MOBILITY ASSISTED DYNAMIC ROUTING FOR MOBILE WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless Sensor Networks (WSNs) is one of the most rapidly growing research domain. This is because of the development of sensor nodes with extremely low cost and the applications of such sensor nodes are ever growing. WSNs are group of sensor nodes with a set of processors and limited memory unit. Reliable routing of packets from sensor nodes to its base station is the most important task for these networks. Also mobility of the nodes is considered to be one major criterion for WSNs. In this paper, a dynamic routing algorithm called the Mobility Assisted Dynamic Routing (MADR) algorithm has been proposed for the mobile wireless sensor networking system, where both the base station and the sensor nodes are in moving condition. The cluster head selection is based on three parameters: the energy efficiency of the sensor nodes, the mobility of the sensor nodes and the accessibility to the neighboring sensor nodes. The concept of cluster head panel is applied additionally to minimize the re-clustering time. The proposed algorithm is compared with an existing algorithm Low Energy Adaptive Clustering Hierarchy (LEACH). The simulation results show an excellent prolongation in overall network lifetime.

KEYWORDS

Mobile wireless sensor networks, Routing Algorithm, Dynamic routing, Mobility, Network lifetime.

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I. INTRODUCTION

In a Wireless Sensor Network (WSN) [1, 2] there are sensors which are mainly used to sense different physical parameters in a particular location or in between people in an area or in a war field. In these WSNs there are thousands of sensor nodes which sense the parameters and send it to the Base Station (BS). Initially the sensors are scattered in a particular area and they group into clusters between themselves [3 - 5]. After forming clusters, in each cluster one Cluster Head (CH) and two Deputy Cluster Heads (DCH) will be assigned. There are three constraints to be considered for a node to be selected as a CH. The energy efficiency of the sensor node [6], the mobility of the sensor node and the accessibility to the neighboring sensor nodes. The major role of this CH is to collect the sensed data from all the sensor nodes, aggregate it and send them to the BS continuously. The other sensor nodes will be sensing different parameters and sends it to the CH in their respective clusters. In Mobile Wireless Sensor Network (MWSN) the BS and the sensing nodes are considered to be in be in moving condition, thereby routing in these networks introduce a challenging research problem. Existing routing protocols [7 - 9] do not consider the mobility of the sensor nodes as well as the BS, therefore these are not directly applicable to a MWSN. In case of MWSNs, the sensor nodes start sensing the physical parameters only when the BS comes in contact with their respective CH range.

When the BS comes within the range of CH of the first cluster, the sensor nodes in that particular cluster starts sensing the parameters and sends the fused data to the CH which in turn forwards it to the BS. The BS sends an acknowledgement to the CH and the sensor nodes after receiving the data from the CH. The role of the deputy cluster head (DCH) is to keep monitoring whether the CH is sending the data to the BS continuously. If the CH loses the range of the BS, the DCH which has the range of the BS will be converted to the CH and the CH which lost the range will be converted into a DCH. If this new CH also goes out of the range of BS, then this CH will send the data to the CH of the nearest cluster, which collects the data from both the clusters and forwards it to the BS. If this too would lose the range, then it sends the two clusters' data to the CH of the nearest cluster, which would send all the collected data to the BS. Time division multiplexing is enabled during this situation. Specific time is allotted for

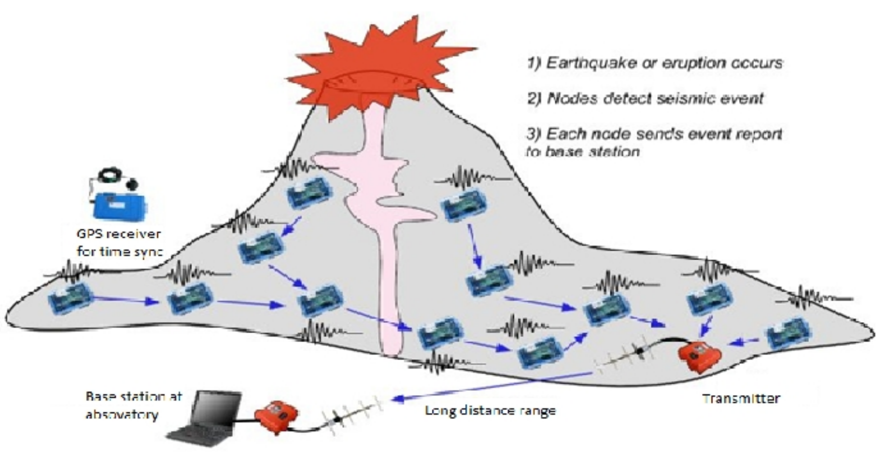

Figure 1. Application of wireless sensor network in earthquake monitoring

each cluster: the first cluster is allowed to transmit initially, followed by the data from the next cluster and so on. Figure 1 pictures one of the common applications of WSN in earthquake monitoring, for sensing the data and transmitting it to the BS which is located far away from the earthquake prone area. In this paper a new routing algorithm for MWSN has been proposed. The concept of the CH panel is used to minimize the re-clustering time. Hence the life time of the sensor nodes are found to be prolonged. The rest of the paper is organized as follows. Section I gives a brief introduction about MWSN, their advantages and few ideas about the proposed algorithm. Section II describes the related work focused towards routing. Section III portrays the system model followed by the problem statement. Section IV explains the proposed routing algorithm and its mechanism of cluster organization. Section V shows the stimulation results and the comparison with an existing algorithm. The last section concludes the paper with some directions towards future enhancement of this work.

II. RELATED WORK

In the literature, several energy aware algorithms [16-19] have been proposed for WSN. There are also several routing algorithms proposed for WSN which focus on reliable data delivery [20-27]. However they are designed mainly focusing on network with static sensor nodes and static BS. Also there are several results reported with a focus on hardware related energy efficiency aspects of wireless communications systems (for example: low-power electronics, power-off modes, energy efficient modulation, etc). Most of these existing routing algorithms do not consider mobility of sensor nodes and BS. DSR, AODV, DSDV and TORA [8, 11] are some representative routing algorithms for mobile ad-hoc networks but are not feasible for WSN. RAPS, SPEED and MMSPEED [9, 10] are some routing algorithms designed for WSN which can meet timely delivery and/or reliable delivery of data packets. LEACH, TEEN, APTEEN, PEGASIS and HEED [10, 12] are some best examples of energy efficient and hierarchical routing algorithms for WSN. HIMALAYA is a hierarchical energy efficient routing algorithm for WSN which considers the BS mobility but not that of sensor nodes. Beam Star, EECS, EAP, SONS, DAST and ERAPL [17, 19] are some recent works focused towards the direction of dynamic routing.

Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH [13] is a clustering mechanism that distributes energy consumption all along its network, the network being divided into clusters, CHs which are purely distributed in manner and the randomly selected CHs collect the information from the nodes which are coming under its cluster. It forms clusters based on the received signal strength (RSS) and uses the CH nodes as routers to the BS. All the data processing such as data fusion and aggregation are local to the cluster. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. Initially a node decides to be a CH with a particular probability and broadcasts its decision. Each non-CH node determines its cluster by choosing the CH that can be reached using the least communication energy. The role of being a CH is rotated periodically among the nodes of the cluster in order to balance the load. The rotation is performed by getting each node to choose a random number between 0 and 1.When this node dies, the whole cluster becomes dysfunctional. Also, the CH is assumed to have a long communication range so that the data can reach the BS from the CH directly. This is not always a realistic assumption since the CHs are regular sensors and the BS is often not directly reachable to all nodes due to signal propagation problems. This algorithm also forms one-hop intra-cluster and inter-cluster topology, where each node can transmit directly to the CH and thereafter to the BS which in turn becoming not applicable to large scale networks. The main drawback of LEACH is that, it uses single-hop routing where each node can transmit directly to the CH. Therefore, it is not feasible for networks deployed in large regions [14].

III. SYSTEM MODEL AND PROBLEM STATEMENT

System Model

The sensor nodes are all similar in hardware, software and capabilities. Initially all the sensor nodes have equal amount of energy but after some time of operation nodes may be left with unequal energy levels. The sensor nodes as well the BS are moderately mobile. The BS is highly reliable and resourceful. After deployment of the sensor nodes in the field, the field is logically partitioned into some clusters. The BS forms these clusters and each cluster contains one CH and two supporting deputy cluster head nodes *(DCH)* (also called cluster management node). Communication takes place in hierarchical fashion (Sensor node $\rightarrow$CH$\rightarrow$BS). Again communication between CH and BS may be multi-hop depending on the situation. The selection of nodes for various roles such as CH or DCH is carried out and processed at the BS.

Problem Statement

The major goal of this work is to design and develop a reliable routing algorithm for a mobile wireless sensor network that operates in an unattended and sometimes hostile environment. As the sensor nodes are resource constrained (specially limited energy and limited onboard storage) the routing algorithm should consume low power and should not burden the nodes with storage overhead. The algorithm should ensure that connectivity is maintained in the network and in presence of link or node failure it should be capable of offering all alternate routes without allowing much degradation in the throughput level at the BS. Most importantly the life time of the network should be prolonged.

IV. PROPOSED ALGORITHM

In this section a reliable routing algorithm for mobile wireless sensor network has been proposed, where both the sensor nodes as well as the BS are mobile. The proposed routing algorithm, Mobility Assisted Dynamic Routing (MADR) is primarily focused towards the improvement in life time of the sensor nodes in the network. In the existing algorithms, the sensor nodes keep on sensing the data and send the data to its respective CH which in turn sends the fused data only when the BS comes in range with the CH. In the proposed algorithm, the sensor nodes start sensing the data only when the BS comes in range with the CH. This algorithm manages the energy efficiency as well as the reliability of the routes. The data packets are routed through multiple hops in order to minimize the transmission energy requirements at the sender node level. This saves large amount of energy and extends the battery life of the sensor nodes. After the deployment of sensor nodes, the BS groups different sensor nodes into clusters. Each cluster contains a cluster head (CH) node and two deputy cluster head (DCH) nodes. There are three criterions based on which the CH gets selected: the energy efficiency of the sensor node, the mobility of the sensor node and the accessibility to the neighboring sensor nodes. This cluster set with one CH and two DCH is also called as cluster head panel. The sensor nodes send the data to their respective CHs. In CH, the data aggregation is carried out to eliminate the data redundancy which further sends the aggregated data to the BS. The DCH nodes do several cluster management tasks such mobility monitoring and also remain ready to act as an intermediate hop in presence of fault. The DCH nodes are also called as Cluster Management Nodes.

If the BS observes less arrival of data packets than a threshold then it informs the respective CH to check the connectivity with its cluster members. The CH considers this as feedback from the BS and accordingly checks the current connectivity with its cluster members. If the connectivity status of the cluster members with the CH is very poor the BS decides to shift the charge of cluster headship to another suitable member from the CH panel already determined or to one of the DCH depending on the situation. If this new CH also goes out of the range of the BS then the sensed data from the sensor nodes will be sent to the CH of the nearest cluster, which in turn forwards the data to the BS along with its own data. If this CH also goes out of the range of BS then the data from the first CH and its own data will be sent to the next nearest CH. At this situation this CH has to send the three CH's data, which is accomplished by the usage of time division multiplexing scheme. The flow chart of the proposed MADR algorithm is clearly given in figure 2 and the discussions about the functionalities of various phases are given below.

Self Organization Phase

After the deployment of the sensor nodes the first phase is the self organization phase. During this phase the clusters are formed and cluster head set, current cluster head, deputy cluster head are selected by the BS. Initially the BS collects the current location information from each sensor nodes and then forms a sensor field map. Based on the velocity of a sensor node the BS prepares a rough estimate of the zone in which the sensor node is going to be in the next time interval. The value of the next time interval can be set manually depending on the type of application and this value is critical as most of the computations (cluster setup validity period and medium access slot) are dependent on the next time interval. Using this information the BS computes the topology. Once the BS creates the sensor field map it forms the clusters.

The cluster formation approach is simple. The basic idea is to maintain geographically uniformly distributed clusters so that coverage is uniform and also the CHs are uniformly distributed over the entire sensor field. Therefore the entire sensor field is geographically uniformly divided into 'n' clusters where 'n' is approximately 5% of the total number of nodes deployed in the sensor field. After formation of the clusters the BS identifies a set of suitable nodes (cluster head panel from within each cluster which can take role of cluster head node and deputy cluster head node).

This selection is based on cumulative credit points earned from the three parameters namely residual energy level of the node, degree of the node (number of neighbors) and mobility level of the node (high, moderate or low). The designer can use a suitable normalization function to compute cumulative credit points earned by a node through these three non-homogeneous parameters. An ideal node suitable for CH role should have higher residual energy, higher degree and low mobility. The BS prepares the cluster head panel consisting of nodes having a cumulative credit point above a threshold value. Again, this threshold value can be set manually at the time of implementation and also depending on the application and the normalization function. The node with highest credit point is selected as the current CH. The next two nodes in the list with second and third highest credit point respectively are selected as DCHs for the same cluster.

Role of cluster head (CH) node

The CH is responsible for collecting the data from each sensor nodes. After collecting the data, CH will do data aggregation on the collected data for eliminating data redundancy. This data will be forwarded to the BS either directly or through a multi-hop fashion according to the communication pattern distributed by the BS.

Role of deputy cluster head (DCH) node

The DCH keeps monitoring the sensors nodes in their cluster and keeps on checking the mobility pattern of the sensor node. They are also known as the cluster management nodes, as they take a major responsibility of collecting current location information from the cluster members and communicating it to the BS. Moreover in the event of the immediate link or node failure in the route from the CH towards the BS, the CH might seek aid of one of the DCH nodes to forward the data to the BS.

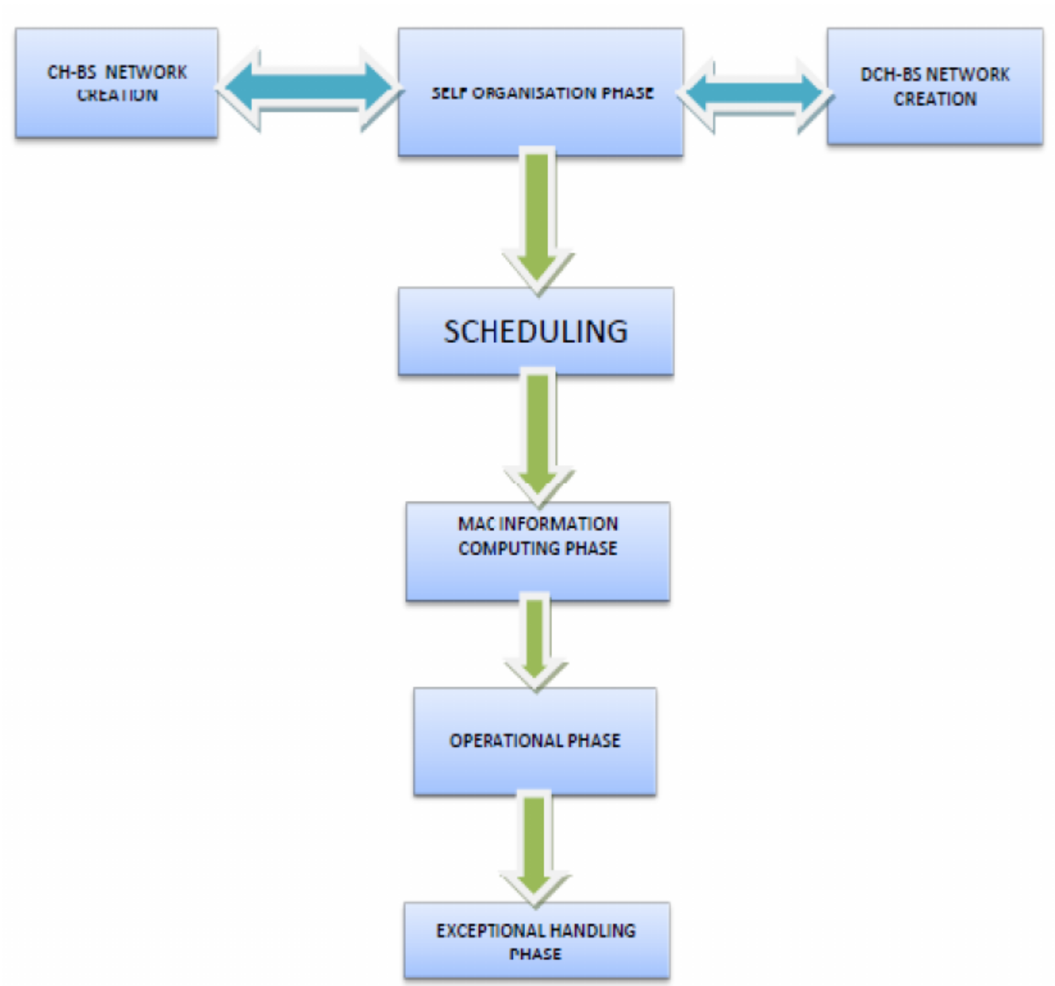

Figure 2. Flow chart of the proposed MADR algorithm

Use of Cluster Head Panel

The cluster head panel is selected initially and remains valid till the end of the cycle length or till re-clustering is initiated. If the current CH loses connectivity with most of its cluster members due to which throughput at the BS degrades and the CH may be asked to relinquish the charge of cluster headship. Even a CH node may drain out its energy beyond a threshold and becomes useless and in this situation, a new CH is necessary. Under such circumstances, the BS may give the charge of headship either to one of the two DCHs or to a node from within the cluster head panel. This saves huge amount of cost required for communication and the time involved in the process of selecting the CH.

V. SIMULATION RESULTS AND ANALYSIS

The effectiveness of the proposed routing approach is validated through simulation experiments using network simulator (NS-2). The results of the proposed MADR algorithm is compared with an existing algorithm LEACH based on some metrics such as average communication energy, life time and throughput.

A. Simulation Setting

In the experiment a sensor network of 50 nodes are considered to be randomly deployed over a field of dimension (210×210) meter square area. The BS is located at the left side of the sensor field. The radio transmission range of the sensor nodes is 50 meters. The sensor nodes move in random direction with a random value of speed in the range of (1-4) meter per second. In the simulation, the location of each of the nodes after a regular interval of 120 seconds has been compared. The simulation has been run for a period of 1800 seconds. All nodes are assumed to have equal amount of initial energy. The initial energy in each sensor node is considered to be 10 J. The sensor nodes are considered to be constant bit rate source. The nodes generate report only at a single rate such as one report per second or two reports per second. The packet drop probability is assumed to be in the range of (0.0- 0.2) at each intermediate hop. The throughput is measured after every 300 seconds and finally the average throughput is computed after 1800 seconds of simulation.

Parameter	**Values**
Cluster topology	210 x 210 m^2
Packet size	64 bytes
Packet rate	1packet/s
Number of nodes	50
Transmission range	50m
Sensing range	15m
Cluster range	30m
Routing protocol	AODV
Antenna model	Omni Antenna

Table 1. Simulation parameter setup

B. Performance Metric

The following metrics have been used to understand the performance of the proposed routing approach (MADR) and to compare its performance with the existing LEACH algorithm.

1) Average Communication Energy: It is average of total energy spent due to communication in the network over a particular time period and also with respect to a specific data rate.
2) Life Time*:* It is time taken since the start of the network (during the simulation) for first node to die. An algorithm with larger life time is desirable.
3) Throughput: It is the measure of the total packets that are efficiently delivered at the output of the wireless sensor networking system. An algorithm with high level of throughput is desirable.

C. Experimental Results

The proposed routing MADR algorithm is compared with LEACH and the comparison graphs have been drawn, the results are analyzed. The performance of the proposed MADR algorithm is compared with LEACH in terms of average communication energy, life time and node death rate. Figure 3 shows the comparison between the average communication energy and time for the two algorithms. It could be clearly seen that the performance of the proposed MADR algorithm reduces in terms of energy efficiency. This is because LEACH has a fixed architecture, with sensor nodes and BS is considered to be static. In case of MADR algorithm, the sensor nodes and the BS are considered to be mobile which consumes higher energy.

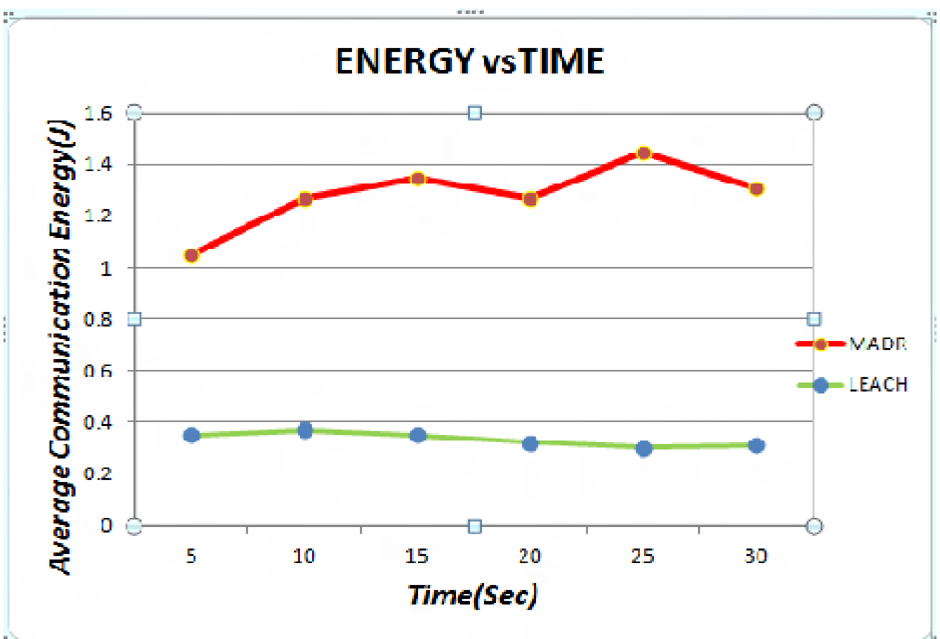

Figure 3. Average Communication Energy versus Time (LEACH and MADR)

The comparison graph between Life Time and Data Rate is clearly described in figure 4. The life time of the proposed MADR algorithm improves twice when compared with LEACH. This is because of the distinctive features employed in MADR algorithm (the way in which the CH gets selected: the energy efficiency of the sensor node, the mobility of the sensor node and the accessibility to the neighboring sensor nodes).

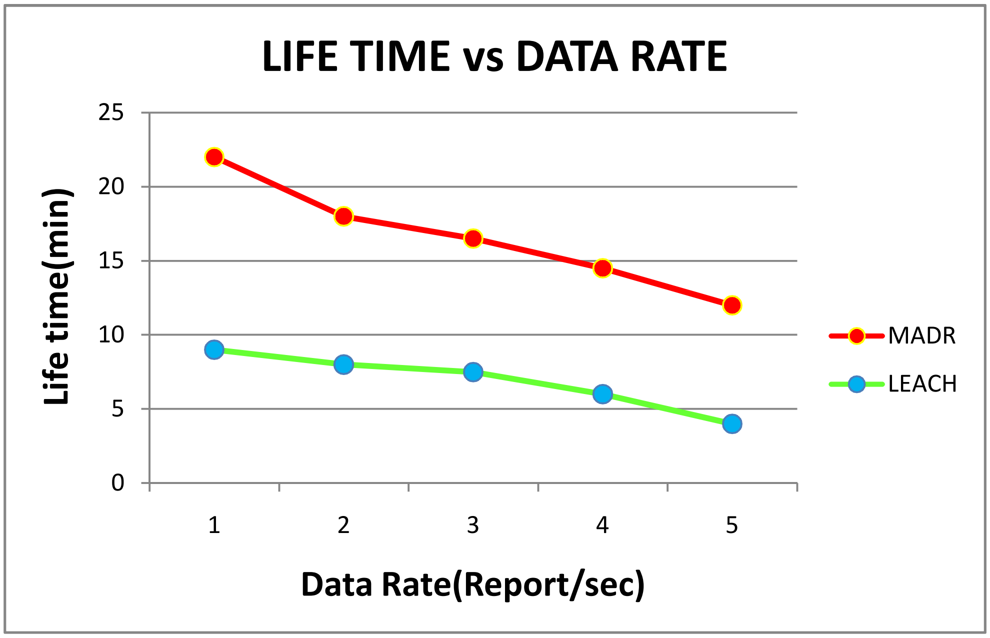

Figure 4. Life Time versus Data Rate (LEACH and MADR)

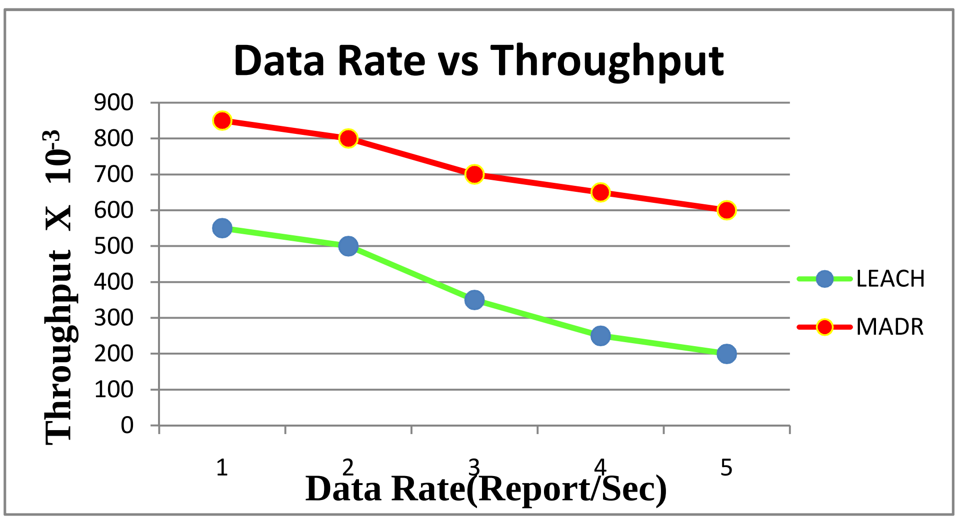

Figure 5. Throughput versus Data Rate (LEACH and MADR)

The comparison graph between Throughput and Data Rate is clearly described in figure 5. The throughput of the proposed MADR algorithm improves to a much greater extent when compared with the existing LEACH algorithm. This is because MADR algorithm uses the mobility of the sensor node and the accessibility to the neighboring sensor nodes in order to select a CH.

VI. CONCLUSION

In this paper Mobility Assisted Energy Efficient Routing (MADR) algorithm has been proposed for mobile wireless sensor networks. The proposed MADR algorithm is assumed to have large number of clusters: each cluster have one cluster head and two deputy cluster heads. The cluster head selection is based on three parameters: the energy efficiency of the sensor node, the mobility of the sensor nodes and the accessibility to the neighboring sensor nodes. The concept of cluster head panel is applied additionally which minimizes the re-clustering time. The sensors start collecting the data only when the base station comes in range with the cluster head. The proposed algorithm is compared with an existing algorithm Low Energy Adaptive Clustering Hierarchy (LEACH). MADR is especially useful when the sensor nodes as well as the base station are mobile. The simulation results show an excellent prolongation in overall network lifetime. An excellent improvement in throughput could be seen from the simulations. This work can be extended in future to large-scale mobile wireless sensor networks with high degree of mobility.

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