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HPIS: A Scalable Routing Protocol for WMN

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***Abstract*— Wireless mesh networks (WMNs) have gained much attention because of their capability of providing reliable wireless coverage to large geographical areas with or without infrastructure requirements. Due to their inherent limitations and the increasing number of users demanding high QoS performances, wireless mesh networks have attracted the attention of researchers world-wide to address the scalability, performance degradation and service disruption issues. In the last decade, the cost, size and energy requirements of radio devices have declined significantly, which allows multiple radios to be used within a single device which can work in multiple frequency bands supporting a variety of functions as needed. In this paper, we propose a scalable routing protocol called HPIS and analyze and compare the scalability performance of BATMAN and HWMP protocols with our proposed protocol by simulation, considering different parameters like end-to-end delay, packet loss, and throughput.**

***Keywords*—WMNs; BATMAN; HWMP; scalability; End-to-end delay; Packet loss; Throughput.**

I. INTRODUCTION

Wireless mesh network(WMN) is a special kind of wireless multi-hop network whose nodes are divided into mesh routers and mesh clients. The benefit of multi-hop communications is that, using lower transmission power the same network coverage can be achieved by a mesh router than that with the typical router [1]. A wireless mesh network can be expanded easily and incrementally as needed without disconnecting currently accessing nodes. But it can generate high traffic load in the network which will degrade the overall performance. So, we should find a strategy to route this traffic in a way to maximize the utilization of available resources.

Here, we are proposing a hierarchical routing protocol which can have better scalability compared to two very well recognized protocols namely, Hybrid Wireless Mesh Protocol (HWMP) [2] and Better Approach To Mobile Ad hoc Network (BATMAN)[3].We have chosen HWMP because it is the default routing protocol for IEEE 802.11s standard. Similarly, BATMAN is another algorithm widely researched upon for WMNs. We are not discussing these two protocols in this paper because these are widely available in the literature.

As stated in [4], a hierarchical clustering routing technique reduces power consumption, network congestion and message collision. So, we choose a Hierarchical Cluster Based Routing Protocol called Hierarchical Cluster Based Routing for Wireless Mesh Networks Using Group Head[4]. But it has some performance drawbacks. Therefore we modified and added some new features in this protocol and perform the simulation.

In the next paragraphs, we first give a brief overview of the Hierarchical Cluster Based Routing for Wireless Mesh Networks Using Group Head routing protocols in Section II. In Section III, we present proposed HPIS routing protocol. In section IV, simulation results and comparison of the three protocols are discussed. Finally, we summarize our contribution and describe future work in Section V.

II. HIERARCHICAL CLUSTER BASED ROUTING FOR WIRELESS MESH NETWORKS USING GROUP HEAD

This approach is further extension of the cluster based routing scheme for wireless mesh networks [9]. In this scheme, WMNs are divided into various domains of Mesh Points and domains are divided into clusters. Each domain has one MP as a Group Head (GH) and every cluster has one MP as a Cluster Head (CH).

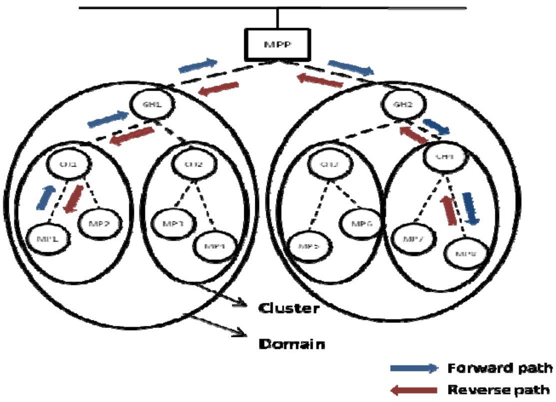

Fig. 1. Example of hierarchical cluster based routing protocol.

MPP maintains the information about all the GH. As shown in figure 1, GH1 and GH2 are group head and maintain two clusters each. Large circle shows the domain and clusters under that circle are within one domain. Every cluster has one cluster head. CH1, CH2, CH3 and CH4 are cluster heads. Here MPs may change their position and MPP, GHs and CHs are fixed. To reduce overhead, a single MP cannot become both CH and GH. Every CH and MP has the information about the MPs within the same cluster. CH also keep the information about its other group member CHs and GH .For this reason CH store the cluster ID and Node ID of CHs. GH stores the information about MPP and CHs under its own group. We use the concept of reverse path and forward path similar to the AODV protocol.

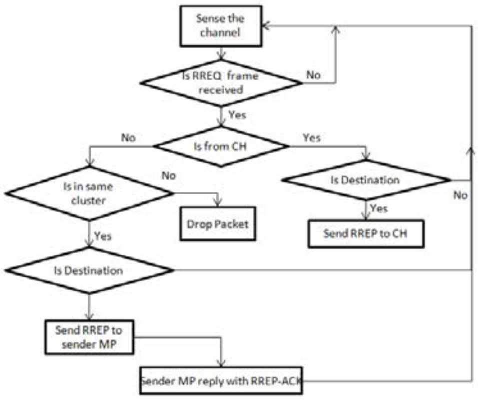

Fig. 2. Flow chart for the working of Mesh Point (MP)

When a source MP needs to send some message to destination MP, it first refers to its routing table. If both are neighbors then source MP can directly send the data to destination MP. But, if source MP does have not any routing information about destination MP then it sends a RREQ to its own CH. CH also checks its routing table to find the routing information about destination MP. If it finds the path then it sends a RREP to source MP, otherwise it forwards the RREQ to its own GH.

Figure 2 represents the flow chart for the working of Mesh Point (MP). Whenever an MP receives a RREQ from its CH it checks whether the node itself is destination. If so, it sends RREP to its CH. But if RREQ comes from a neighbor MP from the same cluster and the receiver node is the destination, then also send RREP to sender MP. If the neighbor is not in the same cluster then drop the packet. Sender MP replies with a RREP-ACK message and sends the data through the forward path.

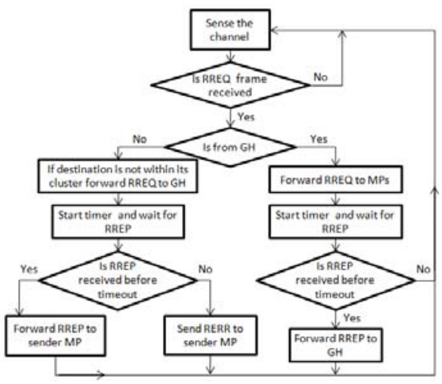

Fig. 3. Flow chart for the working of Cluster Head (CH)

Figure 3 represents the flow chart for the working of *Cluster Head (CH).* If CH receives any RREQ from GH it forward RREQ to all MPs and wait for reply. If RREP is received before timeout it is forwarded to the GH. But when a RREQ is received from any of its MPs and if destination is not within its cluster, it forwards the RREQ to its GH and wait for the reply. If RREP come back within timeout the RREP is forwarded to sender MP or else a RERR message is sent to the sender MP.

Flow chart for the working of Group Head (GH) is presented in the figure 4. The GH is used to share the load of MPP. If source and destination MPs are in same group then RREQ does not need to reach MPP and therefore, load in MPP is shared by GH. Figure 4 represents the working of GH through a flow chart. GH receives a RREQ by two ways either from the CH or from MPP. If request comes from CH to GH then GH forwards this RREQ to all CHs under it except the sender and starts the timer. If within the timeout period GH does not receive a reply then it will resend the RREQ to MPP and if it receives the RREP by any of the CH associated with it then it forwards RREP to CH using reverse path. All CHs which received the RREQ will look for for destination MP in its routing table. If any CH finds the path information about the destination MP , it sends a RREP to GH otherwise do nothing. If GH gets a RREP message from any CH , it sends the RREP to CH through reverse path and CH sends the RREP to source MP. If RREQ comes from MPP to GHs, all GHs forward it to all CH associated with them. If any one of these CHs finds the routing information, it sends RREP to its own GH and that GH in turn forwards the RREP to MPP.

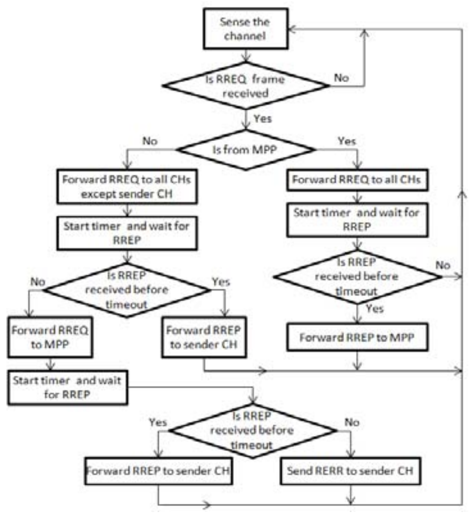

Fig. 4. Flow chart for the working of Group Head (GH)

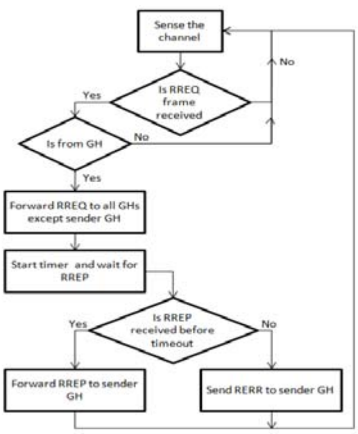

Fig. 5. Flow chart for the working of Mesh Point Portal (MPP)

Figure 5 represents the flow chart for the working of Mesh Point Portal (MPP). If GH sends the RREQ to MPP, it starts the timeout timer and waits for the RREP. If it receives the reply from MPP then it forwards the RREP to the GH by using reverse path. If within timeout it does not receive any RREP , it will send a RERR to the GH through the reverse path.

Drawbacks:

In the “hierarchical cluster based routing for wireless mesh networks using group head” we have noted the following drawbacks: Firstly: if a node is not reachable by any CH, there is no scope to connect that node with the reachable leaf MP nodes. Secondly: if destination is a one hop neighbor node but is in another cluster, there can’t be a direct communication between these two neighbor nodes. The routing path has to pass through their two CHs if the CHs are in the same group or else path should pass through their GHs. Thirdly: since MPP, GHs and CHs are fixed in position we have to assign some dedicated devices for these purpose. Further, since there are many wireless nodes present in the same geographical area the selection of GHs by MPP is very difficult without using a suitable predefined technique.

III. PROPOSED ROUTING PROTOCOL

To improve the performance of the protocol discussed in the last section we add some new features and propose a new protocol, which we may call as “Hierarchical Protocol with Improved Scalability (HPIS)”. As an example shown in figure 6, each cluster contains only five MPs. Among these five MPs, one is cluster head. The complete path of RREQ and RREP has been shown in the figure 6. The nodes from different clusters or domains connected by red colored dashed lines can communicate directly.

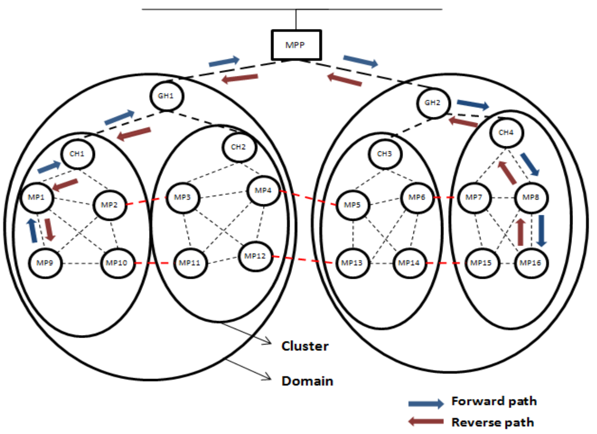

Fig. 6. Example of Hierarchical Protocol with Improved Scalability.

In HPIS the cluster head may not be directly connected with all its MPs but they can be reached through its other 1-hop neighbor MPs. Other characteristics of CH are same in both protocols. The working of GH is also almost same for both protocols. Here only difference is that the MPP identifies the group heads GH1 and GH2 by exchanging a secret key.

Figure 7 represents the flow chart for the working of *Mesh Point (MP) in HPIS.* Whenever an MP receives a RREQ from its CH it checks whether the destination is its neighbor MP. If so, it sends RREP to its CH. But if RREQ comes from a one hop neighbor MP (may be from another cluster/domain) and is the destination, then also send RREP to sender MP. If the neighbor is not the destination neither in same cluster, then drop the packet. If sender MP is in the same cluster, then forward RREQ to its CH and wait for reply. If reply comes within timeout, forward RREP to sender MP or else send RERR. If sender MP is the source point, then it replies with a RREP-ACK message.

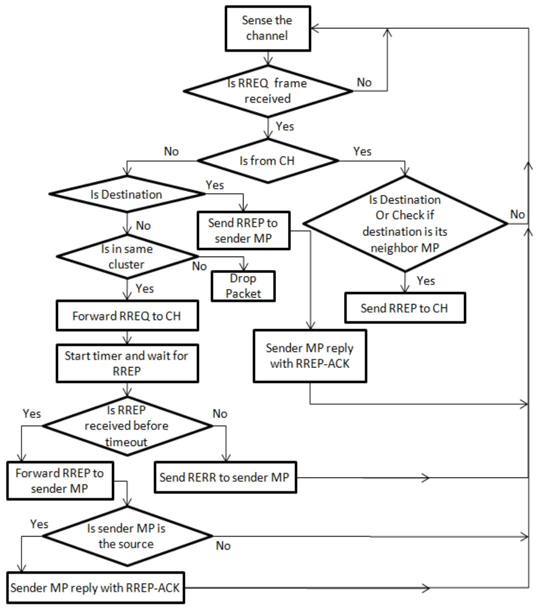

Fig. 7. Flow chart for the working of Mesh Point (MP) in HPIS

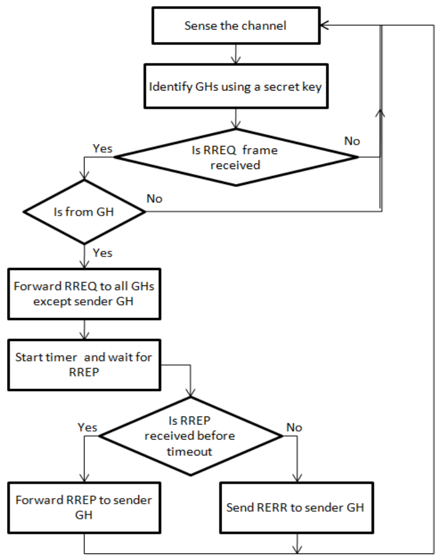

Fig. 8. Flow chart for the working of Mesh Point Portal (MPP) in HPIS

If MPP receives any RREQ from GH it forward RREQ to all GHs except the sender GH and wait for reply. If RREP is received before timeout, it is forwarded to the sender GH or else a RERR message is sent to the sender GH. Figure 8 represents the flow chart for the working of *Mesh Point Portal (MPP) in HPIS.*

The following features are added in the proposed approach:

i) If a node is unreachable by any CH, the node can be connected to a reachable leaf MP node.

ii) There can be direct communication between any pair of one hop neighbors irrespective of their cluster or domain.

iii) The GHs are identified by using a key exchange with MPP.

IV. SIMULATIONS RESULTS

The simulator we have used here is ns-3 version 16 on Ubuntu 12.04.2 LTS[13].As evaluation metrics we considered packet delivery ratio(PDR),scalability, routing overhead, throughput and end to end delay. The simulations are done using 10,20,30,40,50 and 60 mobile nodes having mobility in a rectangular flat space of 4 km^2 area. Movements of the nodes are controlled by the Random direction 2D model in ns-3.It is assumed that all nodes transmit and receive constant data traffic.

We have used Gnuplot version 4.6.2 [15] (a portable command-line driven graphing utility) to present the simulations results as graphs. In Figure 9-12, we compare the scalability performance of HPIS, BATMAN and HWMP routing protocol.

Figure 9 shows that if number of node is greater than 30, throughput (in kbps) of HPIS is higher than both HWMP and BATMAN. When number of node is large, the least number of control packets (e.g., RREQ, RREP or ORG) are successfully received from the clients to choose the routes in HWMP, so its throughput degrades in larger network.

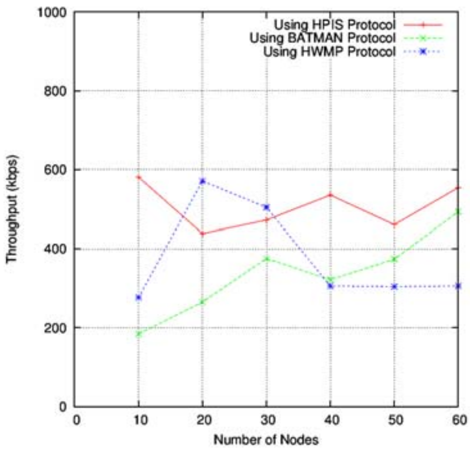

Fig. 9. The graph shows the variations of Throughput (kbps) and Number of Nodes

Figure 10 shows end-to-end delay (in milliseconds) of HPIS is lower than BATMAN but slightly higher than HWMP. A distance-vector tree rooted at a single root mesh point is proactively selected by HWMP, so as to quickly select a routing path. On the other hand, BATMAN divides the information about the best possible end-to-end paths between nodes in the mesh to all participating nodes. Therefore, more time is required to select the routing path. In HPIS, path selection takes some time if destination is in other cluster or domain but congestion of packets is decreased using this clustering technique.

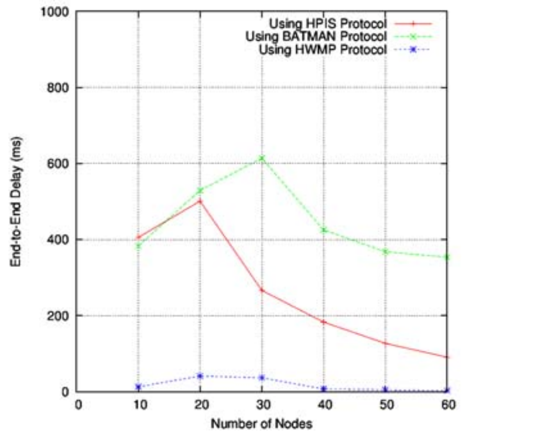

Fig. 10. The graph shows the variations of End-to-End Delay (in milliseconds) and Number of Nodes

Figure 11 shows packet delivery ratio (%) of HPIS, BATMAN and HWMP is higher if number of nodes is small, i.e., less than 20. However, if the number of nodes is large, i.e., more than 30, packet delivery ratio of HPIS is nearly equal with that of BATMAN and HWMP.

Increase in number of node cause much collision in HPIS, BATMAN and HWMP, which may be caused by the following reasons: firstly, there is increased number of nodes looking for the channel to send their data packets. Secondly, for choosing routes, the clients have to send control packets, like RREQ, RREP or ORG message. Although these are small sized packets, the nodes have to contend for the channel evry time to send these control packets. This leads to more packet loss.

Figure 12 shows increase in number of node (> 30 nodes) in HPIS requires more number of routing packets than that of BATMAN due to repeated path selection process. Also, BATMAN requires higher number of routing packets than that of HWMP.

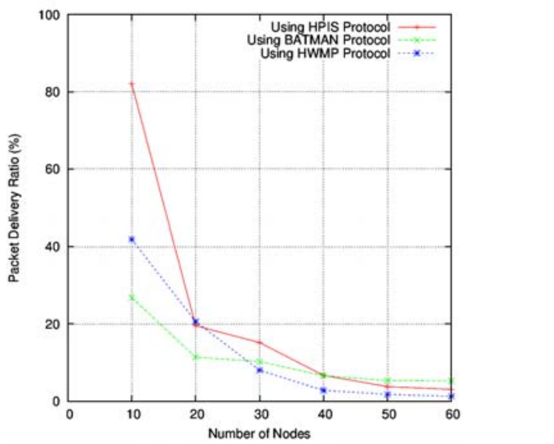

Fig. 11. The graph shows the variations of Packet Delivery Ratio (%) and Number of Nodes

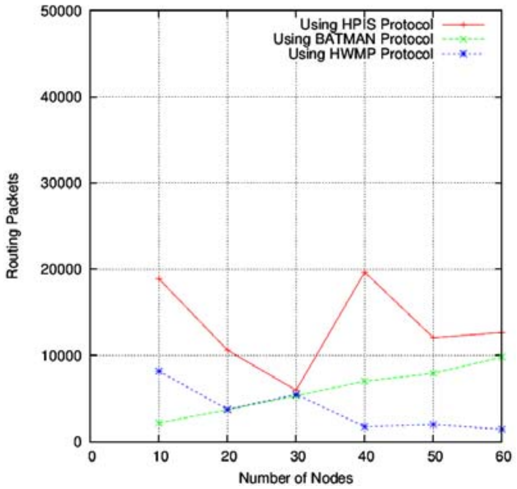

Fig. 12. The graph shows the variations of Total Routing Packets (packet size is 128 bytes) and Number of Nodes

V. Conclusion

In this paper, at first we have simulated HWMP and BATMAN protocols and study their performance. We find that in large networks BATMAN outperforms HWMP with respect to throughput and PDR. But end-to-end delay is very high in BATMAN. We proposed a hierarchical cluster based routing approach with improved scalability (HPIS) for wireless mesh networks. It reduces the number of broadcast messages used for route discovery. Due to this, the chance of message collision also reduced. If source MP and destination MP are neighbours, there is no need of route discovery at all. Thus message flooding is reduced which also reduces the chance of network congestion.

In a large network the Hierarchical Protocol with Improved Scalability (HPIS) gives higher throughput and minimum latency than the other two protocols. Packet delivery ratio comparison shows nearly equal results for all the protocols. Routing overhead is slightly higher for HPIS in comparison with that of BATMAN and HWMP. When more numbers of node are added there is a significant decrease in packet delivery ratio (PDR) in all the protocols.

For the future research work, we think there is a requirement to improve the packet delivery ratio and also reduce the routing overhead in the proposed protocol. The secret key used for identifying the group heads in HPIS will be generated using a random key generator. We plan to further improve the performance of this proposed clustering technique, so that we could come up with an optimized routing protocol for wireless mesh networks which can work with reasonable trade-off among the performance matrices like routing overhead, PDR, latency and throughput.

References

[1] I. F. Akyildiz, X. Wang, and W. Wang,“Wireless mesh networks: a survey”, Computer Networks, vol.47, no.4,Mar.2005.

[2] Sudip Misra, Subhas Chandra Misra and Isaac Woungang, Guide to Wireless Mesh Networks, Springer, pp. 369-370, 2009 .

[3] Anne Gabrielle Bowitz, Stig Frode Mjolsnes and Martin Gilje Jaatun, “Simulation of a Secure Ad Hoc Network Routing Protocol,” ITEM, NTNU, SINTEF, Norway, pp. 6-42, June 2011.

[4] Deepesh Kaushal, Gami Niteshkumar A., Buddhdev Prasann K. and Varun Agarwal, “Hierarchical cluster based routing for wireless mesh networks using group head,” International Conference on Computing Sciences (ICCS), Phagwara, pp. 163-167, 2012.

[5] A. Neumann, C. Aichele, M. Lindner and S. Wunderlich, “Better Approach To Mobile Ad-hoc Networking (B.A.T.M.A.N.),” Work in Progress, Technical Report, [Online]. Available:http://tools.ietf.org/ id/draft-wunderlich-openmesh-manet-routing-00.txt, 2008.

[6] Z.J. Haas, Joseph Y. Halpern and Li Li, “Gossip-based ad hoc routing,” IEEE/ACM Transactions on Networking, vol. 14, no. 3, pp. 479-491, June 2006.

[7] IEEE P802.11s. Part 11: IEEE Standard for Information Technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 10: Mesh Networking, September 2011.

[8] B.A.T.M.A.N. protocol concept, [Online]. Available:http://www.open-mesh.org/projects/open-mesh/wiki/BATMANConcept/, 2013.

[9] M. Singh, Sang Gon Lee, Whye Kit Tan and Jun Huy Lam, “Cluster based routing scheme for Wireless Mesh Networks,” 13th International Conference on Advanced Communication Technology (ICACT), 2011, pp. 335 – 338, 2011.

[10] Klaus Wehrle, Mesut Gunes and James Gross, Modeling and Tools for Network Simulation, Springer, 2010, pp.18-19.

[11] IEEE 802.11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, IEEE Computer Society Std., June 2007, [Online]. Available:http://standards.ieee.org/getieee802/download /802.11-2007.pdf/.

[12] Pei Tingrui, Zeng Wenli, Zhang Zhaoxiao and Peng Tao, “An improved hierarchical aodv routing protocol for hybrid wireless mesh network,” International Conference on Networks Security, Wireless Communications and Trusted Computing, NSWCTC '09. vol. 1, pp. 588-593, 2009.

[13] Ubuntu 12.04.2 LTS, [Online]. Available:http://www.ubuntu.com/ download/desktop/, 2013.

[14] NS-3, “The ns3 network simulator,” [Online]. Available: http://www.nsnam.org/, 2013.

[15] Gnuplot 4.6.2, [Online]. Available:http://www.gnuplot.info/, 2013.

[16] Zainab Senan Mahmod and Aisha Hassan Abdalla, “A scalable routing protocol for hybrid wireless mesh networks,” International Conference on Computer and Communication Engineering (ICCCE), Kuala Lumpur, Malaysia, pp. 51-54, 2012.

[17] R. Bruno, M. Conti and Enrico Gregori, “Mesh networks: commodity multihop ad hoc networks,” IEEE Communications Magazine, vol. 43, no. 3, pp. 123 – 131, 2005.