Life Time Sensitive Weighted Clustering on Wireless Sensor Networks

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Abstract: The present paper considers weighted clustering algorithms for mobile ad hoc networks (MANET) and wireless sensor networks (WSN). First, we summarize the similarities and differences between the two types of networks as then examine the existing weighted clustering algorithms proposed so far. We specifically examine the objective functions and performances of the algorithm in terms of various parameters. In addition, we proposed a new algorithm called as the Life Time Sensitive Weighted Clustering Algorithm (LTS-WCA), which aims to adapt the already existing weighted clustering algorithm (WCA) proposed for MANET to WSN and modify and enhance it. WCA was proposed in the literature for forming cluster-heads in mobile ad hoc networks but we have demonstrated that it can also be effective when used in a wireless sensor network domain.

1 INTRODUCTION

Sensor networks include a large number of sensors, which are able to sense the environment and process data in order to transfer gathered information to the sink(s). Wireless sensor nodes started to play critical roles in our lives. Many researchers have attempted to utilize the existing theoretical studies in order to apply them on practical applications in various areas such as medicine (e.g. health monitoring (Li, *et.al.* 2009)), environment (e.g. disaster monitoring), military (e.g. target surveillance and battlefield mapping (Dechene, *et.al.* 2008)) and agriculture (Burrell, *et.al.*, 2004), etc.

Clustering a network leads to a creating a hierarchical one by partitioning the existing flat network into several groups of nodes, where each group has a leader node called 'cluster-head' and the remaining local nodes, which are connected to their associated cluster-heads, are called 'cluster members'. The cluster-heads then are usually connected in the shape of a backbone of the corresponding network. One of the main issues in a clustering algorithm is the process of categorizing the nodes into disjoint groups and choosing the most appropriate nodes as cluster-heads for having an efficient network. There are different types of clustering algorithms running on mobile ad hoc networks (MANET) and wireless sensor networks (WSN).

The present work aims at modifying and enhancing the weighted clustering algorithm (WCA), which was frequently cited for the purpose of forming cluster-heads in mobile ad hoc networks. The main argument for choosing it as the subject of this study is its potential effectiveness when used in a wireless sensor network domain.

The paper concentrates on the issue of energy efficiency in clustering in WSN and especially on increasing the network life time by considering several critical parameters in this new algorithm called as the Life-Time Sensitive Weighted Clustering Algorithm (LTS-WCA).

Section 2 describes MANET and WSN and briefly overviews the existing weighted clustering approaches proposed for them. Section 3 presents our new method, called as Life-Time Sensitive Clustering Algorithm (LTS-WCA) while emphasizing the differences between this proposal and its original version called as Weighted Clustering Algorithm (WCA). Section 4 includes our implementation of the algorithm, the simulation study carried out on LTS-WCA using ns2 simulator, and evaluation results. Finally, section 5 concludes the paper.

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2 MANET VS WSN

Mobile ad hoc networks and wireless sensor networks have both similarities and differences. The main similarities between MANET and WSN are described as follows (Jindal, *et.al.*, 2011), (MANET vs WSN):

- Both are distributed and self-organized networks without any central infrastructure.
- Both use wireless links for communication purposes.
- Communication and routing among nodes may be in multi hop fashion.

The main differences between MANET and WSN can be listed as follows (MANET vs WSN):

- MANET users are generally appliances designed for human beings (e.g. laptop, computers, PDAs, mobile radio terminals, etc.) but WSNs focus mostly on interactions with the environment (monitoring and sensing the environment or maybe tracking objects and/or activities in the sensing environment).
- MANET network density is smaller in comparison with WSN and the number of WSN sensor nodes is higher in comparison with MANET.
- The number of active users in the deployment area specifies the network size in MANET, however the extension of the observed area, characteristics of the nodes and the required redundancy level define the number of nodes in WSN.
- Data traffic in MANET is higher than WSN because of using services like web, mail, video, etc.
- Sensor nodes in MANET are powerful computation devices however in WSN they are cheap tiny nodes.
- Energy concerns in MANET are of secondary importance in comparison to WSN. Stored energy in tiny sensor nodes in WSN is very restricted and the quick loss of energy is considered as a main problem in WSN.

The purposes of running clustering algorithms on these two types of networks are slightly different. Wireless sensor networks mostly concentrate on how to sense the environment and send the gathered data to sink(s) aiming to increase the network life time and energy efficiency but in mobile ad hoc networks the main goal is to distribute the generated traffic among nodes by routing it in a multi hop fashion.

Weighted Clustering Algorithm (WCA) is one of the clustering algorithms, which was originally and initially applied on mobile ad hoc networks. It considers several different parameters in order to select a cluster-head (CH) while running the algorithm. We believe it to be more beneficial compared to other clustering algorithms that take one or two parameters into account at most. The main objectives of applying WCA on MANET are choosing an optimal number of CHs, decreasing latency as much as possible and decreasing the number of re-affiliations. Since there exists many similarities between MANET and WSN, the application of WCA is conjectured to be helpful and beneficial for WSN also, however it surely needs modifications in order to adapt it to wireless sensor network environments.

2.1 Weighted Clustering Algorithms for MANET

There is a vast amount research work carried out on the weighted clustering algorithms. Each of these studies has its own specific objective employing various parameters. This section reviews the existing weighted clustering approaches very briefly.

2.1.1 On-demand Weighted Clustering Algorithm for Ad Hoc Networks (WCA)

On-demand weighted Clustering algorithm (WCA) is the original weighted clustering algorithm cited by many other studies in the field (Chatterjee, *et.al.,* 2000). WCA is an on-demand algorithm, which aims at optimizing the operation of the medium access control protocol and decreasing the cost of both communications and computations. In this algorithm, cluster heads use 'dual power' mode in order to transfer a message among clusters in a higher transmission range. WCA procedure is as follows:

1- Each node finds its neighbors and the node degree

$$d_v = |N[v]| = \sum_{v' \in V, v' \neq v} \{dist(v, v') < T_x\}.$$

where N[v] denotes the set of neighbors of node v, dist(u,v) denotes the distance between nodes u and v, and T_x denotes the transmission range of a node.

2- Each node calculates its degree difference

$$\Delta_v = |d_v - \delta|$$

where d_v defines the number of node degree and δ is a predefined ideal number of nodes placed within a cluster.

3- Each node calculates the sum of the distances to all its neighbors

$$D_v = \sum_{v' \in N(v)} \{dist(v, v')\}$$

4- Each node defines the running average of its speed until current time T

$$M_v = \frac{1}{T}\sum_{t=1}^{T}\sqrt{(x_t - x_{t-1})^2 + (y_t - y_{t-1})^2}$$

where x and y denote the rectangular coordinates of the node in time.

5- Each node computes its cumulative time, P_v, which is the time a node can act as a cluster-head.

6- Each node then calculates its total weight as follows:

$$w_v = w_1\Delta_v + w_2D_v + w_3M_v + w_4P_v;$$

where $w_1+w_2+w_3+w_4=1$

7- Considering global minima, the node with the smallest weight value is selected as a cluster-head.

The remaining nodes repeat the above steps until the moment when each node starts acting as a cluster member or a cluster-head. Nodes that belong to the chosen clusters are not allowed to participate in the clustering election again and steps 2 to 7 repeats for the rest of the nodes that are not signed as a cluster head or cluster member.

2.1.2 Weight based Adaptive Clustering in Wireless Ad Hoc Networks (WBACA)

Weight based adaptive clustering in wireless ad hoc networks (WBACA) (Dhurandher and Singh, 2005) uses the local minima of weight instead of global minima in order to decrease the number of re-affiliations and the time delay within the network; it specifies several parameters such as transmission power, transmission rate, mobility, battery power and the degree of a node to make clusters within a mobile ad hoc network domain (Dhurandher and Singh, 2005). An initial phase finds neighbourhoods. Each node periodically broadcasts 'Hello packet' messages including its identification number. Nodes lying within the same transmission range receive the 'Hello packet' messages and broadcast it to their neighbours in response. The second phase includes calculating weight values. Each node calculates its weight and sends it to all its neighbours. The clustering calculation is as follows:

$$w_n=w_1*M+w_2*B+w_3*T_x+w_4*D+w_5/T_r;$$

$$w_1 + w_2 + w_3 + w_4 =1$$

where M is node mobility, B is battery power, T_x is transmission range, D is degree difference, and T_r is transmission rate.

While running WBACA, in a case when there is no node with the smallest weight, the node itself becomes a cluster-head. Otherwise, the node sends a 'Join-Req' message to the neighbouring cluster-head with the smallest weight. The cluster-head sends a 'Join-Ack' message to reply 'Join-Req' messages. The cluster-head accepts nodes as its cluster members until its degree becomes equal to the defined threshold value. In a case when a node cannot belong to any cluster, it identifies itself as a cluster-head. Restarting the algorithm takes place at the moment when a link between a node and its cluster-head gets broken.

2.1.3 Weighted Clustering Algorithm using Local Cluster-Heads Election for QoS in MANETs

Weighted clustering algorithm using local cluster-heads election (WCA-L) aims at turning isolated nodes into cluster-heads and forms their clusters by invoking an election immediately at the moment when two cluster-heads are one-hop neighbors (Bricard-Vieu and Nasser, 2006). The ordinary nodes attempt to affiliate to another cluster and only the gateway nodes that lie within the transmission ranges of two different cluster-heads are successful. The remaining nodes and the cluster-heads keep electing clustering process, which is the same as the one defined in WCA.

2.1.4 Entropy-based Weighted Clustering Algorithm for Ad Hoc Networks

Entropy-based weighted clustering algorithm (EBWCA) aims at demonstrating the uncertainty concerning the amount of disorder within a network (Wang and Bao, 2007). One of the parameters taken into account in EBWCA is the relative position between two nodes, which is set as below:

$$a_{m,n}=\sum_{i=1}^{N} | \rightarrow p(m,n,t_i)|$$

Where *m* and *n* are node IDs and t_i refers to the time instant of the i-th calculation and *N* is the number of separate times, t_i. And the entropy of the node *m* is $H_m(t, \Delta t)$ that is defined as follows:

$$H_m(t,\Delta_t)= \frac{-\sum_{k\in F_m} P_k(t,\Delta t)\log P_k(t,\Delta t)}{\log C(F_m)}$$

where

$$P_k(t, \Delta_t)= \frac{a_{m,k}}{\sum_{i\in F_m} a_{m,i}}$$

F_m defines the set of the node *m*'s neighbors and $C(F_m)$ is the cardinality of set F_m. The proposed algorithm EBWCA then calculates overall weight for node v as follows:

$$w_v = c_1\Delta_v + c_2D_v + c_3(-H_v) + c_4P_v$$

where c_1, c_2, c_3, c_4 are the corresponding weighing factors.

2.1.5 Advanced Efficiency and Stability Combined Weight based Distributed Clustering Algorithm in MANET

This algorithm has a hierarchical structure, which aims to optimize network performance by minimizing energy consumption and improving probable problems of efficiency and stability that a network may face (Hwang, *et.al.*, 2007). The initial phase of this algorithm is the recognition of a neighbour. Each node calculates its total weight as follows:

$$W_v=w_1D_v+w_2M_v+w_3Ev+w_4\Delta_v;\ w_1+w_2+w_3+w_4=1$$

where D_v is the sum of distances of node v with all its neighbours, M_v is the average running speed of node v, E_v is the remaining amount of node v's battery and Δ_v is the degree difference of node v.

Finally the node with smallest amount of W acts as a cluster-head. This algorithm uses local minima instead of global minima and moreover there is a maintenance stage, which includes cluster maintenance when cluster-head role is resigned and when cluster member nodes move out.

2.1.6 Weight based Adaptive Clustering for Large Scale Heterogeneous MANET

Weight based adaptive clustering algorithm (WACHM) attempts to make a large scale hierarchical MANET by utilizing heterogeneous nodes to build various layers (Hwang, *et.al.*, 2007). The objectives of this algorithm are considered to be choosing the optimal number of cluster-heads, using optimal hop counts and defined dependency probability and link stability within the network domain.

The first step of the algorithm is to find neighbours, which are categorized as two different types: type-1 (cluster-heads) and type-0 (cluster members). After that each node calculates the following parameters:

$$w_i=w_2AP_s+w_3AP_d+w_4E_r-w_1d_i;\ w_1+w_2+w_3+w_4=1$$

Where AP_s is the average of link stability Ps over all neighbors:

$$Ap_s=\frac{1}{K_{N(i)}}\sum_{K=1}^{K_{N(i)}} P_s(i,j)\ ; \qquad (j \in N(i))$$

AP_d is the average dependency probability P_d over all neighbors:

$$Aps=\frac{1}{K_{N(i)}}\sum_{K=1}^{K_{N(i)}} P_d$$

Finally the node with the highest W_i is chosen as a cluster-head this time and all the neighbors of the selected cluster-head are not permitted to participate in the election process.

2.1.7 Dynamic Energy Efficient Clustering Algorithm for MANETs

Dynamic energy efficient clustering algorithm (DEECA) contains two important stages: cluster formation and network maintenance (Safa, *et.al.*, 2008). Two defined energy thresholds are taken into account in order to equilibrate the amount of load among cluster-heads within the network. At the beginning all nodes have an undecided status which means they do not belong to any cluster. After that each node broadcasts 'HELLO' messages during 'BROADCAST-PERIOD' interval. Then each node calculates its own weight as follows:

$$W_v = w_1v+w_2E_v+w_3M_v; \quad w_1+w_2+w_3+w_4=1$$

After the weight calculation process each node sends 'HELLO' messages including the amount of its weight. Therefore, each node is aware of its immediate neighbour's weight. Lastly the node with the minimum weight acts as a cluster-head and the nodes in its immediate neighbourhood are its cluster-members.

2.1.8 Improved Weight-based Clustering Algorithm in MANETs

Improved weight-based clustering algorithm (IWCA) has been proposed to overcome the problem of high rate of re-affiliations that leads to an increase in the network overhead (Zou, *et.al.*, 2008). The algorithm starts finding the neighbours of each node and at the end calculates weight as follows:

$$w=w_1M_v+w_2P_v+w_3D_v+w_4\Delta_v\ ; \quad w_1+w_2+w_3+w_4=1$$

where D_v is the distance of a node with its neighbours, M_v is the average speed of node v, Δ_v is the degree difference of node v and P_v is the cumulative time P which shows how long a node acts as a cluster-head in a network. Finally each node chooses the node with minimum weight as a cluster-head and moreover the isolated nodes also act as cluster-heads.

2.1.9 Energy Efficient and Stable Weight based Clustering for MANETs

Energy efficient and stable weight based clustering algorithm (EE-SWBC) tries not to send any additional weight messages and select the most promising node as a cluster-head and decrease the amount of general overhead within the network (Bouk and Sasase, 2008). It uses Grey Decision Method (GDM) in order to calculate the weights of nodes. Firstly, each node sends a 'Hello message' which includes ID, status, *σ1(u), Mt(u), Pt(u), D(u)* and coordinates. Each node calculates the following parameters:

- Node Degree of node u [σ1(u)]
- Average Speed of node u [Mt(u)]
- Residual Battery Power of node u[Pt(u)]
- Average Distance of node u [D(u)]

EE-SWBC assumes the node degree and the residual battery power parameters to be the positive criteria and the average speed and distance parameters to be the negative criteria. Finally, the maximum combined weight of neighbour nodes is calculated by multiplying the weight factors w_i by the relations coefficient matrix utilized in GDM.

2.1.10 Flexible Weighted Clustering Algorithm based on Battery Power for MANETs

Flexible weighted clustering algorithm (FWCA) aims to make a network stable by decreasing the number of clusters and an amount of overhead due to forming clusters (Hussein, *et.al.*, 2008). Moreover it tries to prevent nodes with less battery power act as cluster-heads. FWCA includes two stages: clustering algorithm and clustering maintenance. The moment clustering algorithm starts, each node broadcasts a 'beacon' message to recognize its neighbors. All the sensor nodes create a neighbor list considering the received beacons. Then each node calculates its weight amount as below:

$$w_i = w_1SP+w_2LCC+w_3BP + w_4S_i;\ \ w_1+w_2+w_3+w_4=1$$

where SP is the spreading degree (meaning the difference between cluster's size (the threshold for the cluster members) and the real number of neighbours R(N)), LCC is the local clustering coefficient (connectivity), BP is the remaining battery power of the node and S_i is the average speed of the node i.

Finally a node with a minimum amount of weight is selected as a cluster head. Clustering maintenance is applied on the network in case of less amount of battery power threshold and a node separation from its cluster.

2.1.11 Enhanced Weighted Clustering Algorithm for Mobile Networks

The objectives in enhanced weighted clustering algorithm (EWCA) are achieving the minimum number of affiliations and the general amount of overhead during the formation process of clusters and increasing the stability of clusters, system performance and nodes' life time through the ad hoc network domain (Li, *et.al.*, 2009). The moment the clustering algorithm starts, each node calculates its weight amount as following:

$$w_i=w_1\Delta_i+w_2M_i+w_3D_i+w_4E_i\ ;\ w_1+w_2+w_3+w_4=1$$

where Δ_i is the degree difference, D_i is the sum of the distances to all its neighbours, M_i is mobility of node i and E_i is the consumed energy of a node.

Finally nodes with smaller weight are elected as cluster-heads and the defined cluster-heads and members are not allowed to participate in the clustering elections. Moreover at the network maintenance stage there is a feature of controlling the battery power consumption of mobile sensor nodes.

2.1.12 Maximal Weight Topology Discovery in Ad Hoc Wireless Sensor Networks

This algorithm specifies two phases. The first one is the 'information exchange' and the second one is the 'cluster discovery' (Fayyaz, *et.al.*, 2010). The main purpose of the algorithm is to minimize the number of reconfigurations and the number of cluster-heads within the network domain in order to achieve the optimal topology for the network. After the neighbor recognition step, each node calculates the following parameters:

$$\Omega_{\varpi} = \omega_1E+\omega_2M +\omega_3\Delta+\omega_4\Pi\varpi+\omega_5\Delta\rho+\omega_6T;$$

$$\omega_1+\omega_2+\omega_3+\omega_4+\omega_5+\omega_6 =1$$

where E is the node energy, M is the node mobility, Δ is the node degree, Π_{ϖ} is the neighbouring node positions, Δ_ρ is the data rate and T is the target revisit rate.

The node with the maximum amount of Ω is selected as a cluster-head and following the second phase (clustering discovery), it creates its own cluster based on 'color' algorithm (Fayyaz, *et.al.*, 2010).

2.1.13 Efficient Cluster-head Election Algorithm based on Maximum Weight for MANET

Efficient cluster-head election algorithm (ECAM) includes two stages of clustering and maintenance. There are two parameters that are checked during maintenance stage (Sivaprakasam and Gunavathi, 2011). The first one is the 'mobility of a cluster' and the second one is the 'cluster maintenance'. The moment ECAM starts running, each node sends its identification number to its neighbors in order to build a neighbor's table. After that each node calculates its weight as shown below:

$$w_n=w_1 n+ w_2 S_n+w_3 T(n)+w_4 T_C+w_5 C_n ;$$

$$w_1+w_2+w_3+w_4=1$$

where n is the set of node's neighbours, S is the sum of the distances between a node and all its neighbours, T(n) is the speed of a node and T_C is the cumulative time that a node acts as a cluster-head.

Finally the node with the maximum weight acts as a cluster-head and sends a 'CH-MSG' to its neighbours in order to build its cluster.

2.2 Weighted Clustering Algorithms for WSNs

It is necessary to mention that since MANET and WSN are relatively similar networks, some of the above weighted clustering algorithms for MANET are applicable to WSN as well.

2.2.1 Clustering Algorithm for Localization in WSNs

Clustering algorithm for localization in wireless sensor networks (CFL) aims at achieving the minimum number of clusters with maximum number of nodes inside in order to improve the general performance of weighted clustering algorithm (Zainalie and Yaghmaee, 2008). At the moment the CFL algorithm starts by all nodes broadcasting the 'Hello' message through the network and building their 'neighbour table' based on received messages, which includes estimation of distances also. Then each node calculates its weight as follows:

$$w_i=aN_i+bE_i+c_1/P_i; \quad (a+b+c\leq 1)$$

where E_i is the remaining energy, N_i is the number of node's neighbours, P_i is the transmission power and W_i is the combined weight.

Lastly, the node with the maximum weight value acts as a cluster-head and sends a 'CH-msg' to its neighbours and the nodes that receive this message change their states to cluster members. The remaining nodes, which do not belong to any clusters, change to cluster-heads.

2.2.2 Improved Weighted Clustering Algorithm for Heterogeneous WSNs

Improved weighted clustering algorithm (IWCA) attempts to increase the network life time and in addition to forming clusters it includes network maintenance. Network maintenance checks two thresholds for energy amount of nodes, which triggers the recalculation of the clustering algorithm (Hong, 2011). Each node calculates w_v as follows:

$$w_v =w_1 \Delta_v+w_2 D_v+w_3 M_v+w_4 T_v+w5C_v;$$

$$w1+w_2+w_3+w_4=1$$

where C_v is the characteristic C of each node (C_v=(C * r_v)/E_v), C is a constant for amplification, r_v is the transmission rate, E_v is the initial energy of a node, D_v is the distance of a node with its neighbours, Δ_v is the degree-difference, M_v is the speed of a node and T_v is the cumulative time which shows how long a node acts as a cluster-head in a network.

The node with minimum weight acts as a cluster-head and makes its cluster.

2.2.3 Distributed Energy-Efficient Hierarchical Clustering for WSNs

This algorithm utilizes two parameters – residual energy and distance with neighbours – in order to calculate the combined weight of each node (Ding, *et.al.*, 2005).

$$w_{weight}(s) = \left(\sum_{u\in N_{\alpha,c}(S)} \frac{(R-d)}{6R}\right) \times \frac{E_{residual}(S)}{E_{initial}(S)}$$

where R defines the cluster range, d specifies the distance from node s to the neighbouring node u, $E_{residual}$ is the residual energy in node *S*, $E_{initial}$ is the initial energy in node *S* which is the same for all the nodes and $N_{\alpha,c}$ is the set of the neighbors of the node *S*. It is assumed that the number of neighboUring nodes of a cluster is at most 6.

3 LIFE TIME SENSITIVE WEIGHTED CLUSTERING ON WSN (LTS-WCA)

Various characteristics of WSNs, such as mobility heterogeneity, large scalability requirement and power restrictions, are all considered in the proposed model. It is expected that during the lifetime of a sensor network, the network may face several problems, such as: (1) lack of energy in sensor nodes that fail in their attempt to cover the environment properly; (2) overloaded cluster-heads; (3) existence of some isolated sensor nodes in the network; (4) fast energy depletion rate used for both transmission and processing purposes. Life-time sensitive weighted clustering algorithm (LTS-WCA) is a fully distributed algorithm, which is applicable for heterogonous mobile wireless sensor networks. It aims to solve the predefined problems included in the reviewed weighted clustering techniques and modifies these previous works efficiently in order to apply them on then WSN domain. Although LTS-WCA is designed for heterogonous WSNs, it can be used on homogeneous WSNs, too. There are several significant modifications on the original version, which can be listed as follows:

- LTS-WCA uses local minima instead of global minimum, which means each decision can be made by a group of nodes in a local manner and there is no need for a node to get aware of the other nodes' decisions and specifications.
- There is a specific life time assigned to each protocol packet of a node in terms of hop counts in order to limit packet retransmissions.
- Sensor nodes communicate in a multi-hop fashion both for inter- and intra-communications.
- Several additional parameters are included in the clustering algorithm to be used to calculate node weights and to find efficient cluster heads. The additional parameters used are:
  - Er: remaining energy of a node
  - Tr: transmission range of a node
  - S: size of a cluster which a node as a cluster head can support
  - dv: number of 1-hop neighbours of a node

At the exact moment when clustering timer is triggered through the network, each mobile wireless sensor node gets prepared to follow the steps below:

Step 1: each node recognizes the nodes in its neighborhood.

Step 2: each node calculates its parameters as follows:

$$S = (NK^2T_r^2\ \pi)/A$$

Where S is the ideal number of cluster members in a cluster,

K is the number of hops that a node can support inside of its cluster in a case it becomes a cluster head,

N is the number of nodes that can receive transmitted packets from a source node,

A is the area of the network,

T_r is the transmission range of a node,

M_v is the speed of a node,

Er is the amount of residual energy of a node,

d_v is the number of 1-hop neighbors of a node

Weight of a node:

$$w=(w_1T_r+w_2M_v)/(w_3d_v+w_4E_r+w_5S);$$

$$w_1+w_2=1,\ w_3+w_4+w_5=1.$$

Step 3: Each node prepares its data structures considering the above calculations and broadcasts it.

Step 4: Each node compares its weight using other neighbors' weights.

Step 5: Each node checks whether it has the smallest weight.

- If a node has the least weight, it sends a 'ch-msg' including its ID and weight to all its neighbours and changes its state as a cluster head. Moreover after receiving each 'join-req' it starts to accept nodes until the number of nodes within its cluster doesn't exceed the defined threshold.
- If a node does not have the least weight amount, it checks whether it receives any 'ch-msg'. If so it sends a 'join-req' to selected cluster head and after receiving acceptance from the cluster head it changes its state as cluster member.
- Isolated nodes, which cannot join to any cluster, change their state as cluster heads.
- At the end of the clustering algorithm each node has a cluster head or cluster member state within the defined clusters. It is worth noting that during the exchange of information among sensor nodes, each node checks whether the received data is new or not. If it is new, it propagates it to its 1-hop neighbors considering the packet's life time field, if it is not, it simply drops it. Moreover, each node updates the packet life time field once in every run of the clustering algorithm considering its remaining energy.
- During the clustering process, in case a node has a possibility to join different clusters, it checks the number of hops it is away from the available cluster heads and selects the least distance. In case of equality, it checks the residual energy amount of the cluster heads and chooses the highest one and joins it.

4 IMPLEMENTATION, EVALUATION OF LTS-WCA

In our tests, we assumed that there are mobile wireless nodes in a 1000*1000 square. They are categorized into three types of nodes with speeds of 7, 5 and 3 m/s. Node transmission ranges are 200, 150 and 100 meters. Initial energy of nodes are 20, 15 and 10 Joules.

It is worth mentioning that although LTS-WCA was designed especially for heterogeneous WSNs, it can be used for homogenous WSNs and it can also be applied on MANET, if the density of the mobile nodes within the network is not large. This is believed to be its biggest advantage.

Table 1: LTS_WCA parameters.

Parameter	Value
Transmission range	100, 150,200
Area	L -1000
Traffic type	CBR
Tx energy	0.036 Joules
Rx energy	0.024 Joules
Initial energy	20, 15, 10 Joules
Number of nodes	50, 100, 200
Max packet in ifq	200 packets
w1,w2,w3,w4,w5	0.5,0.5,0.4,0.4,0.2

In order to compare the result of LTS-WCA with WCA and WBACA, we applied the same MANET environment (1000*1000 square) with same values of speed for nodes (10m/s). The following LTS-WCA plots are obtained as averages of 50 consecutive runs of the simulation, each starting with a new randomly assigned node distribution.

The simulation results of CFL, WCA and WBACA are directly borrowed from the respective publications (Dhurandher, and Singh, 2005), (Zainalie and Yaghmaee, 2008). The comparison results of LTS-WCA performance with the existing weighted clustering algorithms on MANET are shown below:

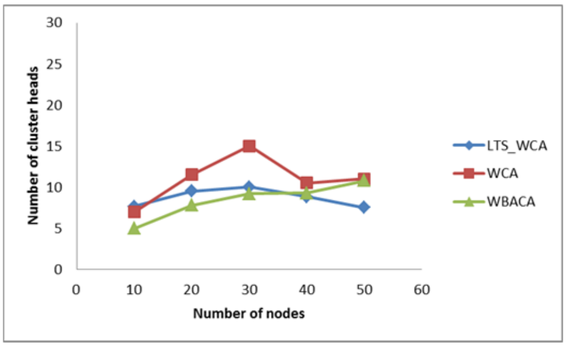

Figure 1: Comparing WCA, WBACA and LTS-WCA in terms of number of cluster heads and number of nodes.

Figure 1 shows the comparison of LTS-WCA with two different Weighted Clustering Algorithms (WCA and WBACA) by considering two parameters: number of cluster heads and number of nodes. As seen in the figure, by increasing the number of nodes the number of clusters increases until the number of nodes reaches 30. After this point in both WCA and LTS-WCA the number of cluster heads decreases. The reason behind this is the fact that when the node density is small, each node takes a cluster head role in the environment. However, by increasing the number of nodes further, the possibility of nodes belonging to a cluster increases and this decreases the number of cluster heads, which in return decreases the energy consumption to transmit data to sink. As figure 1 shows the performance of LTS-WCA is much better than that of WCA (Chatterjee, *et.al.,* 2000) and it is also better than WBACA (Dhurandher and Singh, 2005) when the number of nodes gets larger.

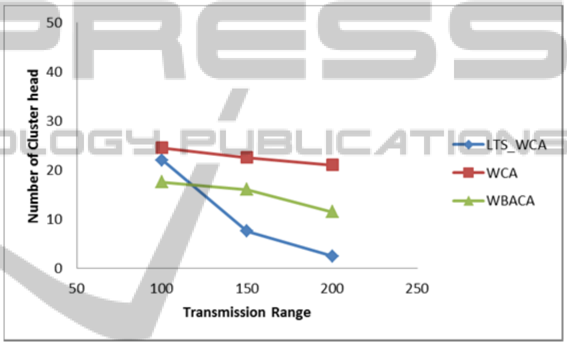

Figure 2: Comparing WCA, WBACA and LTS-WCA in terms of number of cluster heads and transmission range.

Figure 2 presents results considering two parameters, namely the number of cluster heads and transmission range. By increasing the node transmission range within the network, the number of cluster heads decreases. As can be seen in the figure the performance of LTS-WCA in decreasing the number of clusters and therefore transmission energy consumption is much better than that of the other two algorithms.

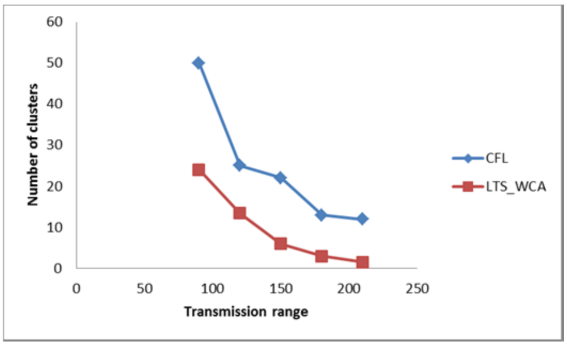

Figure 3: Comparing CFL and LTS-WCA in terms of number of clusters and transmission range.

Figure 3 shows the comparison between LTS-WCA and CFL (Zainalie and Yaghmaee, 2008) algorithm on WSN. By increasing the transmission range, the number of clusters within the network decreases and this leads to the decrease of the amount of energy needed to transmit data from the source to a sink. As the plot represents LTS-WCA has a considerably better performance in comparison with CFL (Zainalie and Yaghmaee, 2008) algorithm.

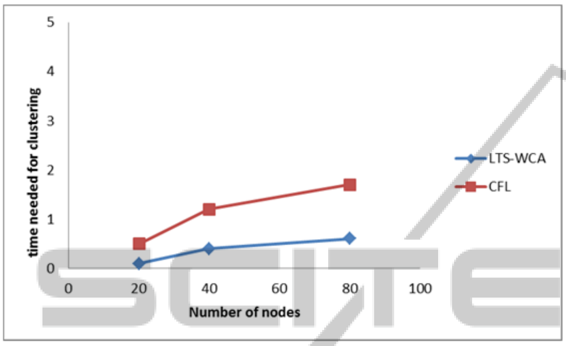

Figure 4: Comparing CFL and LTS-WCA in terms of number of nodes and time needed for clustering.

Figure 4 illustrates the change in the time needed for clustering vs the number of nodes in WSN. As seen in the figure, LTS-WCA is quite successful to decrease the clustering time in comparison with CFL (Zainalie and Yaghmaee, 2008).

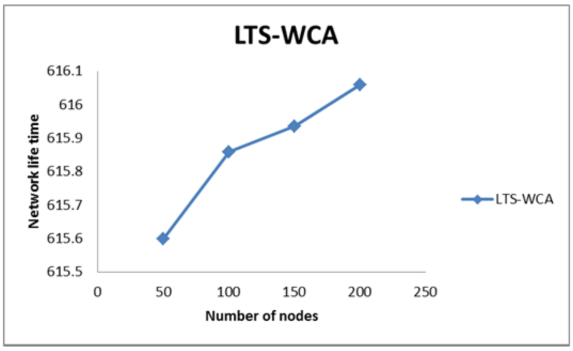

Figure 5: LTS-WCA life time performance in function of number of nodes (homogenous network).

Figures 5, 6 and 7 present the performance of LTS-WCA in a homogenous WSN to show how energy efficient it is in terms of network life time. As was mentioned earlier, the moment the first node dies is considered as a network life time in LTS-WCA for simplicity. In Figure 5 by increasing the number of nodes, the network life time increases gradually.
Figure 6 shows the considerable increase the network life time if initial energy of nodes within the environment is increased. Figure 7 presents the decrease of the network life time of WSN while

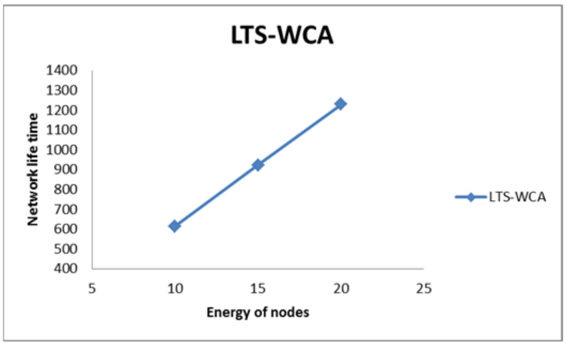

Figure 6: LTS-WCA life time performance in function of energy of nodes (homogenous network).

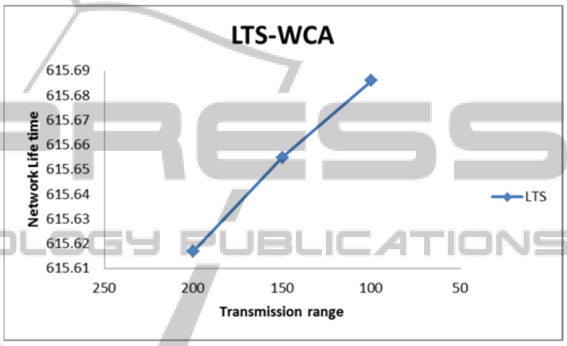

Figure 7: LTS-WCA life time performance in function of transmission range of nodes (homogenous network).

node transmission range increases. The reason behind this is the fact that by increasing the transmission range of nodes, the size of clusters increases, too. Finally cluster heads become overloaded and they start to lose their energy much faster. As a result, the network life time also decreases.

Figure 8 represents the performance of LTS-WCA on a heterogeneous WSN. By increasing the number of nodes, the network life time also increases.

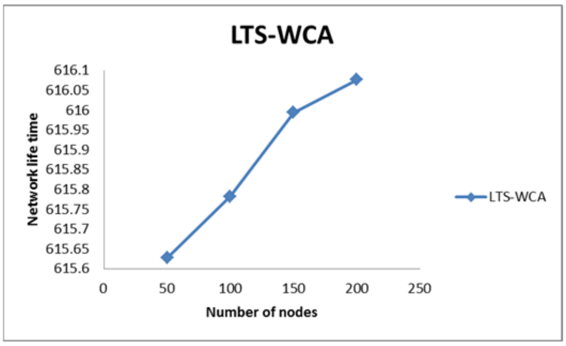

Figure 8: LTS-WCA life time performance in function of transmission range of nodes (heterogeneous network).

5 CONCLUSIONS

In the present work, we studied the vast amount of research done in the field of weighted clustering algorithm for two different network types, namely mobile ad hoc networks and wireless sensor networks. We examined their main motivations concentrating mostly on the energy efficiency and network overhead. Since in WSN life time is considered to be a vital issue, researchers mostly take it as a significant parameter to be improved within their proposed clustering algorithms (Hong, 2011), (Ding, *et.al.,* 2005). However, along with life time, the issue of energy efficiency plays an equally important role. Therefore, it became the second emphasized area of the present study.

LTS-WCA is a weighted clustering algorithm which is designed in this work specifically for distributed heterogeneous wireless sensor networks. The algorithm includes two phases: clustering and network maintenance. It employs five key parameters in order to choose the best cluster head through the network environment. These parameters are transmission range of a node (Tr), minimum distance to a neighbour cluster's cluster head (Dmin), speed of a node (Mv), degree of a node (dv), remaining energy of a node (Er) and number of nodes that a node can handle inside of its cluster in case it becomes a cluster head (S). After choosing cluster heads and grouping the network nodes in clusters, the maintenance phase starts. In the maintenance phase, three parameters are checked periodically within the network environment: the residual energy of mobile wireless sensor nodes, the mobility of sensor nodes and the amount of load put on a cluster head. In the present paper, maintenance part is not implemented since it is proposed as an enhancement.

The main purpose of LTS-WCA is to overcome the problems which a wireless sensor network faces. LTS-WCA increases network life time by decreasing the number of clusters within the network environment. Decreasing the number of clusters leads to less usage of transmission power and finally keeping the nodes alive for much longer within the network environment. Moreover decreasing the time needed to group the network into clusters also in increasing the network life time and LTS-WCA acts successfully to increase the overall network life time on a Wireless Sensor Network.

One of the advantages of LTS-WCA is that it is applicable to MANET and homogenous networks also. As a result, as shown in our simulation study, it has a much better performance in terms of energy efficiency in comparison with existing weighted clustering algorithms on both MANET and WSN such as WCA (Chatterjee *et.al.,* 2000), WBACA (Dhurandher and Singh, 2005) and CFL (Zainalie and Yaghmaee, 2008).

In terms of increasing energy efficiency and network life time, there is still a lot of work to be done. There are several parameters such as 'transmission range', 'number of neighbours', 'degree differences', and 'remaining battery power' and 'distances with neighbours', which play significant roles in the process of selecting cluster-heads and clustering formations, and these parameters should be thoroughly worked out and developed further. There is still lack of research done in this area and scant written materials covering the aforementioned issues.

Further improvements on weighted clustering algorithms should concentrate on clustering formation and cluster-heads election for creating a more stable network structure with less energy cost. In order to maintain the network, efficient thresholds should be used in terms of energy amount of nodes, mobility of nodes and cluster size; this should be done in order to decrease the number of re-affiliations as well as the number of re-clustering the network domain. Replacing some parameters for calculating the combined weight with some other parameters may help to keep the amount of load on the cluster-head balance and decrease the general overhead within the network.

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