Effect of Mobility Models on Performance of Novel Centralized Clustering Approach based on K-means for Wireless Sensor Networks

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Abstract

Wireless sensor network consists of sensor nodes which are deployed in the area in order to collect and transmit information about a phenomenon. In some applications of WSN, the nodes are more mobile than static where in each of them has a limited energy and random mobility. Therefore, the mobility and routing are important issues and they are considered as key to researchers in WSN. In this paper, we propose a new improved version of the LEACH-C protocol based on the clustering approach. Our main contribution consists of the evaluation of the performance of integration an unsupervised algorithm which is inspired from K-means method under diverse mobility models with varying the density of mobile nodes in order to produce a new cluster scheme and find the optimal clusters. Three mobility models (Random Waypoint Mobility Model, Manhattan Mobility Model and Gauss Markov Mobility Model) were used for performance analysis with respect to Packet Delivery Ratio (PDR), Average Throughput, Normalized Routing Load (NRL), Average End-to-End Delay and Energy Consumption for nodes. Simulation results verify that our new approach called LEACH-C-KMEANS for mobility models Random Waypoint and Gauss Markov under different densities gives better results than the LEACH-C protocol in terms of energy consumption and performance parameters.

Keywords: Wireless Sensor Network, LEACH-C, K-means, Performance Parameters, Random Waypoint, Manhattan Grid, Gauss Markov, BONNMOTION.

INTRODUCTION

Wireless sensor network consists (WSN) of the diverse density of fixed and mobile sensor nodes, which are deployed in the geographic zone in order to collect and transmit information about a phenomenon or event. The dynamic topology change of WSN imposes the use of mobility as a critical issue on modeling network in order to avoid loss of packets in the destination within acceptable delays [1] [2] [3] [15]. In mobile WSN, hierarchical routing and various clustering mechanisms [27] [28] [29] are an important challenge to minimize the energy consumption required to route the packets, gather data efficiency and using a clustering approach than non-clustering approaches. To optimize clustering protocols, mobility movements of nodes and associated metrics should be considered [16] [17]. The rest of paper is structured as follows: the section 2 describes briefly the hierarchical routing protocols (LEACH, LEACH-C) and the technique of clustering k-means. The description of the flow chart of the new proposed algorithm and the mobility models with their scenario’s creation are presented in the section 3. The section 4 shows the results of simulation. Finally, the section 5 resumed our contribution and our perspectives.

HIERARCHICAL PROTOCOLS AND K-MEANS APPROACH

A. LEACH

LEACH (Low-Energy Adaptive Clustering Hierarchy) [4] [18] is the original hierarchical clustering approach used in WSN. The formation of clusters is based on the received signal strength from the nodes and use local cluster head for delivery information to the base station (BS) [19] [20]. However, LEACH protocol is not unable to support mobility of the nodes within each round after setup phase. It suffers also from the problem of high packets loss in the network and non-uniform clustering [5].

B. LEACH-C

LEACH-C (Low-Energy Adaptive Clustering Hierarchy-C) [4] [21] is a centralized version of LEACH protocol when the base station finds k-optimal clusters and determines cluster heads (CHs) based on the energy level of a node, its position and its distance by using the Simulated Annealing algorithm (SA).

C. K-MEANS ALGORITHM

The K-Means algorithm [6] [7] [22] [26] is used in many clustering tasks. It consists to partition a set of n objects into k clusters distinct based on the criterion of intra-cluster and inter-cluster similarity. The corresponding algorithm of this technique is given as follows:

1) Input nodes with their positions, noted by $x_i$
2) Determine the number of cluster $k$
3) For initial iteration, determine the centroid of each cluster $C_k$
4) Calculate the distance between nodes and centroids
5) Grouping all nodes to the closest centroid based on the minimum distance
   \[ x_i \in C_k \text{ if } \forall j \left| x_i - \mu_j \right| = \min_{j} \left| x_i - \mu_j \right| \quad (1) \]
   $\mu_k$: Center of the cluster $k$
6) Recalculate the centroid for each cluster until the obtained centroids are the same as in the previous iteration and k-cluster heads fix down

**PROPOSED ALGORITHM AND MOBILITY SCENARIO**

After evaluating the performance of the tree hierarchical protocols LEACH, LEACH-C and PEGASIS in [8], we try in the present work and for a domain mobile to find the best configurations of clusters and overcome the problems indicated in LEACH protocol. We have investigated the performance of LEACH-C based on the k-means algorithm as noted in [26]. Our approach consists of using the sum of the square of the Euclidian distance between each mobile node and the centroid of the cluster to which it belongs instead of using the probabilistic heuristic in Simulated Annealing (SA) under weighing density and mobility models as shown in the figure 1.

In the first step:
Each nodes transmit location information and energy level to BS.

BS calculates the average energy of the member nodes in the current round and each mobile node decides whether or not to become a cluster head (CH).

In the second step:
BS uses k-means algorithm to find the minimum distance between the centroid position and the cluster members using only nodes that are eligible.

Therefore, the cluster diagram is formed and the number of changes in the assignment of clusters is calculated until convergence the algorithm.

The selection of nodes with minimum distance from the centroid node as a new cluster head. The elected CH broadcast advertisement message and listen the medium till its selection.

After receiving an association request from nodes, TDMA schedule is used to send data from node to CH in the cluster and it was sent from CH nodes to BS using a fixed spreading code and CSMA.

In this work, we have focused on the evaluation of the new routing protocol LEACH-C-KMEANS according to various mobility models such as Random Way Point Model, Manhattan Grid Model, Gauss Markov Model under varying number of nodes and diverse metrics like Packet Delivery Ratio (PDR), Average Throughput, Normalized Routing Load (NRL), Average End-to-End Delay and Energy Consumption. Mobility scenarios are created by means of the BonnMotion [12] [25] Tool.

**A. Random Waypoint Mobility Model (RWP)**

In the research community, the Random Waypoint Model [9] [10] [13] [23] is used as random model for the movement of mobile nodes with constant velocity chosen uniformly and randomly at every instant. Each node has a pause time before the changes in direction and speed. After this pause, the nodes choose a new location randomly as shown in Fig.2. The process is repeated until the simulation ends.

**Figure 2:** Random Waypoint mobility model

This scenario was created by:
```
./bm -f rwp RandomWaypoint -x 100 -y 100 -i 3600 -n 60 -d 3600
```
where n: number of nodes, x and y: mobility area, d: mobility duration, i: initial phase to be skipped

**B. Manhattan Grid Mobility Model (MANHT)**

The Manhattan Grid Model [10] [11] [13] [24] is used in modeling the movement of mobile nodes in an urban area based on the row and column streets represented by grid
topology where the paths of movements are allowed along the grid on the map as shown in fig.3

Figure 3: Manhattan Grid mobility model

The corresponding mobility model was created by:
```
./bm -f manht Manhattan Grid -n 60 -d 3600 -i 100 -y 100 -u 2 -v 3 -u, -v : Number of block between the source and destination paths.
```

C. Gauss Markov Mobility Model (GMM)

Gauss-Markov Model [11] is designed to different levels of random via a tuning parameter. At fixed intervals of time, each mobile node is assigned the value of speed and direction which can be calculated on the basis of the value of previous speed and direction as shown in the following equation.

\[ V_n = \alpha V_{n-1} + (1 - \alpha) \mu + \sqrt{(1 - \alpha)^2} x_{n-1} \]  

\( \alpha \) is a tuning parameter for randomness variance.

\( \mu \) is a constant that represents the mean value of speed and direction. \( x_{n-1} \) is a random variable from the Gaussian distribution.

Based on the same parameters of the different mobility, this mobility model was generated by:
```
./bm -f gmm GaussMarkov -n 60 -d 3600 -i 3600 –x 100 –y 100
```

For each scenario, the following results are created:
- rwp.params, manht.params, gmm.params: contains mobility parameter.
- rwp.movements.gz, manht.movements.gz, gmm.movements.gz: contains the gzipped movement data.

For to be compatible with NS2.34, these files need to be converted by using:
```
./bm NSFile -f rwp
./bm NSFile -f manht
./bm NSFile -f gmm
```

The converter scenarios produce the following files:
- rwp.ns_params and rwp.ns_movements for Random Waypoint Model
- manht.ns_params and manht.ns_movements for Manhattan Grid model
- gmm.ns_params and gmm.ns_movements for Gauss Markov model

**SIMULATION RESULTS**

In this section, we present our evaluation for LEACH-C-KMEANS protocol that uses the k-means clustering algorithm to identify better clusters based on the squared sum of errors (SSE) instead of using the probabilistic heuristic based optimal strategy in Simulated Annealing in LEACH-C. Then we have done some comparisons based on different mobility models under varying density with a previous hierarchical protocol LEACH-C in terms of performance metrics. The simulations have been carried out Network Simulator version 2.34 [14] under platform Ubuntu10.10. The mobility model scenarios were created by using the tool BonMotion-2.0 with minimum speed of 0.5m/s and maximum speed of 1.5m/s and they were converted to the supported ns2 format. The results generated in the trace files were analyzed by the AWK script.

All nodes are homogeneous and randomly distributed on 100m x 100m area with initial energy of 2 Joule and using the following radio dissipation energy model [4]:

\[
E_{TX(L,d)} = \begin{cases} 
L \cdot E_{elec} + \epsilon_{fs} \cdot d^2, & d < d_0 \\
L \cdot E_{elec} + \epsilon_{mp} \cdot d^4, & d \geq d_0
\end{cases}
\]  

\( E_{TX(L,d)} \): Energy spent for transmitting an L bit message over a distance d

\( E_{elec} \): Energy electric of transmitter or receiver

\( \epsilon_{fs}, \epsilon_{mp} \): energy spent in amplifier according to the cross over distance \( d_0 \), which \( d_0 = \left( \frac{E_{fs}}{\epsilon_{mp}} \right)^{1/4} \)

The energy expanded to receive an L bit message is given by equation (4)

\[
E_{RX(L,d)} = L \times E_{elec}
\]  

Similar in [8] [26], the following table provides the rest of simulation parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Nodes</td>
<td>60, 80, 100, 120, 140</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>3600 s</td>
</tr>
<tr>
<td>Routing Protocol</td>
<td>LEACH-C, LEACH-C-KMEANS</td>
</tr>
<tr>
<td>Base Station</td>
<td>(50, 175)</td>
</tr>
<tr>
<td>Mobility Models</td>
<td>Random WayPoint, Manhattan Grid, Gauss Markov</td>
</tr>
<tr>
<td>Propagation Model</td>
<td>Free Space / Multipath Fading</td>
</tr>
<tr>
<td>MAC Type</td>
<td>802.11</td>
</tr>
<tr>
<td>Link Layer Type</td>
<td>LL</td>
</tr>
<tr>
<td>Packet Size</td>
<td>512 MB</td>
</tr>
<tr>
<td>Queue Length</td>
<td>50 Packets</td>
</tr>
</tbody>
</table>
A. Packet Delivery Ratio (PDR):
It indicates the ratio of the number of packets delivered to the number of packets sent. Fig.4 shows the packet delivery ratio of mobility models, here our proposed protocol presents high values of PDR for GMM and RWP compared with MANHT model. This indicates that the high packets are delivered to the higher layers and it dictates the new protocol is better. For both mobility models GMM and RWP, we can conclude that LEACH-C-KMEANS presents lost packets in terms of congestion, error rate and broken links.

![Figure 4: Packet Delivery Ratio vs Number of Nodes](image)

B. Average Throughput:
Throughput is the rate of number of packets, per second, that can be transferred through the network until it reaches the destination in a unit time. In the fig.5 and compared to the original protocol LEACH-C, we observe that LEACH-C-KMEANS gives consistent performance in RWP and GMM but gives lower performance for MANHT when we increase the network density. This proves that the new protocol produces best bandwidth to pass data successfully for RWP and GMM models.

![Figure 5: Average Throughput vs Number of Nodes](image)

C. Normalized Routing Load (NRL):
It represents the ratio between the number of all control packets sent in the network by the total received packets at the destination. Compared to model MANHT, the mobility models RWP and GMM reduce hugely the number of control packets when the density network increase as shown in the fig.6. This demonstrates that LEACH-C-KMEANS is a efficient routing protocol in terms of generated control packets for two mobility models RWP and GMM.

![Figure 6: Normalized Routing Load vs Number of Nodes](image)

D. Average End-to-End Delay
It represents the average delay related the transmission the packet from a source to a destination which includes all delay caused by buffering, queuing, retransmission and propagation. From the Fig.7, we observe that LEACH-C-KMEANS has a lowest delay in two mobility models RWP and GMM compared to MANHT and has the high performance due to the best delay than LEACH-C protocol. For all mobility models, we notice that the Average End to End delay decreases when the network density increase. Consequently, this explains that the inter-cluster interactions are limited and the congestion in the network is lower.

![Figure 7: Average End to End Delay vs Number of Nodes](image)

E. Energy Consumption:
The figures: figure 8(a,b,c) plots the energy consumed by network per rounds for number of nodes 60, 100 and 140. For all mobility models, we can conclude that the new protocol LEACH-C-KMEANS is more efficient compared to LEACH-C in term the energy consumed.
CONCLUSION

To illustrate the performance of the proposed protocol for wireless sensor network under three different mobility models and varying density of the network, we have used the k-means algorithm for formation and choice of the best clusters based on the minimum Euclidian distance between mobile nodes instead of using the probabilistic cost in Simulated Annealing. For mobility models Random Waypoint and Gauss Markov within diverse density, simulation result shows that the proposed protocol LEACH-C-KMEANS is better than LEACH-C in terms of energy efficiency and performance metrics. In future work, it would be worth considering other scenarios like traffic generators adaptive, speed, pause time etc.

REFERENCES


