Optimized Multi-Factor Based Energy Efficient Sleep Scheduling in Duty-Cycled Wireless Sensor Networks

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Abstract—Wireless Sensor Networks has emerged one of the hot research area due to its wide applicability in different remotes and hostile places. Wireless sensor networks have been under concern to increase its lifetime to adapt hostile and remote places. In this paper, we have improvised the sleep scheduling in duty cycled WSN using a multi factored based sleep node making process. An improved CKN algorithm is used in deciding the sleep mode of a node having k-neighbors. The two factors such as distance of a node from base station and its energy at that instant are used to make a rank that decides a node to go sleep or not. The concept of weightage to the different parameters has been used. The Clustering approach is used to route the packets to base station. The clustering is done using Fuzzy C-Means method and cluster head selection is done using simple linear neural network model. Our approach has focused on inclusion of both residual energy and distance of the node from base station to do the sleep scheduling rather than solely dependent on energy of the node and also the network is connected during sleep scheduling. Our proposed approach has successfully improved some of the parameters such as sleep nodes, lifetime of the network etc.

Keywords—WSN, CKN Algorithm, sleep scheduling, duty-cycled WSN etc.

I. INTRODUCTION

Wireless sensor networks are composed of small, inexpensive sensors which collects the data from their surroundings where they have been deployed such as forest areas, volcano eruption areas etc [1]. These are also used in home automation where the range of sensor nodes are small as compared to nodes deployed in big terrain. Due to the wide applications of wireless sensor networks, researchers are continuously monitoring these networks for making them more and more efficient. The main aim of WSN is to use them in those places where human are inaccessible on regular basis or they can monitor only on some periodic basis. The main concern of sensor nodes is theirs batteries. These nodes are operated on their batteries and also these cannot be checked out on regular basis. So it is very important to employ those strategies or protocols to minimize their battery consumption. The sensor nodes are connected to the base station which are high powered control station to further process the data collected from the sensors. Now a days the base station are also being connected to cloud computing system. Thus this types of arrangements help in cloud users to gather the information from the remotes places via wireless sensor networks. To conserve the batteries of the nodes, some of the approaches are used which use the concept of sleep scheduling. In this scheduling, the nodes which are not sensing any data from environment or sending data further to nodes or base station are kept in sleep mode to save their consumption of batteries. The network where nodes change either in sensing mode or sending data to nodes or base station. The duty cycled WSN involves nodes switching from sleepness to activeness state. This switching is decided by a rank which is calculated using some parameters. CKN algorithm is used in switching the state of a sensor node. A CKN algorithm is used to solve the connected neighborhood problem. This problem is defined in a graph of nodes as represented (N,S) where N is no of atleast min(k,Ne_n) active neighbors and all should be connected, where Ne_n are neighbors of node n. So a node n can be in sleep mode if atleast min(k,Ne_n) neighbors are active to process the data. A node n would be in sleep mode or not, it is decided by the rank of nodes and its neighbors. A rank is calculated by node n which is shared with their neighbors and neighbors also share their ranks to node n. If node n has less than k neighbors then it would be remain in active or awake state so it means a node should have at least k neighbors to go into sleep mode. Now node n assures that at least k neighbors that may be subset of total neighbors of node n which have shared their ranks should have greater rank than rank of node n. If this happens it would be go to sleep mode. Sleep scheduling is the mechanism of maintaining the switching of states of nodes from sleep to awake and vice-versa. This sleep scheduling assures that minimum number of nodes should be in awake state so that energy of the nodes can be conserved. This also assures that nodes should also be connected so that information flow can be done smoothly among the nodes and base station. In this research, we tried to improvise the process of calculation of ranks using some parameters and so that a node having less energy should be in sleep mode and high energy node will be active to sense and process the data to other nodes. The architecture of the WSN and location of BS is always a matter of concern to make the network to be deployed in a way so that the lifetime of the network can be increased. In this paper architecture of network and location of BS has been discussed and successfully inserted in our research to make network energy efficient. Also [2] discussed the various factors affecting the lifetime of the network and state of the network is one of the factor that we have also considered in our research. The different factors considered in this paper are deployment of the nodes, deployment of base station, sleep node selection and cluster head selection for routing of the packets.

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Authors in [3] discussed the bound on the lifetime of the network taking the one base station and multiple base station WSN scenarios. In this authors successfully estimated the location of base station for improving the lifetime of the network. We have taken the single-base station based network where we deployed the base station according to the results found in [3]. The deployment of the base station and nodes are described in Figure 1. Nodes in the sensor networks should efficiently deal with energy conservation. In this the sleep scheduling is included in sensor networks. In this the nodes are scheduled in a way such that nodes which are not doing communication are made in sleep mode while the lifetime is also discussed in further sections. The architecture of WSN is sensitive to values of different factors such as lifetime of the network, alive or dead nodes in the network etc. So the nodes and base station should be deployed in a way that effectively improves these factors aforementioned. We in this paper adopt the deployment of the nodes as discussed in the [2] and shown in Figure 2. Some of the points are:

1. Given D which is the distance between two nodes and the number of intervening relays (K € 1), \( P_{\text{link}}(D) \) is minimized when all the hop distances (i.e. \( d_s \)) are made equal to \( D/K \).
2. The minimum energy relay for a given distance D has either no intervening hops or some number of equidistant hops.
3. The optimal number of hops (\( K_{\text{opt}} \)) is always
   \[
   K_{\text{opt}} = \frac{d_{\text{char}}}{d}
   \]
   where \( d_{\text{char}} \) is termed as characteristic distance between two intervening nodes and it is calculated as
   \[
   d_{\text{char}} = \frac{\alpha_1}{\alpha_2(n-1)}
   \]
   \( \alpha_1 \) and \( \alpha_2 \) are amplification energy required in first and multi-path radio model.
4. The most efficient results occurs when D is integral multiple of \( d_{\text{char}} \).

Working nodes are in awake mode. Now which node has to be in sleep mode and which has to be in awake mode, this is decided by the particular sleep scheduling algorithm used in sensor network. In [5], a technique termed as CKN algorithm which is connected K-neighborhood algorithm is used to decide whether a node goes to sleep or not. The algorithm [5] is as follows:

**ALGORITHM 1. CONNECTED K-NEIGHBORHOOD (CKN)**

(This algorithm is run at every node u)

1. Pick a random rank \( r_{\text{rank}} \).
2. Broadcast \( r_{\text{rank}} \) and receive the ranks of its currently awake neighbors N_u. Let R_u be the set of these ranks.
3. Broadcast \( R_u \) and receive \( R_v \) from each \( v \in N_u \).
4. If \( |N_v| < k \) or \( |N_u| < k \) for any \( v \in N_u \), remain awake and return.
5. Compute \( C_u = \{ v \in N_u \text{ and rank } < r_{\text{rank}} \} \).
6. Go to sleep if both the following conditions hold. Remain awake otherwise.
   - Any two nodes in \( C_u \) are connected either directly themselves or indirectly through nodes within u’s 2-hop neighborhood that have rank less than rank_u.
   - Any node in \( N_u \) has at least k neighbors from \( C_u \).
7. Return
In this algorithm, a node u first generate a random rank rank_u from a random number generator in Step 1 of the algorithm and computes a subset of neighbors C_u having rank less than rank_u. Before node u can go to sleep it needs to make sure that all nodes in C_u are connected by nodes with rank < rank_u and each of its neighbors has at least k neighbors from C_u as shown in step 6. This algorithm ensure that if a node has less than k neighbors, none of its neighbors goes to sleep and also if it has more than k neighbors, at least k of them decide to remain awake. This algorithm assures following points
1. Suppose a node u has d_u neighbors in the original network. After running Algorithm CKN, u will have at least min(k, d_u) awake neighbors.
2. Running Algorithm CKN on a connected network produces a connected network.

This CKN has some weak points which were explored in [6]. In this paper Author explored that the rank which is used to select the mode of a node can choose a lower energy node to be in awake state. This CKN algorithm may choose a low energy node to do all communication while a high energy node resides in sleep state. So this algorithm may not always choose correctly the sleep nodes. A more improvised scheme efficient CKN is used in [6] where rank is calculated using residual energy of the node. So its main motive to node having high residual energy should be in awake mode. And this energy efficient CKN successfully improved the sleep scheduling of the nodes and lifetime of the nodes.

II. PROPOSED APPROACH

The K-CKN algorithm is used to schedule the nodes to switching of states from sleep to active and vice-versa and also it ensures the connectivity the network for better communication. But it lacks in the factors controlling this scheduling. It uses random number generation to decide whether a node would goes to sleep or not. In [5] this is improved using factor of residual energy. In our approach we used two factors in sleep scheduling where one is same as used in [6] i.e. residual energy (the energy of the node at particular instant) and second is distance of the node from base station. These two factors are used with some attached weightage. In this mechanism, a node has to feed two values, the energy of the node and distance of node from base station and some weights are associated with each factor. Now these two factors are opposite of each other. It means for better lifetime of a node distance of node should be less and the energy should be high. So weightage system which has been applied works in reverse manner. The weight associated with energy would act towards positivity and one with base station for negativity. This weightage system is used to see overall impact of both factors. Figure 3 is describing this model.

In our approach the calculation for rank is done as
Rank= w1*DISBS + w2*ENERGY

After the calculation of rank, the node broadcasts its rank to all its neighbors. Now, the sleep scheduling is done using improved rank calculation method as described in below procedure.
1. Stores the two variables with values distance from base station (DISBS) and energy of the node (ENERGY).
2. Calculate rank of node n as follows
   \[ \text{rank}_n = \text{w1*DISBS} + \text{w2*ENERGY} \]
3. Broadcast rank_n of node n and receive the ranks of its currently awake neighbors N_n. Let R_n be the set of these ranks.
4. Broadcast R_n and receive R_v (set of all awake neighbors of nodes in N_n) from each v \( \in \) N_n.
5. If \( |N_n| > k \) or \( |N_v| < k \) for any \( v \in N_n \), remain awake and return.
6. Compute \( R_v \) = \{ \forall v \in N_v, \text{rank} < \text{rank}_v \}
7. Go to sleep if both the following conditions hold. Remain awake otherwise.
   • Any two nodes in C_v are connected either directly themselves or indirectly through nodes within u’s 2-hop neighborhood that have rank less than rank_u.
   • Any node in N_v has at least k neighbors from C_u.
8. Return

If a node is awake then it routes the packet to the base station. In our approach this routing has been using mechanism of clustering. The clustering approach was explored in leach[8][9] protocol where the nodes routes the packets by making clusters by electing a cluster head for each cluster. This cluster head election is done using some expression based on probabilistic mechanism. And clusters are made on the basis of distances of the nodes from different cluster heads. But this election wholly depends upon the probability but did not take account the energy of node while electing cluster head. So a node having low energy can become cluster head and affect the lifetime in bad way. Different authors used this clustering concept in routing of packets and some of them also improved this method of cluster head election. Authors in [10] modify the expression for electing the cluster head and insert the factor of residual energy to make it efficient and effective for cluster head election. SEP [10] was based on LEACH and it used the heterogeneity in the wireless sensor network to increase the stability period and lifetime of node. DEEC [11] improved the SEP by including the ration of...
residual and average energy in calculation of cluster head expression. As the network in which we are working is homogenous so we have used different method of cluster head election. The method specified in[13] is the basis of our method of cluster head selection. The routing of message has two parts cluster forming and election of cluster head for each cluster. The problem with clustering is that the clusters which are formed are oftenly non-uniform and which lead to non-uniform dissipation of energy among nodes. This lack of non-uniformity leads to decrease the lifetime of the network. To resolve this problem, we have used Fuzzy C-means Clustering (FCM)\(^{14}\) to make similar sized clusters and optimal clusters. The clusters and their cluster members have been shown in Fig.3. The clusters formation are uniform and are of similar size. This uniform clusters lead to uniform dissipation of energy and thus lead to increase in lifetime. This Clusters help in maintaining network coverage and also in increase the data transferred to the monitoring station. FCM involves the use of fuzzy membership values in which a sensor node is related to each cluster with some membership value. For a node the cluster to which it has highest value belongs to that cluster.

When clusters are formed then cluster heads are elected for each cluster. In our approach we have used the neural network model as explored in[13]. As our system is homogenous type so we have removed the heterogeneous factor in election of cluster heads. In cluster head election combined effect of energy of node and distance of the node from base station is used and finally a value is calculated according to weights associated with the energy and distance from base station respectively. As we have discussed earlier the effect of energy and distance of the node on the lifetime of the network as they have reverse effect on life of network. Thus FCM formed clusters and choose cluster head for each cluster. In each cluster, each cluster member calculated this value from its energy and distance from base station. In a cluster, the cluster member having highest calculated value become cluster head. All cluster members shares their calculated values and highest value node become cluster head. All cluster members send their data to their corresponding cluster head and their cluster heads send this further data to base station. For data communication, we have two communication models free space and two-ray (multi-path) model.\(^{1}\) describes the free space model and \(^{2}\) describes the multipath model.

\[
\begin{align*}
E_{tx} &= E_{elec} \times l + E_{fs} \times l \times d^2 \quad \text{if } d > d_0 \\
E_{tx} &= E_{elec} \times l + E_{mp} \times l \times d^4 \quad \text{if } d < d_0
\end{align*}
\]

Where \(E_{tx}\) is energy required to transmit the packet of size l and \(E_{elec}\) is energy required to start the process of transmission while \(E_{fs}\) and \(E_{mp}\) are amplification energy required to transmit the packet while losing its strength. \(d\) is the distance of transmission and \(d_0\) is defined as

\[
d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}}
\]

III. SIMULATION RESULT AND ANALYSIS

We have used MATLAB software to simulate our proposed approach. We have used an area of 200 by 200 meters. For deployment of nodes we have an approach as discussed in\([2]\). In deployment we have deployed nodes in circular way and nodes are equally separated for efficient communication. We have used 120 nodes in our project. The simulations have been for capturing various parameters such as sleep nodes, alive nodes, dead nodes etc. We have done different simulations of the network taking different values of \(k\) where \(k\) is the neighbors of nodes in \(k\)-connected neighborhood algorithm. We have compared our approach with the algorithm proposed in\([6]\) which modified the connected \(k\)-neighborhood mechanism. We have compared our approach using the alive nodes, dead nodes and sleep nodes in different rounds of the network and so for different values of \(k\). Here the \(k\) denotes the number of neighbors of a node. In figure 5 the alive nodes are more in our proposed approach as existence of nodes in compared proposed is less. The sleep nodes in the network having changing value of \(k\) are shown in figure 7. In this figure we can observe that more nodes are in sleep mode as we increase the value of \(k\). As we increase the \(k\) the chances of node going to sleep mode decreases. The network
coverage is also maintained in our network which increased alive nodes and decreases the dead nodes. In figure 8 the alive nodes are shown for different values of k and alive nodes are much greater than compared approach to increase the lifetime of the network. This higher number in lesser rounds shows the effectiveness of our algorithm. Also dead nodes are plotted in different rounds and for value of k and our algorithm are performing better than earlier approach.

So our approach is ultimately increasing the lifetime and which shows the effectiveness of method used for choosing cluster head in our network.

IV. CONCLUSION

In this project we focused to increase the lifetime of the network by inculcating efficient sleep scheduling method. Here we have incorporated another parameter for calculating the rank using in deciding the node state transition. We have taken those approaches which have been done before to calculate rank using K-CKN algorithm. In this approach we have increased the sleep nodes in the network and also we have maintained the connectivity of the network. Also we have increased alive nodes and decrease dead node in the network.

Fig.5. Figure showing the existence of sensor nodes in different rounds (x-axis).

Fig.6. Figure showing dead nodes in different rounds.

Fig.7. Figure showing sleep nodes in different approaches with different k values.

Fig.8. Showing alive nodes in different approaches with different k values.

Fig.9. Figure showing dead nodes in different approaches with different k values.
REFERENCES