AN OPTIMIZED WEIGHT BASED CLUSTERING ALGORITHM IN HETEROGENEOUS WIRELESS SENSOR NETWORKS

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ABSTRACT

The last few years have seen an increased interest in the potential use of wireless sensor networks (WSNs) in various fields like disaster management, battle field surveillance, and border security surveillance. In such applications, a large number of sensor nodes are deployed, which are often unattended and work autonomously. The process of dividing the network into interconnected substructures is called clustering and the interconnected substructures are called clusters. The cluster head (CH) of each cluster act as a coordinator within the substructure. Each CH acts as a temporary base station within its zone or cluster. It also communicates with other CHs. Clustering is a key technique used to extend the lifetime of a sensor network by reducing energy consumption. It can also increase network scalability. Researchers in all fields of wireless sensor network believe that nodes are homogeneous, but some nodes may be of different characteristics to prolong the lifetime of a WSN and its reliability. We have proposed an algorithm for better cluster head selection based on weights for different parameter that influence on energy consumption which includes distance from base station as a new parameter to reduce number of transmissions and reduce energy consumption by sensor nodes. Finally proposed algorithm compared with the WCA, IWCA algorithm in terms of number of clusters and energy consumption.

KEYWORDS

Wireless sensor network, Two-tiered architecture, Clustering, Energy consumption

1. INTRODUCTION

In recent years, wireless sensor networks (WSN) have a wide application prospect, so it has attracted great interests in several related research fields and industries. Wireless Sensor Network (WSN) consists of a large number of limited resources such as CPU, storage, battery power, and communication bandwidth, tiny devices, which are called sensors. These sensor nodes can sense task-specific environmental phenomenon, and communicate wirelessly to other sensor nodes or to a sink also, called data gathering node. WSNs can be used for a variety of applications dealing with monitoring, control and surveillance.

Sundarapandian et al. (Eds): ICAITA, SAI, SEAS, CDKP, CMCA, CS & IT 08,
pp. 185–195, 2012. © CS & IT-CSCP 2012 DOI : 10.5121/csit.2012.2516

A two-tiered wireless sensor network, as shown in Figure 1, consists of sensor nodes (SNs), application nodes (ANs), and one or several base stations (BSs). Sensor nodes are usually small, low-cost and disposable, and do not communicate with other sensor nodes.They are usually deployed in clusters around interesting areas. The raw data obtained from sensor nodes are first transmitted to their corresponding application nodes. After receiving the raw data from all its sensor nodes, an application node conducts data fusion within each cluster.It then transmits the aggregated data directly to the base station or via multihop communication.The base station is usually assumed to have unlimited energy and powerful processing capability. It also serves as a gateway for wireless sensor networks to exchange data and information to other networks. Wireless sensor networks usually have some assumptions for SNs and ANs. Sensor networks may be divided into homogeneous and heterogeneous ones. All sensor nodes in a homogeneous sensor network possess the same parameters and in a heterogeneous one possess different parameters. Besides, sensors may be fixed or moveable. Here, heterogeneous sensor networks are considered. Sensor nodes may have different capability and different parameters. Besides, each node may act as both the roles of a sensor node and an application node [1].

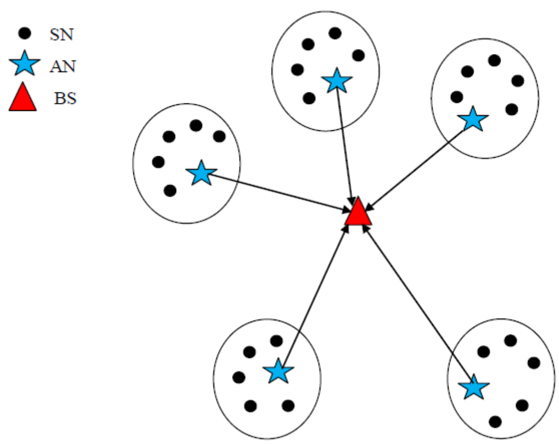

Figure.1. A two-tiered architecture of wireless sensor networks

An optimised algorithm based on the weighted clustering algorithm used in mobile ad hoc networks is proposed to determine the cluster heads in a given mobile wireless sensor network. The cluster heads chosen will act as the application nodes and may change in different time intervals. The distance between base station to each sensor node taken into consideration in the algorithm. After a fixed interval of time, the proposed algorithm is re-run again to find new applications nodes such that the system lifetime can be expected to last longer. An example is also given and experiments are made to show the effectiveness of the proposed algorithm in wireless sensor networks for lifetime.

The remaining parts of this paper are organized as follows. Section II gives a short overview of some clustering algorithms proposed in the literature. The section III explains proposed OWCA. Simulation results of this protocol are presented in section IV. Finally, section V concludes this paper.

2. RELATED WORK

Clustering algorithms can be based on criteria such as energy level of nodes, their position, degree, speed and direction. Probably the most crucial point when dealing with clustering is the criterion how to choose the CH. The number of CHs strongly influences the communication overhead, latency, inter- and intra-cluster communication design as well as the update policy.

Tzung-Pei Hong proposed, An Improved Weighted Clustering Algorithm for Determination of Application Nodes in Heterogeneous Sensor Networks with additional constraints for selection of cluster heads in mobile wireless sensor networks. They add one more factor about the characteristic of a sensor node transmission rate and initial energy.

S. Muthuramalingam et al**,** proposed a An enhanced clustering algorithm for mobile ad hoc networks to improve the throughput (EWCAMP). They have added improved parameter as relative mobility in the cluster head election phase to elect the desired cluster head and the admission criteria in the cluster maintaining phase to place the moving node in the right cluster. EWCAMP mainly focuses on reducing the instability caused by high-speed moving nodes, by taking the relative mobility of the node and its neighbors into consideration. WCA and other algorithms support stable cluster head election but the high re-affiliation of nodes. This is reduced by EWCAMP and results in stable clustering by minimizing the nodes number of re-affiliations with clusters, which results in higher throughput. The performance of the EWCAMP demonstrates that it outperforms WCA and the existing algorithms [2].

Ayman Bassam Nassuora et al, proposed A New Weighted Distributed Clustering Algorithm for Mobile Ad hoc Networks (MANETs) to select optimal cluster heads that aims to achieve stability, reliability, and low maintenance. It has the flexibility of assigning different weights and takes into account a combined metrics to form clusters automatically. They assumed a predefined limit for the number of nodes to be held by a cluster-head, so that it does not degrade the MAC function and be able to improve the load balancing in the same time. They conducted simulation that shows the performance of the proposed clustering in terms of the average number of clusters formation, reaffiliation count, and cluster head change. They also compared results with the CEMCA. The simulation results show that algorithm have a better performance on average and gives a convenient decomposition of the network with balanced clusters [3].

Chatterjee et al, proposed a weight based distributed clustering algorithm (WCA) which can dynamically adapt itself with the ever changing topology of ad hoc networks. This approach restricts the number of nodes to be catered by a cluster head so that it does not degrade the MAC functioning. It has also the flexibility of assigning different weights and takes into account a combined effect of the ideal degree, transmission power, mobility and battery power of the nodes. The algorithm is executed only when there is a demand, i.e., when a node is no longer able to attach itself to any of the existing cluster heads. The algorithm tries to distribute the load as much as possible. They conducted simulation experiments to measure the performance of our clustering algorithm and demonstrate that it performs significantly better than both of the Highest-Degree and the Lowest-ID heuristics. In particular, the number of reaffiliations for WCA is about 50% of that obtained from the Lowest-ID heuristic. Though approach performs marginally better than the Node-Weight heuristic, it considers more realistic system parameters and has the flexibility of adjusting the weighing factors [20].

Clustering is efficient scheme for reducing the energy consumption in the wireless sensor network. In which each sensor node sends data to the aggregator node means cluster head (CH) and then cluster head perform aggregation process on the received data and then send it to the base station(BS). But so far researches on weighted based clustering have not taken consideration of base station for cluster head selection. Since the base station distance from each sensor node is also major parameter in energy consumption it has been added also to weight based clustering algorithm. Thus an energy efficient clustering algorithm must be implemented to reduce the number of transmissions as most of the energy in WSN is consumed by transmissions and thereby to minimize the energy consumption by sensor nodes.

3. PROPOSED ALGORITHM

The WCA algorithm was designed to select cluster heads dynamically in mobile ad hoc networks. The sensor networks in general have more constraints than traditional networks. It is thus not so appropriate to directly apply the WCA algorithm to the sensor networks since it does not take the energy and the base station distance from each sensor node among others into consideration. In this paper, we are modifying the weighted clustering algorithm incorporating distance of each sensor node from the base station as additional factor such that it can be used in sensor networks with the specific constraints of sensor networks being considered.

3.1 Basis for our algorithm

To decide how well suited a node is for being a cluster head, we take into account its degree, transmission power, mobility, cumulative time, initial energies of each sensor nodes and distance from base station to each sensor node. The following features are considered in our clustering algorithm:

- The cluster head election procedure is *periodic*.
- Each cluster head can ideally support only *M* nodes. M is the average node degree.
- If the node degree is higher, then the node is more stable as a cluster head. Here we are taking, *degree difference* Δ_i as $|d_i\text{-}M|$ where d_i is the practical degree of node i and M is the maximum degree. Smaller the $\Delta_{i,}$ better the node i as a cluster head.
- A cluster head is able to communicate better with its neighbors having closer *distances* from it within the transmission range. As the nodes move away from the cluster head, the communication may become difficult mainly due to signal attenuation with increasing distance.
- *Mobility* is an important factor in deciding the cluster heads. It is desirable to elect a cluster head that has less mobility. When the cluster head moves fast, the nodes maybe detached from the cluster head and as a result, a re-affiliation occurs. Re-affiliation takes place when one of the ordinary nodes moves out of a cluster and joins another existing cluster. In this case, the amount of information exchange between the node and the corresponding cluster head is local and relatively small.
- *Cumulative time* is time in which the node acted as a cluster head. Larger the Cumulative time; implies that the node has spent more resources (such as energy).
- The *initial energy* can be efficiently used within certain transmission range, i.e., it will take less power for a node to communicate with other nodes if they are within close distance to each other. A cluster head consumes more battery power than an ordinary node since a cluster head has extra responsibilities to carry out for its members.
- The *distance from base station* to each sensor nodes is also important parameter in cluster head section as well as energy consumption.

3.2 Network model

Consider a sensor field consisting of set of randomly deployed sensors in a rectangular field. In this network, the sensing tasks and data reporting are periodic. The algorithm assumes the following properties about the sensor network model:

- Sensor nodes are densely deployed and are mobile.
- Sensor nodes have different capabilities for sensing, processing and communication.
- All sensor nodes have unique ID.
- Sensor nodes transmit data to its immediate cluster head in the allotted time slots.
- The BS is fixed and located far from the sensors.
- Each node can communicate with the BS directly.
- All nodes are energy constrained and perform similar task.

3.3 The Optimized WCA algorithm (OWCA) for heterogeneous sensor networks

The details of the Optimized WCA algorithm for heterogeneous sensor networks are stated below.

Input: A set of sensor nodes, each with the same transmission radius R_v, degree difference Δ_v, sum D_v of the distances between node v with all its neighbour's, mobility speed M_v, its individual cumulative time T_v, the initial energy E_v, Distance between Base station to each sensor node BS_v the six coefficients $w1$ to $w6$.

Output: A set of application nodes with its neighbours.

STEP11: Find the neighbours (node degree) $N(v)$ of each node v, within R_v.

$$N(v) = \{v^{'} \mid dis\tan ce(v, v^{'}) \leq R_{v\}}$$

STEP 2: Compute the degree difference $\Delta_v = \mid d_v - M \mid$ for every node v. M is maximum node degree.

STEP 3: Compute the sum D_v of the distances between nodes v with all its neighbours.

$$D_v = \sum\nolimits_{v^{'} \varepsilon N(v)} \{dis\tan ce(v.v^{'})$$

STEP4: Compute the mobility speed of every node v by

$$M_v = \frac{1}{T}\sum_{t=1} \sqrt{(X_t - X_{t-1})^2 + (Y_t - Y_{t-1})^2}$$

where (X_t, Y_t) and (X_{t-1}, Y_{t-1}) are the coordinate positions of node v at time t and $t-1$.

STEP 5: Assume the cumulative time T_v in which node v has acted as a cluster head. A larger T_v value with node v implies that it has spent more resources (such as energy).

STEP 6: Assume initial energies E_v of each sensor nodes.

STEP 7: Calculate distance between Base Station to each sensor nodes.

$$M_{BS-v} = \sqrt{(X_{BS} - X_v)^2 + (Y_{BS} - Y_v)^2}$$

where, (X_{BS}, Y_{BS}) and (X_v, Y_v) are the coordinate positions of base station and each sensor node respectively.

STEP 8: Calculate the combined weight

$$W_v = w_1\Delta_v + w_2 D_v + w_3 M_v + w_4 T_v + w_5 E_v + w_6 BS_v$$

where,

w_1=0.1-weight of Degree difference (Δ_v)

w_2=0.05- weight of Sum D_v of the distances between node v with all its neighbours

w_3=0.1-weight of Mobility speed of every node (M_v)

w_4=0.05-weight of Cumulative time (T_v)

w_5=0.3-weight of Initial energy (E_v)

w_6=0.4-weight of Distance between Base Station to each sensor node (BS_v).

STEP 9: Choose the node with a minimum W_v as the cluster head.

STEP10: Consider the nodes which are there within the transmission range as member/follower nodes of that cluster.

STEP 11: First cluster formation.

STEP 12: Eliminate the chosen cluster head and its neighbours from the set of original sensor nodes.

STEP 13: Repeat 1 to 12 for the remaining nodes until each node is assigned to a cluster.

Energy Computation Algorithm

STEP 1: Initialize all the first order radio model parameters

STEP 2: Calculate the energy consumed by CH node in receiving data signals from its members

$$E_{CH} = (E_{elec} \cdot k \cdot CH_{\deg ree} + E_{DA} \cdot k) + (E_{elec} \cdot k + E_{amp} \cdot d^2_{tonextCH} \cdot k)$$

STEP 3: Energy used in all CH node is

$$E_{TOT\_CH} = E_{CH(1)} + E_{CH(2)} + E_{CH(3)} + \ldots\ldots\ldots\ldots + E_{CH(NC)}$$

NC number of clusters.

STEP 4: Calculate the energy consumed by non-CH node to transmit data signals to the CH.

$$E_{non\_CH} = (E_{elec} \cdot k) + (E_{amp} \cdot R^2_{Tx} \cdot k)$$

STEP 5: Energy used in all non-CH node is

$$E_{TOT\_nonCH} = (N - NC) \cdot E_{non\_CH}$$

N number of nodes.

STEP 6: Total energy consumption is sum of energy used in all CH node and energy used in all non-CH node.

$$E_{TOT} = E_{TOT\_CH} + E_{TOT\_nonCH}$$

Table 1: Simulation parameters

PARAMETERS	SYMBOL	VALUE
Nodes	N	5-200 in steps of 20
Simulation area	X*Y	100 X 100
Transmission range	r	5-200 in steps of 20
Weights	$(w_1, w_2, w_3, w_4, w_5, w_6)$	(0.1, 0.05, 0.1, 0.05, 0.3, 0.4)
Bits	k	256
Electronics energy	E_{elec}	50nJ/bit
Amplifier energy	E_{amp}	100pJ/bit/m^2
Energy for aggregation	E_{DA}	50nJ/bit

4. OBSERVATION AND RESULTS

Figure 2 shows number of clusters v/s number of nodes for transmission range 5m.In this case approximately all 3 algorithms giving same number of clusters for transmission range 5m. But for the nodes from 125 to 200 range, clusters number for our proposed algorithm is slightly less compare to IWCA and WCA. From this we can conclude that for nodes in the range 125 to 200 proposed algorithm giving good results compare to previous algorithms.

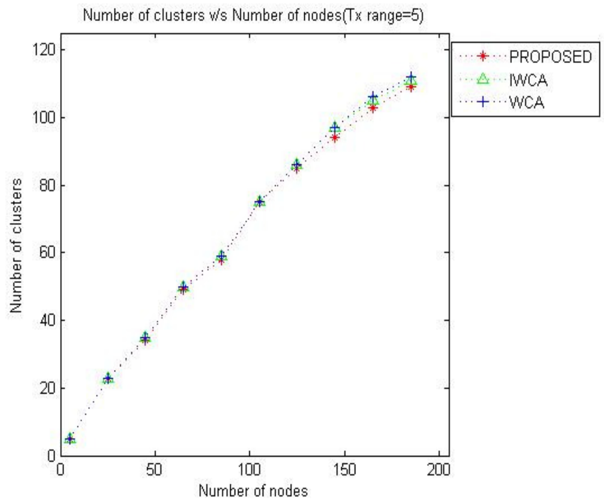

Figure 2: Number of clusters v/s Number of nodes (Tx range=5)

Figure 3 Shows number of clusters v/s number of nodes for transmission range 15m. In this case up to 50 nodes, number of clusters is same for all 3 algorithms. But for the nodes from 50 to 200 range, clusters number for our proposed algorithm is less compare to IWCA and WCA. From above figure, from nodes 50 onwards we can easily see that proposed algorithm giving significantly less number of clusters. From this we can conclude that for transmission range 15m, nodes in the range of 50 to 200, the proposed algorithm gives best results comparatively.

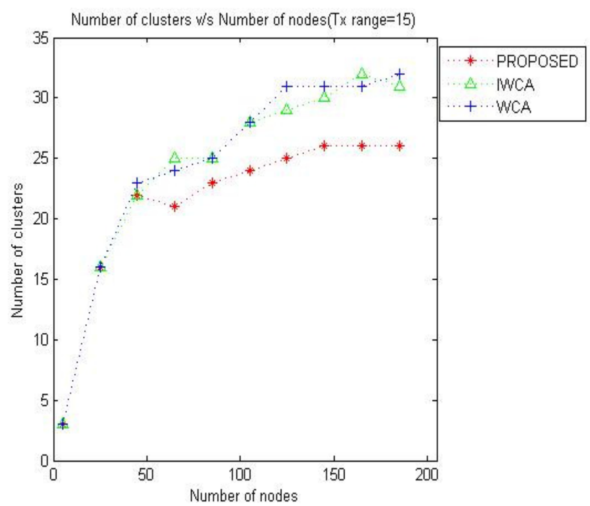

Figure 3: Number of clusters v/s Number of nodes (Tx range=15)

Figure 4 Shows number of clusters v/s number of nodes for transmission range 25m. In this case for the nodes from 50 to 200 range, clusters number for our proposed algorithm is less compare to IWCA and WCA. From above figure, from nodes 50 onwards we can easily see that proposed algorithm giving significantly less number of clusters. From this we can conclude that for transmission range 25m, nodes in the range 50 to 200, proposed algorithm giving best results compare to previous algorithms.

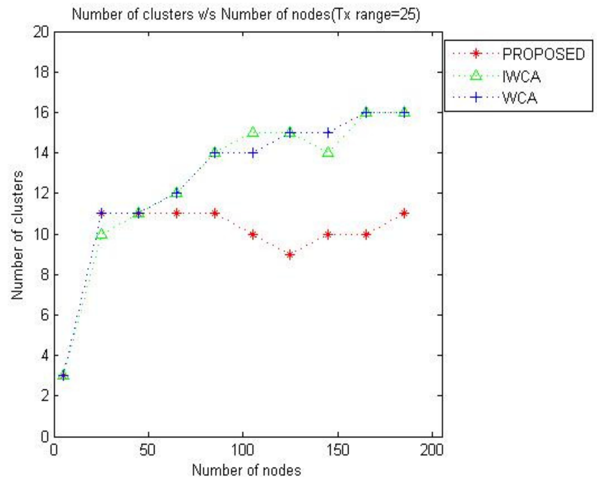

Figure 4: Number of clusters v/s Number of nodes (Tx range=25)

Figure 5 Shows number of clusters v/s number of nodes for transmission range 5, 15, 25m for proposed OWCA. From figure we can see that as the number of node increases, number of clusters also increases.

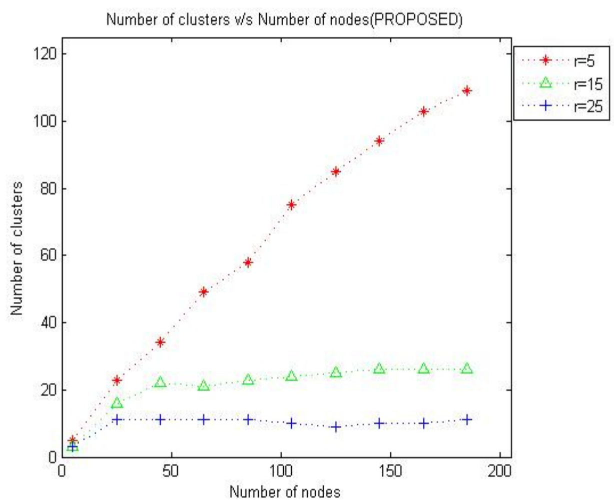

Figure 5: Number of clusters v/s Number of nodes (Tx range=5,15,25)

Figure 6 shows Number of clusters v/s Transmission range for different number of nodes. Here we are varying number of nodes from 5 to 105 in steps of 20. From figure we can see that as the transmission range increases, number of clusters decreases. Because as the transmission range increases, area will increase and hence more number of nodes will come under the same area. So number of clusters will get reduced.

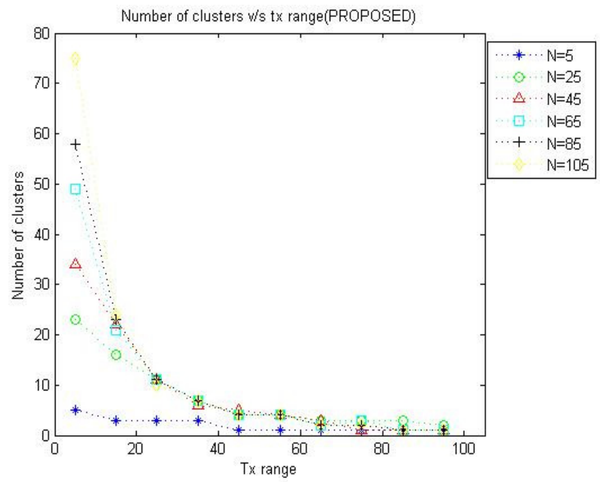

Fig.6: Number of clusters v/s Tx range (N=5,25,45,65,85,105)

Figure 7 shows Energy consumption v/s Number of nodes for transmission range 5m. From nodes 5 to 125 all 3 algorithms merged on one another which results same energy consumption. But from nodes 125 onwards energy consumption for our algorithm is slightly less than previous 2 algorithms ie. IWCA and WCA. From this we can conclude that for transmission range 5m, nodes in the range 125 to 200 proposed algorithm giving best results compare to previous algorithms.

Figure 8 shows Energy consumption v/s Number of nodes for transmission range 15m. From nodes 5 to 50 all 3 algorithms merged on one another which results same energy consumption. But from nodes 50 onwards energy consumption for our algorithm is slightly less than previous 2 algorithms ie. IWCA and WCA. From this we can conclude that for transmission range 15m, nodes in the range 50 to 200, proposed algorithm giving best results compare to previous algorithms.

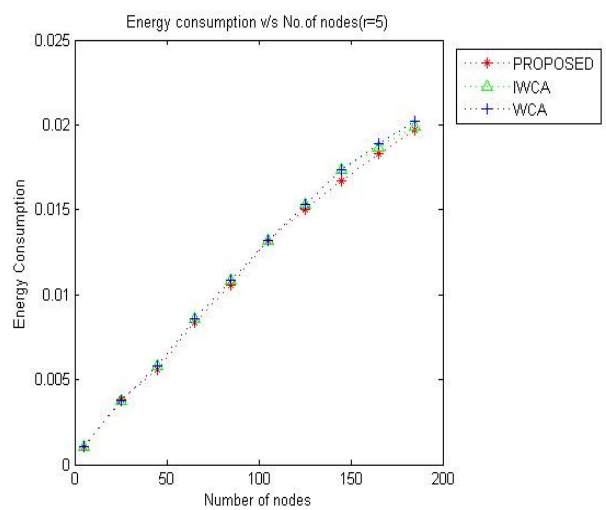

Figure 7: Energy consumption v/s Number of nodes (Tx range=5)

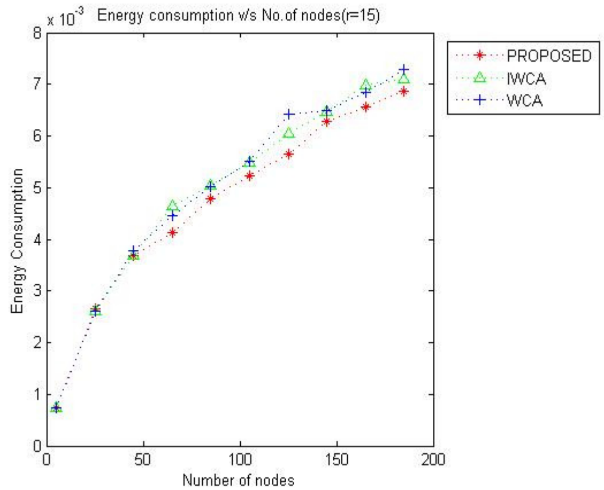

Figure 8: Energy consumption v/s Number of nodes (Tx range=15)

Figure 9 shows Energy consumption v/s Number of nodes for transmission range 25m. From nodes 5 to 70 all 3 algorithms merged on one another which results same energy consumption. But from nodes 70 onwards energy consumption for our algorithm is slightly less than previous 2 algorithms ie. IWCA and WCA. From this we can conclude that for transmission range 25m, nodes in the range 70 to 200, proposed algorithm giving best results compare to previous algorithms.

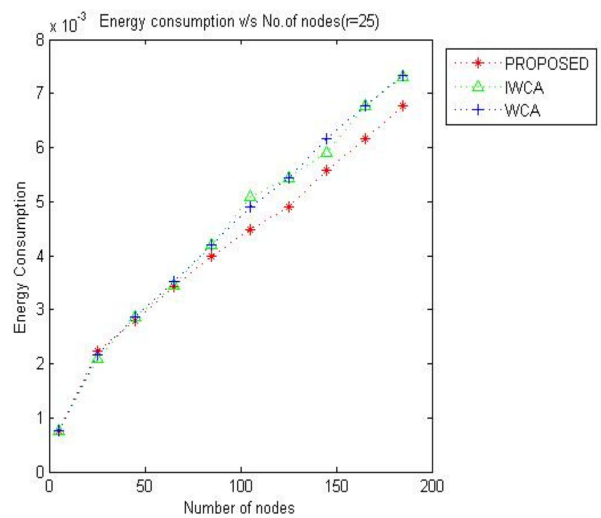

Figure 9: Energy consumption v/s Number of nodes (Tx range=25)

5. CONCLUSION

In wireless sensor networks, power consumption is an important factor for network lifetime. Here, An optimized clustering algorithm is proposed based on the weighted clustering algorithm with additional constraints for selection of cluster heads in mobile wireless sensor networks. The distance from base station to each sensor nodes considered in the proposed algorithm. The cluster heads chosen can act as the application nodes in a two-tired wireless sensor network and may change in different time intervals. After a fixed interval of time, the proposed algorithm is re-run again to find new applications nodes such that the system lifetime can be expected to last longer.

An example has also been given to illustrate the proposed algorithm in details. Experimental results have shown the proposed algorithm behaves better than WCA and IWCA on wireless sensor networks for improved system lifetime.

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