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EFFECTIVE CLUSTERING MECHANISM WHEN BOTH THE SENSOR NODES AND BASE STATION ARE MOBILE

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ABSTRACT

In this paper, a dynamic clustering algorithm for mobile wireless sensor networks, the MADCA has been proposed. The proposed clustering methodology MADCA is hierarchical, dynamic and energy-efficient algorithm for mobile wireless sensor network. MADCA forms multiple clusters with each cluster having one cluster head and two deputy cluster heads. The sensor nodes start collecting the data only when the base station comes in range with the cluster head. The performance of the proposed algorithm has been evaluated through simulations and the results have been compared with the existing LEACH-M algorithm. MADCA shows drastic reduction in average communication energy when compared to LEACH-M. The network lifetime has been found to be greatly prolonged in MADCA. The node death has been found to be greatly reduced in the proposed algorithm. Thus the proposed clustering methodology has been found to be greatly useful when both the sensor nodes as well as the base station are mobile.

Keywords: LEACH-M, mobile wireless sensor network, mobility, sensor nodes, base station, aggregation, clustering.

1. INTRODUCTION`

Wireless sensor network is gifted for accessing real-world information about the physical environments. Few deployments of wireless static sensor network are done using Berkley smart dust, µ-Adaptive multi-domain power aware sensors and wireless integrated sensor networks. In static wireless sensor network, few parameters like mobility is not considered thereby mobility becomes the next evolutionary criterion to be carefully considered. The dynamic environment of wireless sensor network introduces exclusive confronts like data management, accuracy, coverage, security and software configuration. One of the vital contemplations in wireless sensor nodes is the route maintenance when the node moves. The conservative protocols for static sensor network are to be optimized carefully when mobility is introduced. To learn the performance of these protocols, the mobility patterns and mobility metrics have to be subjectively considered.

In this paper, an enhancement over the LEACH-M protocol has been anticipated, which is appropriate for mobile wireless sensor networks (MWSN).The proposed clustering algorithm, the mobility assisted dynamic clustering algorithm (MADCA) has been well-evaluated to support mobility. This is a hierarchical one, and the concept of cluster head panel has been employed in the proposed algorithm to minimize re-clustering time and energy consumption. By employing these techniques to the proposed algorithm, energy efficiency and life time of the sensor nodes have been found to be greatly prolonged.

This paper has been organized as follows. Section 1 gives a brief introduction about mobile wireless sensor network. Section 2 describes the related works in the domain of mobile wireless sensor network. Section 3 gives a clear idea of the system model with detailed problem statement. Section 4 enumerates the details of the proposed clustering methodology. Section 5 elaborates the simulation results and the comparison of results with the existing LEACH-M algorithm. Finally, section 6 concludes the paper.

2. RELATED WORKS IN MOBILE WIRELESS SENSOR NETWORK

This section briefly outlines the related works in mobile wireless sensor network and LEACH protocol improvements. In general, the mobility of sensor nodes perks up the sensing coverage as worked out by (Liu *et al.* 2005). Few techniques like the Robotic Fleas project in Berkeley, the Robomote and the Parasitic Mobility attempts to facilitate mobility in wireless sensor network as demonstrated by (Laibowitz and Paradiso, 2005). The data mule technique could be used to powerfully gather the data by reducing data delivery latency with bare minimum energy consumption in mobile sensor network (MSN) as formulated by (Anastasi *et al* 2007; Ekici *et al* 2006).

One real world application of MSN is the Adaptive Sampling and Prediction (ASAP) in which a fleet of undersea mobile sensor nodes manages and collects the measurements of ocean without any human intervention. An adaptive navigation system has been devised, in which the sensors equipped on vehicles is capable of collecting the real time traffic information and exchanging them among the neighbouring vehicles as formulated by (Huifang *et al*. 2007). A mobility management service layer in the Sensor-Net Protocol has been implemented, which is a cross layer approach and the mobility information is stored in a database so that it is noticeable across all the layers as illustrated by

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(Ali *et al.* 2006). A novel idea called the network dynamics has been investigated to crack the mobility management issue which is a previous effort to devise the laws that oversee mobility annoyed by classical dynamics as investigated by (Ma *et al*., 2008). Ultimately, the mobility of sensor nodes is of immense significance and there is rising research inclination towards leveraging the sensor node mobility to augment the network performance in terms of energy efficiency, lifetime and fault tolerance.

LEACH is one of the most admired hierarchical clustering protocols for wireless sensor network. LEACH motivated the proposal of several other descendant protocols which attempts to perk up the cluster head selection process as illustrated by (Yang and Sikdar, 2007; Zhixiang and Bensheng, 2007). LEACH protocol does not support sensor node mobility. In mobile environments, an agent based data collection methodology has been investigated, where a mobile agent efficiently processes the data and reduces the total energy expended by the network as worked out by (Jeong *et al*. 2008). A novel methodology LIMOC has been proposed, which is a system to augment the lifetime of the sensor network in which the moving cluster heads work together intelligently with each other to route the data to the distantly located base station as illustrated by (Banerjee *et al*. 2007).

The improvement over LEACH to sustain mobility has been pioneered as LEACH-Mobile (LEACH-M) which was brought out by (Do-Seong and Yeong-Jee, 2006). The fundamental idea in LEACH-M is to verify whether a mobile sensor node is capable of communicating with a particular cluster head. LEACH-M uses the similar set-up process as used in the basic LEACH protocol. Sensors elect themselves to be local cluster heads at any given time with a definite probability. These cluster head nodes broadcast their condition to other nodes in the sensor network. Every node determines to which cluster it wants to fit-in by deciding the cluster head that requires the least amount of communication energy. When every sensor nodes are prearranged into clusters, each cluster head forms a TDMA schedule for the sensor nodes in its cluster for collecting the sensed data. The wireless components of each non-CH node is turned off at all times excluding it's transmit time, thereby reducing the energy dissipated by individual the sensor nodes. The aggregated data is then forwarded to the base station by the cluster head.

3. SYSTEM MODEL AND PROBLEM STATEMENT

The sensor nodes are all similar in hardware, software and capabilities. Initially all the sensor nodes have equal amount of initial energy of 1 Joule, but after some time of operation, the nodes may be left with unequal energy levels. The sensor nodes as well the base station are moderately mobile. The base station is highly reliable and resourceful. After deployment of sensor nodes in the field, the field is logically partitioned into clusters. The base station forms these clusters and each cluster contains one cluster head node and two supporting deputy cluster head (DCH) nodes. Communication takes place in hierarchical fashion from sensor node to the base station through the cluster head. The communication between a cluster head node and base station will be in multi-hop fashion depending on the situation. The selection of nodes for various roles such as cluster head or deputy cluster head will be carried out at the base station level.

The key aim of this work is to design an energy efficient clustering algorithm for mobile wireless sensor network that operates in unattended and sometimes in hostile environments. As the sensor nodes are resource constrained (specially limited energy and limited on-board storage), the 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 throughput level at the base station. Most importantly, the lifetime of the wireless sensor network should be prolonged.

4. THE PROPOSED MADCA METHODOLOGY

In this section, the mobility assisted dynamic clustering algorithm (MADCA) has been investigated for effective clustering in mobile wireless sensor network, where both the sensor nodes as well as the base station are mobile. The objective of the proposed algorithm is to improve the lifetime of sensor nodes in the network. In the existing algorithm (LEACH-M), the sensor nodes keeps on sensing the data and sending the data to its cluster head, and this cluster head sends the data only when the base station comes in range with the cluster head. In the proposed algorithm, the sensors start sensing the data only when the base station comes in range with the cluster head. The algorithm manages the energy efficiency of the routes as well as the reliability of the routes. The data packets are routed through multiple hops in order to minimize the transmission energy requirement at the sender nodes. This help to trim down large amount of energy and also the battery life of the sensor nodes get increased.

After the deployment of sensor nodes, the base station groups different sensor nodes into clusters. Each cluster contains one cluster head node and two deputy cluster head nodes. There are three criteria to select the cluster head: the energy efficiency of the sensor node, the mobility of the sensor node and the accessibility to the neighbouring sensor nodes. This arrangement is also called as cluster head panel. The sensor nodes send the data to their respective cluster head. At the CH level, data aggregation has been carried out to remove data redundancy and then the CH forwards the aggregated data to the base station. The DCH nodes do several cluster management tasks such as mobility monitoring and also remain ready to act as intermediate hop in the

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presence of fault. The DCH nodes are also called as cluster management nodes. Figure-1 shows the flowchart of the proposed MADCA clustering methodology for mobile wireless sensor network.

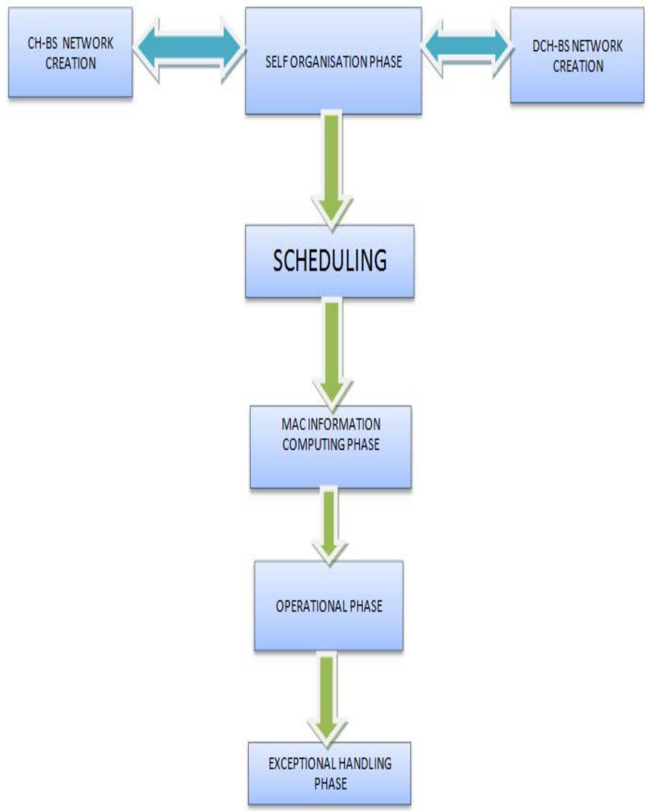

Figure-1. Flowchart of proposed clustering methodology (MADCA).

If the base station observes that the arrival of data packets is lesser than a threshold value, then it informs the respective CH to check the connectivity with its cluster members. The CH considers this as feedback from the base station and accordingly checks the current connectivity with its cluster members. If the connectivity status of the cluster members with the cluster head is very poor, the base station decides to shift the charge of cluster head to another suitable member from the cluster head panel already determined or to one of the deputy cluster heads depending on the situation. If this new CH also goes out of the range of the base station, the sensed data from the sensor nodes will be forwarded to the cluster head of nearest cluster, thereby the data will be forwarded to the base station. If this CH also goes out of range with the base station, then the data from the first CH and the data collected from this CH will be forwarded to the next nearest CH. In this situation, this CH sends the data of all the three cluster heads. Since the base station keeps on collecting the data, data aggregation will be done by the CH to remove data redundancy.

After the deployment of wireless sensor nodes, the first phase is the self-organization phase. During this phase, clusters are formed and cluster head gets finalized. The current cluster head and deputy cluster heads are also selected by the base station. Initially, the base station 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 base station 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 e.g., cluster setup validity period, medium access slot, etc., are dependent on the next time interval. Using this information, the base station computes the topology. Once the base station creates the sensor field map, it forms the clusters. The cluster formation approach is quite simple. The basic idea is to maintain geographically uniform distributed clusters, so that the coverage is uniform and also the cluster head nodes are uniformly distributed over entire sensor field. Therefore, the entire sensor field is geographically and uniformly divided into multiple clusters. After formation of clusters, the base station identifies a set of suitable nodes which can take the role of cluster head and deputy cluster heads. This selection is based on cumulative credit point earned from the three

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parameters namely the residual energy level of the node, degree of the node and mobility level of the node.

The user can use a suitable normalization function to compute the cumulative credit point earned by a sensor 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 base station then prepares the cluster head panel consisting of nodes having cumulative credit point above the threshold value. This threshold value can be set manually at the time of implementation, also depending on the type of application and normalization function. The node with highest credit point is selected as the current cluster head. The next two nodes in the list with second and third highest credit points are selected as deputy cluster heads for the same cluster.

The cluster head is responsible for collecting data from every sensor nodes. After data collection, the CH carries out data aggregation on the collected data to remove data redundancy. The aggregated data is sent to the base station either directly or in multi-hop fashion based on the communication pattern distributed by the base station.

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

The cluster head panel is selected initially and remains valid till re-clustering process is initiated. If the current cluster head drops out the connectivity with most of its clusters members, due to which throughput at the base station degrades, the cluster head might be asked to relinquish the charge of cluster headship. Even a cluster head node might drain out its energy beyond a threshold value and becomes useless, whereas in this situation a new cluster head is necessary. Under such circumstances, the base station gives the charge of headship either to one of the two deputy cluster heads or to a node from within the cluster head panel. This saves huge cost and time involved in the process of selecting a cluster head. An instance of shifting the charge of cluster headship from CH to DCH is very important, as the base station also instructs the sensor nodes to join the DCH as their new CH.

5. SIMULATION RESULTS AND ANALYSIS

The effectiveness of the proposed clustering methodology has been validated through simulation. The results and the evaluated values have been compared with a well-evaluated distributed clustering algorithm (LEACH-M).

Table-1. Simulation parameter setup for MADCA.

Simulation parameter	Values
Network Topology	500 x 500 m^2
Number of mobile nodes	30
Data packet size	4000 bytes
Control packet size	550 bytes
Initial energy	1 Joule
Transmitter power	31.32 mW
Receiver power	35.28 mW
Ideal power	712 mW
Sleep power	144 mW
Mobility Model	Random Way Point Model
Radio Model	First Order Radio Model
Sensor Node Deployment	Random Deployment

For simulation purpose, a sensor network of 30 nodes is randomly deployed over a field of dimension 500 x 500 m^2area. The sensor nodes move in random directions. The simulation has been executed for a period of 1800 seconds. All the sensor nodes are assumed to have equal amount of initial energy. The initial energy of the sensor nodes are considered to be 1 Joule. All the simulation works have been carried out using NS-2. Table-1 exhibits the parameters needed for conducting simulation works.

The simulator consists of different modules such as deployment module, topology construction module, mobility management module, medium access control module, routing module, energy expenditure computing module and throughput computing module. The performance of the proposed algorithm has been evaluated against LEACH-M in terms of average communication energy, network lifetime and node death rate. Figure-2 shows the performance evaluation of the proposed MADCA algorithm with LEACH-M, in terms of the average communication energy. Initially at 100 seconds, the average communication energy of LEACH-M is 0.17 Joules and that of MADCA is 0.13 Joules. Similarly at 1800 seconds, the average communication energies of LEACH-M and MADCA are 0.28 Joules and 0.18 Joules respectively. At an average, the proposed MADCA algorithm shows a reduction of 29.05% in terms of average communication energy when compared to LEACH-M. Thus the average communication energy is found to be reduced linearly in MADCA, when compared to the existing LEACH-M algorithm, which is mainly because of the above mentioned novel features employed in the proposed MADCA algorithm.

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Table-2. Tabulated values for average communication energy.

Time (seconds)		**100**	**300**	**600**	**900**	**1200**	**1500**	**1800**
Average Communication Energy (Joules)	**LEACH-M**	0.17	0.18	0.18	0.195	0.23	0.245	0.28
	MADCA	0.13	0.12	0.12	0.14	0.175	0.185	0.18

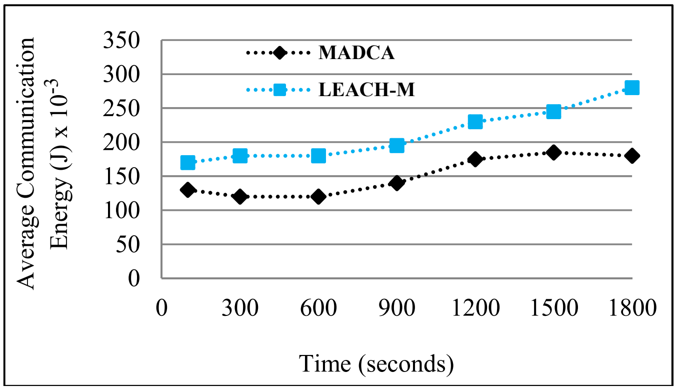

Figure-2. Average communication energy of LEACH-M and MADCA

Figure-3 shows the lifetime comparison of both LEACH-M and MADCA algorithms. At 100 seconds, the lifetime of both LEACH-M and MADCA are 84%. The network lifetime falls rapidly in LEACH-M, but in MADCA the network lifetime reduces slowly. In 1500 seconds, the lifetime of LEACH-M drops to 0%, but in MADCA the lifetime is 27%. At an average, MADCA shows 15.87% improvement in network lifetime when compared to LEACH-M. This lifetime improvement is mainly due to the novel concepts employed in MADCA methodology.

Table-3. Tabulated values for percentage lifetime.

Time (seconds)		**0**	**100**	**300**	**600**	**900**	**1200**	**1500**	**1800**
Lifetime (%)	**LEACH-M**	100	84	63	33	23	7	0	0
	MADCA	100	84	73	57	43	33	27	20

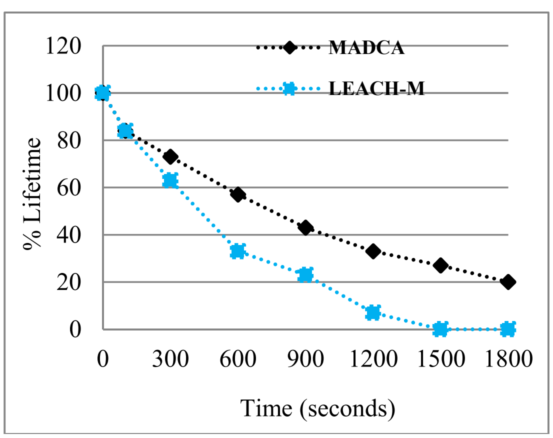

Figure-3. Lifetime comparison of LEACH-M and MADCA.

Figure-4 depicts the comparison of node death for both LEACH-M and MADCA. At 100 seconds, the number of node death is only 5 nodes for both LEACH-M and MADCA. Node death is drastic in LEACH-M and at 1500 seconds every nodes die. But in MADCA, the node death is less and even at the end of simulation (1800 seconds) 6 nodes are still alive. Thus, MADCA shows reduced node death when compared to the existing LEACH-M clustering methodology.

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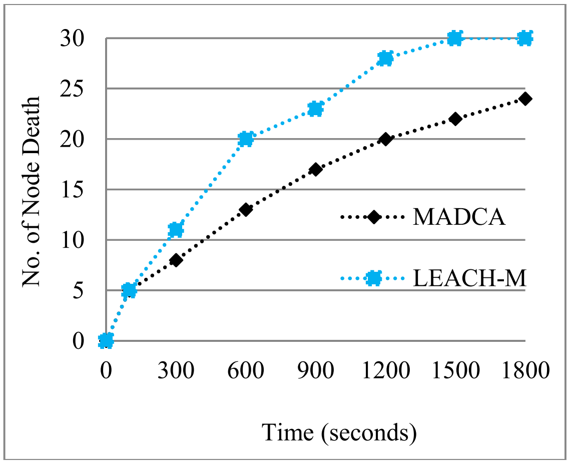

Figure-1. Node death versus Time (LEACH-M and MADCA).

7. CONCLUSIONS

A dynamic clustering algorithm for mobile wireless sensor networks, the MADCA has been proposed. The proposed clustering methodology MADCA is hierarchical, dynamic and energy-efficient algorithm for mobile wireless sensor network. MADCA forms multiple clusters with each cluster having one cluster head and two deputy cluster heads. The sensor nodes start collecting the data only when the base station comes in range with the cluster head. The performance of the proposed algorithm has been evaluated through simulations and the results have been compared with the existing LEACH-M algorithm. MADCA shows drastic reduction in average communication energy when compared to LEACH-M. The network lifetime has been found to be greatly prolonged in MADCA. The node death has been found to be greatly reduced in the proposed algorithm. Thus the proposed clustering methodology has been found to be greatly useful when both the sensor nodes as well as the base station are mobile.

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