Energy Efficient Design of Mobile Wireless Sensor Networks: Constrained Clustering

Garimella Rama Murthy, Mohammed Nazeer, Padmalaya Nayak

Abstract: ***The performance in Wireless sensor network (WSN) is improved by endorsing mobility e.g. reduces traffic by avoiding un necessary and less transmission and reception of packets, while less attention has been focused on selection of cluster head. Thus in this existing paper we design an energy efficient hierarchical routing protocol, we formulate cluster head choosing problem by considering both distance and energy as a quadratic optimization problem and provide a solution to it. To the best of our knowledge, the derivation of centroid of patterns based on interesting optimization problem is novel and is not known in the literature. We derive the position of centroid by formulating and solving an optimization problem by allowing mobility to sensors and base station/sink.***

Keywords: Wireless Sensor Network, Mobility, Energy Efficiency, Clustering.

I. INTRODUCTION

In most of the hierarchical energy efficient routing protocols clusters are formed and rotation of the cluster head is done based upon various constraint such as threshold energy, distance etc. in LEACH, HEED etc. In WSN, a group of sensor nodes sensed a value and sends it to the sink the challenge is the battery power of the sensor node has to utilized minimum since changing of battery most of the time is challenging or not even possible. Thus in this existing paper we design an energy efficient hierarchical routing protocol, we formulate cluster head choosing problem by considering both distance and energy as a quadratic optimization problem and provide a solution to it. The choosing of cluster head is done based upon CENTROID of sensor position coordinates. To the best of our knowledge, the derivation of centroid of patterns based on interesting optimization problem is novel and is not discussed in the literature. We consider the Wireless Sensor Network (WSN) where the sensors know their position (i.e. 3 spatial co-ordinates are known through, say GPS).Cluster head election in LEACH and other energy efficient algorithms involves local exchange of hello messages among the members of a cluster.

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Ensuring that cluster head is located at the centroid (that is through minimization of squared distances from centroid node (CH) to sensors) ensures that the strength of the signal is as good as possible for wireless messages. Also, with selection of cluster heads as centroids ensures that here lying of messages from sensors to Base Station/ Sink is of good quality. Since remaining battery energy is a quantity utilized to select a CH, The selection of CLUSTER HEAD is done based upon node with higher residual energy and distance closer to previous cluster head.

Also, in case sensors are mobile, the mobile sensor chosen as the CH is moved to the CENTROID position. The idea of cluster head selection as being close to centroid applies to all hierarchical protocols where clustering of sensors is carried out. If the placement of sensors (mobile or static) is under the control of user, cluster head is placed at the centroid position. Specifically, in the initial deployment of sensors over the sensors field, cluster heads are placed at the centroid. (I.e. cluster reconfiguration) We consider two cases

Planned deployment

Random deployment

In both cases, we derive the position of centroid by formulating and solving an optimization problem. By allowing mobility to sensors and/or base station/sink we are led to the following four paradigms of wireless sensor networks.

i) Both sensors and base station is static
ii) Mobile sensors and base station static
iii) Static sensors and base station mobile
iv) Both sensors and base station is mobile

In this research paper, we consider the paradigm where Base station / Sink are mobile, and sensors are static. The results of this paper are potentially applicable to other mobile paradigms the remaining of the paper is planned as follows. Section2 covers literature study. Section 3 explains Random Sensor Deployment: Clustering, we evident that global minimum point is a centroid. Section 4 presents Constrained Clustering: planned sensor placement, it formulates and solves the constrained clustering problem. Finally, we conclude the paper by conclusion in section5.

II. RELATED WORK

Clusters Based Topology (CBT)Yeetal. And Liu[2][3]

Clustering is widely used in static and mobile WSN paradigms to perform various task such as transmission and reception of data surveillance, agriculture, etc. clustering is mostly popular in hierarchical network consist of hundreds of nodes where instead of each node sending data to the sink only cluster head of a cluster is used to transmit and receive the data. Which reduce energy utilization and increases the network life time. It basically consists of two steps setup phase and ready phase. In step up phase the cluster head selection is done by using various algorithms which consider different parameters for the selection of the cluster head such as (distance, energy, threshold value, etc). The selection of the cluster head is also depend upon type of network whether it is centralized or distributed and type of nodes static or mobile. The selection of the cluster head is done by sink in centralized process. In distributed approach it uses random methods, probability, and intra communication of cluster. In intra communication of cluster the node at centriod position of the cluster is consider as the cluster head and data can be transmitted to cluster head by the cluster members in a single hop or multi hop.

In ready phase it is responsible for transmitting the data from cluster head to base station. Different algorithm uses different approach for this purpose to transmit the data to base station. Some of the algorithm uses inter clustering were the data is transmit from one cluster head to another cluster head until it reaches the base station the path between the cluster head is determined by using minimum spanning tree. In mobility based environment the mobile node is selected as cluster head and it is allowed to travel to the network by using path planning algorithm along with TDMA protocol. It can be consider for a scenario were some of the nodes are mobile and most of the nodes are static but if all the nodes are mobile then based on the velocity of the node either of them base station or sensor nodes are consider as static.

Low Energy Adaptive Clustering Hierarchy (LEACH) [4] This protocol was consider as one of the initial hierarchical clustering routing protocol in which the nodes used to communicate with in its own cluster, it form several cluster based on their location, it has been implemented for static network with fixed base station. Based upon the energy level and energy utilization it changes the cluster head, it is based upon nonrealistic assumption that each node can reach base station directly in single hop but practically it is not possible since each node has different coverage range and they may not reach base station directly.

Younis and Fahmy [5] this protocol provide multi hop energy efficient clustering algorithm, the cluster head selection is based upon average residual energy compared with neighbor nodes, and it also consider intra cluster communication cost. In multi hop communication it supports energy conservation, scalability between cluster head and base station. The drawback of this protocol is they are several sensor nodes that may not lie in any cluster. It required broadcasting of several control packets due to which increases the number of iteration and packet overhead is high due to which nodes near to base station may die first since it is participating in every transaction.

Muruganathan et al. [6] In this protocol the base station acts as centralized authority to form equal number of clusters and at same time make sure that each cluster consists of same number of nodes to equalize the cluster head load. Subsequently after every round the nodes of cluster are supposed to upgrade their location and energy value to the sink. The sink must be capable of handling complex computational processing. The sink will done selection of CH based upon energy level value. The node with highest energy level value is selected as CH. The CH is connected using minimum spanning tree to reach the sink. The drawback of this mechanics due to centralized approach is poor scalability and robustness. The node should upgrade value of energy and location to sink on each round, therefore it's not suitable protocol for periodically retrieving of data.

Jung et al. [7] it provides a new routing protocol know as concentric clustering scheme which is compared with PEGASIS. It reduces energy consumption of the entire network and reduces the reverse data flow from the base station. In PEGASIS it divides the network topology into levels based upon different radius values and assumes the base station is to be at the center of the topology. The values of radius is increased in the incremental process by one and form various levels, the data was supposed to transmit from higher level to lower level and to its neighbor nodes until it reaches the base station but not allowed to transmit from lower to higher level and it will save the energy by this mechanism. But the energy save in concentric clustering scheme is more than the PEGASIS.

Deng et al. [8] the drawbacks of this protocol is packet drop, link failure and reduce network utilization. Its advantage is it over perform LEACH, HEED and other mobility based protocols. In this protocol it performs intra clusters and inter clusters election based upon threshold value. In intra cluster the data is forwarded from cluster members to cluster head. In inter cluster the data is forward from cluster heads to base station.

[9] The analytical expression for energy saving (quantification) is done for the existing and proposed system by using gauss's lattice point problem. The existing system consist of gossip, flooding and proposed system consist of circular leveling and sectoring algorithm. [10] Mobility based algorithms for highly configured MANET and VANET are as described below. Clustering algorithms are based upon map routes, speed, velocity, and traffic condition and geo location to create stable hierarchical topology.

Mobility Based Clustering protocol [8] It firm bigger clusters in stable networks, size of cluster is based upon the mobility level, the mobility level is estimated based on mobility level of nodes or mobility level of clusters.

Stable Clustering algorithm [11] the more stable nodes are selected as cluster heads; stability of the nodes is determined by comparing its speed with the average speed of 1 hop neighbors and to guess contact loss. Zheng's [12]

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each node sends its position and mobility information to a server, which acts as a centralized process. The algorithm can determined the nodes mobility and position even it is not updated frequently. K-hop Compound Metric Based Clustering [13] it proposes link expiration time for dynamic broadcast, the link expiration times are evaluated based upon mobility. The nodes are selected as cluster head if it has more stable links.

Wang's [14] It reduces cluster life and affiliation events by considering mobility metric of Shannon entropy for selecting cluster head.

Hassanabadi's [15] It uses data mining algorithm to form clusters based on their mobility by considering data samples as sensor nodes.

Young-jun's [16] The selection of CH is done by angle resolution tuning at each division and we can modify the CH density by ensuring homogeneous distributions, the network area is circularly bounded and divided by angles.

III. RANDOM SENSOR DEPLOYMENT: CLUSTERING

WE NOW CONSIDER A WSN IN WHICH THE SENSORS ARE RANDOMLY DEPLOYED (I.E. THE SPATIAL POSITION COORDINATES SUCH AS (X_1, $X2$, $X3$) ARE RANDOM VARIABLES). FOR GENERALITY IN DERIVATION,

Consider N data points in M-dimensional pattern space (i.e. M-dimensional random vectors. (I.e. components of these vectors are random variables).

$X_1, X_2 . . . X_N$ with $X_j=[x_{j1},x_{j2}. . .x_{jm}]$ for $1 \le j \le N$ (1)

Let X_0be the desired centroid

i.e., $X_0 = [x_{01}, x_{02} . . . x_{0m}]$ and

$EX_0= [\tilde{x}_{01},\tilde{x}_{02}...\tilde{x}_{0}m]$.The problem is to determine the mean values $\tilde{x}_{0i}$ $1\le i \le m$ (i.e. compute EX_0 mean centroid vector in such a way that mean value of square of Euclidean distances from it to pattern vectors is minimized).

Thus, the objective function is

$$J(X_0)=J[\tilde{x}_{01},\tilde{x}_{02}...\tilde{x}_{0m}]=E[\textstyle\sum_{j=1}^{N}\sum_{i=1}^{m}[x_{ji}-\tilde{x}_{0i}]^2] \quad (2)$$

We provide a solution to unconstrained optimization problem. We exchange differentiation and summation.

$$\frac{\delta J(X_0)}{\delta x_{0i}} = \sum_{j=1}^{N}(-2)E[x_{ji}-\tilde{x}_{0i}] \quad (3)$$

Setting it to zero, we have

$$\sum_{i=1}^{N} Ex_{ji} = (N)(\tilde{x}_{0i}) \text{ for } 1 \le i \le M \quad (4)$$

Thus, we have

$$\tilde{x}_{0i} = \frac{1}{(N)}\textstyle\sum_{j=1}^{N}(Ex_{ji}) \text{ for } 1 \le i \le M \quad (5)$$

That is

$$\tilde{x}_{0i} = \frac{1}{(N)}\sum_{j=1}^{N}(Ex_{ji}) \quad (6)$$

And so on

We will now prove that such a centroid $X_0 = [Ex_{01}, Ex_{02}, . . . ,Ex_{0m},]$ It is a global minimum point we have a diagonal hessian matrix by performing second partial derivatives and all positive Eigen values.

$$\frac{\delta^2 J(x_0)}{\delta \tilde{x}_{0k}^{\ 2}} = 2N \quad \text{for } k = i \quad (7)$$

$$\frac{\delta^2 J(x_0)}{\delta \tilde{x}_{0k}\,\delta \tilde{x}_{0_l}} = 2N \quad \text{for } k \neq i \quad (8)$$

Hence, the positive definite diagonal matrix is hessian matrix since N >0

A. Proposed Algorithm

Consider a WSN Network consist of N quantity of nodes deploy in the sensor field by using planned or randomly deployment. The proposed algorithm consists of the following steps

Step 1: Ensure that cluster head is located at the centroid. The position of centroid is calculated by using above expression.

Step 2: If the cluster head is not located at centroid, then sensor node with relatively large residual energy and also closer to centroid is chosen as the CLUSTERHEAD.

Step 3: In case sensors are mobile, the mobile sensor chosen as the cluster head. And it is moved to the CENTROID.

Step 4: If the placement of sensors (mobile or static) is under the control of user (i.e. initial deployment), cluster head is placed at the centroid position.

Step 5: If the placement of sensors (mobile or static) is not under the control of user then consider step2 or step3 based upon the type of nodes (mobile or static).

We consider both cases of planned and random deployment. In both cases, we derive the position of centroid by formulating and solving an optimization problem.

The major goal of Constrained Clustering is to find centroid for the globally near optimal solutions by using Hessian matrix. The flow chart of a proposed algorithm is as represented in Figure 1.

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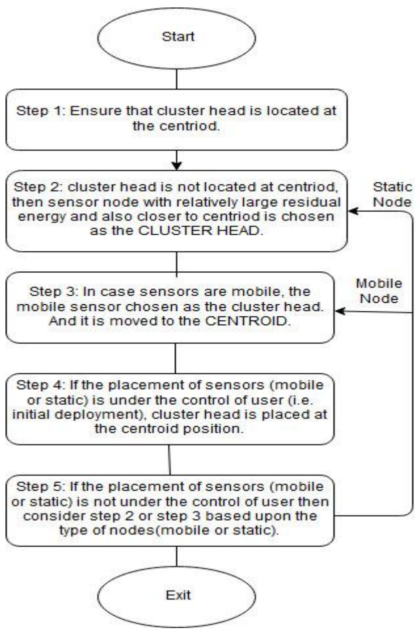

Figure 1: Constrained Clustering Algorithm Flowchart.

IV. Constrained Clustering: planned sensor placement

We now formulate and solve the constrained clustering problem. Specifically, we consider the case where patterns are deterministic and NOT random vectors. Problem: The optimization problem is to minimize (i.e. squared Euclidean distance from pattern vectors to centroid vector).

$$J(X_0) = E\left[\sum_{j=1}^{N-1}\sum_{i=1}^{m}[x_{ji} - x_{0i}]^2\right] + \lambda\left[\sum_{k=1}^{m}(x_{Nk} - x)_{0k}\right)^2 - S \quad (9)$$

Subject to the following constraint

Constraint: The squared Euclidean distance from pattern vector x_N to the centriod is equal to value of"S" i.e. X_N is the extreme pattern.

Set L = (N-1)

$$\frac{\delta J(X_0)}{\delta x_{0i}} = \sum_{j=1}^{L}(-2)[x_{ji} - x_{0i}] + \lambda(-2)(x_{Ni} - x_{0i})$$

$$\text{for } 1 \le i \le M \quad (10)$$

Setting it to zero, we have

$$\sum_{j=1}^{L} x_{ji} - L(x_{0i}) - \lambda(x_{0i}) + \lambda(x_{Ni}) = 0 \text{ for } 1 \le i \le M \ (11)$$

$$\sum_{j=1}^{L} x_{ji} - x_{0i}(L+\lambda) + \lambda(x_{Ni}) = 0 \text{ for } 1 \le i \le M \ (12)$$

$$x_{0i} = \frac{\sum_{j=1}^{L} x_{ji} + \lambda(x_{Ni})}{L+\lambda} \text{ for } 1 \le i \le M \quad (13)$$

Equality constraint

$$\sum_{k=1}^{m}(x_{Nk} - x_{0k})^2 = S \quad (14)$$

$$\sum_{k=1}^{m}\left(x_{Nk} - \frac{(\sum_{j=1}^{L} x_{jk} + (\lambda)x_{Nk})}{L+\lambda}\right)^2 = S \quad (15)$$

$$\sum_{k=1}^{m}\left[\frac{(L+\lambda)x_{Nk} - (\lambda)x_{Nk} - \sum_{j=1}^{L} x_{jk}}{L+\lambda}\right]^2 = S \quad (16)$$

$$\sum_{k=1}^{m}\left[\frac{(L)x_{Nk} - \sum_{j=1}^{N-1} x_{jk}}{L+\lambda}\right]^2 = S \quad (17)$$

Let

$$\sigma = \sum_{k=1}^{m}\left[Lx_{Nk} - \sum_{j=1}^{N-1} x_{jk}\right]^2 = (L+\lambda)^2 S \quad (18)$$

$$(\lambda^2 + L^2 + 2\lambda L)S = \sigma \quad (19)$$

$$\text{Let } \frac{\sigma}{S} = \beta \quad (20)$$

$$\lambda^2 + 2\lambda L + L^2 = \beta \quad (21)$$

$$\lambda^2 + 2\lambda L + L^2 - \beta = 0 \quad (22)$$

i.e., there are two solution for 'λ'

$$\lambda = \frac{-2L + \sqrt{4L^2 - 4(L^2 - \beta)}}{2} \quad (23)$$

$$\lambda = \frac{-2L \pm \sqrt{4\beta}}{2} \quad (24)$$

$$\lambda = -L \pm \sqrt{\beta} \quad (25)$$

We now calculate the hessian matrix of second partial derivatives

$$= \sum_{j=1}^{L}\frac{\delta}{\delta x_{0i}}(-2)(x_{ji} - x_{0i}) + \lambda(-2)\frac{\delta}{\delta x_{0i}}(x_{Ni} - x_{0i}) \quad (26)$$

$$= \sum_{j=1}^{L}(2) + (-2\lambda)(-1) = 2L + 2\lambda \quad (27)$$

$$\frac{\delta^2 J(X_0)}{\delta x_{0k}\,\delta x_{0i}} = 0 \text{ for } k \ne i \quad (28)$$

Hessian matrix:

$$\begin{bmatrix} 2L+2\lambda & 0 & \dots & 0 \\ \vdots & \vdots & \dots & \vdots \\ 0 & 2L+2\lambda & & 0 \\ 0 & 0 & \dots & 0 \\ 0 & 0 & & 2L+2\lambda \end{bmatrix}$$

Thus, for uniqueness of minimal solution

$$2L + 2\lambda > 0 \qquad (29)$$

$$2L + 2\left(-L + \sqrt{\beta}\right) = 2\sqrt{\beta} > 0 \qquad (30)$$

i.e. Solution $\lambda = -L - \sqrt{\beta}$ is eliminated

Note: [17] The derivation in this section can easily be generalized for random sensor pattern deployment (as derived in section 2). Detailed duplication of derivation is avoided for brevity.

Remark: The above derivation applies to the following practically useful constrained clustering problem. x_N denotes the centroid of extreme patterns which are clustered in a region different from main cluster patterns i.e. $x_1, x_2, \ldots, x_{N-1}$. These extreme patterns influence the location of overall centroid.

V. CONCLUSION

In this research paper, hierarchical energy efficient routing protocols are considered (such as LEACH, HEED) and proposed cluster head position as the centroid of sensor positions. We considered random deployment as well as planned deployment of sensors. We formulated and solved the associated optimization problems using Lagrange multiplies method (for N sensors/patterns in M–dimensional space i.e. M=3 for WSN application). We thus proposed OPTIMAL CLUSTERING of sensor nodes (with respect to centroid position) for a certain paradigm of mobile wireless sensor networks (WSN). We expect the results to be useful for DYNAMIC CLUSTERING in arbitrary mobile WSN.

REFERENCES

1. G.Rama Murthy, E.Damoder Reddy and K.Venkata naresh babu, Energy Efficient Design of wireless sensor network: clustering. Proceedings of international conference on recent trends in engineering and science (2018)
2. M. Ye, C. Li, G. Chen, and J. Wu, EECS: An energy efficient clustering scheme in wireless sensor networks. International Conference on Performance Computing and Communications (IPCCC) pp. 535–540(2005).
3. X. Liu, A survey on clustering routing protocols in wireless sensor networks. Sensors (8)(2012)
4.Heinzelman,W.R.,Chandrakasan, A., Balakrishnan, Energy efficientcommunication protocol for wireless micro sensor networks. Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, pp.79–84, 2000.
5. O. Younis, S. Fahmy, HEED : A hybrid, energy-efficient, distributed clustering approach for Ad Hoc sensor networks. IEEE Transactions on Mobile Computing (4), 366 (2004)
6. S.D. Muruganathan, D.C.F. Ma, R.I. Bhasin, and A. Fapojuwo, A centralized energy-efficient routing protocol for wireless sensor networks IEEECommunications Magazine (3), 8-13 (2005)
7. S.M. Jung, Y.J. Han, and T.M. Chung, The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS . Proceedingsofthe9thInternationalConference on Advanced Communication Technology, (1),PP: 260-265(2007)
8. S. Deng, J. Li, and L. Shen, Mobility-based clustering protocol for wireless sensor networks with mobile nodes. IETWirelessSensorSystems(1),PP:39-47(2011)
9. Mohammed Nazeer, G.Rama Murthy, RPratap singh, Leveling and Sectoring Algorithm: Lattice Point Problem(Quantification of Energy Savings). ACM IML conference,United Kingdom 2017, (2017)
10. Victor Sucasas a , b , ∗, Ayman Radwan a , Hugo Marques a , b , Jonathan Rodriguez a , Seiamak Vahid b , Rahim Tafazolli b , A survey on clustering techniques for cooperative wireless networks. ACM IML conference,United Kingdom 2017, (2017)
11.K. Liu, J. Su, J. Zhang, F. Liu, C. Gong , novel stable cluster protocol for mobile ad hoc networks. Propagation and EMC Technologies for Wire- less Communications pp. 1328–1332(2005)
12. Y. Zhang, J.M. Ng, A distributed group mobility adaptive clustering algorithm for mobile ad hoc networks.IEEE International Conference on Communications pp. 3161–3165(2008)
13. S. Leng, Y. Zhang, H.-H. Chen, L. Zhang, K. Liu , A novel k-hop compound metric based clustering scheme for ad hoc wireless networks . Wireless IEEE Trans. Commun pp. 367–375(2009)
14. Y.-X. Wang, F. Bao, An entropy-based weighted clustering algorithm and its optimization for ad hoc networks. Third IEEE International Conference on Wireless and Mobile Computing, Networking and Communications p. 56(2007)
15. B. Hassanabadi , C. Shea , L. Zhang , S. Valaee, Clustering in vehicular ad hoc networks using affinity propagation C. Shea, Ad Hoc Networks pp. 535–548(2014)
16. K.w.L.Y.-j.Oh, A clustering algorithm based on mobility properties in mobile ad hoc networks. WirelessIEEETrans.Commun.pp:117(2015)
17. Duda, Richard O. Duda, Peter E. Hart, *Pattern Classification* (John Wiley Sons, pp:654 (2006)

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