2015 13th International Conference on Frontiers of Information Technology

Impact of Mobility on Energy and Performance of Clustering-Based Power-Controlled Routing Protocols

Atta ur Rehman Khan[*,1], Abdul Nasir Khan[2], Saad Mustafa[2], S. Khaliq uz Zaman[2]
[1]College of Computer & Information Sciences, King Saud University, Saudi Arabia.
[2]Department of Computer Science, COMSATS Institute of Information Technology, Abbottabad, Pakistan.

dr@attaurrehman.com, anasir@ciit.net.pk, saadmustafa@ciit.net.pk, skhaleeq@ciit.net.pk

***Abstract*— This paper presents a performance analysis of cluster-based power-controlled routing protocols for wireless sensor networks. The selected protocols are analyzed using various mobility models to investigate the impact of mobility on the packet delivery ratio, packet loss, and network lifetime of WSNs. The results show that power-controlled routing protocols perform better than the fixed-power protocols for different mobility models. Moreover, the mobility models incur significant impact on the performance and energy efficiency of the clustering-based power-controlled routing protocols.**

Keywords- Sensor networks; clustering; Power-Controlled Routing (PCR); Enhanced Power-Controlled Routing (EPCR); routing; power-controlled; mobility models.

I. INTRODUCTION

Wireless sensor network (WSN) is a popular class of ad-hoc networks, which is used in multiple domains, namely but not limited to military, habitat, healthcare, smart homes, safety, and transportation [1]. WSN consists of a large number of sensor nodes, deployed in a defined area to monitor a physical phenomenon. Sensor nodes are usually deployed in remote inaccessible and hostile environments due to which the battery replacement processes is not feasible, laborious, or costly [2].

Despite the remarkable advancement in technology, limited energy is one of the critical outstanding issues in WSNs [3]. Consequently, researchers proposed numerous protocols to minimize the energy consumption of the sensor nodes and prolong the network lifetime. These protocols can be broadly classified into two main categories, namely **(a)** hierarchical, and **(b)** flat routing protocols. Hierarchical routing protocols are preferred over flat routing protocols due to scalability and energy efficiency.

Clustering based protocols are among the most popular hierarchal protocols [4]. In mobile networks, the performance of clustering based protocols suffers due to packet loss during the intra-cluster and inter-cluster communications. However, the impact of mobility models on the performance and energy efficiency of the clustering-based power-controlled routing protocols is still unexplored.

In this paper, we select three clustering-based routing protocols (one fixed power, two power-controlled) to analyze their behavior in terms of network lifetime, packet loss, and packet delivery ratio. The selected protocols are analyzed by varying the nodes speed and mobility models. Through extensive simulations, it is concluded that power-controlled routing protocols provide better network lifetime as compared to fixed-power protocols, but may experience high packet loss and low packet delivery ratio. However, in presence of a recovery mechanism, power-controlled routing protocols can supersede fixed-power protocols in all performance metrics, namely network lifetime, packet loss, and packet delivery ratio. It is also observed that in power-controlled routing protocols, mobility models and variable node speeds have significant impact on the network lifetime, whereas in fixed-power routing case, the nodes speed have no impact on the network lifetime.

The paper is organized in five sections. Section II presents the related work. Section III explains the comparison strategy. Section IV presents the simulation results, and Section V concludes the paper.

II. RELATED WORK

A given protocol may perform well in one environment, but may fail in another [5, 6]. Likewise, a protocol may perform well under one mobility model, but may fail under another, or may show degraded performance. The reason is that the performance of wireless routing protocols for mobile environments highly depends on the mobility models, which may affect the packet delay, packet delivery ratio, and control overhead of the routing protocols [7, 8].

In [13], the authors highlighted the importance of the underlying mobility models. They highlighted seven synthetic entity mobility models and five group mobility models. Through extensive simulations, the authors concluded that the random waypoint mobility model provides the highest packet delivery ratio and lowest end-to-end delay.

In [14], the authors investigated the impact of mobility models on the performance of the network and applications. Through extensive simulations, the authors concluded that the mobility patterns affect the routing protocols in different ways, because they alter the physical link dynamics and cluster stability. Consequently, the performance ranking of the routing protocols depends on the selection of the mobility model.

In [15], the authors simulated a single routing protocol for different mobility models. The simulation results concluded that the performance of the protocols not only varies on the basis of mobility models, but also on the basis

978-1-4673-9666-0/15 $31.00 © 2015 IEEE
DOI 10.1109/FIT.2015.51

of the parameters of a single mobility model. Therefore, the routing protocols must be simulated using mobility models that are closer to their real world applications.

In [16], the authors simulated position and non-position based fixed-power routing protocols using different mobility models. Through extensive simulations, the authors concluded that position based routing protocols perform better as compared to non-position based protocols, irrespective of the mobility model used.

To best of our knowledge, there is no study on the impact of mobility models on the performance and energy efficiency of the clustering-based power-controlled routing protocols. To proceed with the experiments, we first need to understand the working of the hierarchical routing protocols.

The key design feature of the hierarchical routing protocols is the cluster formation. To do so, the sensing environment is divided into logical blocks called clusters. From each block, a node is selected as a cluster head and the rest of the nodes (of that block) are associated with the cluster head. These nodes are called normal nodes which are responsible for sensing information. In intra cluster communication phase, the sensed information is sent to the cluster head. Similarly, the cluster head propagates the received information to other cluster heads in inter cluster communication phase. Having the basic concepts on hand, we precede to the discussions of the routing protocols.

To investigate the impact of mobility on energy and performance of clustering-based power-controlled routing protocols, we have selected three routing. One of the selected protocols is based on fixed-power communications, while the other two uses variable power during communications. The former is called Distributed Efficient Multi hop Clustering protocol (DEMC) [13], while the later are called Power-Controlled Routing (PCR) and Enhanced Power-Controlled Routing (EPCR) [1]. In DEMC, fixed-power communications are performed in all phases of the clustering process. Alternatively, in PCR and EPCR, fixed-power communications are employed in the clustering phase, but when the ordinary nodes send their data to their respective cluster-heads, they change their transmission power according to the distance from their respective cluster-heads. In PCR, the nodes are associated with the cluster-head on the basis of weight, while in EPCR, it is done on the basis of distance. Due to space limitations, we advise readers to see [1] for more detailed working on the aforementioned protocols.

III. COMPARISON STRATEGY

For the performance analysis of the selected protocols, we considered three performance metrics and three mobility models. The performance matrices and mobility models are discussed as follows.

A. Performance Metrics

The following metrics were used to evaluate the performance of the selected protocols.

1) Network lifetime

This parameter represents energy efficiency and (indirectly) reliability of a protocol. Network lifetime represents a state of the network where a pre-defined percentage of the total network nodes become dead. The network lifetime is measured with respect to increasing mobility and number of nodes.

2) Packet loss

This performance metric helps to find the reliability of a protocol. Therefore, the lower the packet loss of a protocol, the more it is reliable. The packet loss is measured in terms of percentage, where the number of lost packets is divided by the total number of sent packets.

3) Packet delivery ratio

It helps to find the performance of a protocol. A good routing protocol must have a packet delivery ratio of one. Therefore, the closer the packet delivery ratio of a protocol to one, the higher is its performance. The packet delivery ratio of a protocol is calculated by dividing the total number of received packets by the total number of sent packets.

B. Mobility Models

To analyze the impact of mobility on the performance of the routing protocols, we used the following mobility models.

1) Random Way Point Mobility Model

In this mobility model [14], the nodes move with a random speed towards a randomly selected destination. When the destination is reached, the nodes wait for a particular period of time and then moves again towards another randomly selected destination. This mobility model does not consider mass of the nodes. Therefore, the nodes can start, stop, or turn instantaneously without following physical laws.

2) Mass Mobility Model

Mass mobility model [14] is a variant of the random waypoint mobility model. In this model, the nodes act as they have a mass due to which they cannot start, stop, or turn instantaneously. This model is more realistic as compared to the random waypoint mobility model.

3) Linear Mobility Model

In linear mobility model [14], the nodes move on a straight path with a defined angle. When the nodes hit any obstacle, they change their path and move in a different direction with the same angle.

IV. SIMULATION AND RESULTS

The simulations were performed using OMNET++ and INET framework [15]. We performed uniform distribution of the nodes in a network field of 1000m × 1000m. The network lifetime is defined as the time when 10% of the network nodes are dead. For energy consumption measurement, we used first order radio model [16]. Figure 1 presents cluster formation in OMNET++ simulation environment.

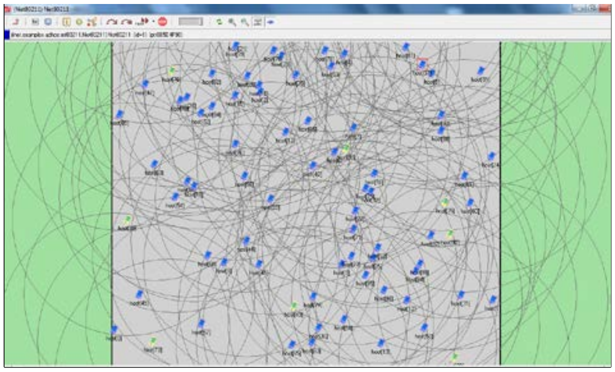

Figure 1. OMNET++ simulation environment

A. *Performance of the Protocols under Different Mobility Models*

In this section, we analyze the performance of the selected protocols under different mobility models.

1) Random Waypoint Mobility

Figure 2 shows network lifetime with respect to variable number of nodes. It is observed that the network lifetime of DEMC is very low as compared to PCR and EPCR protocols. The primary reason for this behavior is that DEMC uses fixed transmission power in all (communication) phases, whereas PCR and EPCR use variable transmission power. As low transmission power consumes less energy, PCR and EPCR perform energy efficient communications and prolong the network lifetime. Moreover, the network lifetime of the network increases along with increase in the number of nodes.

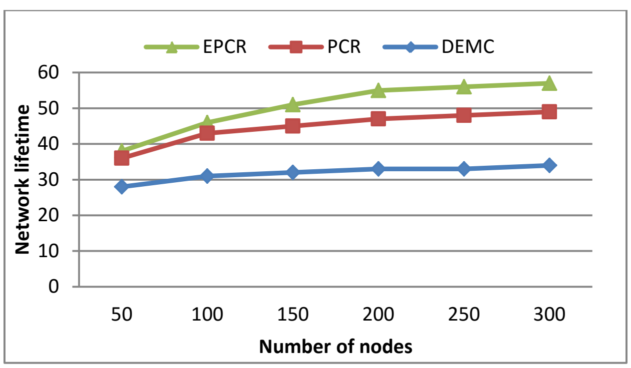

Figure 2. Network lifetime with respect to increasing number of nodes

Figure 3 shows network lifetime with respect to variable speed of the nodes. As DEMC uses fix transmission power, its network lifetime remains the same for all speeds. Alternatively, PCR and EPCR perform well under low mobility. However, increase in node speed also decreases network lifetime of PCR and EPCR. The aforementioned behavior is because of the increase in distance between the nodes and their respective cluster-head. Therefore, the nodes transmit with high power reduces the energy efficiency gained via variable transmission power technique.

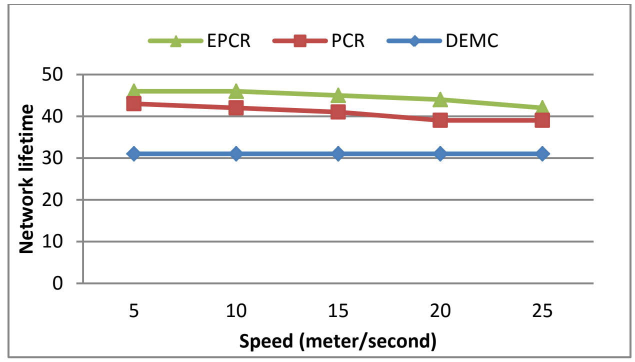

Figure 3. Network lifetime with respect to increasing speed

Figure 4 presents packet loss with respect to increasing speed. It is evident that there is a major difference between the packet loss of DEMC and PCR. The primary reason for this behavior is that PCR uses variable transmission power during the communications, and transmits with sufficient power to deliver the packets. However, due to network mobility, there is a probability that the cluster-head or the associated nodes move out of the transmission range of each other. This probability increases along increase in the nodes speed which raises the packet loss. In EPCR, this issue is handled by using a recovery mechanism which improves connectivity and reduces packet loss. Consequently, there is a minor difference between the packet loss of DEMC and EPCR.

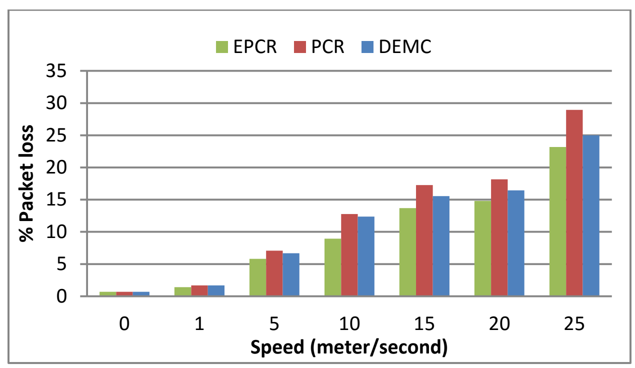

Figure 4. Packet loss with respect to increasing speed

Figure 5 presents packet delivery ratio with respect to increasing speed. As discussed earlier, the packet loss increases with the increase in mobility. Consequently, the packet delivery ratio decreases with the increase in packet loss. The important point is that the packet delivery ratio of the selected protocols is not exceeding one, but it decreases along increase in the speed.

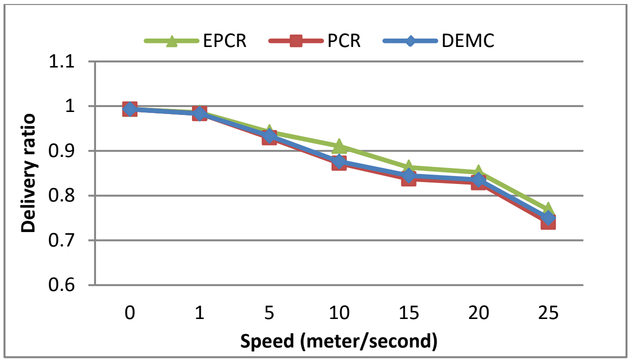

Figure 5. Packet delivery ratio with respect to increasing speed

2) Mass Mobility

Figures 6-9 presents the performance and energy efficiency of the selected protocols using mass mobility model. It is evident that EPCR shows the highest energy efficiency followed by PCR and DEMC, respectively. The reasons for such behavior are already discussed in the previous section.

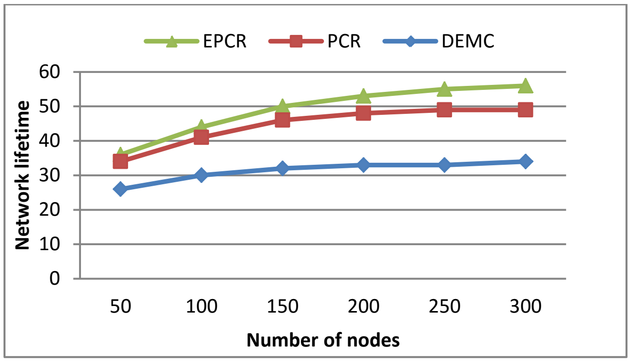

Figure 6. Network lifetime with respect to increasing number of nodes

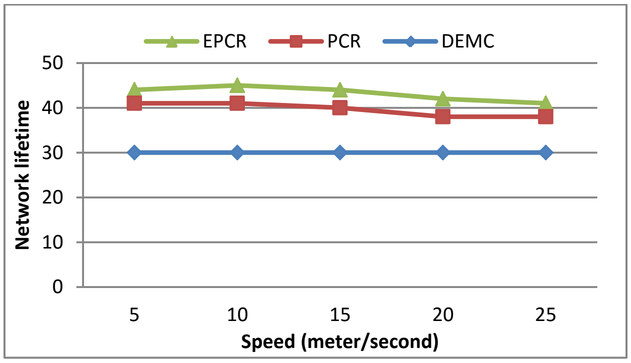

Figure 7. Network lifetime with respect to increasing speed

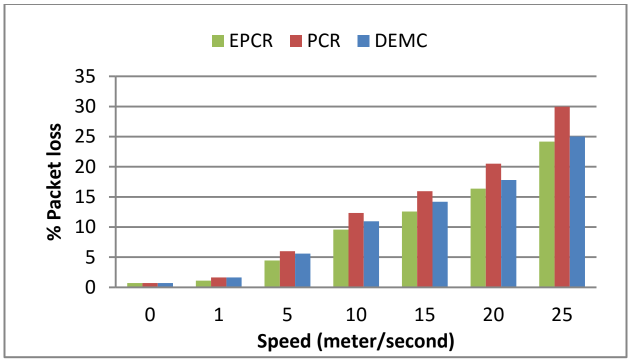

Figure 8. Packet loss with respect to increasing speed

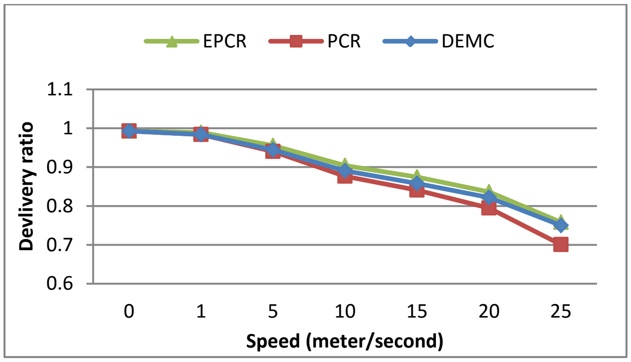

Figure 9. Packet delivery ratio with respect to increasing speed

3) Linear Mobility

Figures 10-13 presents the performance and energy efficiency of the selected protocols using linear mobility model. Similarly, EPCR supersedes in terms for energy efficiency followed by PCR and DEMC. However, in terms of performance, DEMC supersedes the PCR due to absence of a recovery mechanism.

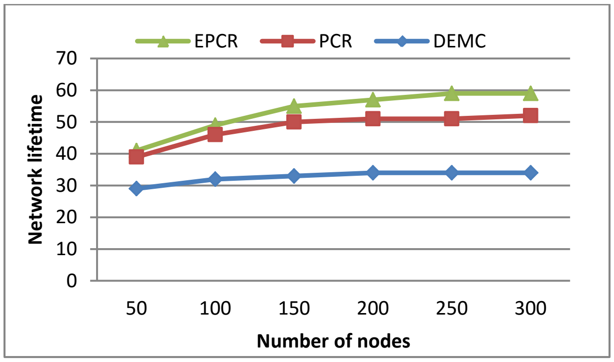

Figure 10. Network lifetime with respect to increasing number of nodes

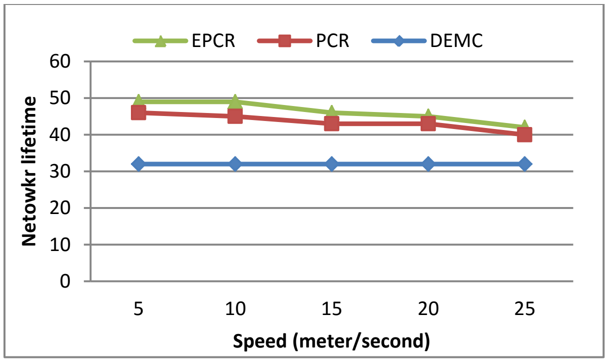

Figure 11. Network lifetime with respect to increasing speed

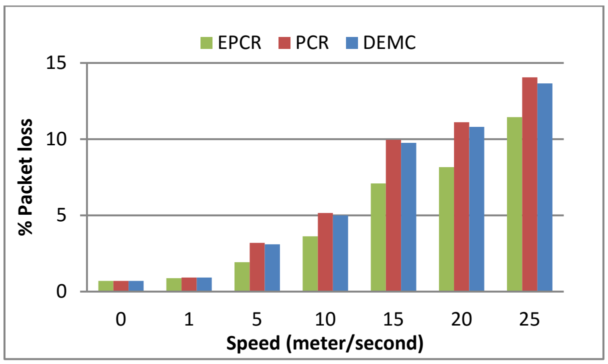

Figure 12. Packet loss with respect to increasing speed

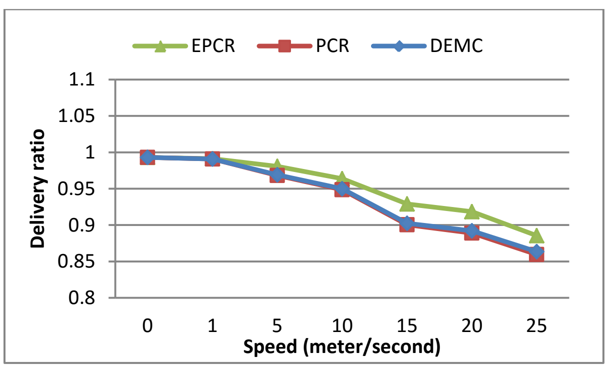

Figure 13. Packet delivery ratios with respect to different speeds

The selected protocols showed almost similar behavior for different mobility models. Therefore, it can be concluded that cluster-based power-control routing protocols (in the presence of a recovery mechanism) perform better than the fixed-power routing protocols. Moreover, the performance and energy efficiency of the routing protocols vary based on the selected mobility model. The selected protocols showed best performance and energy efficiency in presences of linear mobility model, followed by random waypoint mobility model, and mass mobility model, respectively.

V. Conclusions

We compared clustering-based power-controlled and fixed-power protocols to analyze the impact of mobility models on their performance and energy efficiency. Simulation results show that the cluster-based power-controlled routing protocols perform better than the fixed-power routing protocols in terms of network lifetime, no matter what mobility model is used. However, the overall network lifetime of the protocols may vary based on the selected mobility model, without affecting the overall behavior. Likewise, power-controlled routing protocols supersede in terms of low packet loss and packet delivery ratio in the presence of a recovery mechanism. However, in the absence of a recovery mechanism, the packet delivery ratio of power-controlled and fixed-power routing protocols may supersede each other, depending on the selected mobility model.

References

[1] K. Atta Ur Rehman, M. Sajjad, H. Khizar, K. Samee Ullah, “Clustering-based power-controlled routing for mobile wireless sensor networks. International Journal of Communication Systems (IJCS),” vol. 4, no. 25, 2012, pp. 529-542, 2011.

[2] F. Tashtarian, A.T. Haghighat, M.T. Honary, H. Shokrzadeh, "A New Energy-Efficient Clustering Algorithm for Wireless Sensor Networks," 15th International Conference SoftCOM on Software, Telecommunications and Computer Networks, September 2007, pp.1 - 6.

[3] Q. Wang, W. Yang, "Energy Consumption Model for Power Management in Wireless Sensor Networks," 4th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks, June 2007, pp. 142 – 151

[4] A. Shahzad, M. Sajjad Ahmad, K. Atta ur Rehman, K. Imran Ali, "Routing Protocols for Mobile Sensor Networks: A Comparative Study," in International Journal of Computer Systems Science and Engineering, vol. 29, no. 1, pp. 91-100, 2014.

[5] T. Paczesny, D. Paczesny, J. Weremczuk, R. Jachowicz, “Position-based Routing Protocol for Low Power Wireless Sensor Networks,” Journal of Universal Computer Science, vol. 16, no. 9, 2010, pp.1215-1233

[6] K. Atta ur Rehman, A. Shahzad, M. Saad, M. Sajjad Ahmad, "Behavior of clustering based routing protocols with respect to different mobility models in mobile WSNs," in Proceedings of the International Conference on Intelligence and Information Technology, October 2010, pp.404-406.

[7] A. Shahzad, M. Sajjad, “Distributed Grid based Robust Clustering Protocol for Mobile Sensor Networks,” International Arab Journal of Information Technology (IAJIT), vol.9, No.2, October 2011.

[8] K. Atta ur Rehman, A. Shahzad, M. Saad, O. Mazliza, "Impact of mobility models on clustering based routing protocols in mobile WSNs," in Proceedings of the IEEE Frontiers of Information Technology, December 2012, pp. 366-370.

[9] C. Tracy, B. Jeff, D.Vanessa, “A Survey of Mobility Models for Ad hoc Network Research. Special Issue on Mobile Ad hoc Networking: Research, Trends and Applications,” Journal of Wireless Communications and Mobile Computing, 2002, pp. 483-502.

[10] H. Xiaoyan, G. Mario, P. Guangyu, C.A. Ching-Chuan, “Group Mobility Model for Ad HocWireless Networks,” Proceedings of the 2nd ACM international workshop on Modeling, analysis and simulation of wireless and mobile systems, 1999, pp-53-60.

[11] S. Giordano, I. Stojmenovic, “Position based routing in ad hoc networks, a taxonomy”, Ad Hoc Wireless Networking, 2004, pp. 103-136.

[12] S. Basagni, “Distributed clustering for ad hoc networks,” International Symposium on Parallel Architectures, Algorithms, and Networks, 1999, pp. 310-315.

[13] A. Shahzad, M. Sajjad, "Distributed Efficient Multi hop Clustering Algorithm for Mobile Sensor Networks," International Arab Journal of Information Technology (IAJIT) vol.8, No.3, July 2011.

[14] A. Varga, "The OMNeT++ Discrete Event Simulation System," Proc. European Simulation Multiconference (ESM 2001), Prague, Czech Republic, 2001.

[15] K. Atta ur Rehman, B. Sardar Mohammad, O. Mazliza, "A Performance Comparison of Open Source Network Simulators for Wireless Networks," in Proceedings of the IEEE International Conference on Control System, Computing and Engineering, November 2012, pp. 34-38.

[16] W. Heinzelman, A. Chandrakasan, H. Balakrishnan (2000), "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," 33rd Hawaii International Conference on System Sciences, 2000.