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Application of Weighted Centroid Approach in Base Station Localization for Minimization of Multipath Losses in Wireless Sensor Networks

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Abstract: *A Wireless Sensor Networks (WSNs) consisting of sensor with strategic locations, and a base-stations (BSs) whose locations are relatively flexible. A sensor cluster consists of many small sensor nodes (SNs) that capture, encode, and transmit relevant information from a designated area. This article is focused on the topology of positioning process for BSs in WSNs. Heterogeneous SNs are battery-powered and energy-constrained, their node lifetime directly affects the network lifetime of WSNs. We have proposed an algorithmic approach to locate BSs optimally such that we can maximize the topological network lifetime of WSNs deterministically, even when the initial energy provisioning for SNs is no longer always proportional to their average bit-stream rate. The obtained optimal BS locations are under different length of area field and number of nodes according to the mission criticality of WSNs. By studying energy consumption due to space loss and amplification losses in WSNs, we establish the upper and lower bounds of maximal topological parameters of area and number of nodes, which enable a quick assessment of energy provisioning feasibility and topology necessity. Numerical results and surface plot are given to demonstrate the efficiency and optimality of the proposed topology of BSs positioning approaches designed for maximizing network lifetime of WSNs.*

Keywords: *Network topology, sensor networks, wireless communications, algorithm design, positioning algorithms.*

I. INTRODUCTION

WIRELESS Sensor Networks (WSNs) [1] have attracted intensive attention in audio streams, temperature readings, motion measures, and so on. In WSNs there is at least one application node (AN) in each cluster responsible for receiving raw data sent from sensor nodes (SNs), creating a local-view by exploring application-specific correlations among these data and forwarding the composite bit-stream toward a base-station (BS). The BS has much better processing and storage capabilities to further increase the value of local views. The BS also serves as a gateway for WSNs to exchange data and control information. SNs and ANs are battery-powered; it is unlikely to recharge them economically once they have been deployed in field. If a single SN runs out of energy, it's AN may still have the capability to reconstruct data sent from other correlated SNs. However, if an AN runs out of energy, the whole cluster coverage is completely lost. In this paper we have discussed these energy constraint of ANs is the foremost concern for WSNs. The location and communication arrangement can be determined before WSN initialization, or can be adjusted throughout a mission.

II. RELATED WORK

From last two decades there are tremendous research and design goals are chassed in the field of WSNs. Elizabeth M. Royer described an adhoc mobile network as a collection of mobile nodes that are dynamically located with the interconnections between nodes are capable of changing on a continual basis. The primary goal of such an ad hoc network routing protocol is correct and efficient route establishment between a pair of nodes so that messages may be delivered in a timely manner [3]. Katayoun Sohrabi present gave algorithms for self-organization of wireless sensor networks having scalably large number of mainly static nodes with highly constrained energy resources. [4].Ram Ramanathan consider the problem of adjusting the transmit powers of nodes in a multi hop wireless network (also called an ad hoc network) to create a desired topology. They formulated a constrained optimization problem with two constraints - connectivity and bi connectivity, and one optimization objective - maximum power used. [5].Further Wendi B. Heinzelman discussed the networking using hundreds or thousands of cheap Micro sensor nodes that allows users to accurately monitor a remote environment by intelligently combining the data from the individual nodes. These networks require robust wireless communication protocols that are energy efficient and provide low latency [6]. Jim Chou and Dragan

Petrovic proposed a novel approach to reducing energy consumption in sensor networks using a distributed adaptive signal processing framework and efficient algorithm. They also compared results with the topic of energy-aware routing to alleviate energy consumption in sensor networks has received attention recently .In this work they proposed an orthogonal approach to previous methods [7]. Jianping Pan designed a generic two-tiered Wireless Sensor Networks (WSNs) consisting of sensor clusters deployed around strategic locations, and base-stations (BSs) whose locations are relatively flexible. Numerical results were demonstrating the efficacy and optimality of the proposed topology control approaches designed for maximizing network lifetime of WSNs [8].

In this paper we have worked on the base station placement in a two-tiered wireless sensor network (WSN) field. The objective is to minimize the overall energy consumption in a WSN. Our results prove that the overall energy consumption is minimized at the centroid of the nodes and proposed point of the node as the compare of the minimum enclosing circle of the centre of the nodes. We know that most of the nodes are close to the base station, whereas a few nodes are far from it. Therefore these far-off sensors nodes use more energy than nearer ones. We have used a weighted centroid method for finding the optimal base station location and investigating how to find the base station location to reduce energy consumption and hence to increase network lifetime.

III. Energy Consumption In WSNs

WSN are a self configured network formed using a large numbers of sensor nodes distributed over a geographical area with either predefined location or randomly deployed. Individual sensor nodes posses limited processing, communicating and energy recourses. These sensor nodes can sense, measure, and gather information from the vicinity and transmit the sensed information (data) to the user or information sink. Communication of sensed data from the sensor nodes to information sink happens to be the main cause of energy depletion in sensor nodes. In order to extend the active life of WSN, it is required to process data locally and send the processed information to sink node. One of possible solution for optimal use of available energy is by using cluster based routing protocols. Hierarchical or cluster based routing is well known technique for scalability and efficient communication. Clustering enables bandwidth re-use and thus can improve the system capacity. Clustering enables efficient resource allocation and helps in designing better power control. In the hierarchical routing the data collected by sensor nodes in the proximity of the event is routed to the sink nodes through cluster heads. These selected head nodes are responsible for routing the information from the sensor nodes to the sink node after application of proper data aggregation or fusion [2].Overall system scalability, life time and efficiency depend upon the creation of optimal number of clusters and the spatial position of cluster head.

IV. Methodology Of Positioning Of BS In WSN

Wireless sensor network (WSN) has self-organizing wireless sensor nodes with limited energy resource, and usually a base station to collect and process the data from sensor nodes. A sensor node consumes energy for event sensing, coding, modulation, transmission, reception and aggregation of data. Data transmission has the highest share in total energy consumption [1, 2]. The required transmission power of a wireless radio is proportional to square or an even higher order exponent of distance in the presence of obstacles. Thus, the distance between transmitter and receiver is the main metric for energy consumption in a WSN. Base station location affects the lifetime of the sensor network as all the data are finally transmitted to the base station for processing and decision making for various applications. We can reduce transmission energy by reducing the distance between the sensor nodes and the base station. This can be achieved by placing the base station at an optimal location. In the literature so far, many heuristic algorithms have been proposed to find sub-optimal solutions of the optimum base station positioning in two-tiered WSN. Although these heuristics are shown to be effective, their algorithms depend on the topology and are based on structural metrics.

In this work we have searched the optimal location of a base station with respect to minimum energy expenditure or maximum lifetime of a sensor network.

The centre of a minimum enclosing circle, is the optimal location for the N-of-N lifetime. N-of-N lifetime means the time after which the first node dies or the time up to which N out of N nodes remain alive. The minimum enclosing circle is equivalent to minimizing the maximum distance between the base station and any sensor node in the network. The overall energy consumption [2] is minimized at the centroid of the nodes, when path loss exponent n is 2. In this method, average energy expenditure is minimized, but the first nodes may die earlier compared with the min max approach, as energy contributions of the sensor nodes, are rather uneven. For example, it may happen that most of the nodes are close to the base station, whereas a few nodes are far from it. Therefore these far-off sensors use more energy than nearer ones and hence deplete their energy at a faster rate and die sooner. This approach is known as minimum average or min avg. The Pan et al. approach consist of location of station based on only free space energy model but in our work we will consider multipath losses along with free space losses to assign different weightage to the sensors which follow a multipath loss. In our approach we have defined a proposed position of BS using weighted positioning of centroid of the sensor nodes as described below:

Step 1: Find centroid (Cx, Cy) of the nodes distributed in the field. This is the point, where energy consumption is minimized, and is given by summation of location of sensor nodes.
Step 2: Find the nodes that are at less than d0 distance from the centroid.
Step 3: Calculation of weights using centroid for all the nodes.
Step 4: Determine the weighted average of nodes' positions as proposed optimal position (xp, yp) for the base station.

V. Simulation Results

In this section we have described our WSN model design using the MATLAB. Using this model we have determined the energy consume by sensors during the force of data transmission from WSN sensor to base station. We have analyzed three different scheme of determining the location of base station with respect to minimum energy expenditure of a sensors network.

VI. Design of WSN Model

The transmitter dissipates energy to run the transmitter radio electronics and the power amplifier, and the receiver dissipates energy to run the receiver radio electronics. If the distance between the transmitter and the receiver is less than a threshold (d_0), the 'free space (fs) loss' model is used; otherwise, the 'multipath (mp) loss' model is used. Here, we are assuming that a suitable power control mechanism exists to regulate transmit power depending on the distance to the receiver. In a transmission amplifier .we used path loss exponent, n= 2, for free space loss model and n = 4 for multi-path loss model. The consumed amplifier energy E_{amp}, of a sensor node is $E_{fs}.d^2$ or $E_{mp}.d^4$ depending on the distance d between node and base station.

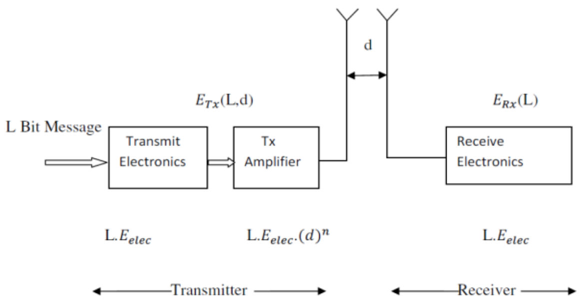

Fig. 1: Radio Model

$$E_{amp} = \begin{cases} E_{fs}.d^2 & d < d_0 \\ E_{mp}.d^4 & d \geq d_0 \end{cases} \qquad (1)$$

Here, threshold distance d0 for swapping amplification model is calculated by equating E_{amp}(fs) to E_{amp}(mp) [6].

$$E_{fs}.d^2 = E_{mp}.d^4 \quad = d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \qquad (2)$$

Where E_{fs} is free space loss constant measured in J/bit/m2 and $E_{mp}$is multi-path loss constant measured in J/bit/m4. If a node transmits L number of bits, the energy used in transmission will be

$$E_{TX}(L,d) = E_{TX-ele}(L) + E_{amp}(L,d) = \begin{cases} LE_{ele} + LE_{fs}.d^2 & d < d_0 \\ LE_{ele} + LE_{mp}.d^4 & d \geq d_0 \end{cases} \qquad (3)$$

To receive L message bits, the radio spend

$$E_{RX}(L) = E_{RX-ele}(L) = LE_{elc} \qquad (4)$$

Here, E_{ele} is the energy, in J/bit in transmission and reception electronics. Most of the earlier work had considered only free space loss (n = 2) as the model of radio communication. We are not aware of any work that considers multi-path loss (n =4) in their radio model or multi-path radio models for analyzing optimal base station positioning. We have designed WSN model having large number of wireless sensor nodes with limited energy resources model having a base station that can collect and process the data obtained from sensor nodes. For this purpose an algorithm using MATLAB 10 software is developed. In this algorithm we have generated randomly distributed sensor node in a given field having square area M×M meter square. The number of nodes are varied from 5 to 200 nodes for a given area .We have also considered field area of different dimensions having length of square area 30 to 500 meters. Every time we have increment of 10 and nodes are increment of 10 also. In this way we have generated about 48×20 random distributed WSN cluster with different areas and different number of nodes. Let we have N sensor nodes randomly distributed in a rectangular field at a location (Px, Py) where ;

Px=X1,X2,X3................Xn
Py=Y1,Y2,Y3................Yn

After that we have calculated the location of centroid for given randomly distributed wireless sensor nodes.
Fig 2 are shown below where x and y axis represents the length of square field and stars shown the location of wireless sensor and a circle shown the location of centroid.

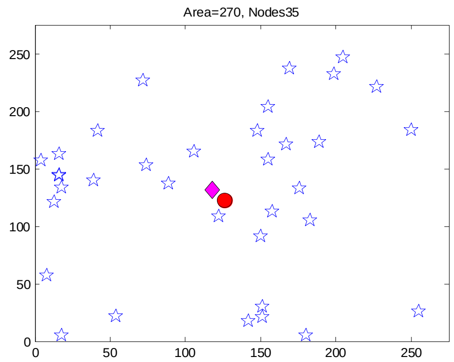

Fig. 2: WSN sensor node cluster for area =270 and node=35

Fig 2 shows the cluster of nodes (blue stars), centroid (mageta diamond) and proposed position of base station (red circle) for area field of length=120 and number of nodes=175 in this Fig. Here area is small hence centroid and proposed position are approximately same with centroid and proposed base station location.
We have shown the surface plot obtained from value of average percent reduction in energy on using proposed point with respect to centroid as BS position (%Ecp) in fig 3(a) using this surface plot we can visualize how does percentage energy reduction varies with different configuration of WSN nodes and field area. In the surface plot the colour of the surface changes from red to blue shades where red shades represents high values, yellow represents medium values and blue represents low values.
In Fig 3(a) we have shown %Ecp on the z-axis, nodes and area are on the x-axis and y-axis. As we can see that x-axis varying from 0-200 and Here we have in circle the portion where %Ecp is significantly larger than the other cluster. for more clearly we have clipped the negative part to zero such that the surface plot becomes blue in the regions having Ec=Ep.

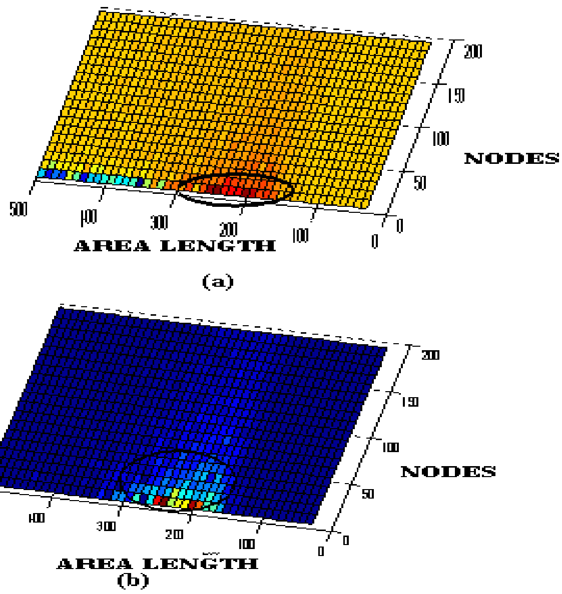

Fig. 3: Top view of Percentage reduction in average amplifier energy for the proposed point compared with centroid (a) without clipping negative part (b) with clipping negative part.

In the Fig 3(b) we can see that a yellow line is drawn in the portion having %Ecp as positive in this region area varies from 100 to 350 meter and number of nodes are varying from 5 to 180. It represents that for area less than 100 the performance of both algorithm are same. However since our threshold distance is 80 for area of length 100 all the nodes will be at a distance less than d_0. So there will be no case of amplification loss there will be only the free path losses that is why for area less than 100 our proposed point and centroid point is similar. For large area above than 350 both algorithm are giving same performance. So we can say that our proposed base station location is good for area of field length less than 150 and for all combination of number of sensor nodes. We have also in circle the region where the surface value is significantly larger for %Ecp with black circle in fig 3(b). This region is under the range 150-300 meter field length with new nodes 5-50. Similarly we have run our algorithm about three times and generated an average % Ecp for 20 results for all three time simulation results .We have also calculated energy consumption on taking centroid as position of BS (Ec) and center of minimum enclosing circle as BS position Em. Using the results we have determined %EM and %EMP. Every time we have found that %Ecp is largest in comparison to %EMP and %EMC.

VII. CONCLUSION

We investigated energy consumption minimization for different schemes of positioning BS in WSNs with variation of area and number of nodes .for area we are considered field length of 30-500 meter and number of nodes 5-200 and nodes and the average percentage reduction in energy consumption for each defined area and nodes evaluated. We found that proposed weighted centroid based approach is best for giving highest percent of reduction in energy consumption compare to centroid and minimum enclosing circle base positioning of base station .maximum percentage reduction approximately 4-6 % compare to percentage reduction when centroid is taken as position of base station .Proposed schemes is better than centroid specially for the region varies from length 100-350 meter and number of nodes 5-180 otherwise the proposed scheme is giving result equivalent to result coming from centroid .We have also design the table for node ratio for calculating the ratio of nodes lies inside the threshold distance where only free space losses occur to number of nodes where both free space and amplification losses occur.

It has been observed that number of nodes are increases as this node ratio decreases and as we increases the area this node ratio again decreases , and it has been found that if we take number of nodes above than 75 for area above than 210 meter length , we can get node ratio less than one. We can reduced the multi-path losses for area 210 meter for the case the proposed schemes but for centroid same result are found from a slightly higher area.

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