireless sensor network by adapting the node constrained linear integer programming technique.

3. Proposed Methodology

The proposed work is efficiently designed for building the energy efficient sensor networks by implementing the linear programming technique. The proposed energy efficient resource optimization in intermittently connected sensor networks is processed under two phases. The first phase describes the process of enhancing the energy efficiency by adapting the linear integer program. The second phase describes the process of enhancing the better coverage and lifetime of the network. The architecture diagram of the proposed energy efficient resource optimization in intermittently connected sensor networks [EEROSN] is shown in fig 3.1.

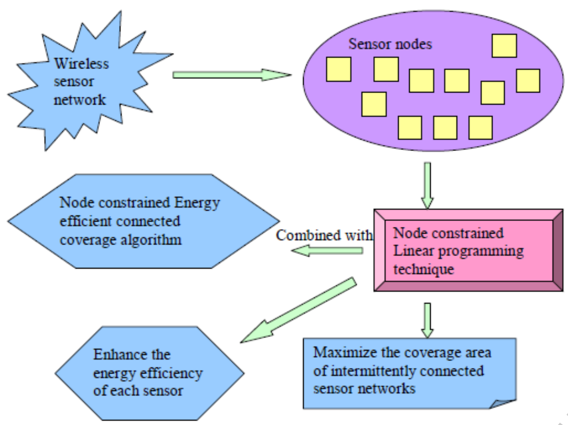

Fig 3.1 Architecture diagram of the proposed EEROSN

From fig 3.1, it is being observed that the EEROSN considers both the energy consumption and coverage area of the sensor networks by adapting the node constrained linear programming technique with energy efficient connected coverage algorithm.

System model

Assume a wireless sensor networks consist of N number of sensor nodes and provides network coverage in T set of target regions in the environment. Since it is wireless networks, sensor nodes and target regions are distributed randomly in the environment. To extend the network coverage, sensor nodes are used redundantly. Before entering into the notion, the basic notations are described here.

For every sensor node, it is necessary to derive the utility (U) based on the number of target regions tϵT, it reaches among the network environment. Then the coverage of the target region (CT) is derived based on the number of sensor nodes covers the particular specified region of target T. A possible set (P) is defined based on, for all target regions T, there might be a presence of sensor nodes s. A cover set (C) is defined based on the set of sensor nodes which provides coverage to the network environment. The utility of the cover set C is defined as,

$$U(C) = \sum_{s \in S} U \quad \text{.............. eqn 1}$$

Concerning about the sensor nodes in the network environment, the coverage set of CS (T) set of target regions is defined as,

$$CS(T) = \sum_{t \in T} CT \quad \text{................ eqn 2}$$

The coverage afforded to the position of target points by any cover set is enclosed only based on the total number of target regions in the network environment and these limits are free from the size of the cover set.

Node Constrained linear integer program for maximizing the energy-efficient coverage in wireless sensor network

For maximizing the energy-efficient coverage of the network, in this work, node constrained linear integer programming technique is presented. The author Chompunut Jantarasorn et. Al., utilized binary integer linear programming [BILP] to minimize the energy consumption in wireless sensor networks. But the demerit of this approach is that the variables/constraints chosen for the objective function takes only the value of 0 or 1 i.e., whether the selection or rejection of sensor nodes if it does not reach the value. There exists a node in the network which has the capability to cover the target region in the network but the restrictions on integer in BILP might get a chance for denying the node because of its high energy consumption. So, this work move on to the node constrained linear integer program for minimizing the energy of the nodes in the network.

The node constrained linear integer program is built based on determining the active status of the nodes in the networks. The linear integer program is applied only to the network which has active set of nodes instead of determining the value 0 or 1 for the active nodes in the network, like in binary linear integer program while implementing the LP.

Since the wireless sensor network has randomized set of sensor nodes, it is difficult to implement the LP. So, in the proposed node constrained linear integer program, the randomized nodes are chosen based on the constraints (TR, RT). After selection, a new network is formed with the set of active sensor nodes. The active status of the node in the network is determined based on the nodes' transmission rate (TR), response time (RT). The transmission rate of the nodes is determined based on how long the transmitting signals (TS) reach the coverage area at the maximum level.

$$TS = \frac{coveragearea}{time}$$

The response time (RT) is determined based on amount of time the sensor node reacts to the input sensor node. After determining the constraints, the nodes are chosen and form a new network. Then the linear integer program is applied to minimize the energy consumption.

Consider S_M as a set of sensor nodes offers coverage to the network which consumes minimum number of sensor nodes for transmission of data. Let S_M might have a minimum set of cardinality. The subsequent conditions are followed for the specification of sensor nodes

i) For all sensor nodes s∈ $S_{M,}$ U(s) value should be greater than or equal to 0

ii) For all target regions in the network t∈T, the cover age range of sensor nodes i.e., CS (T) should be greater than or equal to 1

iii) The coverage range of the target regions for the set of sensor nodes is identified as,

$$CR(S_M)^t = |S_M| + U(S_M) \text{ .... Eqn 3}$$

Therefore,

$$|S_M| = CR(S_M)^t - U(S_M) \text{ .... Eqn 4}$$

From Eqn. 4 it is being identified that S_M reduces overall sensor nodes and derive the objective function O(S) expressed as,

$$O(S) = C_S(T) - U(S) \text{ .... Eqn 5}$$

Whereas,

$$U(S) \geq S$$
$$C_S(T) \geq T$$

The energy efficient coverage problem of the wireless sensor network is defined with the linear integer program with V set of variables and V + n constraints.

$$\text{Minimize } \sum_{i=1}^{V} a_i \text{ subject to,}$$

$$a_i(\sum_{j=1}^{n} b_{ij} - 1) \geq 0$$

……………. Eqn 6

From the structure of the deriving the linear integer program, it is examined that reducing the objective function O (S) is the identical as reducing the summation of coverage of all target regions in the network concerning the sensor nodes S and maximizing the utilities of all sensors s belongs to S, concurrently. This process normally enhances the coverage lifetime of the network.

Node constrained Energy efficient connected coverage algorithm

The node constrained energy efficient connected coverage algorithm [ECA] calculates a sub-optimal resolution to the lifetime coverage and connectivity crisis in polynomial time and can simply be comprehensive to work in a dispersed environment. The energy efficient connected coverage algorithm is processed in terms of iterations. For every iteration, the ECA algorithm identified a dynamic set from the accessible set of sensors. After the end of each iteration, the accessible set is customized by eliminating the sensors which be owned by the dynamic set established in the current iteration. Once the active status of the sensor nodes is difficult to recognize, then the algorithm stops its process to identify. To provide an energy efficient network coverage and network lifetime, at present, sets of sensors are stimulated in sequence. The process is of ECA is shown in fig 3.2.

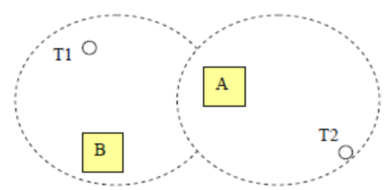

Fig 3.2 Coverage and connectivity of sensor nodes A and B covers the target transmission regions T1 and T2

The algorithm below describes the entire process of ECA algorithm to attain the better coverage of the network by minimizing the energy rate.

Algorithm

Input: set of sensor nodes S, target regions in the network T

Begin

Let A (S) be the active sensor nodes in the network with t as set of target regions of the network

For each sensor node S

Determine the energy drain rate (EDR)

EDR = RBPs / DRs

RBP – Residual Battery Power
DR – Battery power drain Drain rate
End For
Assign A as an empty set
Do {
Select t which is not yet chosen by s
If t > 1
Choose the t which has min (CS (t))
Else
Select the obtained t as T
End if
Select s which has the capability to reach T
If s > 1
Choose the t which has min (U (t))
Else
Select the obtained s as S
End If
} **While** (A reaches max (CS (T)))
Assign the network connectivity graph G
If A has active set of sensor nodes
B = A
Else
Add transmit nodes to the set A to form a connection with B
End if
Form the connectivity graph for the set A and B
If redundant set of sensor nodes are found
Identify the degree of sensor nodes D(s),
D(s) = number of sensor nodes access among the transmission Range
Identify the energy drain rate of sensor node EDR
If D(s) in set B has minimal value
Discard it
Else
Check other set of sensor nodes with EDR
End If
End if
Modify the set B after removal of redundant nodes
Return A;
Repeat until no more active set of sensor nodes found in the network environment which lies among the transmission range
End

The above algorithm describes the entire process of increasing the coverage and connectivity of the sensor nodes in the network. By determining the energy drain rate of each sensor node in the network, the coverage area of the sensor network is considerably increases.

4. Experimental Evaluation

In this section, we evaluate the performance of the proposed energy efficient resource optimization in intermittently connected sensor networks. In the simulation, n sensors are arbitrarily organized in a 10 * 10 square area, with n changing from 100 to 500. The sensing range of the nodes in the network is 1 if not, specified. We particularly scrutinize the situation where the coverage and network lifetime constraint cannot be pleased at the similar time. Consider a set of sensor nodes n = 600 and the battery/network lifetime ratio is 2 / 5. Both standardized and mixed battery states are measured. In the standardized case, every node has the identical battery/network lifetime ratio v, but in the mixed case, V_i is a arbitrary variable consistently dispersed in [v/2, 3v/2] with v as the average ratio. The proposed EEROSN technique modelled the network based on the network and battery lifetime of each node in the sensor networks. Then the linear integer program is implemented to minimize the energy consumption of each node in the network by determining the coverage set and the target regions of the particular area. The energy efficient connected coverage algorithm is accessed to enhance the network lifetime. By integrating the linear technique and ECA algorithm, the intermittently connected sensor networks achieved energy efficient resource optimization.

The performance of the proposed energy efficient resource optimization in intermittently connected sensor networks is evaluated in terms of

i) energy efficiency
ii) time consumption
iii) network lifetime

5. Results and Discussions

In this work, we evaluate the performance of the proposed energy efficient resource optimization in intermittently connected sensor networks. Experiments are achieved for a variety of network sizes with a grid of size 100x100. The below table and graph describes the performance of the proposed EEROSN technique and compared with the existing POP technique.

Energy efficiency

The energy efficiency is measured based on the total number of sensor nodes utilized over all the lifetime of the network.

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Number of nodes	Energy efficiency (%)	
	Proposed EEROSN	Existing POP
20	65	40
40	72	43
60	78	48
80	83	54
100	86	59
120	89	62

Table 5.1 number of nodes vs. energy efficiency

The energy efficiency is measured based on the number of sensor nodes in the network for transmission of data from source to destination. The energy efficiency of the proposed energy efficient resource optimization in intermittently connected sensor networks is compared with the existing POP technique illustrated in table 5.1.

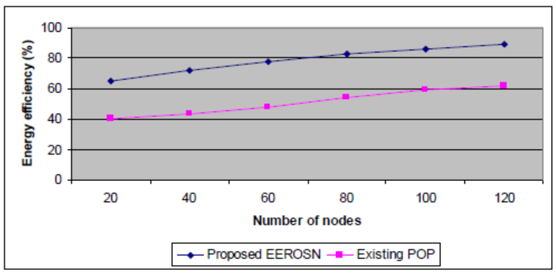

Fig 5.1 number of nodes vs. energy efficiency

Fig 5.1 describes the energy efficiency of sensor nodes in the network based on the presence of total number of sensor nodes in the network. The efficiency of energy is measured based on the number of nodes covers the target regions in the network. Compared to the existing POP technique, the proposed EEROSN technique provides high efficiency in energy for the better transmission of data from source to target region in the network. Since the existing POP utilized optimization technique for the process of achieving the energy efficiency, the accuracy of the coverage area determined to accomplish are not reached well. So there might be a chance of loss of signals in the middle to reach the coverage area of the wireless sensor networks. But in the proposed EEROSN technique, the active status of the nodes in the network is determined first based on the constraints, and then the linear integer program is deployed. This improves the scalability of the network and provides efficiency in energy for transmitting the signals from source to target regions. The variance in the energy efficiency is 20-30% high in the proposed EEROSN technique.

Time consumption

The time required to perform the coverage and connectivity of the sensor nodes in the network environment.

Number of nodes	Time consumption (sec)	
	Proposed EEROSN	Existing POP
25	8	20
50	11	24
75	14	29
100	17	38
125	21	45
150	25	52

Table 5.2 number of nodes vs. time consumption

The time consumption is measured based on the number of sensor nodes in the network for transmission of data from source to destination. The time consumption of the proposed energy efficient resource optimization in intermittently connected sensor networks is compared with the existing POP technique illustrated in table 5.2.

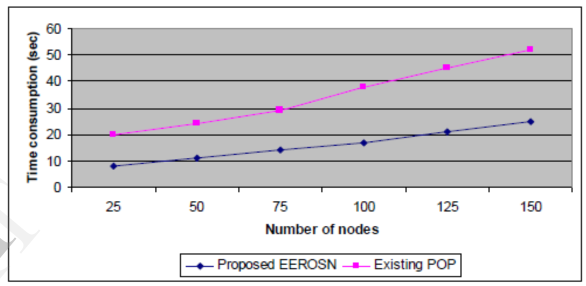

Fig 5.2 number of nodes vs. time consumption

Fig 5.2 describes the time consumption is measured based on the number of sensor nodes in the network for transmission of data from source to destination. The time consumption is measured in terms of seconds. Compared to the existing POP technique, the proposed EEROSN technique consumes less amount of time for the better transmission of data from source to target region in the network. Since the existing POP technique runs the processes simultaneously to achieve the better coverage area of the network, this consumes more time. But in the proposed EEROSN technique, the linear integer program is applied only after the construction of the network with active set of nodes. So, the process of achieving the connectivity and coverage in the sensor network is simple. The variance in the time consumption is 20-30% less in the proposed EEROSN technique.

Network lifetime

The lifespan of the network is determined based on the active status of the sensor nodes in the network.

Number of nodes	Network lifetime (%)	
	Proposed EEROSN	Existing POP
25	70	33
50	74	36
75	79	39
100	84	42
125	87	45
150	90	49

Table 5.3 number of nodes vs. network lifetime

The network lifetime is measured based on the number of sensor nodes in the network for transmission of data from source to destination. The network lifetime of the proposed energy efficient resource optimization in intermittently connected sensor networks is compared with the existing POP technique illustrated in table 5.3.

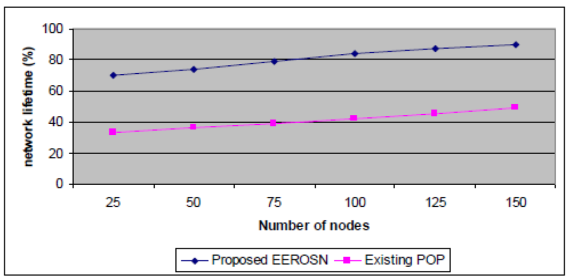

Fig 5.3 number of nodes vs. network lifetime

Fig 5.3 describes the network lifetime which is measured based on the number of sensor nodes in the network for transmission of data from source to destination. The time network lifetime is measured based on the rate at which the active set of nodes in the network transmits the signals effectively at minimal amount of time. Compared to the existing POP technique, the proposed EEROSN technique attains high level of network lifetime for the better transmission of data from source to target region in the network. The variance in the network lifetime is 20-30% high in the proposed EEROSN technique.

Finally, it is being observed that the proposed EEROSN technique attains better energy efficiency, connectivity and coverage in the wireless sensor network. The node constrained linear integer program is implemented for the process of achieving the connectivity and coverage of the wireless sensor networks.

6. Conclusion

In this paper, the proposed EEROSN technique efficiently addressed the issues of coverage, connectivity and energy-efficiency in wireless sensor networks. An efficient EEROSN method utilized node constrained linear integer program technique to prolong the network lifetime by devising the activation schedules for the sensor nodes in the network. The node constrained linear integer program processes the node based on three constraints like transmission rate, response time and energy drain rate. Based on these constraints, the wireless sensor network has been built effectively and the linear integer program is implemented to manage the coverage area and active status of the nodes in the network. Then the node constrained energy efficient coverage algorithm is implemented which clearly describes the process of maximizing the lifetime of the network and coverage connectivity. Experimental results reveal that the proposed EEROSN technique achieves better in terms of energy efficiency and network lifetime and minimizes the time consumption. Compared to the existing POP technique, the EEROSN technique achieves 46% high in maximizing the network lifetime.

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