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Transmission of image data using fuzzy logic based clustering infrastructure in mobile multimedia sensor networks

Aysegul Alaybeyoglu*
Department of Computer Engineering, Izmir Katip Celebi University, Izmir, Turkey

Abstract. In this study, by considering nodes mobility, image data is transmitted distributedly to the base station via fuzzy logic based clustering infrastructure. This study is composed of two phases. In the first phase, fuzzy logic based clustering infrastructure is constructed with six input parameters namely, nodes speed, energy, centrality, distance to base station, number of hops and node density. In the second phase, huge amount of image data is distributed among the nodes to compress and send it to the base station. The proposed system is compared with the centralized approach and ICGA for energy consumption, network lifetime and image quality parameters on different mobility models of the sensor nodes.

Keywords: Mobile multimedia sensor networks, fuzzy logic, clustering, distributed image compression

1. Introduction

Clustering is a widely used technique in wireless sensor network applications in order to decrease energy consumption and increase network lifetime. In clustered networks, nodes are defined as either member or head nodes. While member nodes are responsible of sending their sensed data to the head node, root node is responsible of collecting, processing and sending this data to the base station. When nodes are mobile in sensor network, more parameters should be considered while designing the system. Because of the mobility, properties of the nodes such as location, distances to base station and to other nodes, centrality and density change by the time. Such a dynamic environment requires updates in clustered infrastructure[1]. The sensed data is transmitted among the nodes in clustered infrastructure. While transmitting the small amount of data is simple, when the amount of data becomes higher such as in transmitting process of the image or video data, compression techniques are needed in order to decrease the workloads of the sensor nodes. Because of the energy constraints of sensor nodes, rather than making a one node compress the huge amount of data centrally, compression process should be distributed among the nodes while transmitting the data to the base station[1].

There are many heuristics which are proposed for constructing energy efficient clusters one of which is fuzzy logic technique. In [2], a distributed dynamic clustering protocol that uses fuzzy logic technique to select root node is proposed. In this protocol, tentative cluster heads are selected based on remaining energy with a non-probabilistic fashion and cluster head selections are performed sporadically. In all of the studies [3–6], fuzzy logic is executed centrally and only the parameters used for inferency changes. There are also some studies for transmitting image data among the sensor nodes [7–11]. In all of these studies, nodes are assumed to be stationary. In [7], a distributed image compression algorithm is proposed for environmental monitoring applications. In [8], image data is splited into blocks and each node in the cluster sends the intermediate results of the wavelet transformed data to its head node. [9] uses embedded block coding

*Corresponding author. Aysegul Alaybeyoglu, Department of Computer Engineering, Izmir Katip Celebi University, Izmir, Turkey. Tel.: +90 232 329 35 35/Ext.: 3731; Fax: +90 232 386 08 88; E-mail: aysegul.alaybeyoglu@ikc.edu.tr.

method in addition to discrete wavelet transform. In [10], distributed vector quatization is used and codebook is created by applying neural network of adaptive resonance theory. In [11], the captured image data is partitioned into region of interest on which the monitored objects appear. Only in [1], a distributed image compression algorithm is proposed for mobile wireless sensor networks. Genetic algorithm is used for clustering infrastructure. The proposed system has some similarities with [1]. Main difference of the proposed system and [1] is transmitting image data among the fuzzy logic based clustering infrastructure rather than the genetic algorithm based infrastructure. Another difference is in the proposed system, fuzzy logic system is executed by the nodes but in [1], genetic algoritm is executed by base station and the calculated clustering information is distributed to the nodes in network area. Nodes send their speed, energy and location information to the base station periodically. When these algorithms are compared, it has been obtained that transmitting image data among the fuzzy logic based clustering infrastructure performs much better than genetic algorithm based infrastructure.

Main contribution of the proposed system is implementing both of the fuzzy logic based clustering infrastructure and the distributed image compression system on a mobile wireless multimedia sensor network. Because of the nodes mobility, clusters are required to be regenerated. Fuzzy Logic engine whose input parameters include nodes speed, energy, centrality, distance to base station, number of hops and node density are used for updating the clusters. The proposed image compression algorithm is executed on the fuzzy logic based clustering infrastructure. Fig. 1 shows the components of the proposed system.

The rest of the paper is organized as follows: System Model that includes image compression and mobility models subsections are given in Section 2. The proposed system is described in Section 3. Simulation results are given in Section 4 and lastly conclusion is given in Section 5.

2. System model

In this section, fundamentals of image compression and used mobility models are described briefly.

2.1. Image compression

The proposed image compression algorithm is based on Discrete Wavelet Transform which is composed of Forward/Inverse Wavelet Transform, Quantization/Dequantization, Entropy Coding/Decoding [1, 8]. With Discrete Wavelet Transform, the signal is decomposed into the signal frequencies and then they are coded. In the proposed system, oktav-band decomposition technique in which low and high pass filters are applied to the signa is usedl. Low pass filter is applied to the each row of the data and then low frequency data at rows are obtained. Similiarly, high pass filter is applied

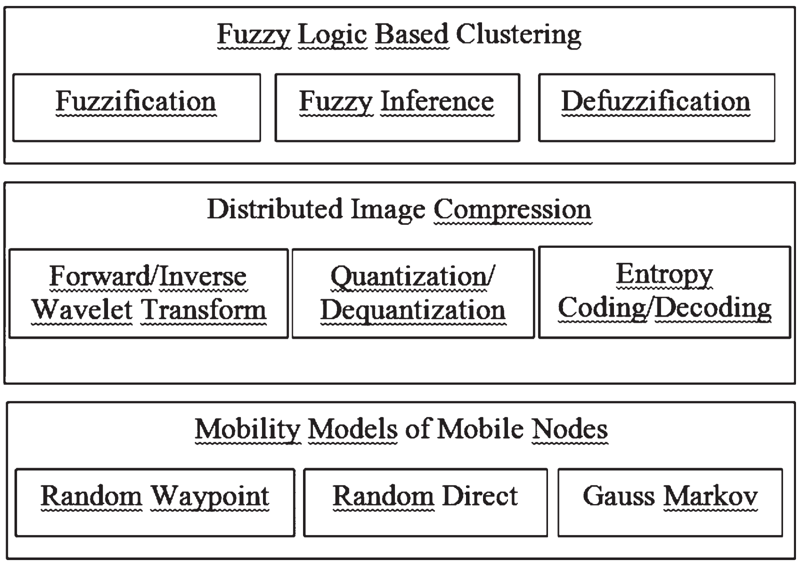

Fig. 1. Components of the proposed system.

to the same row of data and by this way high and low frequencies of data are seperated. This operation which is applied on rows is called "1D Wavelet Transform". The same filtering operation is applied to each coloums of intermediate output data and this whole process is called "2D Wavelet Transform". At the end of these steps, four subbands are obtained, namely: LL(low-low), HL(high-low), LH(low-high) and HH(high-high) [1, 8]. After discrete wavelet transform is performed on image data, vector quantization and entropy coding steps are implemented [1].

2.2. Mobility model

Three mobility models namely; Random Waypoint, Random Direct and Gauss Markov are used for nodes movement scenarios. In Random Waypoint Model, each node travels from a starting coordinate to a random ending coordinate with a randomly generated constant velocity. In Random Direction Model, instead of choosing a random destination, nodes choose a random direction which reaches the boundary of the simulation area [14]. Gauss-Markov Model is proposed to prevent unrealistic behaviors occured in RWM and RDM such as sharp turns, sudden stops, and sudden accelerations [14].

3. The proposed system

The proposed system includes two phases namely; fuzzy logic based clustering infrastructure and distributed image compression algorithm. In this section, these systems both of which are proposed for mobile wireless multimedia sensor networks are described in details.

3.1. Fuzzy logic based clustering infrastructure

Main difference of the proposed fuzzy logic clustering from [13] is considering nodes mobility and hence using nodes speed as an input to the fuzzy logic engine. Fuzzification, Fuzzy Rules, Aggregation of the Outputs and Defuzzification are the main steps of the proposed Fuzzy Logic Inference System. Fig. 2 shows the structure of the fuzzy logic system.

- **Fuzzification**: Six input parameters namely; node speed, energy, centrality, distance to base station, number of hops and node density and an output parameter namely probability are used in the system. Membership functions of these parameters, which are responsible of determining the relationships between the inputs and outputs of the fuzzy system, are given in Fig. 3.
- **Applying Fuzzy Rules**: Fuzzy rules are applied to the fuzzified inputs. Some of them are given in Table 1.
- **Aggregation of Outputs**: Outputs of all rules are aggregated to obtain unificated output. From the fuzzy rules, probability fuzzy output variable can be obtained. The higher probability means that the node has more chance to be a root node.
- **Defuzzification**: Center of Area (COA) is used as a defuzzification method in which the fuzzy logic controller first calculates the area under the scaled membership functions and within the range of the output variable.

Table 1
Fuzzy rules

NE	C	DBS	NoH	NS	ND	P
low	close	close	low	low	low	strong
—	—	—	—	—	—	
low	adequate	close	low	low	low	strong
—	—	—	—	—	—	
medium	adequate	adequate	medium	high	high	medium

3.2. Distributed image compression algorithm

In order to transmit huge amount of image data among the mobile sensor nodes, image is compressed by the fuzzy logic based clustered sensor nodes distributedly while it is transmitted to the base station. General idea of the proposed system for transmitting the image data from camera node to destination is shown in Fig. 4. [1] is used for distributed image compression technique. According to [1], when a sink node requires a data, it floods a REQUEST message to the network. A camera node which receives this message, checks its sensed data to decide whether they match or not. If the requested data and sensed data matches, camera node sends INFO message to the head node which locates closest to the direction of the destination node to get information about the member nodes of the head node.

When the head node receives INFO message, it replies with *RESPONSE_INFO* message which includes the information about member nodes that will take roll in the process of of distributed discrete wavelet transform. Camera node splits the image data into blocks and sends BLOCK message including block information to the member nodes which then apply 2D discrete wavelet transform on these blocks and send intermediate results seperately with $2D\_BLOCK$ message to the next head node that locates closest to the direction of the sink node. The head node that receives

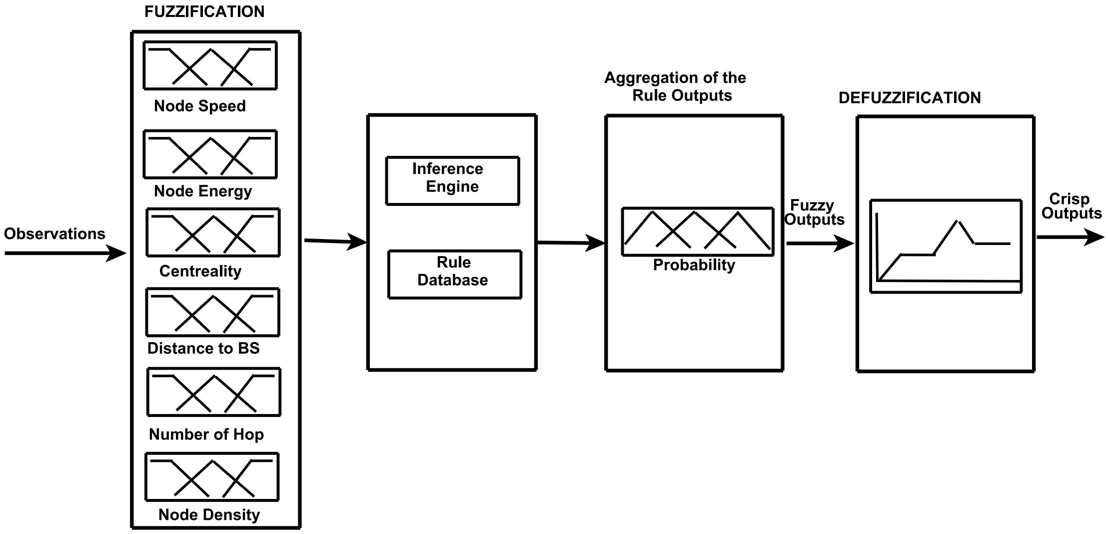

Fig. 2. The structure of the fuzzy logic system.

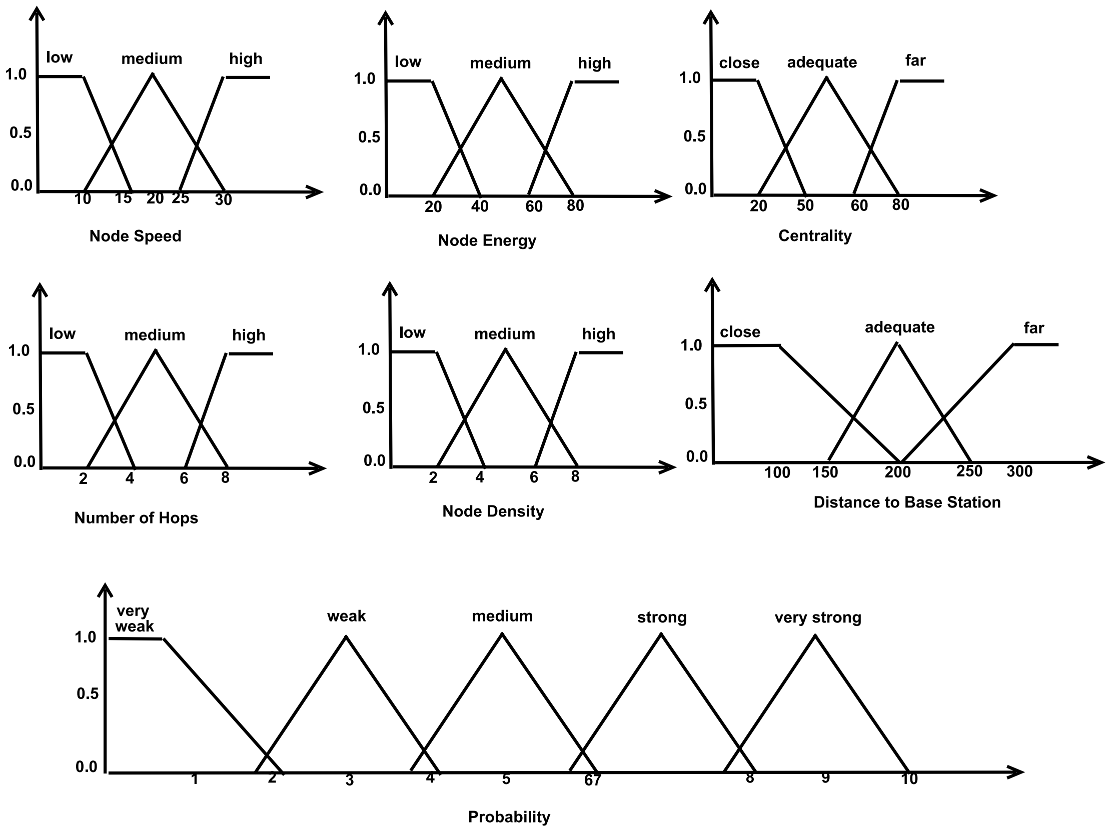

Fig. 3. Membership functions of the proposed system.

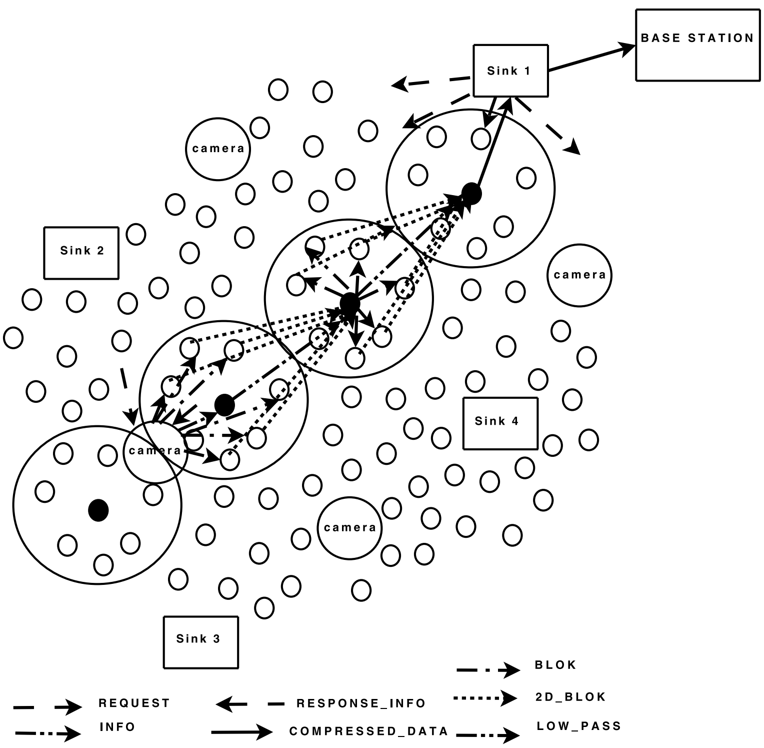

Fig. 4. Transmitting the image data by compressing with distributed discrete wavelet transform [1].

$2D\_BLOCK$ message, sends BLOCK message including the low frequencies of each block to its member nodes which then apply 2D discrete wavelet transform. Head node sends LOW_PASS message including LH, HL and HH parts of the blocks to the next head node. This process continues till the required quality and related sink node are reached. Quantization and entropy coding steps are processed by each node centrally and these steps are held before data exchange [1, 8]. Main difference of the proposed system from the study proposed in [8] is considering the nodes mobility and reconstructing the clustering infrastructure dynamically. Another difference is data can be distributed from multisource to multidestination rather than single source to single destination as in [8]. Main difference of the proposed system from [1] is transmitting image data among the fuzzy logic based clustering infrastructure rather than the genetic algorithm based infrastructure.

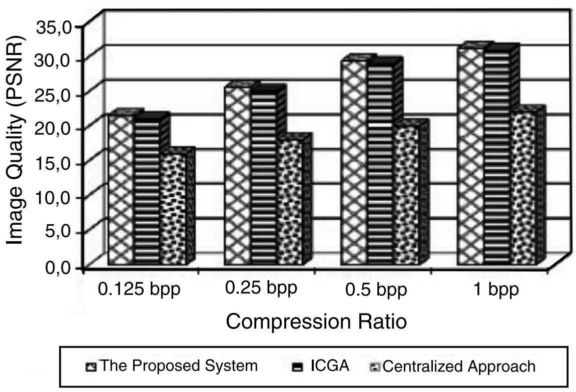

Fig. 5. Image quality comparison of the algorithms for random waypoint mobility model.

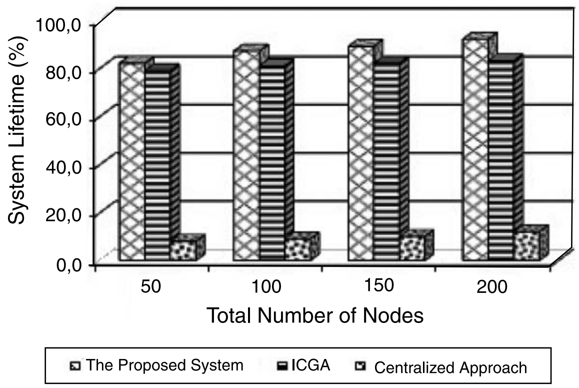

Fig. 6. System lifetime comparison of the algorithms for random waypoint mobility model.

4. Simulations

The proposed and the compared systems namely centralized approach and ICGA are implemented using ns-2 network simulator. Nodes mobility scenarios that include mobility models namely Random Waypoint, Random Direct and Gauss Markov are generated with ANSim. The proposed system, centralized approach and ICGA are compared in terms of energy consumption, system lifetime and image quality parameters on different mobility models and speeds. Image quality is determined by calculating the peak signal to noise ratio (PSNR)[8]. Nodes are distributed randomly to the 5100x1200m network area[1].

Figure 5, shows the quality comparison of the algorithms for random waypoint mobility model. It can be seen from the figure that the proposed system and ICGA perform close the each other while the centralized approach perform worst for each of the compression ratio.

System lifetimes of the algorithms are compared for random waypoint mobility model in Fig. 6. As it can be seen from the figure, system lifetime of the proposed system is the highest for each of the total node numbers. The reason for this is distributing the workload of image transmission process among the sensor nodes. By this way, energy consumptions of the nodes are balanced. It can also be obtained that ICGA performs much better than centralized approach but close to the proposed system.

Figure 7 shows energy consumption comparison of the algorithms for different mobility models and speeds. As it can be seen from the figure, for each of the mobility models and speeds, energy consumption in the proposed system is less than the ICGA and centralized approach. It can also be obtained that for each of the mobility models, as the speed of the node increases, energy consumption also increases. The reason for this is, as the nodes move far away from their head nodes, frequency of reconstructing the clusters also increases. When we compare the mobility models, it can be seen that while the best performance for energy consumption is obtained in gauss markov mobility model, the worst is obtained in random waypoint mobility model. This is because of the reason that, in gauss markov mobility model nodes move also to the borders of the network area rather than moving to the center. By this way, more balanced clustering infrastructure can be achieved.

5. Conclusion

In this study, a system for transmitting and compressing the image data distributedly on a fuzzy logic based based clustering infrastructure is proposed for mobile wireless multimedia sensor networks. The system is composed of two subsystems namely fuzzy logic based clustering infrastucture and distributed image compression and transmission. Considering nodes mobility, dynamic clustering infrastructure and distributed image compression are the main contributions of the proposed system. Besides these, the proposed system is implemented on three different mobility models and compared to ICGA and centralized approach in terms of energy consumption, image quality and system lifetime parameters. When the simulation results are analyzed, it can be seen that for each of the parameters, the proposed system performs best. It can also be seen from the simulation results that energy consumption performance of the nodes is high when they move with gauss markov mobility model. Lastly, as the nodes increase their speeds, energy consumption also increases in all of the systems.

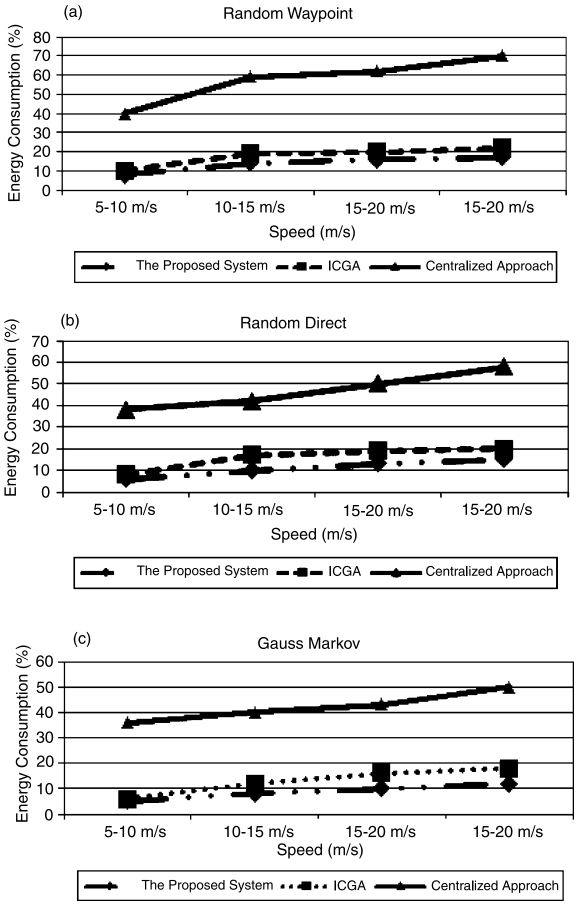

Fig. 7. Energy consumption comparison of the algorithms for different mobility models and the speeds.

References

[1] A. Alaybeyoglu, A distributed image compression algorithm based on a genetic algorithm based clustering infrastructure for mobile wireless multimedia sensor networks, *Life Science Journal* **10**(4) 2013.

[2] H. Taheri, P. Neamatollahi, O.M. Younis, S. Naghibzadeh and M.H. Yaghmaee, An energy-aware distributed clustering protocol in wireless sensor networks using fuzzy logic, *Ad Hoc Networks* **10**(7) (2012), 1469–1481.

[3] Md. Abdul Alim, Y. Wu and W. Wang, A Fuzzy Based Clustering Protocol for Energy-effcient Wireless Sensor Networks, *2nd Int Conf on Computer Science and Electronics Engineering*, 2013, pp. 2874–2878.

[4] V. Godbole, Performance analysis of clustering protocol using fuzzy logic for wireless sensor network, *IAES International Journal of Artificial Intelligence* **I**(3) (2012), 103–111.

[5] R. Mhemed, N. Aslam, W. Phillips and F. Comeau, An Energy Effcient Fuzzy Logic Cluster Formation Protocol in Wireless Sensor Networks, *The 3rd International Conference on Ambient Systems, Networks and Technologies*, 2012, pp. 255–262.

[6] H. Ando, E. Kulla, L. Barolli, A. Durresi, F. Xhafa and A. Koyama, A New Fuzzy-based Cluster-Head Selection System forWSNs, *Int Conf on Complex, Intelligent, and Software Intensive Systems* (2011).

[7] A. Alaybeyoglu, A distributed image compression algorithm For environmental monitoring applications, *Electronics World* **119** (2013), 26–29.

[8] H. Wu and A.A. Abouzeid, Energy effcient distributed image compression in resource-constrained multihop wireless networks, *Computer Communications* **28** (2005), 1658–1668.

[9] A. Karthikeyan, T. Shankar, V. Srividhya and S. Sarkar, Gupte A. Energy effcient distributed image compression using JPEG 2000 in wireless sensor networks, *Journal of Theoretical and Applied Information Technology* **47**(2) (2013).

[10] M. Dabestani and M. Moin, Distributed image compression in wireless sensor networks using intelligent methods, *International Research Journal of Applied and Basic Sciences* **4**(7) (2013), 2011–2017.

[11] E. Sun, X. Shen and H. Chen, A low energy image compression and trans-mission in wireless multimedia sensor networks, *Advanced in Control Engineering and Information Science* **15** (2011), 3604–3610.

[12] I. Gupta, D. Riordan and S. Sampalli, Cluster-head Election using Fuzzy Logic for Wireless Sensor Networks, *Communication Networks and Services Research Conference*, 2005, pp. 255–260.

[13] A. Alaybeyoglu, A Distributed Fuzzy Logic-Based Root Selection Algorithm for Wireless Sensor Networks, *Computers and Electrical Engineering*.

[14] F. Bai and A. Helmy, *A Survey of Mobility Models in Wireless AdhocNet-works*. Wireless Ad Hoc and Sensor Networks, Kluwer AcademicPublishers, 2004.