An Optimization Technique for Routing in Mobile Wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSNs) becomes a very popular technology and enabling new applications in this era. It is highly demanding in the civil and military applications. WSN nodes may be mobile. So it can be called Mobile Wireless Sensor Network (MWSN). MWSNs require unconventional protocols due to several environmental constraints. A proper balance between communication and signal/data processing capabilities must be found. In this paper, four of the most important performance metrics of MWSNs was analyzed and tested to observe and compare the throughput, Packets delivery fraction, average end to end delay and normalized routing loads of the Network. It was implemented to compare the network's behavior with five routing protocols (DSR, DSDV, AODV, OLSR and AOMDV) to select the best routing protocol from the point of view of the user. This was done with the help of simulation results derived by using Network Simulator (NS-2) for certain proposed Network Model in different scenarios.

The purpose of this paper is to build a mathematical model that can be used to select the optimal number of required nodes, optimal speed and optimal pause time for each new designed Wireless Sensor Network. New mathematical models were developed depending on these metrics to find certain output values. The final simulation results showed that this model is more flexible and efficient in designing the optimal routing protocol (which is the best among the available routing protocols) for any new designed MWSN.

Keywords: *Wireless Sensor Networks, performance metrics, mathematical modeling, optimal choice, simulation.*

Introduction

Wireless technology is simplifying the networking by enabling different users to simultaneously share resources without intrusive wiring. Mobile Ad hoc network (MANET) was defined as a system of wireless mobile nodes that connected among each other in a wireless manner without any infrastructure devices [1]. Any WSN can be described as a wireless network of nodes that cooperatively sense and may control the environment enabling interaction between computers (sensors). Wireless Sensor Networks (WSNs) offer a powerful combination of distributed sensing, computing and communication [2]. It becomes a very popular technology and enabling new applications in this era. MWSN is highly demanding in many civil and military applications especially in the field of monitoring, observing, controlling and risky experimenting. The transmitted data packets can reaches the destination node either directly or through multi-hops [1]. A reliable transmission of packets data information, with secure low latency and reliable energy-efficiency are the essential factors for the wireless sensor networks. The proper selection of the routing protocol to achieve maximum efficiency is one of the most important challenging tasks. One of the first considerations facing the designer that wants to deploy wireless networking is "which wireless technologies he/she must adopt and when".

MWSN can be modeled as a Mobile ad hoc network (MANET) due to several similar common aspects. It can be considered as a special case of them. This could be lead to erroneous conclusions, especially when protocols and algorithms designed for ad hoc networks are used in WSN [3]. MANET and MWSN have special features such as limitation in its bandwidth and batteries. It seems to be complex due to its dynamic topology. Dynamic topology happens due to the frequently and unexpected movement of its nodes [4]. These reasons and others complicated the packets routing process. It requires special suitable routing Protocols. There are many routing protocols were developed and classified to be to be reactive, proactive and hybrid [5]. The reactive routing protocols are (DSR (Dynamic Source Routing), AODV (Ad hoc On Demand Distance Vector), AOMDV (Ad-hoc On-demand Multi-path Distance Vector) and others). These routing protocols are required when there is a special need to indicate the route to the destination. The proactive routing protocols are (DSDV (Destination Sequenced Distance Vectored), OLSR (Optimized Link State Routing), and others). These are periodically broadcasting to store the view of the network and the correct route to each node in a routing table. The other type of the routing protocol is the hybrid routing protocols which merges the advantages of the above two types in small domain.

The main essential task of the network designers is “what is it can provide and what protocol should be designed”?. The routing protocol is representing the spirits in the Wireless Sensor Network (WSN). So this study aims to select the optimal routing protocol (among the many possible available routing protocols) that can achieve the best possible performance of the new designed Wireless Sensor Network. The network simulator (NS-2) was used as a simulation tool to evaluate and implement all the required scenarios. The increasingly demand on wireless sensor networks is due to the ability of deploying large number of small sensing self-powered nodes which gather information or detect special events and communicate in a wireless fashion [6].

Wireless Sensor Networks

A WSN was defined as networks of devices (denoted as nodes) which can deals with their deployed environment and communicate the information gathered from the monitored field through wireless links [6]. The data is transmitted via multiple hops. The WSN nodes can be deployed to be moving or stationary. They can be aware or not of their location and they can be either homogeneous or not. The WSNs wide applications to the real world are practically unlimited. Their applications are ranging military and civil field from positioning and tracking, to logistic, localization, controlling and so on. Due to the wide variety of possible applications of WSNs, system requirements could change significantly [6][7].

One of the main features of the WSN are the scalability with respect to the number of nodes in the network, self-organization, self-healing, energy efficiency, a sufficient degree of connectivity among nodes, low-complexity, and low cost [6]. In [6] they advised that the WSN protocols architectures can be considered as a potential framework for the creation of these networks, but, unfortunately, the definition of such a protocol architecture and technical solution is not simple, and the research still needs to work on it.

Performance metrics

There are many performance metrics can be used to select the best routing protocol in WSN. In this paper, the most four reliable effective performance metrics were used and utilized in the proposed decision process. The decision process in this study was built on selecting the "optimal routing protocol" which is the best suitable routing protocol (for certain WSN environment) among five possible routing protocols (DSDV, OLSR, DSR, AODV, and AOMDV). These metrics are:

1. Throughput

Throughput represents the mount of data received by the destination nodes in some period of time [8]. This value is wanted to be increased.

2. Average end-to-end delay (average E2E delay)

It represents the time that spent by the packet to reach to the destination

E2E delay [packet_id] = received time [packet_id] – sent time [packet_id]

The average end-to-end delay can be calculated by summing the times taken by all received packets divided by their total numbers [9]. This value is preferred to be decreased.

3. Packets delivery fraction (PDF)

PDF can be measured as the ratio of the received packets by the destination nodes to the packets sent by the source node [10]. This value is preferred to be increased.

*PDF = (number of received packets / number of sent packets) * 100*

4. Normalize Routing Load (NRL)

Is the number of transmitted routing packets per delivery data packets [11]. This value is preferred to be decreased.

NRL = number of routing packets/ number of received packets.

Simulation Environment

The following environment was suggested to perform this simulation study. NS-2 was used to implement this environment in many different runs to collect the required quantitative values of the required performance metrics. Table (1) represents the suggested WSN simulation environment parameters.

Table (1): The suggested simulation environment

Parameter	Value
The simulator	NS-2.34
MAC	802.11
Propagation model	Two ray round
Routing protocols	DSR, DSDV, AODV, OLSR, AOMDV
Simulation time	75s
Traffic generation	CBR
Antenna	Omni Antenna
Packets size	512 bytes/packet
Transition rate	4 packets/second
Mobility model	Random way point model
Pause time type	Uniform distribution
Speed type	Uniform distribution

Mathematical modeling

Examples of certain possible MWSN environment with different parameters (as shown in table (1)) were simulated and tested in NS-2. The resulted trace file was used with AWK programming language to calculate the four performance metrics values for each protocol in each implementation. The value of each of the four performance metrics was calculated as the average of 50 repeated simulation implementations for each one of the five suggested routing protocols in this study. The simulation study is heavily depending on the pseudo random numbers, so the 50 repeated simulation implementations will reduce the errors and approximate the results to the reality. The following equation was developed and tested. It can be applied as a mathematical model to calculate the resulted V values for different iterations.

$$V(i) = (M_1(i) * W_1) + (M_2(i) * W_2) - ((M_3(i)$$

Where:
V(i) : the resulted performance value of the network with the routing protocol (i).
M_1(i) : the WSN throughput with the routing protocol (i).
M_2(i) : the WSN Packets delivery fraction with the routing protocol (i) .
M_3(i) : the WSN Average end-to-end delay with the routing protocol (i).
M_4(i) : the WSN Normalize routing load with the routing protocol (i).
W_1 : the throughput weight.
W_2 : the Packet delivery fraction weight.
W_3 : the Average end-to-end delay weight.
W_4 : the Normalize routing load weight.
(i) : from 1 to 5 (1. DSR, 2. DSDV, 3. AODV, 4. OLSR, 5. AOMDV).

The weights are assigned depending on the main objective of the user (or WSN designer). In each WSN the designer will prefer or focus on certain performance metrics. The WSN will design to achieve certain goal. This goal will be achieved through certain performance metrics. The user will assign higher weights to these performance metrics depending on the MWSN aim. The following cases were suggested to apply the developed model on the four performance metrics results of the simulated proposed MWSN environment with each one of the five routing protocols. In addition to the simulation environment suggested in table (1), table (2) shows the five WSN scenarios that were considered in the simulation study.

Table (2): MWSN scenarios of the case study

Scenario number	Number of nodes	Pause time	Nodes Speed	Simulation area
1	10	6	5	1000m*1000m
2	20	6	10	1000m*1000m
3	30	10	20	1000m*1000m
4	40	10	5	1000m*1000m
5	50	10	10	1000m*1000m

After calculating the performance metrics values of the suggested MWSN with the five routing protocols. The following cases were suggested as samples to implement and validate our suggested mathematical model.

Simulation Results

After 50 running simulation times for each suggested scenario in table (2). The MWSN performance metrics results for each of the five routing protocols were averaged and used as inputs (M_j; (j =1 to 4)) to the mathematical model. The final resulted V values are shown in the following graphs. The following mathematical model results represent the final V values of the MWSN for each routing protocol after applying the proposed weights. The following cases were suggested as samples.

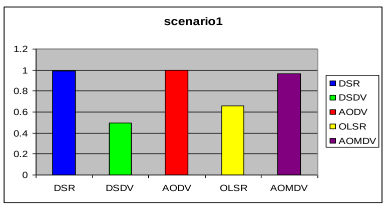
Case1:

The suggested mathematical model was applied when the weight of one performance metric is 1 and other metrics weights are set to zero.

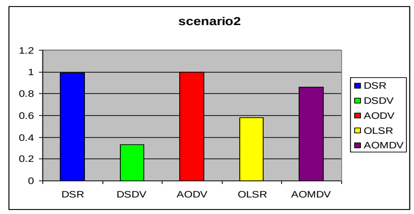
Case1.1: the weight of the throughput is one and other performance metrics weights are zero.

Case1.2: the weight of the average end-to-end delay is one and other performance metrics weights are zero.

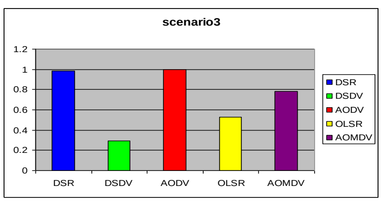
Figure (1) shows case1.1 resulted MWSN (V values) for each of the five routing protocols in each of the five suggested simulation scenarios.



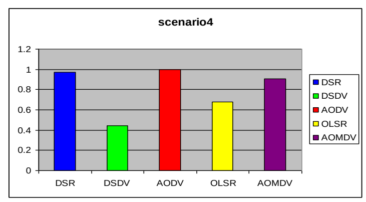
(a) Scenario 1; V values for the routing protocols.



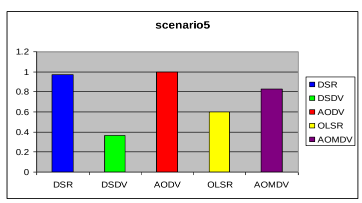
(b) scenario 2; V values for the routing protocols.



(c) Scenario 3; V values for the routing protocols.



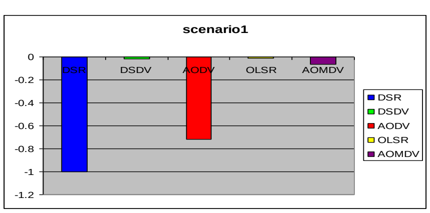
(d) Scenario 4; V values for the routing protocols.



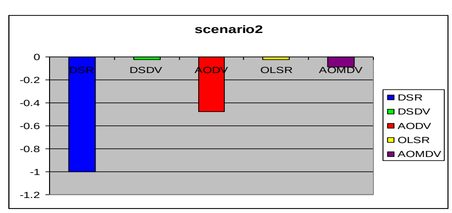
(e) Scenario 5; V values for the routing protocols

Figure (1): V values for the routing protocols in case1.1.

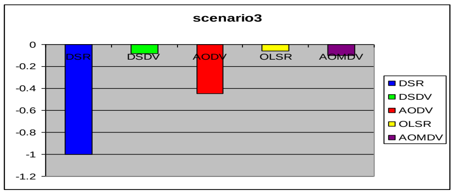
Figure (2) shows case1.2 resulted MWSN (V values) for each of the five routing protocols in each of the five suggested simulation scenarios.



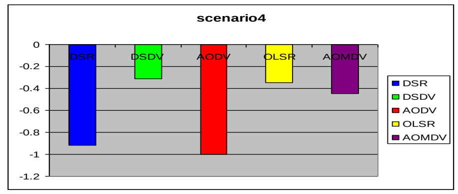
a) Scenario 1; V values for the routing protocols



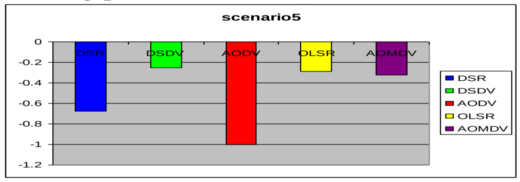
b) Scenario 2; V values for the routing



c) Scenario 3; V values for the routing protocols.



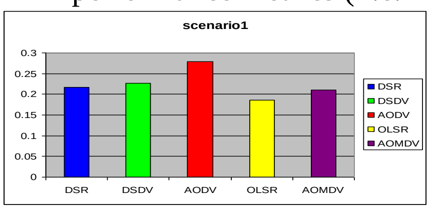
d) Scenario 4; V values for the routing protocols.



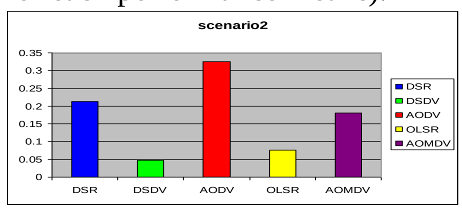
e) Scenario 5; V values for the routing protocols.

Figure (2): V values for the routing protocols in case1.2

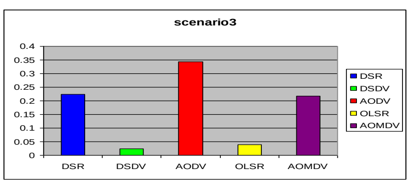
Case2: in this case a special situation was applied by assigning equal weights for each of the four performance metrics (i.e. let W = 0.25 for each performance metric).



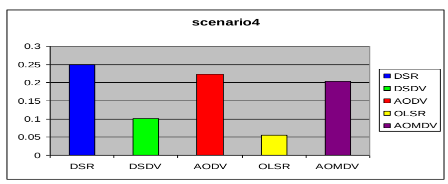
(a) Scenario 1; V values for the routing protocols.



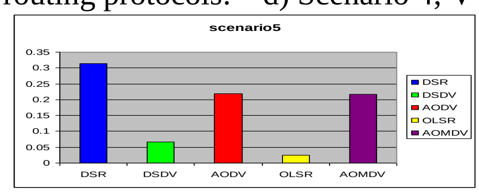
(b) Scenario 2; V values for the routing protocols.



c) Scenario 3; V values for the routing protocols.



d) Scenario 4; V values for the routing protocols.



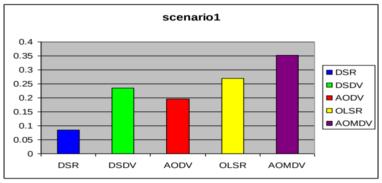
e) Scenario 5; V values for the routing protocols.

Figure (3): V values for the routing protocols in case 2.

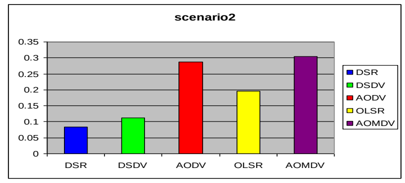
Case3: in this case, three different situations were applied as samples when the performance metrics weights are different.

Case3.1:

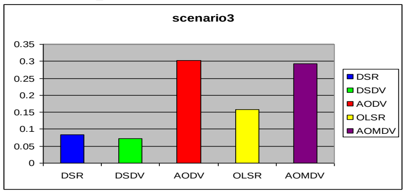
The throughput weight = 0.4
The average end-to-end delay weight = 0.4
The packets delivery fraction weight = 0.1
The normalize routing load weight = 0.1



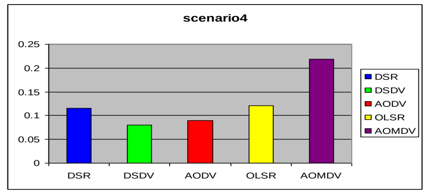
(a) Scenario 1; V values for the routing protocols.



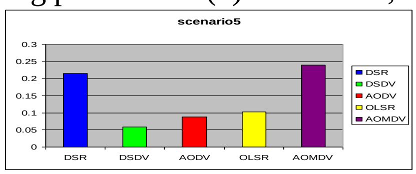
(b) Scenario 2; V values for the routing protocols.



(c) Scenario 3; V values for the routing protocols.



(d) Scenario 4; V values for the routing protocols.

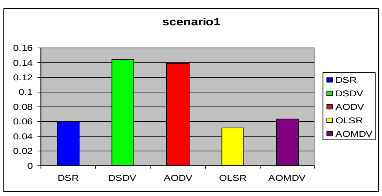


(e) Scenario 5; V values for the routing protocols.

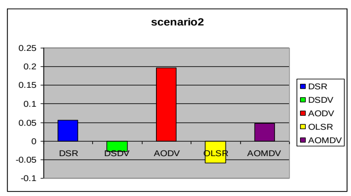
Figure (4): V values for the routing protocols in case 3.1.

<u>Case3.2:</u>

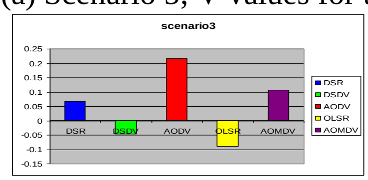
The throughput weight = 0.3
The average end-to-end delay weight = 0.3
The packet delivery fraction weight = 0.1
The normalize routing load weight = 0.3



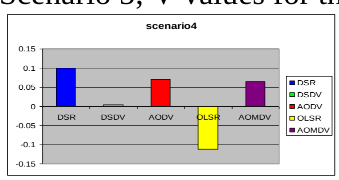
(a) Scenario 5; V values for the routing protocols.



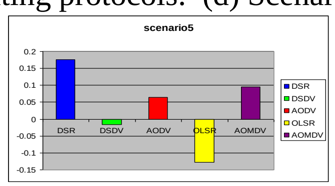
(b) Scenario 5; V values for the routing protocols.



(c) Scenario 5; V values for the routing protocols.



(d) Scenario 5; V values for the routing protocols.

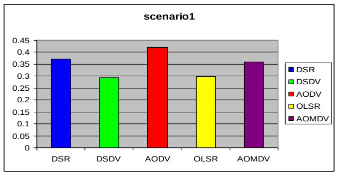


(e) Scenario 5; V values for the routing protocols.

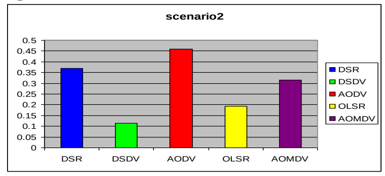
Figure (5): V values for the routing protocols in case 3.2.

Case3.3:

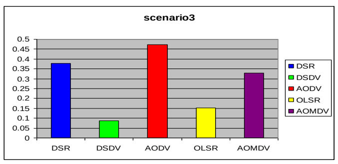
The throughput weight = 0.3
The average end-to-end delay weight = 0.2
The packet delivery fraction weight = 0.3
The normalize routing load weight = 0.2



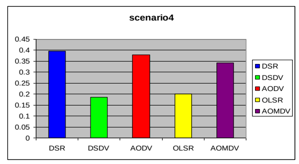
(a) Scenario 1; V values for the routing protocols.



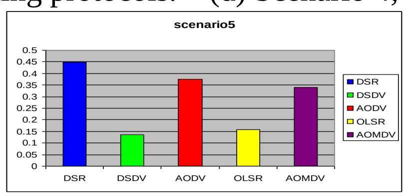
(b) Scenario 2; V values for the routing protocols..



(c) Scenario 3; V values for the routing protocols.



(d) Scenario 4; V values for the routing protocols.



(e) Scenario 5; V values for the routing protocols.

Figure (6): V values for the routing protocols in case 3.3.

Implementations and Discussions

Most of the previous studies focused on the evaluation of the routing protocols and MWSN and the MANET's performance. This paper tends toward developing a mathematical method to select the best routing protocol among five possible available wireless routing protocols that can be used in any new designed (MWSN) or MANET. The best routing protocol is that one achieves maximum possible values of the MWSN throughput and Packets delivery fraction. It must also achieve the minimum possible values of the end to end delay and normalized routing loads in the same time.

The selected protocol must make the network behaves in a reliable and efficient manner. As a result of applying this selected protocol, The MWSN performance metrics will reach the best possible values comparing with their values when using any of the other routing protocols.

The proposed method suggests three alternatives in selecting the best routing protocol. All these alternatives are planned to be under the control of the MWSN designer and/or its user. The user can assign certain weight to each performance metric depending on the designed MWSN objectives. These weights and the simulated quantitative values of the MWSN performance metrics are depicted in the suggested equation (mathematical model). The final decision will depends on the maximum resulted value from this equation. This equation can be implemented for all available protocols in addition to that used in this study. The final resulted values will be compared to choose the maximum one which represents the best (Optimal) suitable routing protocol. This approach can be used with different MWSN environments and all its feasible routing protocols.

Conclusions

In this paper, a mathematical model was built to choose the optimal routing protocol depending on the values of four effective performance metrics (throughput, Packets delivery fraction, average end to end delay and normalized routing loads). This model was implemented with certain MANET environment and five routing protocols (DSR, DSDV, AODV, OLSR, and AOMDV).

Each MWSN (or MANT's) designer objective is to achieve maximum possible values of the throughput and Packets delivery fraction and minimum possible values of the end to end delay and the normalized routing loads. This aim was utilized in this study to find certain relation between these for metrics under different operation characteristics. The user may aim to improve one, two or all of these performance metrics. Assigning higher weight (between 1 and zero) to certain performance metric will achieve this aim. These weights must also heavily depend upon the MWSN goals and objectives. The suggested model calculations was took low running time comparing with the running times required in operating the evaluation systems implemented in many previous studies.

This developed model can be implemented to evaluate or suggest an optimal routing protocol for a new or used MWSN and MANET. It can be also developed in future works to cover the effects of the other performance metrics and their limitations.

REFERENCES

[1] Tachtatzis, Christos and Harle, D.A., "Performance evaluation of multi-path and single-path routing protocols for mobile Ad-Hoc networks" In: International Symposium on Performance Evaluation of Computer and Telecommunication Systems, IEEE Xplore, pp. 173-180, ISBN 978-1-56555-320-9, 2008.

[2] Verdone, R.; Dardari, D.; Mazzini, G.; Conti, A. *Wireless Sensor and Actuator Networks*; Elsevier:London, UK, 2008.

[3] Basagni, S.; Conti, M.; Giordano, S.; Stojmenovic, I. *Mobile Ad Hoc Networking*; Wiley: San Francisco, CA, USA, 2004.

[4] Yangcheng Huang, Søren-Aksel Sørensen, and Saleem Bhatti, "Improving Signalling Performance of Proactive MANET Routing Protocols", PhD thesis, University of London, Department of Computer Science, 2007.

[5] Ravi Kumar Bansal, "Performance Analysis of Cluster based Routing Protocol in MANETs", Computer Scienece and Engineering Departmet thapar Institute of Engineerin and Technology, Patiala-147004, May-2006.

[6] Chiara Buratti, Andrea Conti, Davide Dardari, and Roberto Verdone; "An Overview onWireless Sensor Networks Technology and Evolution"; *Sensors* 2009, *9*, 6869-6896; doi:10.3390/s90906869, ISSN 1424-8220, www.mdpi.com/journal/sensors.

[7] Ong, J.; You, Y.Z.; Mills-Beale, J.; Tan, E.L.; Pereles, B.; Ghee, K. A wireless, passive embedded sensor for real-time monitoring of water content in civil engineering materials. *IEEE Sensors J.* 2008, *8*, 2053–2058.

[8] Ducksoo Shin, Jonghyup Lee, Jaesung Kim, and Jooseok, "A^2OMD : AN Adaptive Ad Hoc On-Demand Multipath Distance Vector Routing Protocol Using Dynamic Route Switching", Journal of Engineering Science and Technology, Vol. 4, No. 2, 171 – 183, 2009.

[9] Aliff Umair Salleh, Zulkifli Ishak, Norashidah Md. Din, and Md Zaini Jamaludin, "Trace Analyzer for NS-2", IEEE, pp. 29-32, Student Conference on Research and Development (SCOReD), Malaysia, 2006.

[10] Er. Deepinder Singh Wadhwa and Er. Tripatjot Singh Panag, "Performance Comparison of Single and Multipath Routing Protocols in Adhoc Networks ", Int. J. Comp. Tech. Appl., ISSN: 2229-6093, Vol 2 (5), 1486-1496, 2011.
[11] Nilesh P. Bobade and Nitiket N. Mhala, "Performance Evaluation of Ad Hoc On Demand Distance Vector in MANETs with varying Network Size using NS-2 Simulation", International Journal on Computer Science and Engineering Vol. 02, No. 08, 2731-2735, 2010.