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# Stable Network Formation by Efficient Clustering of Mobile Nodes in Wireless Sensor Network

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***Abstract*—The Wireless sensor nodes are small electronic devices capable to do certain duties like sensing, processing and communicating data. They are usually deployed in severe environments for the applications such as disaster management, combat field survey, security surveillance, etc. Energy constraint is one of the most significant challenges in Wireless Sensor Networks. Sensors are battery powered devices and the replacement of the batteries can be expensive and difficult and sometimes impossible in some cases. Node mobility is the chief cause of drainage of energy, the disconnection between nodes and thus the instability of the whole network.**

**Thus, it is necessary to design protocols to make the efficient use of available energy in the nodes and to acquire complete operability. This problem can be solved to some extent by clustering of the sensor nodes. This paper proposes an approach which takes the mobility of the node and the link strength into account in order to form clusters and also uses fuzzy logic rules to establish cost efficient routing path from source to destination for data transmission. This approach is then compared with previous clustering algorithms for mobile nodes and performance evaluation is presented.**

***Index Terms*— Wireless Sensor Networks, Clustering, Mobility, Fuzzy Logic.**

## I. INTRODUCTION

### *A. Wireless Sensor Networks*

Wireless sensor networks (WSNs) have recently got importance because of its ability to revolutionize many aspects of our day to day life from environmental monitoring to the healthcare industry, manufacturing, etc. Sensors are often deployed in abnormal environments, such as rainforests, mountains or construction sites, for monitoring or detecting particular events. Sensor nodes, to a great extent depend on the power source for energy, which gets exhausted very quickly because of the unsupervised operations and communication they need to accomplish with different device nodes. Today, the most important challenge to be tackled is the energy source constraints of Wireless Sensor Networks.

Sensors are used to sense information from the events taking place around it and collect relevant data from those events. Transmitting this data requires power from the limited battery storage with the nodes. Thus, the main task is to minimize the energy consumption to extend the lifetime of the sensor nodes. There are few schemes that can be implemented to save energy and have a larger lifetime for the sensor networks [1]. These schemes may involve programming the state of the nodes to switch between transmitting, receiving, idle or

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sleep mode [12]; using an appropriate clustering algorithm to form a network; applying optimal routing methods [2].

Using appropriate clustering algorithm can also contribute in curtailing the consumption of energy because clustering algorithms are found to be more energy efficient than direct routing algorithm [9,10]. In this, sensor nodes are bunched together to form small clusters and a cluster head (CH) is selected for each cluster. In this architecture, each cluster head receives data from a set of sensor nodes and CH aggregates data and forwards them to a base station. Sensor nodes in clusters transmit messages over a limited range of distance within own clusters therefore a small amount of energy is drained from sensor nodes in clusters but in case of CHs, more energy is exhausted because a message has to be transmitted over a larger distance i.e. CHs to the base station [1]. In recent years, a new branch of wireless sensor networks has come into limelight called Mobile Wireless Sensor Networks (MWSNs) [11]. They have all the features of WSN with an additional feature of mobility. The mobility of sensor nodes posed some new challenges particularly in energy expenditure and this required cosideration by the researchers for the solutions.

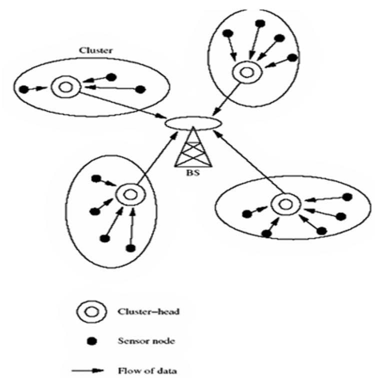


Figure 1. Basic architecture of clustered wireless sensor network (Source: Google)

### B. *Mobile Wireless Sensor Networks*

Mobile wireless sensor networks (MWSNs) have a vital role in real world applications where the sensor nodes are mobile. MWSNs are more multipurpose than static WSNs as the sensor nodes can be installed in challenging circumstances and survive the continuous changes in network topology. Mobile sensor nodes are embedded with a microcontroller, several sensors (i.e., light, temperature, humidity, pressure, mobility, etc.), a radio transceiver, which is powered by a battery. The major applications of MWSNs are economics, environmental monitoring, mining, meteorology, seismic monitoring, energy control systems, health care applications, process monitoring, urban terrain tracking, transportation and logistics, undersea navigation, smart grids, animal tracking and tactical military surveillance. The main hardware restrictions are limited battery power and low-cost requirements. i.e., the mobile sensor nodes should use energy resourcefully, low level of complexity of algorithms is required for microcontrollers and it is expected to use only simplex radio. Varying topology and shared medium constitute major environmental constraints.

## II. RELATED WORK

Clustering can be used to fulfill different purposes. Many times the clustering objective is fixed in order to meet the specific requirements of the applications [3]. Clustering can be employed to address different objectives along with dealing the energy constraints.

WSNs are often deployed in tough environmental conditions as per the application. The sensor nodes are exposed to risky situations where they may malfunction or may endure from energy depletion, malicious attacks, transmission errors and so on [7]. To deal with such failures, re-clustering is the most intuitive way which helps in tolerating the faults to avoid the loss of important sensor data. However, re-clustering is often very disruptive to the operation in process [3] [7]. An untimely exhaustion of the energy of CHs can be prevented by constructing equal-sized clusters. This helps in prolonging the lifetime of the network [7]. To carry out the expected duties, the CHs are expected to balance the load among themselves. Even distribution of sensors can influence the delay that may occur in the transfer of data [3][9]. Thus, even distribution of sensor among the cluster is generally the aim of the setup where CHs execute the intra-cluster duties. Clustering helps in reducing the size of the routing table stored at the individual sensor nodes which makes it

simpler to govern the network and is more scalable to react to the incidents in the surrounding.
Researchers have used different methods for the purpose of CH election. Surveyed works on cluster head election algorithms and clustering algorithms have been done under research studies on clustering in WSN [3, 9]. The Mobile Adaptive Clustering Algorithm is one of the approaches introduced by the researchers. The MACA [4] is capable to generate steady and balanced clusters and increase the efficiency, stability and prolongs the life of the wireless sensor network with mobile nodes. This algorithm is divided into two phases viz. the set-up phase and the steady-state phase. The set-up phase comprises the organization of the group of clusters and creating a TDMA schedule for the time slots of when it can transmit. Whereas the steady-state phase is that stage when the data is being delivered to the base station.
The Clustering Approach using Node Mobility [5] takes into consideration the mobility level ML which is a measure of node's mobility. Clustering using this approach needs two levels of selection to determine the efficiency of a node to become a cluster head. Node mobility and the link quality indicator i.e. RSSI is used in the algorithm as the initial step to determine the appropriate nodes and the most steady nodes are selected as cluster heads. The objective of this clustering algorithm, is to have stable clusters in WSNs, where the node mobility determines the quantitative stableness of the network.
For mobile wireless sensor networks, LEACH-Mobile protocol is introduced which is an improved version of LEACH [8]. The aim of the protocol is to make sure that the specific cluster head receives the data from the mobile sensor node. The clusters are given a TDMA schedule where a time slot is allocated for sensor node to send a transmit message which requests for the cluster head to send data back to the node. -All the sensor nodes i.e. cluster head and non-cluster head nodes receive transmission messages so as to organize the cluster again with lesser energy consumption.
In some applications like search-and-rescue operations or military operations, intra and inter-group communication are required as the nodes are moving in groups. Thus, in these situations, it is required to simulate the cooperation and coordination using the group mobility models efficiently. In response to these challenges, Group Mobility Adaptive Clustering scheme is proposed in [6] for MWSN. It provides an efficient method to build clusters with the nodes moving in groups ensuring maximum stability of the clusters. In this scheme, to select the fixed number of clusters, the area considered is divided into different zones according to the geometrical patterns given by the information of localization. A sensor node becomes the cluster head of its zone depending on the attributes it has. A mobility metric "MobilityGroup" defined by the scheme measures the weight of each sensor and the residual energy.

## III. Proposed Approach

The algorithm has three sections that involves the use of mobility of nodes and signal strength of the links and fuzzy logic to establish optimized path for communication [13,14]. Depending on the mobility of nodes, the nodes with or less than certain threshold value are promoted for further step. Then signal strength is checked to determine the suitability of node and then, a combination of some particular attributes is used to calculate and filter the most stable nodes for participation for election of cluster heads. The objective of the approach is to form stable cluster with balanced load for all clusters.

### *A. Section I*

As the energy is the resource that we are concerned to conserve in the wireless sensor networks, the lifetime of the wireless sensor networks increase by curtailing the energy consumption. Mobility is one of the major causes of the over consumption of energy. Thus, we choose such nodes that have low mobility which restricts the usage of energy and therefore improves the overall network lifetime. First, we determine the node's mobility denoted $M_v$ by using the distance formula below:

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

The equation measures the node's mobility till current time T. $(x_t;y_t)$ and $(x_{t-1}; y_{t-1})$ are the coordinates of node v at time t and (t-1) respectively. Therefore, we can define a mobility for sensors. The nodes with more or equal mobility $M_v$ are considered to be malicious. This type of nodes are prohibited from participating for election of CH. Some assurance is presented by the nodes with a weak mobility speed and are forwarded to the second section of the approach. The figure 1 shows the flow diagram of first section of the approach.

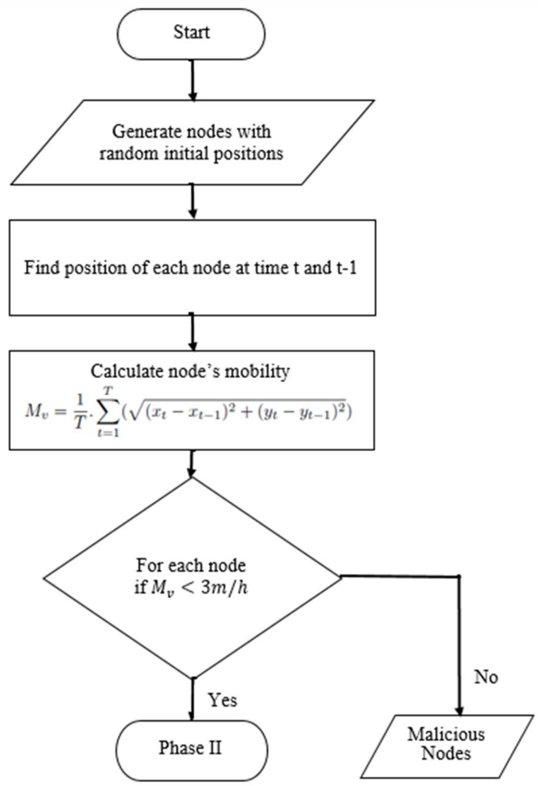


Figure 2. Flow Diagram of Section I

*B. Section II*

At this level, we take into consideration only the nodes with mobility lower than the value previously defined. The process of this selection is represented by the flow diagram in figure 2. In order to discover the neighbors, each node broadcasts a hello message. Then every node is supposed to compute its connectivity with neighboring nodes, residual energy and distance between the nodes in its vicinity. Now, for CH election purpose, each node calculates its weight using the method as per [5].

$$weight_v = a_1.\overline{N} + a_2.E_{resid.} + a_3.Dist._v \qquad (2)$$

Here, the average of the cluster size is given by $\overline{N}$ which is calculated as following:

$$\overline{N} = \frac{N_{CH}+N_{SM}}{N_{CH}} \qquad (3)$$

Where $N_{CH}$ and $N_{SM}$ are the number of the cluster head and sensor member respectively.
After the calculation of weights by all the nodes, the highest weight node becomes the cluster head. The CHs again broadcast hello message to the sensor nodes and the neighboring nodes join the cluster. Malicious nodes having mobility greater than the threshold value also receive the message from CHs and thus they also join the cluster depending on the weight.

*C. Section III*

After the CH election and cluster formation, we introduce the data transmission phase in which along with the shortest path, we check the node cost for load balancing and enhance the lifetime of the network further. This can be done by using the fuzzy logic rules. In wireless sensor networks efficient energy utilization for communication is very important as they operate on limited source of battery. Route selection greatly affects the network lifetime which constitutes the main feature of wireless networks. Uneven consumption of energy

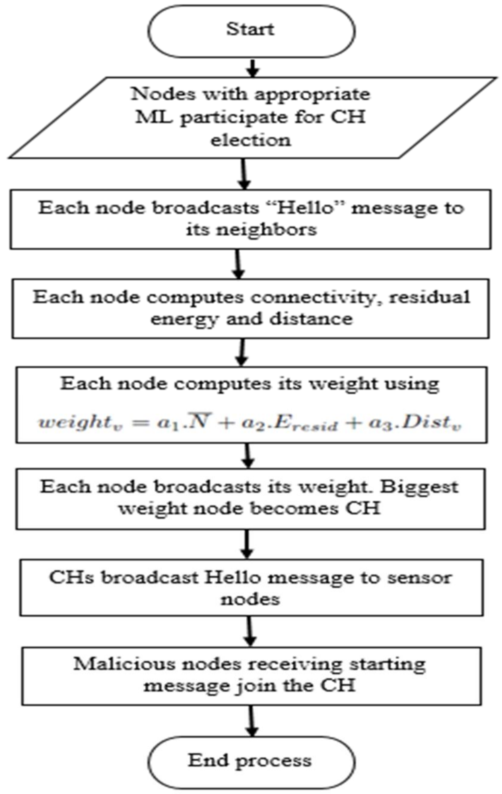


Figure 3. Flow Diagram of Section II

is an integral challenge in WSN and to efficiently send the data through the transmission path from source to destination and to increase the lifetime of network fuzzy approach as proposed in [13] is implemented. Optimal routing path is selected from the source node to the sink node by choosing the highest remaining energy, minimum number of hops and traffic with lowest load.

## IV. Simulation and Results

Here we have evaluated the performance of the proposed method using NS2. We have simulated about 50-120 nodes in an area of 100m x100m. We have compared the performance between the proposed approach and the weighted clustering algorithm and clustering approach with node mobility. The comparison of energy consumption and network lifetime for each approach is shown in the figure. It can be understood the proposed approach outperforms the other two methods.

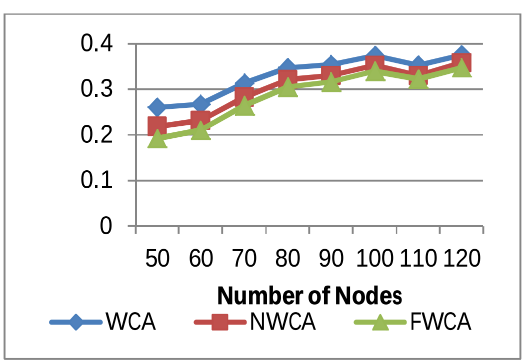


Figure 4. Comparison of Energy Consumption

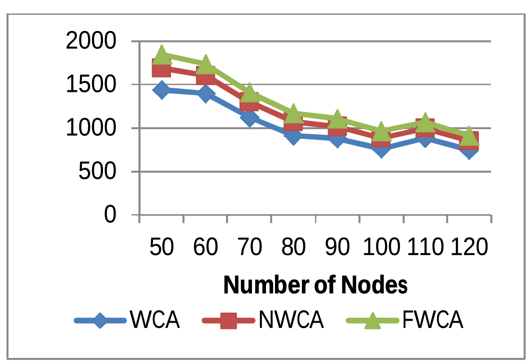


Figure 5. Comparison of Network Lifetime

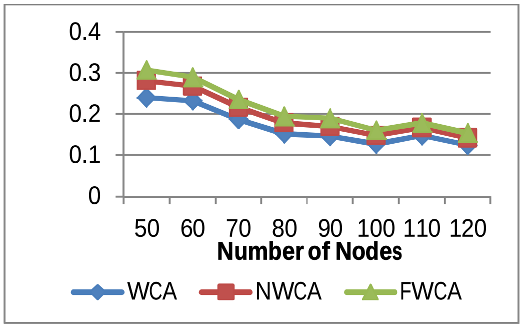


Figure 6. Comparison of residual Energy

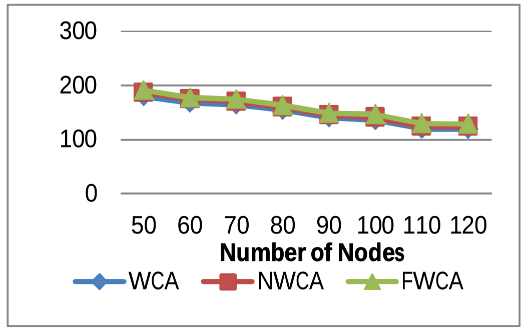


Figure 7. Comparison of Throughput

Also the transmission range of the nodes in network is varied and the performance is evaluated for proposed approach and following results are obtained for energy consumption, throughput and network lifetime.

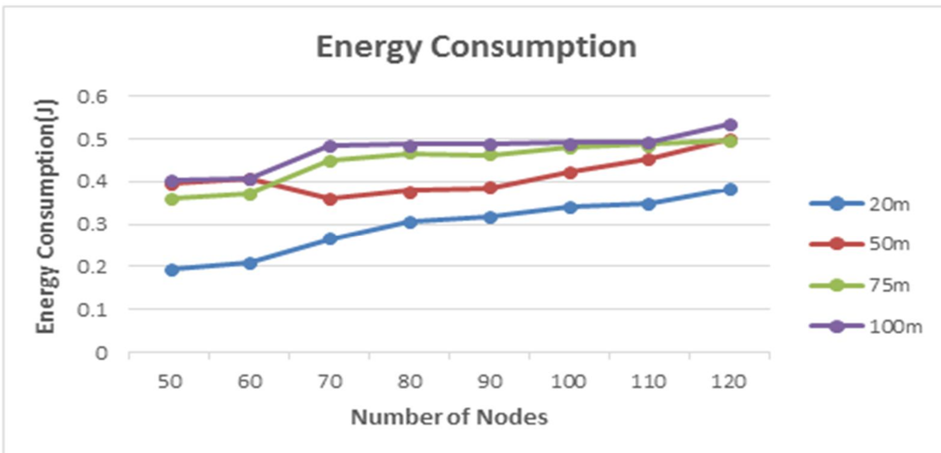


Figure 8. Energy Consumption

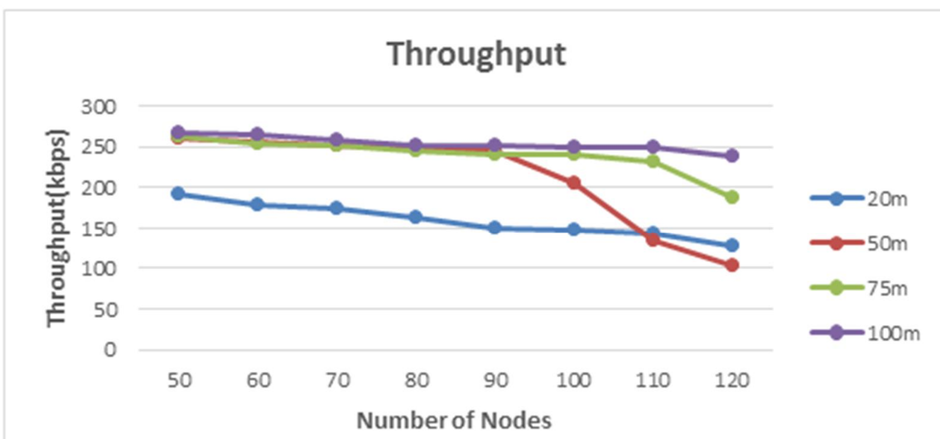


Figure 9. Throughput

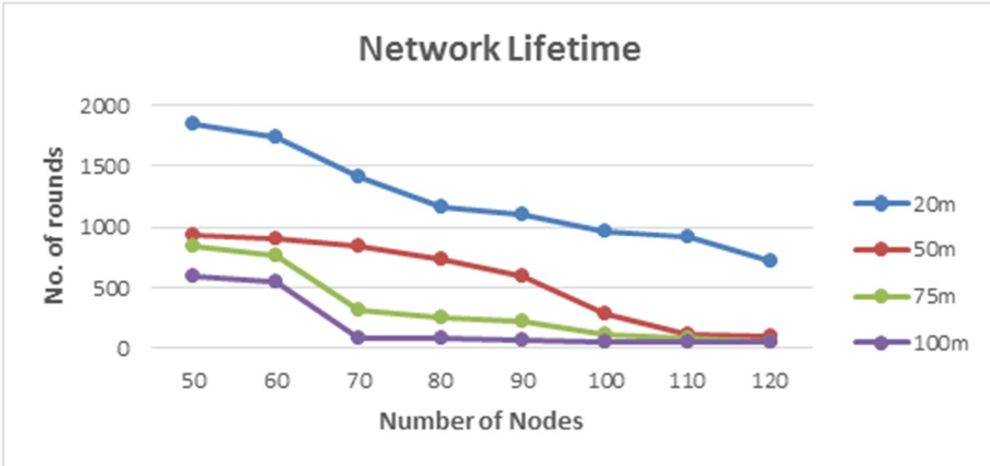


Figure 10. Network Lifetime

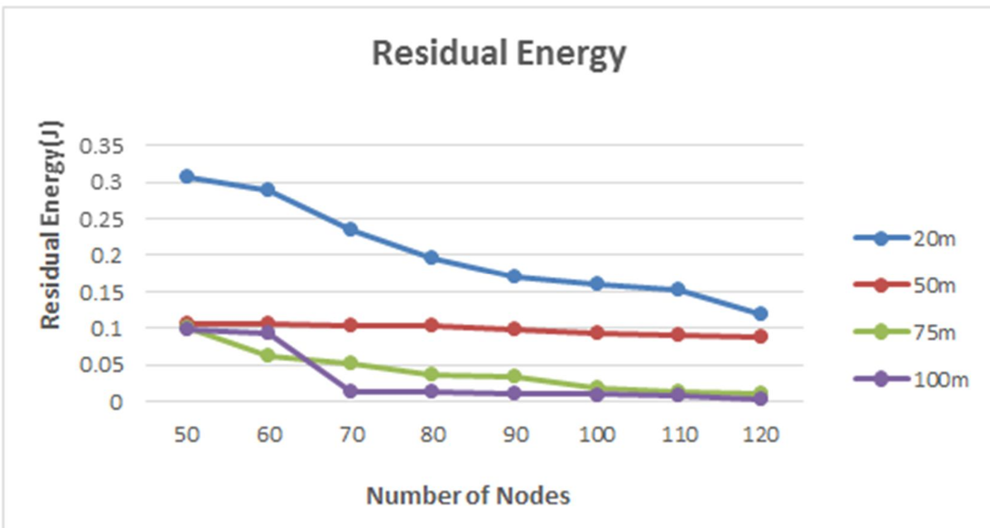


Figure 11. Residual Energy

The above figures shows the results for various performance metrics when the transmission range is set at 20m, 50m, 75m and 100m for the network.

## V. Conclusion

The attributes of WSNs and the characteristics of the environment within which sensor nodes are typically deployed make it very challenging to sustain longer. Along with the adverse environmental conditions, mobility of nodes also add to the challenges to manage the network and to have longer connectivity. The proposed approach proved effective in limiting the sensor nodes with low mobility to participate for CH election and using fuzzy logic rules for optimal routing causing energy to be spent efficiently and thus extending the network lifespan considerably.

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