# Improving Connectivity of Nodes in Mobile WSN

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***Abstract*—How to maintain connectivity is an important issue in ad hoc networks. A special cases of such network is Wireless Sensor Networks (WSN), which are often deployed in harsh environments and also susceptible to a number of problems that may negatively affect the connectivity among the nodes. An moreover factor that increases the charge of connectivity maintenance in ad hoc networks is when the nodes can move. When it come to the WSN domain, this aspect is still more problematic, as the often small sensor nodes have in general a limited energy budget, and then should not use maximum energy in the management of their connectivity. The aim of this work is to choose a topology for mobile WSN and improve the network connectivity as a whole while considering and influencing the energy consumption among all the nodes in the network. Different network topologies are considered and discussed. After assessment of the pros and cons of the estimation quality, when applied to each studied topology, a clustered hierarchical algorithm was chosen for network deployment. By means of a link valuer and considering different variables, a metric have been defined to estimate the link reliability. As a result, improved network connectivity is reported.Keywords-component; Mobile WSN connectivity; distributed energy consumption deployment; clustered hierarchical topology; link estimator.**

## INTRODUCTION

Wireless sensor networks (WSN) are in use in a number of application areas nowadays. However, some of the expected deployment and adoption have been delayed due to shortcomings in fulfilling important application requirements. Therefore, supporting the requirements and the environments in which they are deployed is essential. This requires an effort in understanding not only the applications, but also the related constraints in their deployment. A possible solution can be to divide applications based on their needs by considering WSN characteristics like mobility, deployment topology, energy, cost, network lifetime, and coverage area. Mobile WSN is composed of several mobile sensor nodes, which use their own power (generally supplied by a battery) to communicate with other nodes located at different distances, via radio frequency signals. The aim is to gather information from the nodes that are spread in an area, and send their information to one or more base stations for further usage. In ad hoc networks, the concept of connectivity is important as such networks have not a controlled deployment as ordinary computer networks. Moreover, when the nodes of these networks are mobile as in Mobile Ad Hoc Networks (MANETs), the connectivity management has even more importance. The purpose of the presented research is to measure the connectivity among nodes while distributing the energy consumption over all of them. To accomplish this, a suitable topology, i.e. one in which the nodes have specific roles, based on the allocation and movement of the nodes, has to be found, so that the mobile WSN (re)configures itself to face the new spatial organization of the nodes. This feature will allow the network to try to recover from failures due to disconnections and unexpected node rearrangements that may occur. In the achievement of this reconfiguration, important constraints related to resource usage, especially the energy use has to be observed. A motivating application of a connectivity measure could be the movement tracking of sheep's or cows in an open landscape or a group of children visiting an open area while making a trip supervised by a teacher. In such applications, different members may have different roles, for instance some teachers would monitor groups of children while the leader of the trip would receive feedback information of the different teachers.

## RELATED WORKS

Different research groups have considered a set of important features in the study of WSN connectivity. A common assumption is that the nodes in a wireless sensor networks have a limited energy resources; therefore, save energy is an ultimate goal to prolong the nodes lifetime. Many protocols and algorithms are thus considering energy efficiency in the networking context. Mobility is an important reason in some WSN applications. Several researchers try to solve the upcoming problems due to mobility of the nodes. Some of them are:

Usage of multi-sink instead of single-sink architecture to get rid of the contention problem that may occur near the sink has been engaged to achieve the best performance in the network. Evaluation of the link behavior by using information from different layers of the protocol (cross-layer protocol), is used to improve the routing decisions and performance based on the most reliable, link to use for communication. Another important aspect is the reliability of a WSN, which is affected by faults that may happen for different reasons and which lead to reduction of network lifetime or functionality problems. There are a number of research efforts exclusively dedicated to WSN reliability and fault tolerance. An approach, presented in, is to measure the connectivity of a network in terms of reach ability defined as the ability of two nodes in the network to communicate which uses graph theory to support the proposal.

Prolonging the network lifespan and improving its connectivity while balancing energy consumption are two necessary research aspects of WSN, the authors try to evolve an efficient WSN topology, based on the mesh scheme, to increase network lifetime and consume less energy. The target is to develop the optimal network topology based on the nodes' behavior. The paper proposed the Leader-based Enhanced Butterfly (LEB) network topology, based on a combination of hierarchical and ad-hoc network properties. The model introduced a three-layer schema, where each layer is managed by its upper layer. Considering the mobility of the nodes in a WSN,- different methods, used to balance the energy consumption, is to make the routing decision a responsibility for each node based on its rest energy. Distributing the routing decision among the nodes rather than localizing it in a specific node, or a base station, balances the energy consumption of the network and avoids having a single point of insolvency in the system.

## PROBLEM STATEMENT

As mentioned, node mobility is a concern that is gaining importance as mobile nodes in WSN networks enables many interesting applications. Mobility causes problems also because of the dynamic environment in which the nodes are moving, resulting in network topology changes. Depending on the type of mobility, these changes can or cannot be foreseen, and accordingly, measures to maintain the network connectivity are needed. Moreover, another important aspect related to the mobility is the speed of the motion in relation to available communications range.

The first aspect is related to the way the network is organized. This refers to the topology that is taken as the basis for the network, and that has to be cared for to perform the rearrangements when it is needed. In view of the sample applications used to motivate this work, the network always reports its connectivity to sink that is responsible for network management, e.g. the sheepherder or the teacher leading a group of students. Therefore, possible topologies to be considered are: 1) Star, which is a simple network topology, consisting of one main node called sink and the rest of the nodes connected to the sink via a one-hop direct link; 2) Mesh, is a multi-hop path network in which all nodes are not necessarily directly connected to the sink and thus can send each other information also indirectly; 3) Clustered, consist of sub clusters each in the form of a mesh network, which communicate with each other using gateway nodes. Figure 1 presents examples of each of these topologies.

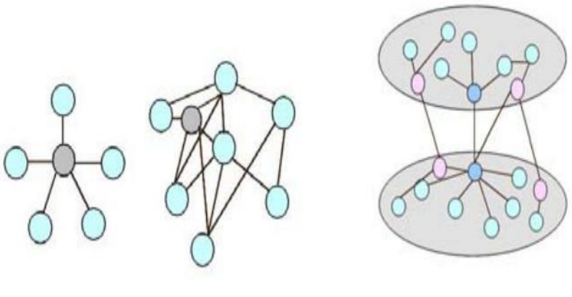


Figure 1. (a) Start and mesh topologies. (b) Clustered topology

A second important aspect of the studied problem is related to how to identify the loos of connectivity in such a way that the network is able to react and manage to heal the problem. This is the quality of the link between nodes and between groups of nodes in the network. The issue is which parameters should be considered and with which importance in order to evaluate the links and then to take decisions. Finally, considering the two mentioned aspects, how should they be consideredtogether in order to address the overall problem of the network connectivity in mobile WSN.

The question is how to formulate an approach to keep track of the nodes based on that the connectivity among them is monitored. Moreover, an important non-functional concern is related to monitoring the energy consumption of the nodes individually and for the network as a whole. This energy consumption is a vital issue in WSN design and is an important aspect that should not be forgotten, especially because this is a factor that distinguishes the handling that can be given to a ordinary ad-hoc network, if compared to a WSN.

### *D. PROPOSED APPROACH*

The purpose of this work is to find a model that can improve the connectivity assessment in WSN composed by mobile nodes, while keeping a balance in the energy used for each node to achieve this goal.

The use of a link estimator (metric) is intended to provide information that makes it possible to find an appropriate mechanism to propagate link states among mobile nodes. This way, the network may consume less energy or a balanced level of energy use among the nodes, as the estimation of the links will not be centralized in a single node or in few nodes of the network. As a result, the network will balance the energy consumption due to the connectivity management among its nodes and in the long run, present a more reliable behavior. The solution proposed in this work is based on the work that has been done in the area of the link quality estimation mechanisms presented in. The idea is to find the minimum intra-communication clustering cost within a cluster. This means finding the minimum cost of communication among the nodes based on the link quality between each pair of nodes and then cluster them based on it. A good link estimator will react quickly on changes in the link quality. This makes it possible for the proposed algorithm to adapt itself to the mobility of the nodes and their remaining energy.

The second step is to develop a self-organizing algorithm that can use the information provided by the link estimator at each node to (re)create the network topology. This algorithm will allow messages to reach the base station, using the best possible link and, at the same time, balance and distribute the energy use among the nodes.

### *A. Link metric*

To create a self-organized and fully connected network, an accurate link estimator is required. There are several challenges to define a good link metric. One is to base it on signal strength, which provides a poor estimation. Another possible metric is channel snooping and following the sequence number of the received packets from each source. This method is very costly, because a node may listen also to many packets that are not addressed to it. A good link estimator should react quickly to network changes. It should need a small memory resource and processing energy; furthermore, it should be simple to calculate.

Each link behavior affects the network behavior and connectivity. A poor link can decrease the entire network connectivity; therefore, link estimation has a direct relation with a total network connectivity measure. In order to have a good link metric, different factors that affect the link quality of a mobile WSN should be considered. Furthermore, the metric should be stable, so it does not affect and change the network topology continuously. In WSN, data transmission is done by using the radio. Low-power radio signals limit the network connectivity since it can only cover a small area. Meanwhile, obstacles in between have a direct impact on the radio transmission power and can decrease it. When mobile nodes are part of a WSN, their movement has impact on the signal power and link reliability, so the received signal strength indicator (RSSI) of a node is one of the factors that can be used in link estimation. Since nodes are moving, it is preferred that they consume less energy in order to decrease their connectivity maintenance cost. Reducing total nodes' energy consumption prolongs network lifetime, which is desirable for WSN. In addition, distributing energy consumption in WSN helps the network to prolong its lifetime, so in this research, the nodes' energy is considered as one of the factors that indicate if a link is good or not. Hence, each sensor's remaining energy is included in the metric formula. Due to the above described factors, it can be concluded that a good link metric for mobile WSN might consist of the three mentioned factors that report the node and link situation dynamically. The proposed link metric is described as:

$$M\ En\ \ RSSI\ \ \ LQI \qquad (1)$$

Where $M$ is the computed link metric, $En$ is the remaining node's energy, $RSSI$ is the received signal strength indicator and $LQI$ is the link quality indicator. To make this metric more accurate, the importance of the mentioned factors was studied, and it was concluded that according to the network topology and the nodes role in the network, the factors of importance can be different. So, weights were added to the terms in (1), resulting in the following formulation for the link metric:

Where $K1$, $K2$, $K3$ are the importance of each relevant factor for the node, and $K1+K2+K3 = 1$. The choice of appropriate values for each term will be discussed in later sections.

E. Network topology

In order to choose an appropriate topology for a WSN application, the main factors to be considered are reliability, energy consumption, scalability, network lifetime, transmission medium, operating environment and topology. Regarding these factors, the network topology plays dominating role, influencing the other ones. For instance, if there is one single main node in the network, star or mesh topologies are appropriate, while if there are more nodes that can be considered as main nodes, a clustered hierarchical topology is more suitable. The choice of a topology can be especially crucial for the networks´ scalability, lifetime and reliability.WSN should be reliable and scalable during the network lifetime and self-organization plays a key role in this context. Since WSNs are ad-hoc networks, it is not practical to group/organize the nodes beforehand. Once again clustered hierarchical topology seems to be appropriate to support the above-mentioned factors and is chosen as the network backbone architecture for this work.

In order to cluster the network, a clustering algorithm is needed. Different clustering algorithms can be distinguished by the method they select cluster heads, but usually they have some basic similarities. Clustering algorithms divide the network nodes into separate groups, preventing clusters to overlap, and minimizing message overhead by choosing separate cluster heads for each cluster. Approximately, in most of the algorithms, non-cluster head nodes send their data to their cluster heads; cluster heads aggregate the received data and, send it to the sink (base station). Some of the available cluster head selection algorithms are Linked Cluster Algorithm, Enhanced Linked Cluster Algorithm, Distributed Cluster Algorithm and Weighted Clustering Algorithm [1, 16]. Each clustering method can group the nodes based on network priorities like Load balancing, Network lifetime and Low-Energy consumption. The clustering algorithm proposed in this work is a derivation of weighted clustering algorithm. The network is divided into a three-level architecture based on link metric values. In each level, the nodes have separate responsibilities, level of communication and access to other parts of the network. This architecture is flexible so it can adapt itself to topology changes of the network. There are two phases to build the clustered hierarchical network. First, the cluster heads should be selected and then the rest of the nodes should be clustered.

After the cluster heads had been elected, each of them broadcasts a message to the rest of the nodes in the network inviting them to join its cluster. Each node may receive several messages. First, they check if they are not cluster heads themselves. If the node is a cluster head it drops the messages, otherwise the node calculates it's metric for all the received messages and then choose the best one as its cluster head. The node then sends a message to the related cluster head and drops all other invitation messages.

Another solution for clustering the network could be to assign the link metric calculation responsibility of the nodes, to the cluster heads and then let the cluster heads choose heir nodes. However, this solution has three drawbacks. First, the energy consumption of the cluster heads will increase and it may lead to degradation of both network lifetime and connectivity. Second, all the nodes will send their information to all the cluster heads, which may cause a broadcast storm and may decrease the network connectivity and performance as well. Third, it requires communication among the cluster heads to compare the calculated metric for a node, which both consume energy, needs more storage capacity and cause unnecessary traffic in the network. In addition, this solution adds delay to the network as all the cluster heads should wait for each other to reach a stable situation and then compare their information; hence, this solution was not implemented, but the one mentioned above.

In the proposed algorithm, each node can only belong to one cluster at a time and each cluster is monitored by just one cluster head. The network is then divided in levels, in which each level has its own conditions and considerations. All the levels together help the network to reach a better connectivity and performance. Since each cluster is a half mesh, this topology can be considered reliable. It is also scalable, since new nodes can join the available clusters. In addition, each cluster head is responsible for managing its own cluster nodes so that energy consumption is divided among the nodes in the network.

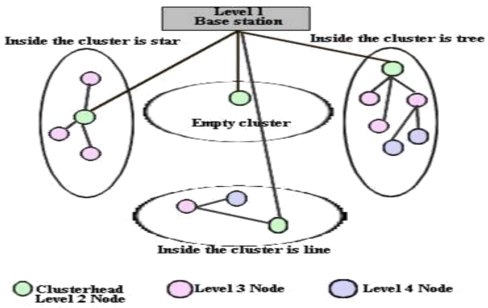
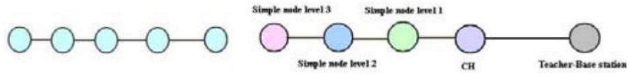



figure 2.Proposed clustered hierarchical topology

The base station (first level of the network) is responsible for managing the cluster heads, calculating and reporting the network connectivity and if necessary reorganizing the network. As mentioned above, to choose the cluster heads that construct the second level of the network, which will then form the clusters (third and forth levels of the network including rest of the nodes), the proposed link metric is used. Keep in mind that level two and level three nodes have different responsibilities, therefore the usage of the link metric for forming different levels is different. This difference is related to the selected weights of the three factors that compose the link metric calculation in (3). Figure 2 presents the basic network topology division in levels. As an example of a border line situation that may occur is when the nodes are moving. A specific situation is when the nodes are physically distributed forming a line as presented in Figure 3(a). This may occur, for instance, when a group of children is guided by a teacher through a track in a forest. Using the hierarchical cluster-based mechanism presented above, the network topology would be organized as shown in Figure 3(b). This arrangement will happen in the case that all the nodes have the same amount of *En* and *LQI*, therefore nodes *RSSI* is the determiner of nodes level. In such a case, it can be considered that the link metric of all the children except the first child in the line, is less than a predefined threshold; hence, all of them will be classified as "next level" nodes that are capable of controlling their neighbors. In this case, if two nodes have the same *RSSI*, one of them can be chosen as a cluster head and the topology will change to a tree, which is the basic clustered hierarchy.




(a) (b)

Figure 3.Line and cluster hierarchical

*F.Connectivity calculation*

The measure that tells how good an ad-hoc network is connected is based on the probability of communication between any two nodes in the network, whether this communication is single hop or multiple hops from the source to the destination. To measure and decide on the connectivity in a mobile WSN is complex as the nodes density and transmission ranges are two important elements that affect network connectivity. This complexity is first due to the despotic node density in a given instant of time due to the nodes' movement pattern, and second due to the transmission range may be affected by interferences, so the theoretical range may not coincide with the effective one.

The proposed topology is a clustered hierarchical one. This makes it possible to assume that the network is describe by graph *G (N, E)*. *N* represents the set of all the nodes in the network, and *E* is the set of all the link. Connectivity in the graph theory consider the probability ($P_{ij}$) of communication between two nodes $n_i$ and $n_j$ to be equal to 1, which means that they can reach each other. A way to assess the connectivity is to measure if every pair of nodes in the network is connected by either a single hop or multiple hops, which is what is called the "Reachability" in graph theory. This is measured by (3) [6], where *N* is the entire number of nodes in the network, *N_Con* is the number of connected pairs of nodes and *R* is the reachability.

$$R = \frac{N\_Con}{\binom{N}{2}} \quad (3)$$

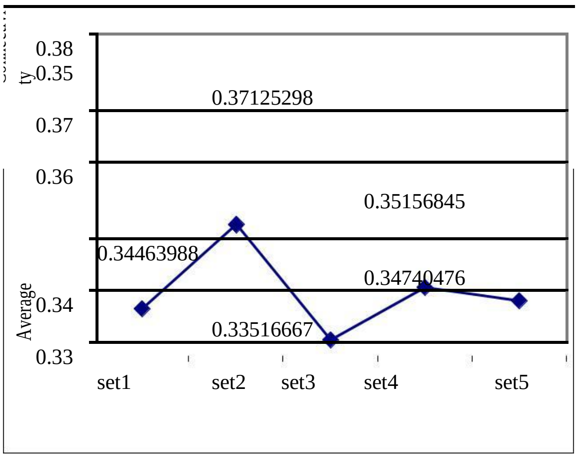
This method of connectivity measurement measures only the availability of a link between two nodes in the network. Therefore, for the whole network the connectivity value will range between 0 and 1, where 0 implies that there are no nodes connected, and 1 implies that all the nodes in the network are connected. However, *R* does not tell how good and reliable the network is, since being able to reach all the nodes does not mean that the available link is good and reliable as the received information may be corrupted or altered due to fading in signal strength. However, the goal is not only to know if two nodes can reach each other, but how well the network is connected and how well the link that connects the base station to each node in the network is, so the information about the existence of the link is not enough. For this reason weights, with the same values that were used in the link metric to form the clusters presented in (2), were added to the reachability measure. Taking into account the above observations, this work proposes to use the concept of reachability (3) combined with the link metric (2) to measure the network connectivity. The link metric is used to attribute a weight to each link considered in the calculation of the reachability, providing a connectivity measure (*C*): Where *N* is the set of all the nodes in the network whether they are connected or not and *Q* is a subset of *N* that consists of all the nodes that are actually (physically) connected. $M_i$ is the metric for the link *i*. Using the above formula not only evaluates the network connectivity, but also how reliable the connections are.

## G. IMPLEMENTATION DETAIL AND TEST RESULTS

A testbed using SunSPOT sensor nodes [5] were deployed in order to evaluate the proposed approach. The definition of the nodes displacement and movement were arbitrary chosen, trying to explore real world operation conditions. In the SunSPOTs sensor, nodes RSSI and LQI are both taken from the CC2420 chip. These values only reflect the characteristics of the link, at the moment the packet is received. Link Quality Indication (LQI) is a characterization of the quality of a received packets. Its value is computed from the, correlation value (CORR). LQI ranges from 0 (bad) to 255 (good). CORR measure the average correlation value of the first 4 bytes of the packet header. A correlation value of ~110 indicates the maximum quality of a packet while a value of ~50 is typically the lowest packet quality. The received signal strength indicator (RSSI) measures the strength (power) of the signal for the packet. It ranges from +60 (strong) to -60 (weak). To convert this measure to decibels relative to 1 mW (= 0 dBm), subtract 45 from it, e.g. for an RSSI of -20 the RF input power is approximately -65 dBm. [5]
In order to find the appropriate weights for the three parameters in the link metric formula, for both cluster head selection and forming of the clusters in the network, five different sets of tests were implemented, which are presented in Table 1. Considering the connectivity and stability results of these sets of tests, presented in Figure 4, the used link metric formulas are defined as (7) and (8):

$$Cluster\ head\ selections = 0.6*En + 0.3*RSSI + 0.1*LQI \quad (7)$$

$$Joining\ the\ cluster = 0.3*En + 0.6*RSSI + 0.1*LQI \quad (8)$$




*K value sets*
Network connectivity
Figure 4.Network connectivity for different group of metric parameters

To prevent the possibility of isolated nodes, which decreases the network connectivity, a timer is set on all nodes for periodic self-checking of its condition in the network.
When the timer expires, the node will check if it is connected to a cluster head. If the node is connected, the timer will start over; otherwise, the node will propagate a broadcast message to all the nodes in the network and ask for their metrics parameters. The node will then calculate its metric for different received data and connect to the best one.
It should be mentioned that in this step, the network may change its infrastructure and increase its number of levels, as a node can connect to either a cluster head or another node with an acceptable metric.
Since the chosen topology is clustered hierarchically, the network can have different levels (like a tree) that each node connects to an upper level node. Additionally, a simple node can connects to another to reach a cluster head.
This way the network is scalable and able to reorganize itself. In addition, since the network is a mobile WSN, a minimum transmission range should be set to cover the whole network, otherwise the nodes that have higher remaining energy or better packet quality are chosen as cluster heads, but since their radio transmission power may not be adequate they cannot send/receive information.In order to show the WSN connectivity improvement using the proposed algorithm, tests for two different algorithms were performed.First, for the one proposed in this paper, and then for an algorithm that takes random decision instead of basing it on calculation as in the proposed algorithm.
In the random algorithm, the network establishes itself based on the time that a connection setup message is received by a node, and the base station chooses the first nodes from which it receives answers as cluster heads and cluster membership is decided by reception of the first invitation by the rest of the nodes.
Table 1. Different set of K values in metric formula

| Link | | Link metric K1,K1,K3 weights | | | | |
|---|---|---|---|---|---|---|
| | *Node remaining En* | | *RSSI* | | *LQI* | |
| | *CH* | *Cluster* | *CH* | *Cluster* | *CH* | *Cluster* |
| Metric | 0.45 | 0.45 | 0.45 | 0.45 | 0.1 | 0.1 |
| Set 1 | 0.6 | 0.6 | 0.3 | 0.3 | 0.1 | 0.1 |
| Set 2 | 0.3 | 0.3 | 0.6 | 0.6 | 0.1 | 0.1 |
| Set 3 | 0.6 | 0.3 | 0.3 | 06 | 0.1 | 0.1 |
| Set 4 | 0.3 | 0.6 | 0.6 | 0.3 | 0.1 | 0.1 |

The proposed topology was implemented using a set of Sunspot sensor nodes. The network is established based on the described algorithm and the corresponding connectivity results are reported. For the random algorithm, the same routine was implemented. Then the connectivity results are

compared to each other, as presented in Table 2 and as a graph in Figure 5.
In addition, to check the quality of the proposed metric, the test was performed with different levels of energy for both algorithms. The result of these tests indicates that in a stable situation and for a fixed structure, the network connectivity using the proposed algorithm is always better and higher than the random alternative. Meanwhile, it was observed that, in the same situation (nodes with same level of battery and placement), the proposed algorithm chooses the same cluster heads and it forms the same clusters, while, each time the random algorithm is used, it chooses different cluster heads and forms different clusters.To check the effect of mobility on the network connectivity four different situations were considered. First, a simple node was moved far from the rest of the nodes. The network connectivity decreased. In these tests, the results indicate that even when a node moves far, the network connectivity of the proposed algorithm is still better and higher that it is with the random algorithm. For a second test, an empty cluster head was moved. Although in this test the network connectivity decreased, yet the proposed algorithm still has a better connectivity if compared to the random alternative, as reported in Table2. For the third test, a cluster head that had nodes in its cluster was moved. The result reported in Table2 shows that although the network connectivity decreased, the proposed algorithm still provides better connectivity.In order to have an accurate estimation of the effects of mobility on the network connectivity, another test was performed in which a simple node was moved to two different distances from the initial position respectively in two separate tests and the network connectivity was reported for both algorithms.The result presented in Table 6 for this test indicates that the network connectivity of the proposed algorithm is better and higher than the random one. After several times establishing the network, first based on the proposed algorithm and then based on the random algorithm (same situation) it was observed that the proposed method always chooses the same cluster heads and forms the same clusters, while the random variation acts differently each time. The most important result is that, the proposed algorithm provides a more reliable and stable network, while for the random algorithm, one node was always about to loose connectivity (blinking in the developed testbed) and once the network lost oe node. As the results showed, the proposed algorithm forms a more reliable network providing less fluctuation. As a comparison for different scenarios that had been deployed, the average of the network connectivity was calculated.

Table 1. Node movement effect on connectivity

| Proposed algorithm | | Random algorithm | |
|---|---|---|---|
| *Connectivity before node movement* | *Connectivity after node movement* | *Connectivity before node movement* | *Connectivity after node movement* |
| 0.32586 | 0.321 | 0.27132 | 0.25794 |
| 0.32802 | 0.32256 | 0.27186 | 0.25758 |
| 0.32838 | 0.3198 | 0.2718 | 0.25722 |
| 0.32934 | 0.3216 | 0.27168 | 0.2544 |
| 0.3294 | 0.32076 | 0.2718 | 0.25464 |

Table 2.Emptyclusterheadmovment effect on connectivity

| Proposed algorithm | | Random algorithm | |
|---|---|---|---|
| *Connectivity before node movement* | *Connectivity after empty cluster head movement* | *Connectivity before node movement* | *Connectivity after empty CH movement* |
| 0.32586 | 0.30006 | 0.27132 | 0.23568 |
| 0.32802 | 0.30276 | 0.27186 | 0.23862 |
| 0.32838 | 0.30114 | 0.2718 | 0.23898 |
| 0.32934 | 0.30042 | 0.27168 | 0.23706 |
| 0.3294 | 0.30084 | 0.2718 | 0.23736 |

The first advantage of the approach is that it prevents a single node to loose its energy due to the fact that it is monitoring the whole network. Instead, energy consumption is distributed among all the nodes. The second advantage is that since the network is established based on the proposed metric, it stays connected longer and presents to be more reliable during its lifetime. In addition, the network can reconfigure itself only when the worst case happens, which is either when the connectivity decreases and it is reported less than the predefined threshold or when the number of cluster heads is less than the predefined threshold. This way, unnecessary rearrangement of the nodes is prevented. Therefore, the network is able to save energy due to optimization of the communication used to keep connectivity.

## H. CONCLUSION AND FUTURE WORK

This paper proposed a method to support connectivity measurement in mobile WSN. The proposed approach can be used for MANETs in general, but as the focus of this research group is on WSN, the aspect related to energy consumption was incorporated in the design of the solution, which may not be so important for other types of MANETs as it is for WSN.
The proposed solution basically is composed by a hierarchical arrangement of the nodes in a clustered preferred topology and by use of a link metric to assist the organization and to measure the network connectivity. The used clustered hierarchical topology makes it possible to divide energy consumption among all the nodes in the network while it allows the network to reconfigure itself to prevent threats such as isolated nodes and then decreasing the overall connectivity. In addition, this topology reduces the unnecessary communication as the nodes are grouped into levels and clusters that restrict the communication. The topology may arrange the nodes in different levels and connect them based on a predefined condition, which is calculated by a proposed link.
This proposal provides a balanced energy consumption among nodes, which prolongs the network lifetime, and as presented by the achieved results, the network connectivity is improved.
Future works are considered in the improvement of the link metric formula, by a best selection of the weights for each considered factor. Besides, further studies are being carried out in order to consider additional factors in this formula, so that a more accurate measurement can be achieved.

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