Journal of Network Communications and Emerging Technologies (JNCET) www.jncet.org
Volume 5, Special Issue 2, December (2015)

Exploiting Mobility of Agents for Data Sharing and Aggregation in a Clustered Mobile Wireless Sensor Networks

Dimple Juneja
Dronacharya Institute of Management and Technology, Kurukshetra

Kavita Gupta
Research Scholar, Maharishi Markandeshwar University, Mullana-Ambala (Haryana), India

Aarti Singh
Maharishi Markandeshwar University, Mullana-Ambala (Haryana), India

Abstract – Data aggregation and result sharing among sensor nodes deployed in the unattended regions has been few of the most researched areas in the field of wireless sensor networks. While data aggregation is concerned with minimizing the information transfer from source to sink to avoid contention and congestion in the network, result sharing focuses on sharing of information among agents pertinent to the tasks at hand. There exists algorithms for data aggregation but very few have considered addressing the need of result sharing among nodes simultaneously. The proposed solution deploys mobile agents at cluster head from where it gets triggered to carry out the task of data aggregation and result sharing. The results achieved are highly motivating for further research.Index Terms – CRN, CRAHNs, MTPR, Shortest path routing, Optimum routing strategy.

Index Terms - Mobile Agents, Wireless Sensor Networks, Data Aggregation, Result Sharing, Clustering

This paper is presented at International Conference on Recent Trends in Computer and information Technology Research on 25th& 26th September (2015) conducted by B. S. Anangpuria Instituteof Technology & Management, Village-Alampur, Ballabgarh-Sohna Road,Faridabad.

1. INTRODUCTION

Energy efficiency, prolonged network life time and secure communication are some of the major challenges faced by wireless sensor networks (WSN) [18].Clustering in WSN [12, 13, 14, 15, 16] has proven to be a breakthrough innovation resulting into improvement in the lifetime of network. Aclustered network is divided in groups and each group consists of number of nodesand a gateway. The nodes are usually grouped having some similar properties. Each cluster has its own cluster head (CH) that collects the data from its members and forwards the aggregated data to the base station through gateways [1]. The aggregation of data demands minimal data should be transferred while avoiding the loss of information. Aggregation of data has played a vital role in avoiding contention and congestion in the network [Wiley-Book of WSN]. It is strongly desired that data aggregation should not lead to transfer of redundant transfer.

Turning our attention to result sharing among nodes, result sharing has not been in focus in WSN. We believe that if the nodes are allowed to share the results related to the event/data they have sensed, it will save lot of energy even during data aggregation. Therefore, the work focuses on finding a solution for data aggregation in WSN and also introducing the concept of result sharing in sensor networks. The concept has been implemented by exploiting the mobility characteristic of mobile agents.

The current work considers that the sensor network is already clustered and follows hierarchical topology [17]. A clusterednetwork offers significant advantages such as expandability, scalability and robustness over other network topologies.Although clustering in sensor networks offers an energy efficient solution but it is poses numerous challenges[19] like redundant data aggregation at cluster headand high communication cost. Latest research indicates that mobile agents [20] are proving significant for providing the solution to above issues. Mobile agents move around the

Journal of Network Communications and Emerging Technologies (JNCET) www.jncet.org
Volume 5, Special Issue 2, December (2015)

network autonomously to carry out the desired operations and return to the source triggering them. However deployment of mobile agents in sensor nodes is very sensitive as it also adds the overhead of consuming the energy of host nodes and hence must be dealt carefully. In order to get the optimum results, mobile agents should be placed at high density locations (maximum sensor nodes). The current work proposes to deploy mobile agents at the cluster head level from where it is originated and triggered to perform data aggregation as well as result sharing.

The paper is structured into five sections. Section 2 acknowledges the work of authors who had been putting efforts to improve the life of a sensor network. Section 3 describes the system model. Section 4 express the proposed work in detail and finally section5 concludes the paper.

2. RELATED WORK

It is evident from the literature that managing energy of mobile sensors is one of the biggest hurdles in the field of MWSN [9, 10, 25, 26]. A clustered network seems to a promising solution towards an energy efficient solution, but data aggregation performed at cluster head is an overhead. A reliable data aggregation scheme offers the prolonged network life time along with lowest communication cost. Mobile agents can also play the role of data collector for providing energy efficient network. Various researchers have offered numbers of ways for data aggregation schem in sensor networks. An efficient and flexible data aggregation approach by Dirk &Mithun [2] suggests to initially conceal the sensed data and later aggregate the data by applying encryption transformations. Charalampos et al. proposed a greedy approach for data collection [3] from nearby nodes that includes itinerary mechanism keeping the low cost itinerary. The approach offers effective performance over the alternatives. An event based scalable and efficient data aggregation [4] uses semi-structured with dynamic forwarding. Different types of data aggregation schemes such as Spatial Temporal Correlation, Scale Free Aggregation in Sensor Networks, Energy Efficient Clustering Scheme, Energy Efficient Spatial Correlation Based Data Aggregation etc. [5] highlights the importance of data-diffusion for flat networks. Data-diffusion process starts with defining the route discovery process. A Comprehensive energy consumption model proposed by [6, 7, 8] is based on energy efficient clustering scheme. This proposed model discusses the level of energy consumption for clustered networks i.e. during transmission, cluster head movement etc. An energy efficient spatial correlation scheme for data collection is available in [11]. The approach utilizes clustering as the founding algorithm where clusters are formed on the basis spatial correlation between the nodes in network. The algorithm reduces the level of communication between source and sink. IN Structure Free and Energy Balanced Scheme proposed by [9] is two phase process in which dynamic aggregator mechanism is used to gather the data and also balance energy during data aggregation. Kai-Wie et al. [21] presented a structure free approach that is highly suitable for spatial and temporal data aggregation. In fact, data aware analyst [23] and randomized waiting mechanisms [24] are also used at different layers for efficient data aggregation scheme. Xu and his co-workers proposed scheduling algorithms for data aggregation in sensor networks [22] which could generate collision free link schedules for data aggregation and could reduce communication time span.

A vital information grilled from the literature presented above is that researchers have been putting efforts towards data aggregation in WSN, but very few have considered MWSN and also less attention has been paid to utilizing the mobility of mobile agents for data aggregation. Further, to the best of our knowledge, data sharing at lowest level nodes has inadvertently being ignored and hence the motivation to take up this research work.

3. NETWORK MODEL

System model used in this model consist of n number of sensor nodes each of which consist of a transceiver with maximum transmission range. Network is represented in the form of tree (see figure 1).

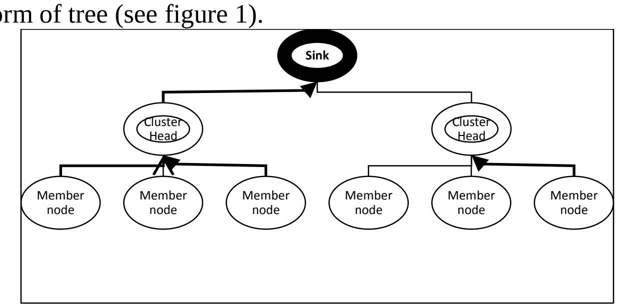

Figure 1: Topology of Network

The proposed approach uses multi-hop transmission in communication model. A hierarchical network structure is formed for this purpose and concept of data aggregation can reduce the size of data that is further forwarded to next higher level which in turn reduce the level of energy consumption. Also, the concept of result sharing i.e. sharing the information which may be useful for other nodes too would save their energy in sensing and transmitting the same data. Following assumptions are being made to simplify the implementation:

- A network which is already clustered and follows hierarchical topology has been considered.

- Cluster head (CH) is elected as per the algorithm given in [16].
- Data aggregation task is implemented at each level so to gather the data from member nodes and fussed data is further forwarded to next higher level.
- Result sharing would be implemented at the lowest level only assuming that sensing nodes are at the lowest level of network.
- The radio energy model is used to calculate the energy consumption rate of sensor nodes. Energy of nodes is consumed with some specified rate during transmission, receiving and idle state. In our case nodes also lose some of their energy due to mobility value. In order to design energy efficient network nodes tries to remain in sleeping mode and turns on either when there is an event to sense or when a mobile agent visits the node to collect the data.

4. PROPOSED WORK

Literature explored indicates that data aggregation is one of the acceptable solutions for improving the energy efficiency as well as prolonging the lifetime of sensor network. Moreover, to the best of our knowledge, idea of result sharing exists but none of the researchers have implemented the same in WSN. The section proposes to deploy mobile agentat to perform the task of data aggregation as well as result sharing in the network. The mobile agent is deployed at each cluster head i.e. at level1. The cluster heads triggers the respective mobile agents periodically to collect the data from its cluster members. The agent is required to traverse each member, collect data and execute data aggregation and result sharing module (discussed later in this section) and sends the processed data structure to next higher level. Out of the all agents deployed at CH, only one mobile agent is migrated to sink for transferring the data. The mobile agent which is selected to migrate is henceforth called as Master Mobile Agent (MMA) and selection procedure of MMA is discussed in section 4.3. MMA calls data aggregation module before forwarding this aggregated data to sink. It is worth noticing that number of agents corresponds to the number of clusters formed within the network. The compiled view of the proposed approach is illustrated through figure 2. As shown in figure 2, the proposed work majorly comprises of four modules i.e. Data Collection Module (DCM), Data Sharing Module (DSM), Selection of Master Mobile Agent (MMA) and Data Aggregation Module (DAM). Each of these modules along with working algorithms are explained in the upcoming sections.

4.1 Data Collection Module (DCM)

The module is based on the assumption that cluster heads at level 1 initiate the process of data collection and hence mobile agents at the level 1 are required to collect the data from the descendents nodes. The agent from each CH is required to follow a particular iternary, known as *Agent's iternary* and is decided by CH. The mobile agent at cluster head makes an announcement regarding "".

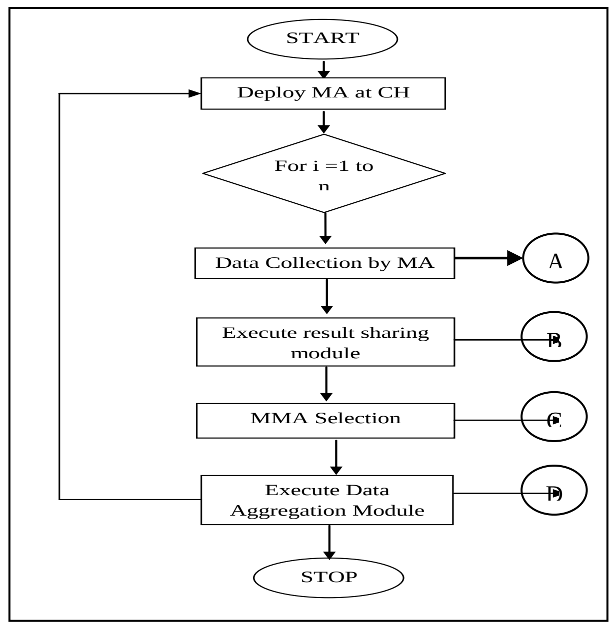

Figure 2: Compiled View of Proposed

All listening descendent nodes who have some data to submit are only required to respond by sending "Yes" message along with their node id and remaining nodes (who have no data to send) remain silent. Each yes message is time-stamped immediately. According to the message received from various nodes, mobile agent is now required to visit only those nodes whose ids have been received and it visits them in the order of the response message received. For the sake of simplicity, during practical implementation we have assumed that a message received earlier implies that node is closer to the CH and hence would be visited first. The procedure is illustrated with the help of figure 3.

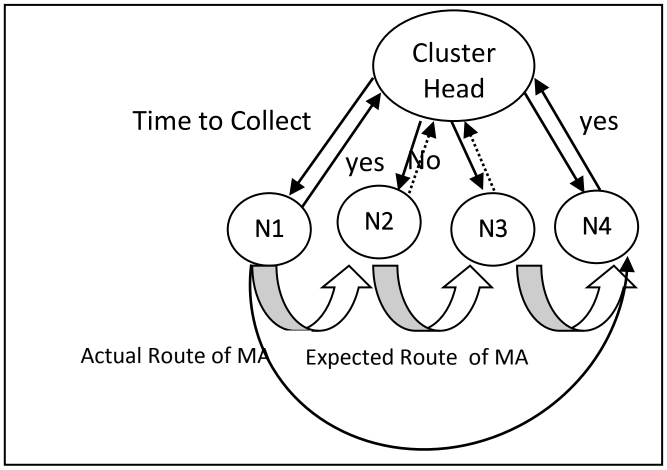

Figure 3 Data Collection Module

The data structure of the agent iternary is shown in table 1.

Table 1: Data Collection by Mobile Agent$_i$	
Visited Sensor node id	Data collected

While visiting the nodes, mobile agent may share the data so collected by calling result sharing module discussed in the next section.

4.2 Data Sharing Module (DSM)

It is desired that mobile agent while visiting the nodes, shall share the data with nodes to be visited.

Table 2 : Structure of Log

Event ID (Eid)	Mobile Agent (MAid)	Data1	Data2
Eid_k	MA_{ij}	D_i	D_j
Eid_j	MA_{ji}	D_k	D_i

The data sharing helps in improving the collecting the useful and meaningfull information. Moreover, if the similar data has already been collected, same can be ignored to be carried forward. Since nodes with similar data now no more transmit the data, empirically it can be accepted that the energy of nodes remains conserved.According to DCM, the mobile agent visits only few selected nodes as per the decided iternary. While visiting the nodes, the agent records the event if and only if $t_e > t_i$ where t_e is the time of event and t_i is the time when agent was triggered by CH. For each collected and finally recorded event (after sharing wih peer agents), agent maintains a data log as per structure shown in table 2. Once all the nodes are polled using agent iternary, mobile agent returns to cluster head. No more events are then recorded. Working algorithm and flowchart forDCM is being given in figure 5(a) and 5(b). The individual implemntation of the module resulted into improved perfromance in terms of covering the entire route is less time and the data collected also appeared to be more accurate when compared with without data collected without executing the module. Results obtained are shown in figure 6. Grey linerepresents the result obtained with DCM and DSM while the dark line represents the results obtained if the agent had visited all nodes ignoring both the modules. The analysis of the same reflects that initially with passage of time agents covers more area and hence more data.

$\boldsymbol{Algorithm}$: $\boldsymbol{Data\ Sharing\ Module}$
$\boldsymbol{Step1}$: $InitiateprocessCH - (Triggers) \rightarrow MA$
$\boldsymbol{Step2}$: $MAvisitsonlymembernodes$
$\boldsymbol{Step3}$: $Recorddata\ \log\ as\ pereventid(eid) and$
$checktimestamps$
$\boldsymbol{Step4}$: $if\, t_e > t_{MA} then$
$recorddatainDSelsediscarddata$
$\boldsymbol{Step5}$: $Pollallnodesif\,(all\ nodesexhausted)$
$if\ t_e < t_{MA} then$
$MAretunstoCH$
record $timestamp$

Figure 5(a) Algorithm for DSM

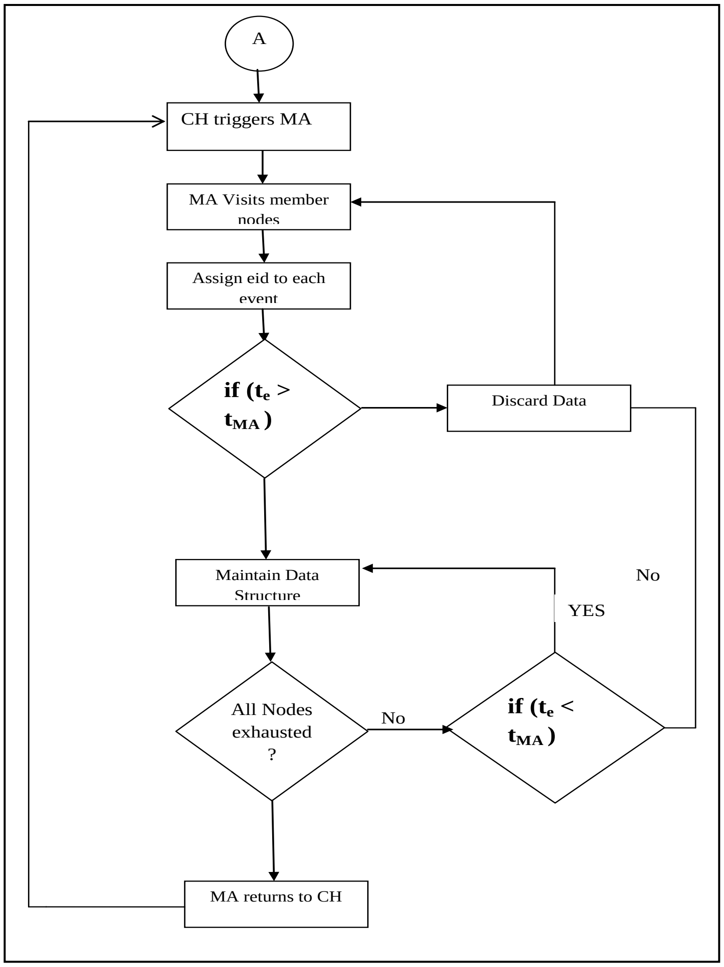

Figure 5(b) Flowchart for Data Sharing Module

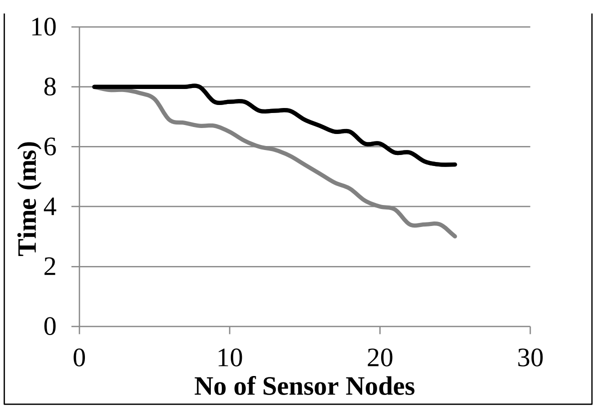

Figure 6 Data Sharing Traversal due to DCM

4.3 Selection of Master Mobile Agent (MMA)

The role of MMA is to collect the data from individual mobile agents and perform data aggregation Since, all agents have been dessigned with equal capabilities,the algorithm offers flexibility to choose any mobile agent at level 1 to become MMA. Selection of MMA is purely a random process and the module for the same is being shown in figure 7. MMA is now required to contact remaining mobile agents at the same level who have some data to transmit to sink. It now perfroms data aggregation as discussed in the next section.

Algorithm: ***Master Mobile Agent***
Step 1: *Start loop for* $i = 1$ *to* n
Step 2: $MMA = randbetween(1, n);$
End loop.

Figure 7 Algorithm for Selection of MMA

4.4 Data Agrregation Module (DAM)

For performing data aggregation, MMA is requiring interacting with its peers and it is strongly desired that these agents would cooperate. However, it is not necessary all agents are active at the same time and agree to share the result. Let us assume that at one instant of time, two CHs trigger their respective mobile agents to collect the data. It is obvious that the two mobile agents will either cooperate (C), refuse to cooperate (RTC) or cooperates but directs off beam i.e. acts destructive (D), at a particular instant of time. In this case, there are eight possible actions and are being depicted through payoff matrix as shown below:

	MA_{jC}	MA_{jRTC}	MA_{jD}
MA_{iC}	1 1	4 1	9 1
MA_{iRTC}	1 4	4 4	9 4
MA_{iD}	1 9	4 9	9 9

The above payoff matrix should be read as follows: Since there are 3 actions being executed, this payoff matrix has 9 cells. Each of the 9 cells corresponds to possible 9 outcomes. The top right value in a cell corresponds to the action taken by agent j while the bottom left value in a cell corresponds to action of agent i. For instance, when both agent i and agent j cooperates, corresponding cells contain {1,1}. On contrary when both agents goes destructive, the cell contains {9,9}. While if one of the agents RTC due to any reason, the agent is treated as honest (because it does not go destructive) and the cell contains4. For example, When agent i RTC while agent j cooperates, therefore cell contains {4,1}. The value in the cell received is known as the payoff value of each agent and lower is the payoff value higher is the credibility of agent and vice-versa. Data aggregation is performed using bottom-up approach. If two or more nodes are having similar data, the same is being discarded immediately at the same level. The algorithm for data aggregation is being given in figure 8(a) and figure 8(b) represents the working flowchart of the same.

$\boldsymbol{Algorithm: Data\ Aggregation\ Module}$

$Step1: Start\ loop\ for\ i = 1\ to\ n$

$Step2: if\ (Data1 \neq Data2)\ then\ goto\ Step3\ else\ Discard\ D2;$

$Step3: DA = f(Data1, Data2);$

$Step4: End\ loop$

$Step5: return\ DA$

Figure 8(a) Algorithm for DAM

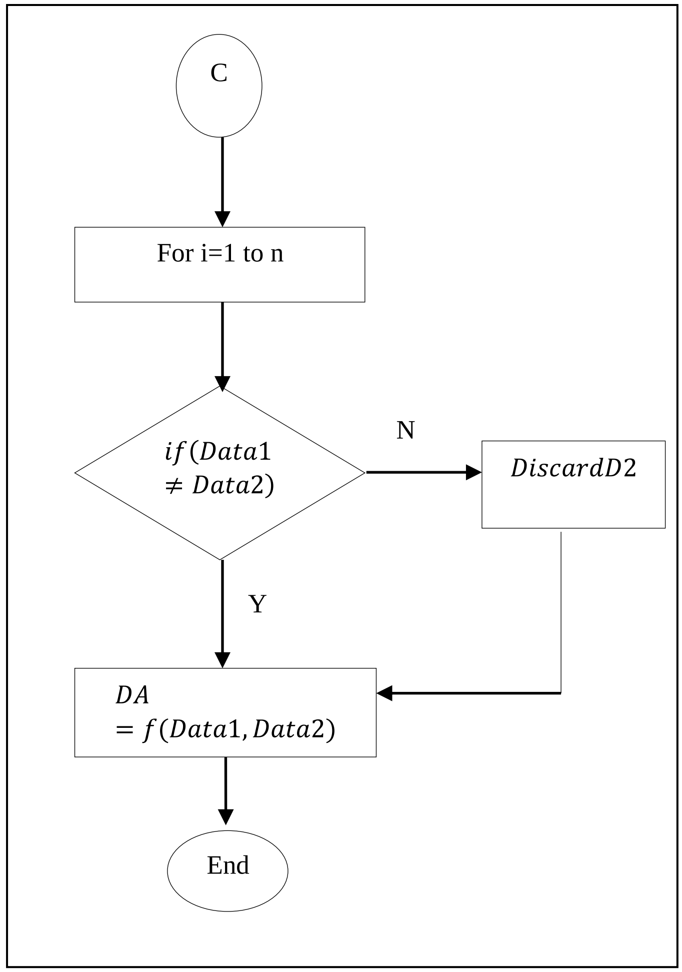

Figure 8(b) Flowchart Data Aggregation Module

The protocol and modules are being implemented using Matlab. A network consisting of hundred mobile nodes was considered and organized in clustered form using algorithm as defined in [17]. While implementing the modules with mobile agents being relocated to different locations, it is observed that deploying mobile agents with cluster heads resulted into significant improvement in the overall life of network and energy consumption as compared to deploying agents either at all nodes or randomly at few member nodes. The complete analysis of the results so obtained is another challenging task and hence we will be taking the same as future work.

5. CONCLUSION

Scarcity of efficient algorithms in the field of data aggregation and result sharing especially has formed the basis of this research work. Moreover, the desire to have minimal hop traversals and maximum data collection demands for efficient modules. The complete framework can not only reduce the number of nodes being traversed but can also provide more accurate and non-redundant data. The strategy uniquely contributes an amalgamation of data aggregation and result sharing but it also offers autonomy to the modules. The partial results achieved so far are highly significant and motivating for further research.

REFERENCES

[1] A.MeenaKowshalya, A. Sukanya, "Clustering Algorithms For Heterogeneous Wireless Sensor Networks – A Brief Survey", International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC), Vol.2, No.3, pp. 57-69, 2011.

[2] [2] SasaSlijepcevic, MiodragPotkonjak, "Power Efficient Organization of Wireless Sensor Networks", International Conference on Communications ICC 2001. IEEE, Vol. 2, pp. 472-476, 2001.

[3] [3] Andrew Howard, Maja J Matari´c, and Gaurav S Sukhatme, "Mobile Sensor Network Deployment using Potential Fields: A Distributed, Scalable Solution to the Area Coverage Problem, Proceedings of the 6th International Symposium on Distributed Autonomous Robotics Systems (DARS02), 2002.

[4] [4] Andrew Howard, Maja J Matari´c and Gaurav S Sukhatme, "An Incremental Self-Deployment Algorithm for Mobile Sensor Networks", Autonomous Robots, Special Issue on Intelligent Embedded Systems, 13(2), pp. 113—126, 2002.

[5] [5] AnkitTripathi, Sanjeev Gupta, BhartiChourasiya, “Survey on Data Aggregation Techniques for Wireless Sensor Networks”, International Journal of Advanced Research in Computer and Communication Engineering Vol. 3, Issue 7, pp. 7366-7371, July 2014.

[6] [6] N. Jain, S. Gupta, and P. Sinha, “Clustering Protocols in Wireless Sensor Networks: A Survey,” Int. J. Appl. Inf. Syst., vol. 5, no. 2, pp. 41–50, 2013.

[7] [7] S. Gupta, N. Jain, and P. Sinha, “Node Degree based Clustering for WSN.,” Int. J. Comput. Appl., vol. 40, no. 16, pp. 49–55, 2012.

[8] [8] Meng, Jin-Tao, Jian-Rui Yuan, Sheng-ZhongFeng, and Yan-Jie Wei. "An Energy Efficient Clustering Scheme for Data Aggregation in Wireless Sensor Networks." Journal of Computer Science and Technology 28, no. 3, pp. 564-573, 2013.

[9] [9] S. Gupta, N. Jain, and P. Sinha, “A density control energy balanced clustering technique for randomly deployed wireless sensor network,”(WOCN), 2012 Ninth …, pp. 1–5, 2012.

[10] [10]S. Gupta, N. Jain, and P. Sinha, “Energy Efficient Clustering Protocol for Minimizing Cluster Size and Inter Cluster Communication in Heterogeneous Wireless Sensor Network,” Int. J. Adv. Res. Comput.Commun.Eng., vol. 2, no. 8, pp. 3295–3305, 2013.

[11] [11]Tharini, C., VanajaRanjan, P.: An Energy Efficient Spatial Correlation Based Data Gathering Algorithm for Wireless Sensor Networks. International Journal of Distributed and Parallel Systems 2(3), 16–24 (2011)

[12] [12]Anitha, R.U., Kamalakkannan, P. , “*Energy efficient cluster head selection algorithm in mobile wireless sensor networks”,* Published in Proceeding of “International Conference on *Computer Communication and Informatics (ICCCI)”*, IEEE ,f ro m 4-6 Jan. 2013,pp.1-5.

[13] [13]Gupta, D. ,Verma, R., “*An enhanced cluster-head selection scheme for distributed heterogeneous wireless sensor network*”, Published in “*International Conference on Advances in Computing, Communications and Informatics (ICACCI)”* , from 24-27 Sept. 2014, pp.1684 - 1689

[14] [14]Tri Gia Nguyen, Chakchai So-In, “*Two energy-efficient cluster head selection techniques based on distance for wireless sensor networks”,* Published in “*International conference on Computer Science & Engineering”,* July 30 2014-Aug. 1 2014,pp.33-38.

[15] [15]VeenaBhat,Sharada U Shenoy, “*Effective Cluster Head Selection Based on EDM for WSN” ,Published in “ The IUP Journal of Computer Sciences”,* Vol. 4, 2014, ISSN 2249-0426 ,pp. 9-13.

[16] [16**]**Samer A. B. Awwad, CheeKyun Ng* and Nor K. Noordin, **“***Cluster Based Routing Protocol with Adaptive Scheduling for Mobility and Energy Awareness in Wireless SensorNetwork”* Published in “*Proceedings of the Asia-Pacific Advanced Network*”, 2010, v. 30, pp. 57-65.

[17] [17]Dimple Juneja, Kavita Gupta, Aarti Singh, “An Improved Cluster Head Selection Algorithm for Mobile Wireless Sensor Network”, communicated to International conference on Recent Trends in Computers and Information Technology, Sept 25-26, 2015.

[18] [18]Vinay Kumar, Sanjeev Jain,SudarshanTiwari, “Energy Efficient Clustering Algorithms in Wireless Sensor Networks: A Survey”, Published in IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 5, No 2, pp. 259-268, 2011.

[19] [19]Ramesh Rajagopalan and Pramod K. Varshney, “Data aggregation techniques in sensor networks: A survey”, Published in IEEE Communications Surveys & Tutorials, 2006.

[20] [20]Keisuke Goto, Yuya Sasaki, Takahiro Hara, ShojiroNishio, “Data gathering using mobile agents forreducing traffic in dense mobile wireless sensor networks”, Published in Mobile Information Systems 9, pp. 295–314, 2013.

Authors

Prof. (Dr.) Dimple Juneja, a Post-Doctorate from Louisiana State University, USA and Ph.D. in Computer Engineering from Maharishi Dayanand University, Rohtak. Dr. Juneja is **Dale-Carnegie Certified Trained Teache**r and also is a recipient of **Best Paper Award**. Her subjects of interest include Multi-Agent Systems, Sensor Networks, Semantic Web, and Distributed Operating System.

Dr. Aarti Singh is presently working as Associate Professor in Maharishi Markendeshwar Institute of Computer Technology & Business Management running under the umbrella of Maharishi Markendeshwar University, Mullana, Haryana. Dr. Singh has a credible academic record, with various degrees like Ph.D. (Computer Science), M.Phil. (Computer Science), MCA, M.Sc. (Computer Science) and B.Sc.(Computer Science & App.). Dr Singh also owe the credit of 55 published research papers in various national &International Journals of repute, with one paper awarded as the **Best Paper in an IEEE Conference**. Dr Singh have also participated in many International conferences within India and abroad.

Dr. Singh is Life Member of Institution of Doctors, Engineers and Scientists (IDES), India. Member of Scientific Technical Committee & Associate Editor for International Journal of Computing Academic Research (IJCAR), Jordan. Editorial Member of International Journal of Advancements in Technology (IJoAT), Reviewer in Springer Journal of Institution of Engineers (India):Series B, Member Editorial Review board of International Journal of Rough Sets and Data Analysis (IJRSDA). Member of International Association of Engineers (IAENG). She has served as IEEE Student branch counselor from September 2013 to December 2014. Dr Singh’s research interests include **Semantic Web, Agent Technology, Web Mining and Web Personalization.**

Kavita Gupta, is a Ph.D. research scholar of Maharishi Markendeshwar Unviersity , Mullana, Haryana. Her domain of research is Mobile Wireless Sensor Networks.