International Journal of Soft Computing and Software Engineering (JSCSE)
Vol.6, No.2, 2016

Published online: February 25, 2016

e-ISSN: 2251-7545

Impacts of MAC Layer on LANDY Routing Protocol Performance

Adam Macintosh

BiMEC, Dept. of Engineering & Design,
London South Bank University, London, SE1 0AA, UK
Email: macintoa@lsbu.ac.uk

Abstract. **The aim of this paper is to investigate the impacts of MAC layer on our proposed MANET routing protocol, Local Area Network Dynamic Routing (LANDY). And to assess how the data load impacts the routing protocol performance under four different MAC layer environments. Our lightweight protocol, LANDY uses a localized routing technique which combines a unique locomotion prediction method and velocity information of mobile nodes to route packets. The protocol is capable of optimizing routing performance in advanced mobility scenarios, by reducing the control overhead and improving the data packet delivery. In this study, LANDY, DSR, GPSR, OLSR are used as the routing protocols to represent the major MANET routing algorithm techniques (Position based, Reactive, and Proactive) with default settings. OPNET simulator was used to design and build a unified simulation environment; to evaluate the performance of the different protocols proposed in the IETF, in different scenarios. Our study results indicate that the factors at the MAC layer not only impact the performance of the routing protocol, but it can even change the relative ranking between routing protocols for the same environment.**

Keywords: *Mobile Ad hoc network, Mobility Models, Mobility Impacts, MAC Protocol, Connectivity, OPNET*

* Corresponding Author:
Full Name, ADAM MACINTOSH
BiMEC, Dept. of Engineering & Design, London South Bank University,
London, SE1 0AA, UK
Email:macintoa@lsbu.ac.uk Tel:0044 777 620 5710

1. Introduction

It is important to explore the MAC layer and the impact on the performance of MANET routing protocol. Research on MANET routing protocols have proved that, multiple OSI layer interactions have major impact on the performance of routing protocol. Therefore, it is essential to investigate the characteristics of lower layers, specifically the physical and MAC (Medium access control) layer [1, 2].

The MAC layer play a key factor in defining the mechanism of medium access to the shared wireless medium. Therefore, it is responsible for providing the resources to mobile nodes (MNs) to gain access to the wireless medium effectively, efficiently and collision free.

Generally, MAC protocols have been classified to contention free and contention based scheme. But many resent research and proposed algorithms combine the two schemes in a single MAC solution and hence it is important to define a new classification approach. MANETs have their unique characteristics and limitations. Several MAC protocols have been developed for MANETs in recent years Figure 1 [6].

Ad hoc network MAC protocols can be classified into four types [6];

A. Contention-based protocols.
   - Source-triggered: Data packet transmissions are triggered by the sender MN. And it can be either single channel or multichannel. In single channel, a node will be able to use the entire bandwidth if it wins the contention to the channel. Where in multichannel, the entire bandwidth is divided into multiple channels.
   - Receiver triggered: The contention resolution protocol triggered by receiver node.
B. Contention-based protocols with reservation mechanisms.
   - Synchronous protocols: It is required that all nodes must to be synchronized. And it is challenging to achieve global time synchronization in dynamic environment.
   - Asynchronous protocols: These protocols uses distributed time information for effecting reservations.
C. Contention-based protocols with scheduling mechanisms.
   - Node scheduling is done in a way so that all nodes get equal amount bandwidth.
   - Scheduling-based schemes are implemented for applying priorities between nodes whose packets are queued.
   - Battery characteristics were also considered by some scheduling schemes.
D. Other MAC protocols which don't fall under the above categories.

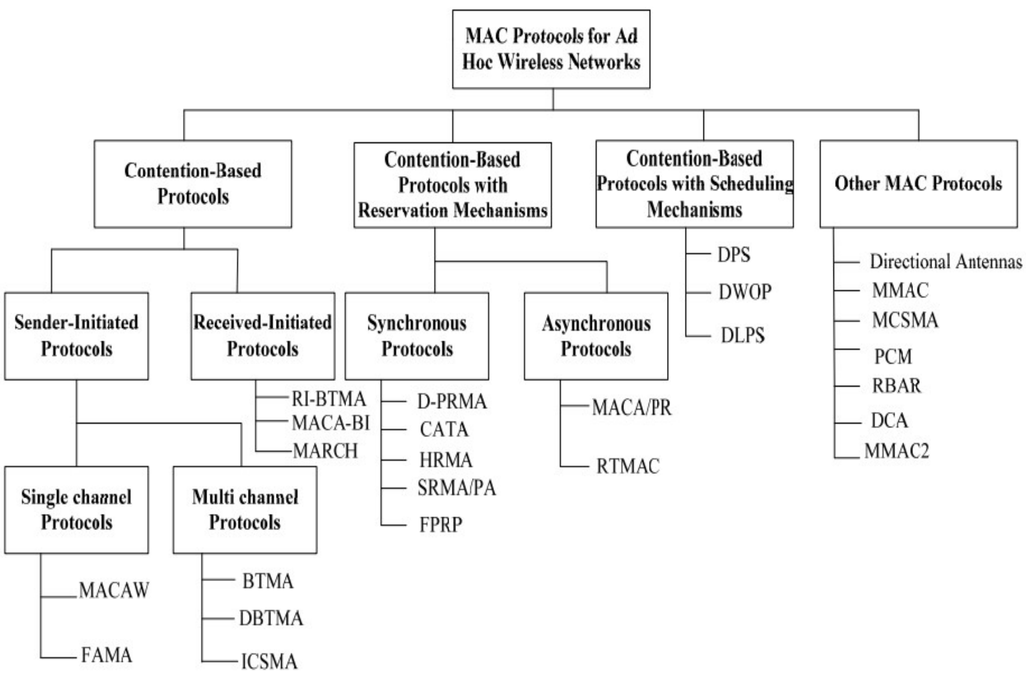


Figure 1. Classifications of MAC protocols

2. Related Works

Extensive research has been done in modelling mobility for MANETs and many mobility models have been proposed in the literature [2, 3, 17]. B.Uma.et al. [1], carried out a comprehensive comparison between MAC and routing protocols in mobile Ad hoc Network. Szott, S. et al. [4], studied the impact of contention window cheating on Single-Hop IEEE 802.11e in MANET. Perkins, C.E., et al. [7] studied the interlayer interactions and their performance implications on MANET routing protocols. Lei G. et al. [10], carried out comprehensive investigation on the vulnerabilities of ad hoc network routing protocols to

e-ISSN: 2251-7545

MAC misbehavior.

Conti, M. et al. [19] designed a cross-layer and investigated the impact on the performance of the protocols in mobile ad hoc network and the interaction between the layers. Gossain, H. et al [20] studied the multicast in IEEE 802.11 based MANET and the interaction with MAC layer.

A comprehensive analysis has been carried out on the impact of MAC layer protocols on MANET routing protocols and evaluate how data load impacts the routing protocol performance under four different MAC layer environments. This research is significant in practice for the simulation study of MANET routing protocols and the design and improvement of mobility models.

3. Local Area Dynamic Routing Protocol

In the previous work, Local Area Dynamic Routing Protocol (LANDY) [11, 13] localizes routing information distribution in the one-hop range Figure.2.

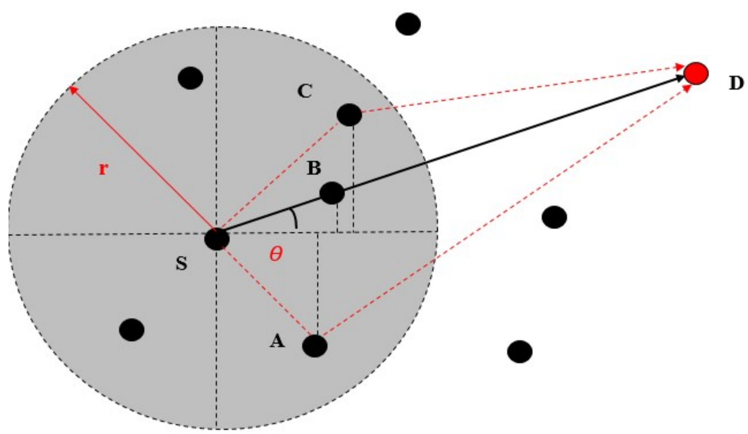


Figure 2. LANDY One - hop Communication

Thus LANDY Figure.3 will reduce the control overhead, simplify routing computation and save memory storage. Each MN in the network needs to maintain the local status of its MNs neighbors only.

For each connection, a MN gets order of query packets. The number of neighbor MNs may increase or decrease based on the movement of MNs within the local region. Therefore, the distribution of the MNs within a region for the network state is S(n) in the worst case scenario.

The MN updates its locomotion components (LC) through position service (e.g. GPS) periodically in LANDY. The MN broadcasts its Mobile code identifier (MCID), Cell code identifier (CCID) and LC in a HELLO message periodically. Data packets are marked with the LC of the sender and the destination, so that the receiving nodes are able to update the neighbor's locomotion information upon receiving the data packet. The MN does not flood the HELLO message.

Thus, the LANDY routing protocol reduces the control overhead and simplifies the routing computation. The HELLO message broadcasting mechanism makes all nodes aware of their neighbors' locomotion information. Each MN broadcasts a HELLO message to its one-hop neighbors, with its MCID, CCID and LC. The HELLO message inter-arrival time is jittered with a uniform distribution to avoid synchronization of neighbors' HELLO messages that could result in conflict.

Each MN updates its locomotion table (LT) of neighbors when it receives a HELLO message. The LT associates an expiration value with each entry. If the node does not receive a HELLO message from a neighbors within the expiration time, it removes the neighbor from the table.

Therefore, the differences LANDY has to other protocols, are it uses the locomotion prediction

e-ISSN: 2251-7545

technique to estimate the future node position. It uses the locomotion instead of the current position to find the MNs locomotion trajectory to predict the future position of MN, which reduces the impact of the inaccuracy of neighbor's positions on the routing performance.

It avoids routing loop or routing failure using the back track process and the recovery process. It uses local locomotion to determine packets' next hop, and this increases the scalability of routing protocol. Recovery with LANDY is much faster than with other location protocols, which use mainly greedy algorithms such as GPSR.

No signaling or configuration of the intermediate node is required after failure. It allows sharing of the locomotion and velocity information among the nodes through locomotion table (LT). It uses backtrack process to the previous node (up to three nodes), for alternative paths before it switches to the recovery process.

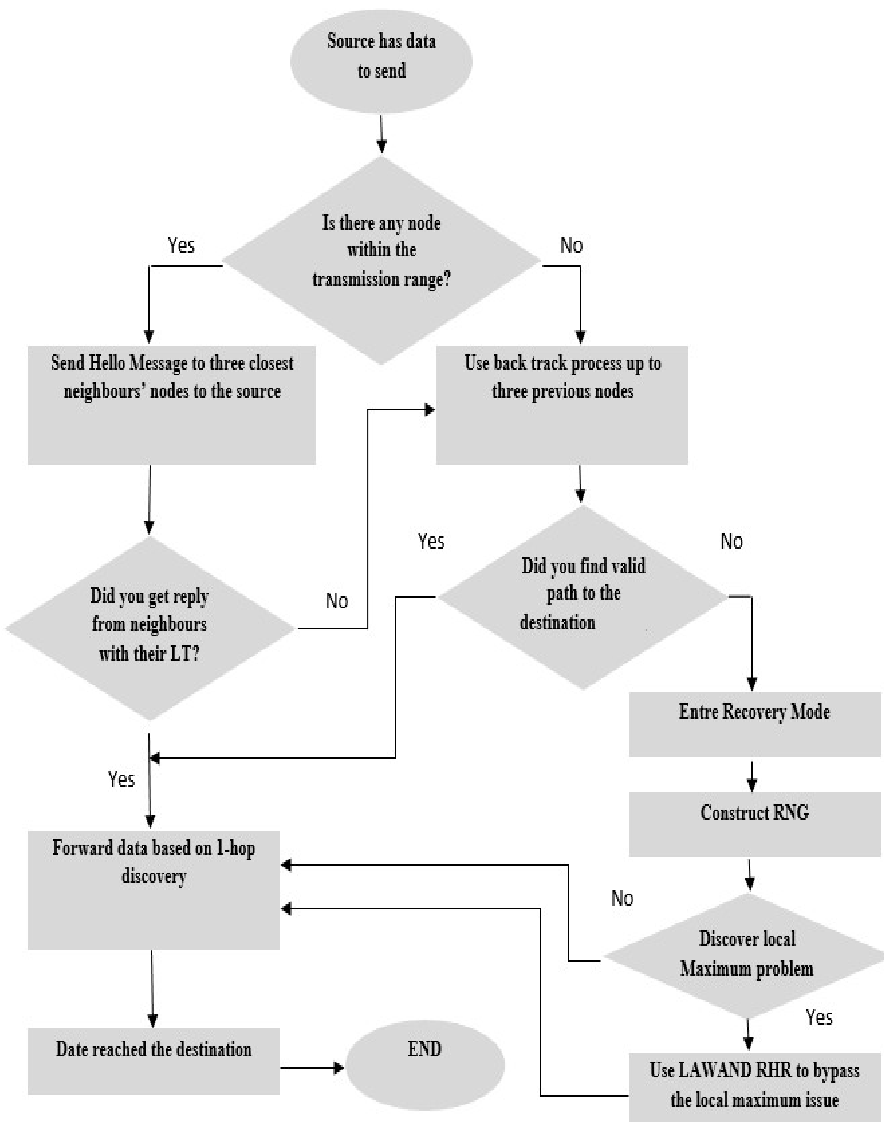


Figure 3. LANDY algorithm

e-ISSN: 2251-7545

4. Effects of MAC Protocols on MANET Routing Protocols

Previous research on MAC protocols which merged the features of both schemes (contention based i.e. Carrier Sense Multiple Access (CSMA) and contention free i.e. Time Division Multiple Access (TDMA) have demonstrated better performance results. Contention based and contention free approaches have been applied to various parts of some MAC algorithms which makes the classification and the difference of MAC protocols distorted.

For slot allocation in contention free MAC protocol, it uses TDMA because resources are identified first and then the get reserved as free to transfer the data [3]. Where the resources are estimates in contended based MAC protocols.

The choice of MAC protocol has major impacts on the performance of MANET routing protocols [4]. Table 1 summaries the mechanism of each of major MAC protocols.

Table 1. Summary of MAC Protocols

MAC Protocol	Mechanism
CSMA	CSMA
MACA	PSMA/RTS/CTS
FAMA	CSMA/RTS/CTS
IEEE 802.11 DCF CSMA/CA	CSMA/CA/RTS/CTS/ACK

4.1. Carrier Sense Multiple Access

The CSMA listen/ sense to other nodes before initiate the transmission. CSMA is the most common MAC protocols implemented in the MANET research. The term multiple access refers to multiple nodes send and receive on the medium, and the broadcast by the source node are received by all other nodes which are connected to the medium. CSMA is a probabilistic MAC protocol in which a node validates the availability of the shared medium before transmitting, such as an electrical bus, or a band of the electromagnetic spectrum. In this CSMA, a node checks the channel for any ongoing transmissions prior sending a packet. If the Channel is free then the nodes start transmission. Otherwise, it sets a random timer if the channel is busy, and then try to transmit the packets after the time expire. CSMA protocol modification;

4.1.1. CSMA with collision detection; CSMA/CD is utilized to increase CSMA performance by ending transmission as soon as a collision is detected, hence cutting the time required by the node before a retry can be initiated [9].

4.1.2. CSMA with collision avoidance; CSMA/CA collision avoidance is utilized to increase the performance of CSMA by trying to be less "greedy" on the shared medium, which decreases the probability of collisions on the channel. If the node sense the channel is busy prior to transmission, then the transmission is delayed for a "random" interval [11].

e-ISSN: 2251-7545

4.1.3. Virtual time CSMA; VTCSMA was introduced to elude collision created by nodes transmitting data at the same time. The VTCSMA implement two type of clocks for each individual node, a virtual clock (vc) and a real clock (rc) which sync and provide "real time". If the channel is busy during the discovery/sensing phase, the vc halts and it reset when the channel is available. Therefore, vc tracks faster than rc when the channel is available.

4.2. IEEE 802.11 DCF CSMA/CA

The IEEE 802.11 DCF [17] is a standardized MAC protocol for wireless local area networks (WLANs), which uses CSMA and collision avoidance (CSMA/CA) with a binary exponential back-off algorithm.

The IEEE 802.11 MAC protocol defines a Distributed Coordination Function (DCF) [14] which is similar to the previous MAC protocols during the transmission phase (unicast transmission) of RTS/CTS (Request to Send and Clear to Send) message exchange. The protocol uses a CSMA/CA with RTS/CTS/DATA/ACK four-way handshaking mechanism.

During the discovery phase, the protocol sense the channel, before initiating the data transmission. It triggers the transmission of the data packets in case the channel is free for a time duration that equals to DCF inter-frame space (DIFS). Otherwise, it keeps sensing until the channel is free [7]

IEEE 802.11 MAC protocol improve the communication speed during the discovery phase because of the ACK (Acknowledgement) inclusion, which allows immediate retransmission by confirming that the data packet was successfully ACK. In addition, the inclusion of ACK help to detect the interference by the hidden terminal which was not detectable during the CTS transmission. Each node is required to wait for a random back-off time instead of transmitting straight away, which help to avoid collisions. The back-off time is calculated by the binary exponential back-off algorithm.

If the back-off timer expire for the first transmitter node, it starts transmitting another RTS frame to its target receiver node, which will respond with a CTS frame after a period of short inter-frame space (SIFS). After transmission and ACK of RTS/CTS frames, the neighboring nodes within the transmission range of the sender or receiver should configure their network allocation vectors (NAVs) and halt their back-off timers [8].

4.3. Multiple Access with Collision Avoidance

The Multiple Access with Collision Avoidance (MACA) protocol improves upon other protocols in relation to the avoidance of the hidden terminal problem. The basic idea of MACA is a wireless network node makes an announcement before it sends the data frame to inform other nodes to keep silent. The hidden terminal issue is illustrate in Figure 4. Two nodes (A and B) trigger the transmission of the packets to node C at the same time. However, neither node A or B can overhear the transmission of each other.

Both nodes send packets to node C at the same time, which result in colliding with each other. MACA improvement to the avoidance of the hidden terminal problem is by denes the RTS and CTS control packets to announce an upcoming transmission which include the length of the data frame in RTS and CTS. Any node receives the announcement either of RTS or CTS control packets must halt for enough period of time for the data packet to be transmitted. This will help to avoid the collision by the neighboring nodes during the data transmission [12].

Figure 5, shows the process of RTS/CTS control messages in simplified environment. When node S transmit the RTS message, both neighboring nodes (A and B) receive the message and halt their RTS transmission tries. And the same principle applies to node D. If node D responds with a CTS, both nodes (B and C) also receive the CTS and are halt throughout the data transmission. In two nodes send simultaneous RTS frames to the same node, the RTS transmissions collide and are lost.

e-ISSN: 2251-7545

If this happens, the source nodes which transmit the failed RTS packets set a random timer employing the binary exponential backoff algorithm for the next transmission try. WLAN data transmission collisions may still happen, and the MACA for Wireless (MACAW) is introduced to extend the function of MACA. It involves nodes sending acknowledgements after each successful data packet transmission [13].

4.4. Floor Acquisition Multiple Access

The Floor Acquisition Multiple Access (FAMA) is evolve from MACA protocol by adding non-persistent carrier sensing to the RTS-CTS exchange phase. FAMA uses random backoff time in case the channel is busy during the listening phase before sensing the channel again. The implementation of the carrier sense to the control packet exchange help to avoid control packet collisions.

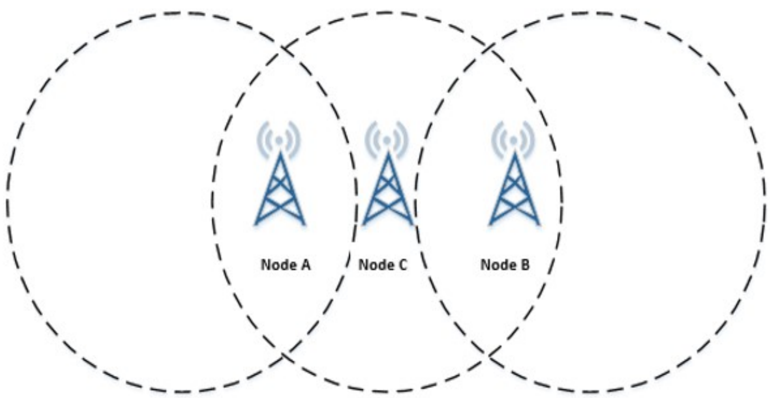


Figure 4. Hidden Terminal Problem

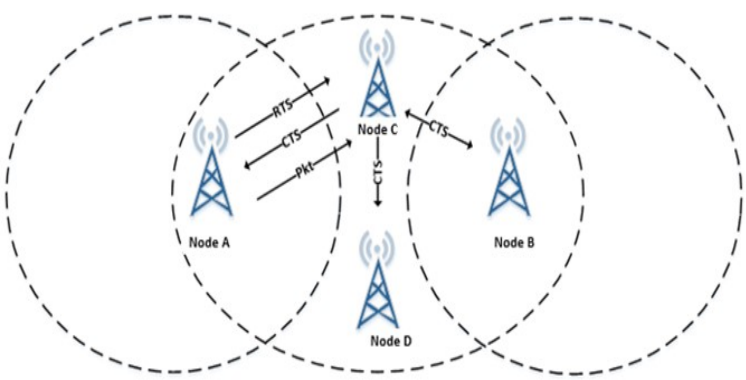


Figure 5. RTS/CTS Mechanism

5. Scheduling Mechanism in MAC Protocols

The dynamic topology and the nature of MANETs poses real challenges in routing and maintaining packets between MNs. The frequent packet transmission, require a scheduling algorithm to control which packet to progress next so that it improve network performance in high mobility and traffic scenarios. Scheduling algorithms are major factor to improve quality of service (QoS) in MANET [20]. The priority scheduling algorithm is very common in the resent simulation research on MANET. In the interface queue, data packets are scheduled in first-in, first-out (FIFO) order and routing packets scheduled in priority algorithm. Network traffic can be categorized into two types: control packets and data packets.

Routing protocols in MANET implement various scheduling algorithms. In all scheduling algorithms, the drop-tail policy is utilized as queue management. And priority is given to control packets instead of data packets, except for the no-priority scheduling algorithm. Scheduling can be categorized in two types: Packet scheduling and Channel Access Scheduling. Packet scheduling determining the order in which packets queueing for transmission at any node must be dispatched. Channel Access Scheduling control the process on how different nodes share a channel in a conflicted area [20]. Since scheduler controls and arrange the traffic packet. Several scheduling algorithms are discussed below [15].

5.1. No-Priority Scheduling

In non-preemptive scheduling algorithm, service are provided on the basis of FIFO order. Consequently, QoS is not achievable. Which is not the case if the traffic is prioritized.

5.2. Priority Scheduling

The priority scheduling is used in MANET research to improve performance. It maintains separate destination rapidly and acquires less queuing in the network. The principle idea of this algorithm is similar to round robin technique, where all paths are considered during the transmissions process. And weighted round robin scheduler is used to avoid starvation. Each data packet header carries a complete list of nodes during the transmission process from the source to the destination. The outstanding hops can be acquired to traverse from the packet headers. In the traditional routing protocols, this information can be acquired from the routing table, which stores the remaining hops to destinations [17, 21].

5.3. Weighted Distance Scheduling

The weighted-distance scheduler is also called a weighted round robin scheduler. The process of weighted-distance scheduler is nodes with shorter distance to the destination get lower weight to data packets that have longer remaining geographic distances to the destinations. The remaining distance is defined as the distance between a chosen next hop node and a destination node [20].

5.4. Round Robin Scheduling

Round robin queue operates per stream queues, and streams are recognized by source and destination pair address. Round robin scheduling control the flow of queue, which send one packet at a time in each path [18].

5.5. Load-Based Queue Scheduling

In load-based queue scheduling algorithm the scheduling service is divided in two steps: scheduling policy and dropping Policy. And priorities are assigned to node based on the level of load. If a node has less load which help in establishing the path to other nodes. This node will get higher priories, otherwise, it avoids the construction of the routes. Node's load level can be determined by queue length, which represented by Min or Max threshold value. If load is low, the threshold value can be set to Min, otherwise it's set in to Max.

5.6. Cluster-Based Multi-Channel Scheduling

In this type of algorithm, the communication process can be established by two methods; the first method is intra cluster communication and seconded method is inter c cluster communications. In cluster based communication, the throughput and QoS can be improved by allocating a fixed time slot per packet to each node over multiple channels (i.e. TDMA). In the first method of cluster communication, the packet process of each node within the cluster is managed within its cluster. If the target node is located within the same cluster, the source transmits directly (direct connection). Otherwise, it forwards the packet to its own cluster head in order to save battery energy (i.e., uplink). In the second method of cluster communication, each cluster head transmit frames received from its cluster members to their destination over specific channels [19].

5.7. Channel Aware Packet Scheduling

Channel aware packet scheduling algorithm can detect the channel bottleneck and confirm the path life time during the transmission process. This route lifetime value is utilized as a parameter to represent channel condition from the end-to-end transmission process [20].

6. Simulation Setup and Results

The simulations were implemented using the OPNET network simulator. Node movement is modelled by the RWpM. Nodes move at a speed between 0 and 10m/s. When the node arrives at its randomly chosen destination, it rests for some pause time. It then chooses a new destination. And begins moving once again. The pause times are varied between 0 and 300 seconds.

Each MAC protocol/routing protocol/ pause time combination is run for five different initial network configurations. Each run is executed for 300 seconds of simulation time and models a network of 100 nodes in a 1500m x 1500m area. Each node has a transmission radius of 250m.

The propagation model is the free space model with threshold cutoff. The radio model also has capture capability, whereby a node may successfully receive a packet even in the presence of noise. There are 20 data sessions between randomly selected sources and destinations.

The bandwidth is 2 Mb/s, the data packet size is 512 bytes, and packets are sent at a rate of four per second by each source. Table 2 shows the parameter values used for the routing protocols in the experiments.

To determine whether the selection of MAC protocols effects the relative performance of the protocols, three results are examined: the number of data packets received by their destinations, the control packet overhead, and the normalized routing load.

The control packet overhead is computed by counting the number of hop-wise control packet transmissions. The normalized routing load is calculated by taking the total number of per-hop control packet transmissions, and dividing this by the number of data packets successfully delivered to their destinations.

Figure 6. illustrates the number of data packets delivered to destinations in each of the networks. The relative performances of GPSR, DSR, and LANDY remains fairly constant while that of OLSR tends to vary by the MAC protocol used. When run over CSMA, OLSR performs best for the higher mobility scenarios; however, while using IEEE 802.11, LANDY outperforms the other protocols.

The protocols achieve nearly the same number of delivered data packets when combined with the MACA and FAMA protocols, with LANDY performing slightly better using the FAMA MAC protocol.

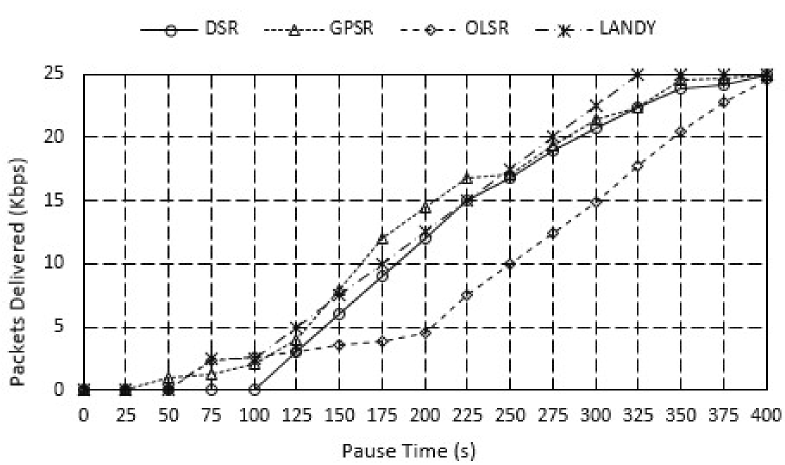
The protocols have better overall performance using CSMA than using MACA or FAMA because of the RTS/CTS messages. MACA sources transmit RTS packets whenever they have a data packet to send without sensing the channel.

This results in an increase in packet collisions and hence decreased throughput. The collision avoidance mechanism incorporated into IEEE 802.11 for the transmission of RTS packets aids in the reduction of the number of collisions.

Table 2. Parameter Values

Parameter Set	Parameter Value
Simulation Area	1500m x 1500m
Number of nodes	100
Traffic Type	CBR
Data Packet size	512 bytes
Simulation Time	300 seconds
MAC Protocols	CSMA, FAMA, IEEE 802.11 DCF, MACA
Routing Protocol	DSR , GPSR, LANDY, OLSR
Node Placement	Random
Transmission radius	250m

Consequently, more data packets reach their destinations. Further analysis of the MAC protocols under UDP can be found in [3].

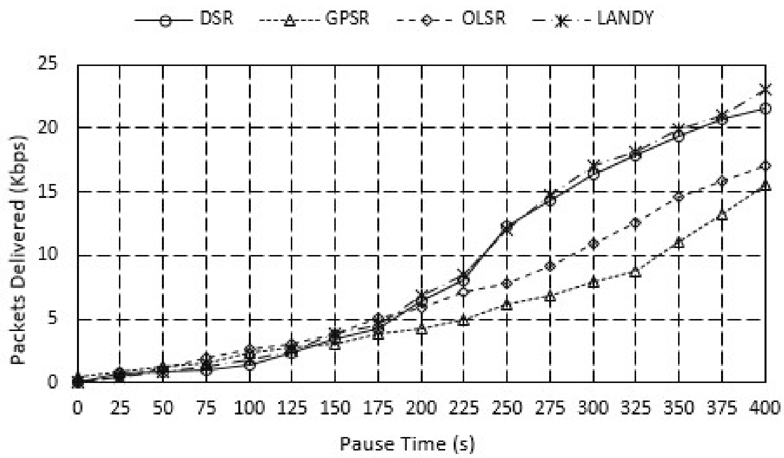


6.a CSMA

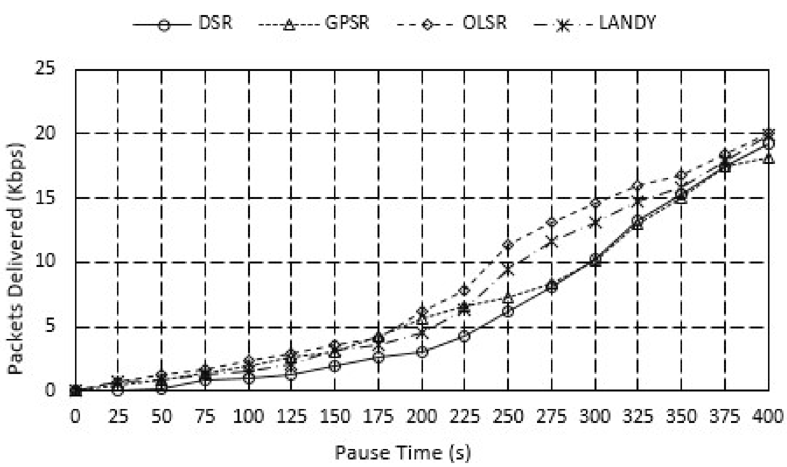
International Journal of Soft Computing and Software Engineering (JSCSE)
Vol.6, No.2, 2016

Published online: February 25, 2016

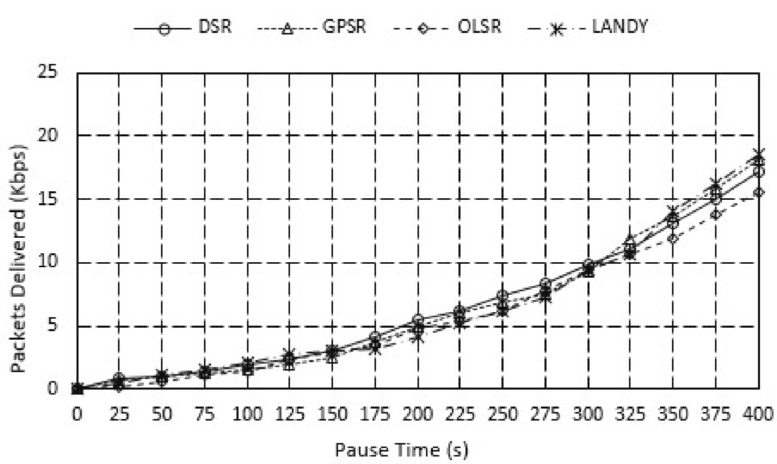
e-ISSN: 2251-7545



6.b MACA



6.c. FAMA



6.d. IEEE 802.11 DCF

Figure 6. Packets Delivery vs Pause Time

The number of hop-wise control packet transmissions during each simulation is shown in Figure 7. Because DSR uses periodic messaging regardless of the underlying MAC protocol, the amount of control overhead generated by this protocol remains relatively constant over the different simulations.

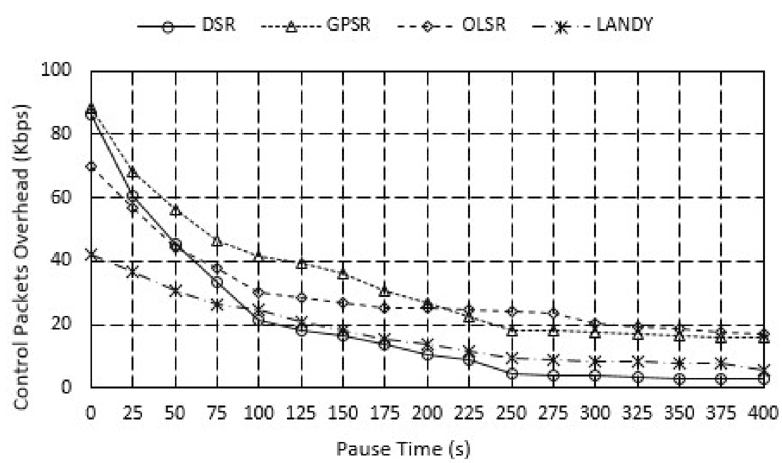
GPSR has both triggered and periodic updates, and hence the amount of control overhead increases as mobility increases (i.e., as the pause time becomes shorter).

GPSR is the only protocol significantly affected by the MAC layer. When run over CSMA, MACA and FAMA, GPSR must utilize and floods the network with Hello messages in order to maintain connectivity. Hence it is expected that the number of control messages in these simulations is greater than in the IEEE 802.11 simulation.

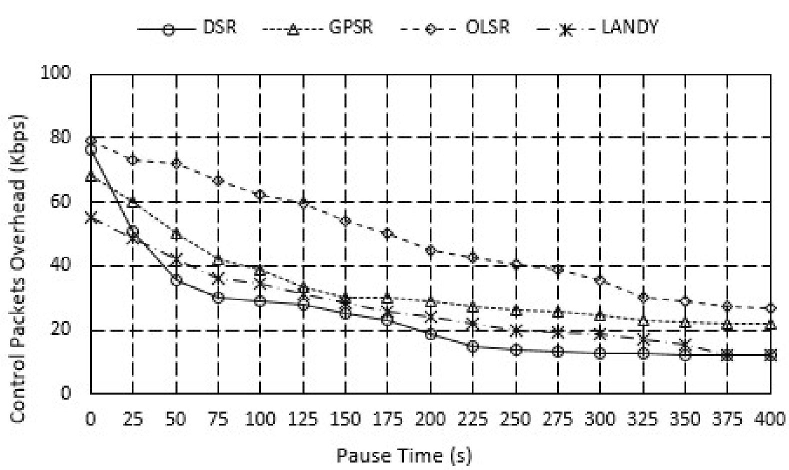
Additionally, the amount of control overhead generated by GPSR is directly related to the number of routes it is maintaining. Because there are so many packet collisions when utilizing the CSMA MAC layer protocol, GPSR is not able to maintain as many routes.

Hence the control overhead is lower for this simulation. As the number of routes GPSR attempts to maintain increases, however, the amount of control traffic generated similarly increases.

The normalized routing load (NRL) is a measure of a protocol's efficiency. This measure is important because link layer protocols in ad hoc networks are contention-based



7.a CMSA

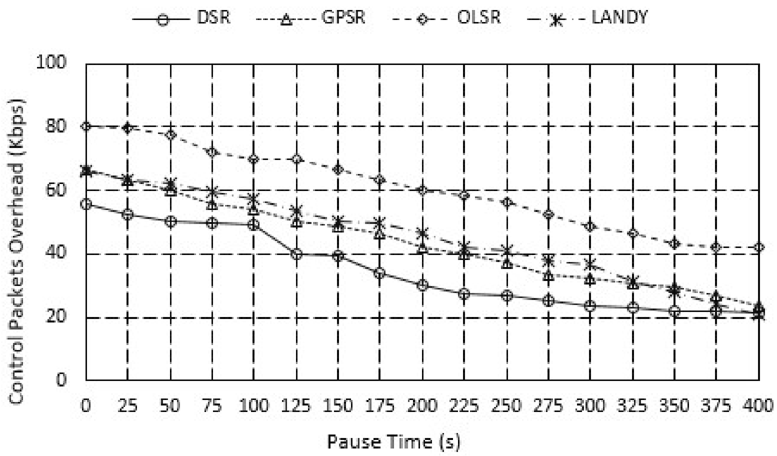


7.b. MACA

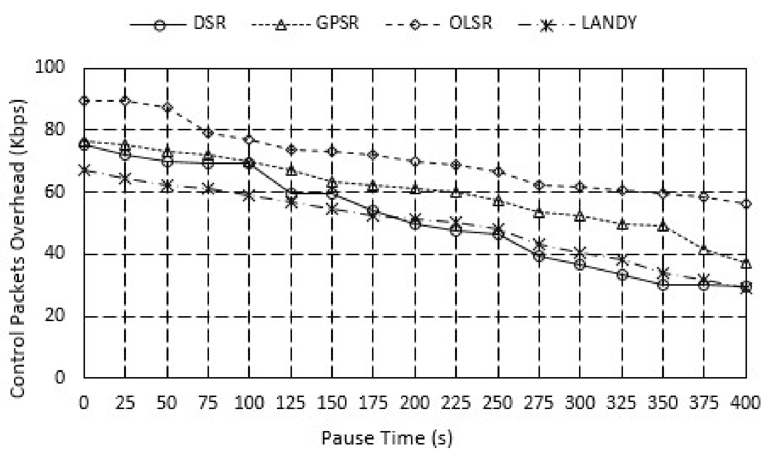
International Journal of Soft Computing and Software Engineering (JSCSE)
Vol.6, No.2, 2016

Published online: February 25, 2016

e-ISSN: 2251-7545



7.c. FAMA



7.d. IEEE 802.11 DCF

Figure 7. Control Packet Overhead vs Pause Time

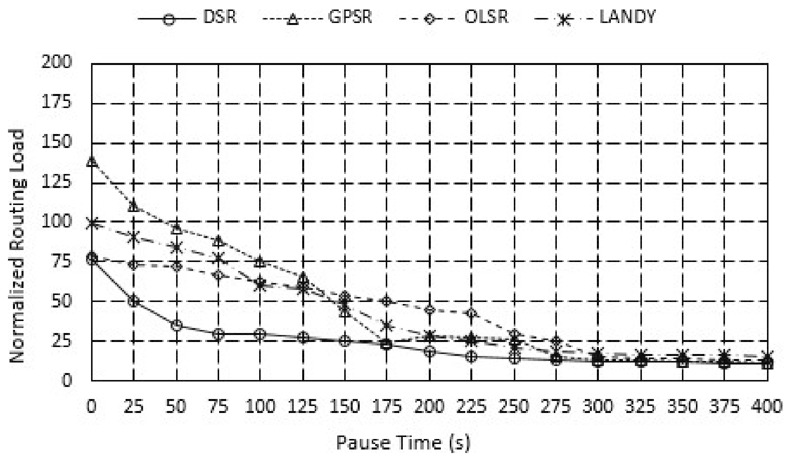
This result is shown in Figure 8. LANDY consistently has a greater NRL than DSR, and has greater NRL than GPSR in all but a few cases of CSMA.

The ratio of control messages generated by LANDY and OLSR remains approximately constant regardless of the underlying MAC protocol. Note the variation in -axis scaling.

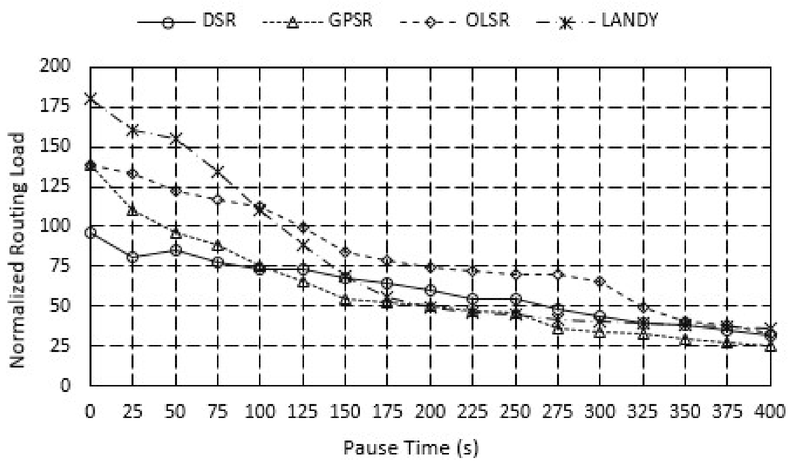
The NRL quantitative measure varies because the throughput of LANDY and OLSR is dependent upon the MAC protocols used.

Hence, this metric aids in the analysis of how efficiently the routing protocols utilize routing packets to deliver data packets.

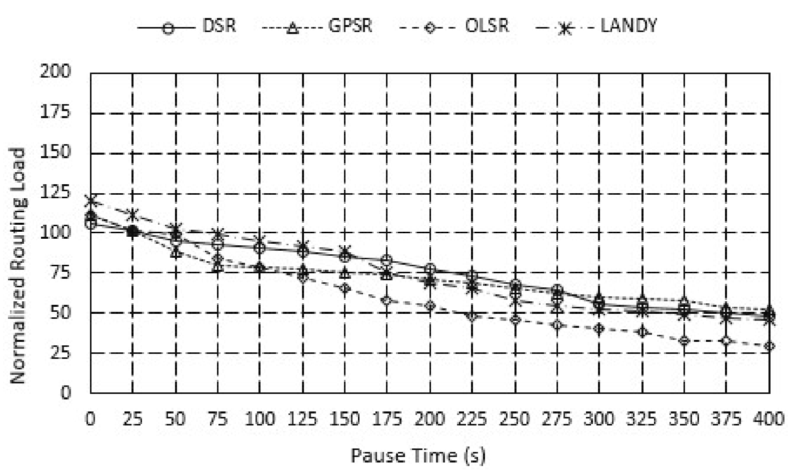
LANDY is most efficient when used with IEEE 802.11. This result is expected since LANDY does not need to flood the network with Hello packet transmissions when combined with IEEE 802.11.



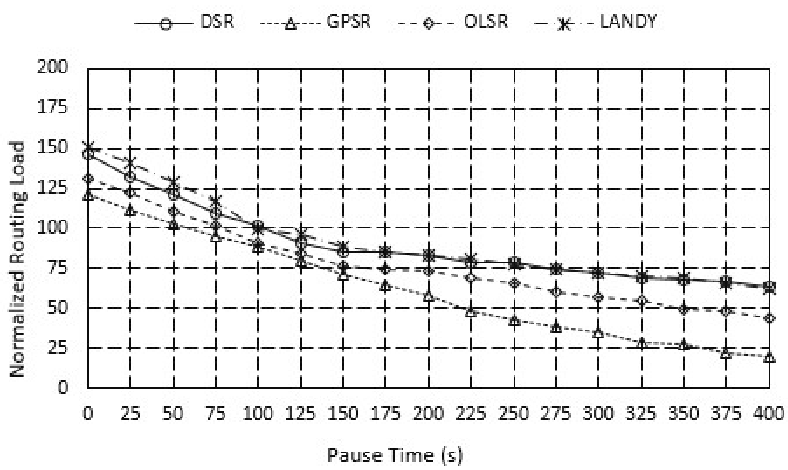
(a) CSMA



8.b. MACA



8.c. FAMA



8.d. IEEE 802.11 DCF

Figure 8. Normalized Routing Load vs Pause Time

7. Conclusion

Our study results indicate that the factors at the MAC layer not only impact the performance of the routing protocol, but it can even change the relative ranking between routing protocols for the same environment.

This study has presented a performance comparison of the DSR, LANDY, OLSR, and GPSR routing protocols when combined with varying MAC protocols. The comparative performance of the OLSR and LANDY protocols does not show notable difference when run over the different MAC protocols. Neither routing protocols needs operational changes reliant on the underlying MAC protocol.

GPSR requires periodic HELLO messaging when the next hop is unreachable, the amount of control traffic generated with these MAC protocols is significantly larger than when it is run over IEEE 802.11 DCF. GPSR proves to be sensitive to the functionality of the MAC protocol, and therefore its relative performance differs depending on which MAC layer is used.

The results also show that LANDY is most efficient when used with IEEE 802.11 DCF. This indicates that the Position based routing protocols performance varies depending upon which MAC protocol is used. The IEEE 802.11 DCF is more efficient than other MAC protocols.

The original MAC algorithms for MANETs are typically single-radio per node, operating on a single channel. Control, data packets, and control messages are essential for coordination of data transfer. As data transmission between all the nodes are broadcasted over the same channel. The most widely used and implemented single-radio, single channel MAC protocol for MANETs is the IEEE 802.11DCF.

Several research have been carried out on improving IEEE 802.11 DCF performance by implementing directional antennas. The disadvantage of this technique is, if a node trying to transmit data, it has to be active node, which means the nodes is receiving data from another node at the same time. Otherwise the node will be idle, because if there is active transmission in the neighborhood then all a node can do is to wait for the channel to become idle before it can transmit data.

REFERENCES

[1] B.Uma and V.R.Sarma Dhulipala. MAC Vs Routing Protocols in Mobile Adhoc Network. IJCA Proceedings on International Conference on VLSI, Communications and Instrumentation (ICVCI) (12):10–12, 2011.

[2] Macintosh, A.; Ghavami, M.; Siyau, M.F., "Performance comparison of position based routing protocols using different mobility models," in Wireless Conference (EW), Proceedings of the 2013 19th European , vol., no., pp.1-6, 16-18 April 2013

[3] S. Kurkowski , T. Camp, and M. Colagrosso, “MANET simulation scenarios: The Incredibles”, ACM Mobile Computing and Communications Review (MC2R), 9(4):70–61, October 2005.

[4] Szott, S.; Natkaniec, M.; Canonico, R.; Pach, A.R., "Impact of Contention Window Cheating on Single-Hop IEEE 802.11e MANETs," in Wireless Communications and Networking Conference, 2008. WCNC 2008. IEEE , vol., no., pp.1356-1361, March 31 2008-April 3 2008

[5] Lal ,C, Laxmi, V. ; Gaur, M.S. “A Node-Disjoint Multipath Routing Method Based on GPSR Protocol for MANETs” , In Proceeding(s) of (IEEE international conference) Advanced Information Networking and Applications (AINA), pp. 399-405, 2012.

[6] Dricot, J., et al. "Impact of the physical layer on the performance of indoor wireless networks." Proceedings of the International Conference on Software, Telecommunications and Computer Networks. 2003.

[7] Perkins, C.E.; Royer, E.M.; Das, S.R.; Marina, M.K., "Performance comparison of two on-demand routing protocols for ad hoc networks," Personal Communications, IEEE , vol.8, no.1, pp.16,28, Feb 2001.

[8] Qunwei Zheng,Xiaoyan Hong,and Sibarata Ray, “Recent Advances in Mobility Modeling for Mobile Ad Hoc Network Research”, In Proc. of the ACM Southeast Regional Conf., New York, NY, USA, 2005.

[9] J. Broch, D. A. Maltz, D. B. Johnson, Y.-C. Hu and J. Jetcheva, “A performance comparison of multi-hop wireless ad hoc network routing protocols,” in Proceedings of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking, ACM, October 1998.

[10] Lei Guang; Assi, C., "Vulnerabilities of ad hoc network routing protocols to MAC misbehavior," in Wireless And Mobile Computing, Networking And Communications, 2005. (WiMob'2005), IEEE International Conference on , vol.3, no., pp.146-153 Vol. 3, 22-24 Aug. 2005.

[11] Macintosh, A.; Ghavami, M.; Siyau, M. F.; Ling, S. L., "Local Area Network Dynamic (LANDY) routing protocol: A position based routing protocol for MANET," in European Wireless, 2012. EW. 18th European Wireless Conference , vol., no., pp.1-9, 18-20 April 2012

[12] F. Bai, N. Sadagopan and A. Helmy, “IMPORTANT: A framework to systematically analyze the Impact of Mobility on Performance of Routing protocols for Ad hoc Networks,” in IEEE INFOCOM, March 2003.

[13] Adam Macintosh, Mohammad Ghavami, Ming Fei Siyau ,"Lightweight Local Area Network Dynamic Routing Protocol for MANET ", International Journal of Soft Computing and Software Engineering [JSCSE], Vol. 2, No. 7, pp. 9-25, 2012, Doi: 10.7321/jscse.v2.n7.2.

[14] Stojmenovic, Ivan, et al. "Physical layer impact on the design and performance of routing and broadcasting protocols in ad hoc and sensor networks."Computer Communications 28.10 (2005): 1138-1151.

[15] Gupta P, Drag R (2006) An experimental scaling law for ad hoc networks, Bell Laboratories Technical report. Bell Laboratories, Murray Hill.

[16] Lal ,C, Laxmi, V. ; Gaur, M.S. “A Node-Disjoint Multipath Routing Method Based on GPSR Protocol for MANETs” , In Proceeding(s) of (IEEE international conference) Advanced Information Networking and Applications (AINA), pp. 399-405, 2012.

[17] Yuefeng Zhou; Tan, Y.-Y.E.; Laurenson, D.I.; McLaughlin, S., "Impact of power saving MAC scheme on ad hoc network routing protocol," in Vehicular Technology Conference, 2005.

[18] C. Bettstetter, On the Minimum Node Degree and Connectivity of a Wireless Multihop Network, MOBIHOC’02, June 9-11, 2002.

[19] H. Takahi and L. Kleinrock, “Optimal transmission ranges for randomly distributed packet radio terminals,” IEEE Trans. on Comm., Mar. 2007.

[20] Conti, M.; Maselli, G.; Turi, G.; Giordano, S., "Cross-layering in mobile ad hoc network design," Computer, vol.37, no.2, pp.48,51, Feb 2004.

[21] Gossain, Hrishikesh, et al. "Supporting MAC layer multicast in IEEE 802.11 based MANETs: Issues and solutions." Local Computer Networks, 2004. 29th Annual IEEE International Conference on. IEEE, 2004.

[22] Adam Macintosh, Mohammad Ghavami, Ming Fei Siyau ,"Speed and Pause Time Impact on Position Based Routing Protocols Under Different Mobility Models", International Journal of Soft Computing and Software Engineering [JSCSE], Vol. 4, No. 3, pp. 33-55, 2014, Doi: 10.7321/jscse.v4.n3.1