Journal of Theoretical and Applied Information Technology
15th November 2016. Vol.93. No.1

ISSN: **1992-8645** www.jatit.org E-ISSN: **1817-3195**

A NODE DEPLOYMENT MECHANISM FOR ENERGY-EFFICIENT ROUTING IN HETEROGENEOUS WIRELESS SENSOR NETWORKS

[1]KAKELLI ANIL KUMAR, [2] DR. ADDEPALLI V.N. KRISHNA, [3]DR. K. SHAHU CHATRAPATI

[1*] Associate Professor, Department of CSE, Indore Institute of Science and Technology, Indore, MP, India.

[2] Professor, Department of CSE, FOE, CHRIST University, Bengaluru, KA, India.

[3]Associate Professor & Head, Department of CSE, COE, Manthani, Jawaharlal Nehru Technological University, Hyderabad, TS, India.

E-mail: [1*]anilsekumar@gmail.com, [2]hari_avn@rediffmail.com, [3]shahujntu@gmail.com

ABSTRACT

Military applications are the primary concern of the wireless sensor networks (WSNs). Efficient target object/event monitoring is a primary goal of military systems in unattended and unmanned areas. Heterogeneous wireless sensor network (HTWSN) is an emerging network for efficient enemy object monitoring in sensitive areas of low cost. The performance of HTWSN is mainly depends on the quality of data transmission and better network lifetime. However, after deployment of HTWSN, the network can experience a serious problem known as path failure. Path failure occurs due to high route overhead, which result poor-quality data transmission and increase the node energy consumption. Path failure results route rediscovery and data packet retransmission. The proposed node deployment mechanism for HTWSN has been minimized the route overhead and improved the path quality, quality data packet transmission by avoid the path failure. The proposed node deployment strategy has given better results in terms of 20 % low node energy consumption, 56 % lower route overhead, 22 % higher network lifetime and 17 % higher data packet delivery ratio than the existing node deployment mechanism of IMCC protocol.

Keywords: *Wireless Sensor Network, Target Object Monitoring, Heterogeneous wireless sensor network, IMCC Protocol, Node deployment mechanism.*

1. INTRODUCTION

Wireless sensor network (WSN) is composed with tiny wireless sensor nodes used for sense, monitor the target events in remote locations. The data transmission in WSN takes place from source node (SN) to control station (CS) through multihop. In WSN, the reliable data transmission with high-energy efficiency is the high-priority task. The network lifetime can enhance only by minimize the energy consumption at each node in the network. The node energy consumption depends upon the amount of the data transmission between the SN and DN. For large-size data transmission like image or video, the node has to spend the high-energy cost due to high data processing and transmission overhead at each node. The routing protocols like IMCC [1], AODV [20] and AOMDV [21] are resulting high routing overhead during route discovery phase, which can severely affect the node performance in the network. The node performance is directly proportional to node or network lifetime and throughput. The excess energy consumption at node lowers the network lifetime and throughput. Hence, for a better network lifetime, it is highly essential for introduce the optimization mechanisms in resource constrained WSN. Generally, communication and computation are two major energy-consuming operations in a node for typical WSN. The network lifetime is defined as the number of network rounds initialized and number of rounds network can survive or the difference between the time of network operation start and the time of first node dead due to battery power off. WSN has resulted in limited energy efficiency and poor network performance due to limited resources. To improve energy efficiency and network performance in WSN, a new deployment mechanism is introduced, which is known as heterogeneous wireless sensor network (HTWSN). Heterogeneous wireless sensor network (HTWSN) [1] is specially designed for military applications for efficient monitor the border areas and target events. The proposed deployment having the sensor nodes equipped with a built-in camera for capture the images and low resolution videos of the target events. The sensed data is transmitted from SN to DN though flexible deployed HTWSN. In HTWSN, the sensor nodes have to cover the large sensor area. Due to that, the data transmission can take place from one hop to another hop in a network which is known as multihop communication. Multihop communication [2] helps to distribute the data traffic among multiple nodes. Multihop communication reduces the sensor node energy consumption by involving the many sensor nodes for data transmission. However, multimedia data transmission [3] in HTWSN can severely affect node's battery power due to large-size data. WSN deployment is two types [15] (1) homogenous (2) heterogeneous. Homogeneous deployment results traditional WSN. It is simple deployment mechanism where all the nodes are similar prioritize with equal capabilities. Due to that, homogeneous deployment capable to handle complex multiple events simultaneously for important applications like military and environment. Heterogeneous wireless sensor network (HTWSN) is introduced with few special application-specific sensor nodes in to the existing homogeneous WSN. HTWSN is a highly efficient and low cost network [16, 17] as compared with homogeneous WSN (HOWSN) [4] [5]. HTWSN can deploy in sensitive, unattended or unmanned areas for efficient monitor the target events/ objects. HTWSN has deployed with few specialized sensor nodes for capture high-quality images and videos of targeted events or objects. Due to the combination of multi configure nodes, the proposed HTWSN deployment has improved the network performance and capable to handle complex multiple objects more efficiently. HTWSN is capable for track the target objects up to longer distances, it can process the information quickly and store the information up to longer durations.

2. RELATED WORK

IMCC protocol [1] has been proposed for heterogeneous wireless senor networks by minimize the interference and control the network congestion in military applications. However, IMCC protocol has increased the high node level overhead due to its route discovery mechanism. I2MR [6] has been proposed for high-quality data transmission by minimize the interference through discovering node disjoint paths. The protocol is preferable only for specially designed networks, and not be suitable to all types of applications. H-WSNMS [7] has proposed based on the web-based network architecture for HTWSN for remote data transmission. However, H-WSNMS is unsuitable for all HTWSN deployment mechanisms. Strategy for HTWSN [8] is proposed by UAV introduce for sensor area surveillance. The Strategy has used pheromone-based alarm routing for UAV search and establish the network with ground WSN. Choose the suitable UAV is a challenging task based upon the target objects. Emerging trends in WSN [9] have been presented with diverse research issues and advanced applications in emerging areas. The existing routing mechanisms have resulted high routing overhead during the routing discovery phase. Hence it is highly essential for introduce new mechanism, which can minimize the routing overhead and improve the node performance in a network.

3. IMCC PROTOCOL IN HTWSN DEPLOYMENT FOR MILITARY APPLICATIONS

IMCC is known as interference minimized congestion control routing protocol specially designed and developed for heterogeneous wireless sensor networks for military applications. IMCC protocol has successfully implemented in HTWSN for high-quality data transmission. The network deployment model of IMCC protocol as follows. Large number multi-configured sensor nodes are air dropped into the preferable locations where the target objects (ETOs) may arrive in a sensor field. In proposed deployment, source nodes (SNs) are high-performing nodes in terms of computational power, sensing capability for sense image and video data, battery power and sensing capability [13]. SNs can capture the image of ETOs up to long distances and easily establish the ground network with low performing sensor nodes known as intermediate nodes (INs). The communication resources like bandwidth are provided by unmanned air vehicle (UAV) [8] or base station. The destination node (DN) is located within the network for receive the data packets and forward to CS. DN is capable for data transmission from ground HTWSN to CS through UAV. The proposed HTWSN deployment is highly capable for enemy objects monitor in border areas efficiently, and information can carry forward from SN to DN through the shortest routing path. Based on the received data at CS, the army official can take intelligent decisions for handle the enemy objects in war fields.

4. THE PROPOSED DEPLOYMENT MECHSNISM IN IMCC PROTOCOL

Consider M number of high-performance sensor nodes and N number of low performance sensor nodes in HTWSN. ETOs are the number of target objects in HTWSN. The communication area of a node is A and r is the radius, A= $\Pi * r^2$, $A_{Overlap}$ is the overlapping area the sensor node communication area with other nodes $A_{Overlap} = \Pi * r^2_{overlap}$. The total effective communication area of network is A_T [14, 18].

A_T = (M*N) A_{Eff} where A_{Eff} =A - $A_{Overlap}$ (1)

Efficient communication area $A_{Ratio} = A_{Eff} \setminus A$ (2)

The target objects ETO $_{(1\ to\ n)}$ may enter on to the sensor field. The respective SNs of the locations will sense the ETO $_{(1\ to\ n)}$. For efficient sense ETO $_{(1\ to\ n)}$, SN can divide it A into four quadrants. These quadrants are considered as right up (RU), right lower (RL), left up (LU) and left lower (LL) as shown below figure 1.

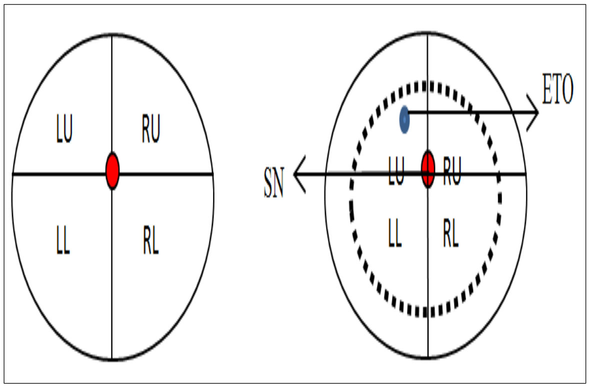

Figure 1: Communication Area Quadrants of Sensor Node

Consider ETO_1 can enter in LU quadrant of the SN. Afterwards, SN can start the sensing operation when ETO_1 may enter the SN's effective communication area A_{Eff}. The existing routing protocols like IMCC and I2MR start the sensing operation when ETO_1 can enter in A. SN does not capture the quality image or video when ETO_1 is out of A_{Eff}. Due to that, SN continues the sensing operation but not receives the quality data. The energy spent for sensing and data transmission operations when ETO_1 is out of A_{Eff} of SN will be unprofitable. This situation can increase the excess energy and memory consumption at SN and all other INs in routing path. This situation can lead to transmission of lower quality data towards DN The poor-quality data are useless and increase the network overhead at each node participating in the routing path. The node level overhead leads to network overhead, which consumes the high memory, energy and lower the network lifetime. The proposed deployment strategy has divided the node communication in to A and A_{Eff}. SN can sense the ETO_1 only when it reaches to A_{Eff}. Hence, with the proposed mechanism, SN utilizes limited battery power and senses the limited high-quality data of ETO_1. After capturing multiple images of ETO_1, SN chooses the best image and transmits to DN otherwise it will discard [10, 14]. This mechanism is highly helpful for minimize the data transmission overhead on each sensor node for improve the node performance in HTWSN with the better node lifetime. In proposed deployment strategy, SN can estimate the distance with ETO based on received signal strength indicator (RSSI) before start data sensing operation. Consider the distance between SN and ETO. If D_{ETO} is less radius of r A_{Eff} then data sensing operation will start. The D_{ETO} is continuously updated in the routing table and estimates the mean distance factor D_{MEAN} as per equation 3.

$$D_{MEAN} = \begin{cases} \frac{D_{ETO}}{r}, \text{where } 0.1 \geq D\ MEAN \leq 0.5 \\ 0, \text{ where } D\ MEAN \geq 0.5 \end{cases} \quad (3)$$

$D_{MEAN} \leq 0.5$ is a threshold value of SN for data sensing operation to capture the high-quality image/video as shown in figure 1. With this mechanism, SN holds the data sensing till the ETO $_{(1\ to\ n)}$ can reach the preferable location for capture high-quality data. Once ETO $_{(1\ to\ n)}$ reaches the effective communication area from interference area, SN starts the data sensing operation. The proposed technique is helpful to minimize the node level overhead and achieves a better node lifetime. The high-quality images can be generated by each SN only when $D_{MEAN} \leq 0.5$. Simultaneously, all SNs can detect ETO $_{(1\ to\ n)}$ and transmit the high-quality data to DN.

5. QULAITY IMPROVEMENT IN ROUTING AND DATA TRANSMISSION WITH PROPOSED MECHSNSIM

When ETO $_{(1\ to\ n)}$ enters in A of node N_i in HTWSN [12], N_i send awake acknowledgement to the nearest SN. Afterwards, SN can identify the ETO $_{(1\ to\ n)}$ belong to the quadrant and estimate D_{MEAN} before sense ETO $_{(1\ to\ n)}$.

$$ETO_{(1\ to\ n)} = \begin{cases} ETO_{1\,to\,n} \in LU, \\ ETO_{1\,to\,n} \in RU, \\ ETO_{1\,to\,n} \in LL \\ ETO_{1\,to\,n} \in RL \\ 0, \quad otherwise \end{cases} \qquad (4)$$

If $D_{MEAN} > 0.5$, SN wait and simultaneously starts the route discovery phase by release the route request RREQ to the neighbor nodes. These neighbor nodes belong to the range $D_{MEAN} \leq 0.5$. With the proposed mechanism, RREQ overhead on each neighbor node can be reduced drastically, which is helpful to prolong the node lifetime. Consider E_S, E_P, E_{TX}, and E_{RX} are the energy required for sense, process, transmission and receiving of image data i of node N_1, E_C is total energy cost required for image data i by the node N_1.

$$E_C = \{E_S + E_P + E_{TX} + E_{RX}\} \qquad (5)$$

$$E_C(i_n) = E_C * (\textstyle\sum_{i=1}^{i=n} i_n) \qquad (6)$$

E_T is the energy cost for single routing path in HTWSN. $E_{C\ single\ path} = N_{P1} * E_C$, N_{P1} is the number of sensor participated in single path routing. In multipath routing scheme, $E_{C\ multipath} = (P * N_{P1} * E_C)$, P is number of multiple active paths from SN to DN. η is the size of images data (in bits) send through routing path P, t_i and t_f are the initial and final time of image sense, and total energy cost E_T is estimate with the equations 7 and 8.

$$E_{T\ Single\ path} = \sum_{ti}^{tf} E_{C\ for\ single\ path} * \eta \qquad (7)$$

$$E_{T\ Multipath} = \sum_{ti}^{tf} E_{C\ for\ multiple\ path} * \eta$$

is the routing path between SN and DN [11] [2].

$$E_R = E_{T\ Multipath} - E_C \qquad (9)$$

$$RPL_1 = \{E_{T\ P1} * (n * IN_i)\} \qquad (10)$$

Hence, RPL is proportional to the active node's lifetime in a path. E_R threshold value is above 50 % of E_R in proposed mechanism. The E_R of the node in the active path may change with respect to simulation time. Consider E_R of a node N_1 during the HTWSN deployment is $N_{(RI)}$, E_R during route construction $N_{(RRC)}$, and E_R after data transmission i_n is $N_{(RF\ n)}$. E_R and E_{RF} are the initial and final residual energy of a node N_1 in the active routing path.

$$E_R = N_{(RRC)} / N_{(RI)} * 100 \qquad (11)$$

$$E_{RF} = N_{(RF\ n)} / N_{(RRC)} * 100 \qquad (12)$$

HTWSN is deployed with the network size of M* N nodes. M are specialized sensor nodes and N are normal sensor nodes. CL communication links between M and N nodes. DP_n is the number of data packet transmission through the routing path RP_n in the network.

$$RP_n = \textstyle\sum_1^n (CL_{1\ n} + IN_{1\ n}) \text{ where } n \leq 3 \qquad (13)$$

$$DP_n = \{SN_n \rightarrow IN_{11}\}.CL_{11} + \{IN_{11} \rightarrow IN_{12}\}.CL_{12} + \{IN_{12} \rightarrow IN_{13}\}.CL_{13} + \{IN_{13} \rightarrow \ldots IN_{1,\ n-1}\}.CL_{1,\ n-1} + \{IN_{1,\ n-1} \rightarrow IN_{1,\ n}\}.CL_{1,\ n} \qquad (14)$$

Let T_s and T_r are the time of DP_n send from SN and received by DN. Consider RP_{Delay}, $RP_{Agg.\ Delay}$, $RP_{Throughput}$ are end to end delay, routing path aggregate and routing path throughput are estimated as

$$RP_{Delay} = T_r - T_s \qquad (15)$$

$$RP_{Agg.\ Delay} = RP_{Delay} / DP_n \qquad (16)$$

$$RP_{Throughput} = \{DP_n \text{ received by } DN * DP_n \text{ send by } SN\} \qquad (17)$$

DP_n in bits are number of data packets transmitting from through routing path P from SN to DN. Network overhead is considered as a node overhead IN_{load} in RP_n is estimated with equation 18. DP_{Delay} is the time of data packet residing time at each IN in RP.

$$IN_{load} = DP_n * DP_{Delay} \qquad (18)$$

$$RP_{Delay} = \sum DP_{Delay} \qquad (19)$$

With the proposed deployment mechanism, the network overhead on each IN in the routing path has minimized and achieved the better network lifetime.

6. EXPERIMENTATION AND RESULT ANALYSIS

All of our experiments are based on simulations with static HTWSN in MATLAB R2010b [19] with SIMULINK tool. The simulation parameters are shown in below Table 1.

Table 1: Network Simulation Parameters

No. of SNs	2 to10
No. of INs	100 to 500
No. of DN	1
Area of Terrain	100*100 m^2
Deployment	Random
Propagation limit	-111
Noise level	10
Radio type	Radio-Accnoise
Bandwidth	244.14KB
Frequency	2.4 ISM GHz
Routing Protocol	IMCC

The proposed deployment mechanism is implemented in IMCC routing protocol [1] for all experiments. IMCC protocol has been proposed for quality data transmission, but the protocol has experienced high network overhead during high data traffic conditions. The proposed mechanism in IMCC protocol is analysed through the performance metrics such as node level energy consumption, network overhead, network lifetime and successful data packet delivery ratio. In figure 2, the energy consumption at each sensor node in HTWSN is estimated and compared the results with proposed deployment mechanism and without proposed mechanism. The proposed deployment technique has given better network performance in terms of a network lifetime than existing technique under high network size.

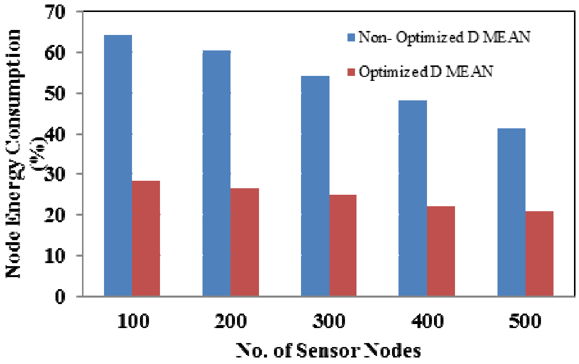

Figure 2: Comparison of Energy Consumption of Each Sensor Node in HTWSN with The Existing And Proposed Deployment Mechanisms

The routing overhead minimization is the most important parameters for analyses the proposed mechanism. Figure 3 is shows that, the proposed mechanism has reduced 56 % routing overhead or network overhead as compared with existing routing mechanism in IMCC protocol.

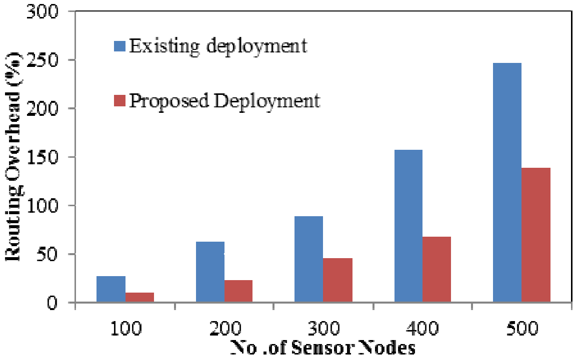

Figure 3: Minimization Routing Overhead Comparison between the Existing and Proposed Deployment Mechanisms

Network lifetime is the most important achievement for any routing protocol in WSN and HTWSN. The proposed deployment technique has improved 22% higher network lifetime in HTWSN with IMCC protocol. The proposed mechanism has achieved the higher network lifetime by improving the node performance in the network as shown in figure 4.

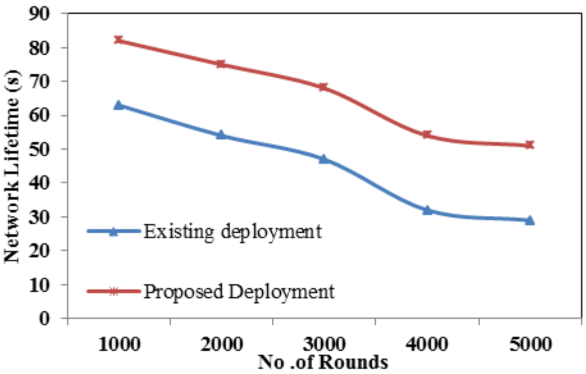

Figure 4: Comparison of Network Lifetime with No. of Simulation Rounds between the Existing and Proposed Deployment Mechanisms

High data packet delivery ratio (PDR) is an important characteristic for any routing protocol in WSN and HTWSN. The proposed mechanism has improved the PDR up to 17% higher than existing mechanism in IMCC protocol for HTWSN. The results are given in figure 5.

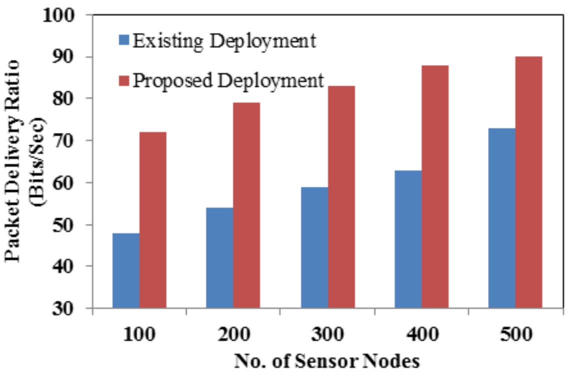

Figure 5: Comparison of Packet Delivery Ratio between the Existing and Proposed Deployment Mechanisms

7. CONCLUSION AND FUTURE DIRECETIONS

The proposed node deployment mechanism for heterogeneous wireless sensor network (HTWSN) has successfully implemented in IMCC protocol. IMCC protocol is introduced with an efficient route discovery mechanism for military application for monitor the enemy objects. However, the protocol experienced the high network overhead. Our proposed new deployment mechanism has improved the performance of IMCC protocol and given better results in terms of 20 % lower energy consumption ay each node, 56 % lower network overhead, 22 % higher network lifetime and 17 % higher data packet delivery ratio. The proposed node deployment mechanism for IMCCS protocol has given satisfactory results under the high data traffic conditions with various simulation parameters.

In our future work, the proposed deployment mechanism has to implement for large network size HTWSN up to 5000 nodes with high data traffic conditions, variable simulation parameters and more target objects. The proposed new deployment strategy has successfully implemented in IMCC protocol, and it is to be tested with other routing protocols like AOMDV and IM2PR.

REFERENCES:

[1] Kakelli Anil Kumar, "IMCC protocol in heterogeneous wireless sensor network for high quality data transmission in military applications", In: 1st IEEE International Conference on Parallel, Distributed and Grid Computing, 2010, pp. 339–343.

[2] P. Bhuvaneswari and P. Thirumoorthy, "A Secure and Energy Efficient Multihop Communication in Wireless Sensor Networks (WSN)" Middle-East Journal of Scientific Research, 2016.

[3] Lei Shu, Yan Zhang, Zhangbing Zhou, Manfred Hauswirth, Zhiwen Yu, Gearoid Hynes, "Transmitting and Gathering Streaming Data in Wireless Multimedia Sensor Networks within Expected Network Lifetime", Springer, Mobile Network Applications, 2008, vol 13, pp 306–322.

[4] Kakelli Anil Kumar , Addepalli V. N. Krishna, K. Shahu Chatrapati, "Interference Minimization Protocol in Heterogeneous Wireless Sensor Networks for Military Applications", Springer, 2016, vol 51, pp 479-487.

[5] Kakelli Anil Kumar , Addepalli V. N. Krishna, K. Shahu Chatrapati, "Congestion Control in Heterogeneous Wireless Sensor Networks for High-Quality Data Transmission", Springer, 2016, vol 439, pp 429-437.

[6] Jenn-yue teo,yajun Ha and chen- knong tham, "Interferences minimization multipath Routing with congestion control in Wireless sensor network for high rate streaming", IEEE transactions on mobile computing, 2008, vol 7, no.9.

[7] Wei Zhao, Yao Liang, Qun Yu, and Yan Sui, "H-WSNMS: A Web-Based Heterogeneous Wireless Sensor Networks Management System Architecture", In proceedings of

International Conference on Network-Based Information Systems, 2009, pp 155-161.

[8] Edison Pignaton de Freitas, Tales Heimfarth, Carlos Eduardo Pereira, Armando Morado Ferreira, Flávio Rech Wagner, Tony Larsson, "Evaluation of Coordination Strategies for Heterogeneous Sensor Networks Aiming at Surveillance Applications", In proceedings of IEEE Conference on Sensors, 2009.

[9] Edwin Prem Kumar Gilbert, Baskaran Kaliaperumal, and Elijah Blessing Rajsingh, "Research Issues in Wireless Sensor Network Applications: A Survey. International Journal of Information and Electronics Engineering", 2012, vol. 2, No. 5.

[10] Raghavendra V. Kulkarni, Ganesh Kumar Venayagamoorthy, "Particle Swarm Optimization in Wireless Sensor Networks: A Brief Survey", IEEE transactions on systems, man and cybernetics, 2010.

[11] Shilpa Mahajan, Dr. Jyoteesh Malhotra, "Energy Efficient Control Strategies in Heterogeneous Wireless Sensor Networks: A Survey", International Journal of Computer applications, 2011, vol 14, No.6, pp 0975 – 8887.

[12] Mark Yarvis, Nandakishore Kushalnagar, Harkirat Singh, Anand Rangarajan, York Liu, Suresh Singh, "Exploiting Heterogeneity in Sensor Networks", In proceedings of 24th IEEE Annual Joint Conference of the IEEE Computer and Communications Societies, 2005, vol 2, pp 878-890.

[13] Bulent Tavli & Kemal Bicakci & Ruken Zilan & Jose M. Barcelo-Ordinas, "A survey of visual sensor network platforms", Springer, Multimed Tools Applications, 2011.

[14] Gaojuan Fan, Ruchuan Wang, Haiping Huang, Lijuan Sun and Chao Sha, "Coverage-Guaranteed Sensor Node Deployment Strategies for Wireless Sensor Networks, Journal of Sensors, 2010, MDPI, vol 10, pp 2064-2087.

[15] N. Alsharabi, L. R. Fa, F. Zing, and M. Ghurab, "Wireless sensor networks of battlefields hotspot: challenges and solutions", In proceedings of Sixth International Symposium on Modeling and Optimization in Mobile ad_hoc and Wireless Networks and Workshops, pp.192-196.2008

[16] Alsharabi,N., "HYMAC: Hybrid TDMA/FDMA Medium Access Control Protocol for Wireless Sensor Networks", In proceedings of 6th International Symposium on Modelling and Optimization in Mobile Ad Hoc, and Wireless Networks and Workshops, 2008.

[17] Zhi Sun a, Pu Wang, Mehmet C. Vuran, Mznah A. Al-Rodhaan, Abdullah M. Al-Dhelaan, Ian F. Akyildiz, "Border Sense: Border patrol through advanced wireless sensor networks", Elsevier, Ad Hoc Networks, 2011.

[18] Nor Azlina Ab. Aziz, Kamarulzaman Ab. Aziz, and Wan Zakiah Wan Ismail, "Coverage Strategies for Wireless Sensor Networks, World Academy of Science, Engineering and Technology, 2009, vol:3, pp 2009-02-23.

[19] Madhupreetha L. Rajaram, " Wireless Sensor Network Simulation Frameworks: A Tutorial Review: MATLAB/Simulink bests the rest", IEEE Consumer Electronics Magazine, 2016, vol 5, pp 63 – 69.

[20] S.J. Lee and M. Gerla, "AODV-BR: Backup Routing in Ad Hoc Networks," in Proceedings of IEEE international conference Wireless Communications and Networking Conf. (WCNC '00), 2000, pp 1311-1316.

[21] M. Marina and S. Das, "On-Demand Multipath Distance Vector Routing in Ad Hoc Networks", in Proceedings of IEEE International Conference Network Protocols (ICNP' 01), 2001, pp. 14-23.