Mobility Based Energy Analysis of Five Mobility Models in MANET Using Five Routing Protocols

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Abstract
In this paper we have analyzed the energy consumption of five mobility models under five different routing protocols. The mobility models considered are Random Walk with Wrapping (RW-W), Random Waypoint with Steady State (RWP-SS), Gauss Markov Mobility Model (GM), Community Based Mobility Model (CM) and Semi-Markov Smooth Mobility Model (SMS). The selected routing protocols are AOMDV, DYMO, FSR, OLSR and TORA. In the literature many have concentrated on the amount of energy consumed by the routing protocols. But there is no detailed analysis of the mobility model's role on routing protocols in energy consumption. We also found contradicting results for TORA routing protocol than that has been found until now. The energy consumed by each of these mobility models are mapped by varying the mobility speed. Our results indicate that the routing protocols are indeed influenced by these mobility models. We also claim that our paper is the first to consider these five mobility models under five different routing protocols and to analyze the energy consumption of each of these mobility models. From our simulation we deduce that with increased complexity of the mobility models the amount of energy consumed also increases among the routing protocols.

Key words:
Ad Hoc networks, energy, mobility models, routing protocols, performance, simulation

1. Introduction

Wireless communications play a very important role in our daily life. An ad hoc network consists of autonomous self organizing mobile devices that communicate with each other by creating a network in a given area. Each of these nodes is battery operated and energy is exhaustible at a very high rate. It is important to recognize the appropriate routing protocol that gets the work done with less energy consumption. These networks find their applications in battlefield and in disaster relief works. Conserving energy is very important in these scenarios so that the deployed network lasts for a long time.

Battery life plays a very important role in establishment of network. Failure of battery life may lead to havoc in the network. Some of the nodes may die leaving a hollow in the communication of the network. Before establishing another route the remaining nodes have to move with in the communication range there by consuming energy which would have not been necessary if intermediate nodes had not died due to low battery.

The main contribution of this paper is that we have made an unassailable effort to study the energy consumption pattern of five mobility models under five different routing protocols. To the best of our knowledge, no work has been reported that compares and studies the performance of all these five mobility models under five different routing protocols in a single research paper.

The rest of the paper is organized as follows. Previous related work is discussed in section two. In the Third section a brief description of the routing protocols, Mobility models and the energy model is given. Various simulation parameters used in this paper is mentioned in section four. Analysis of the result is done in section five and finally we conclude the paper.

2. Related Work

In [1] the energy analysis of four routing protocols namely AODV, DSR, DSDV and TORA is carried out. The energy consumption of these routing protocols are studied with varying mobility, different dimensions of area, node density, number of sources and the traffic pattern. At different mobile speed and traffic load the DSDV routing protocol has less energy consumption. On varying the node density, AODV and DSR have less energy consumption. When different dimensions are considered TORA has the worst performance while the remaining protocols more or less have the same performance.

The effect of routing protocols on mobility models and the effect of mobility models on routing protocols is carried out in [2]. The routing protocols considered are AODV,

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DSDV and DSR. The underlying mobility models are Random Waypoint, Manhattan Grid and RPGM. Under Random Waypoint DSR has the least energy consumption. For Manhattan Grid mobility model at lower speed DSR consumes less energy but as the mobility speed is increased then DSDV shows better performance. AODV and DSR routing protocols score over DSDV by consuming less energy for RPGM mobility model.

The authors of [3] have considered Entity Mobility Model and Group Mobility Models as the two groups of mobility model. Random Waypoint, Manhattan Grid and Gauss-Markov mobility models are compared under Entity Mobility Model while RPGM and Column model are studied under Group Mobility Model. These mobility Models are compared by varying the mobile speed. The metric considered is Energy-Goodput. This metric indicates the network lifetime. The less the energy goodput the more the lifetime of the network. As the mobility speed is increased the energy goodput of the group mobility models also decreases.

The energy consumption of TORA routing protocol is studied under Random Waypoint and Reference Point Group Mobility by varying the mobility speed [4]. Through simulation it is shown that the UDP traffic consumes less energy than that of TCP traffic for RPGM mobility model.

3. Description of Routing Protocols, Mobility Models and Energy Models

In this section we give a description of routing protocols, mobility models as well as the energy model used in this paper.

3.1 Adhoc On Demand Multipath Distance Vector Algorithm

Adhoc On Demand Multipath Distance Vector Routing Algorithm (AOMDV) is proposed in [5]. AOMDV employs the “Multiple Loop-Free and Link-Disjoint path” technique. In AOMDV only disjoint nodes are considered in all the paths, thereby achieving path disjointness. For route discovery RouteRequest packets are propagated through out the network thereby establishing multiple paths at destination node and at the intermediate nodes. Multiples Loop-Free paths are achieved using the advertised hop count method at each node. This advertised hop count is required to be maintained at each node in the route table entry. The route entry table at each node also contains a list of next hop along with the corresponding hop counts. Every node maintains an advertised hop count for the destination. Advertised hop count can be defined as the “maximum hop count for all the paths”. Route advertisements of the destination are sent using this hop count. An alternate path to the destination is accepted by a node if the hop count is less than the advertised hop count for the destination. We have used the AOMDV implementation for NS-2 provided by [6].

3.2 DYMO Routing Protocol

DYMO Routing protocol is an improved version of AODV routing protocol. Routes are established on demand. When a source node needs to establish a route to the destination the RouteRequest (RREQ) messages are flooded through out the network. During broadcasting only those nodes that have not broadcasted previously will forward the messages. The RREQ message includes its own address (source address), sequential number, a hop count and the destination node address. A hop count of one is added to a RREQ packet originating at the source node. Each node that forwards the RREQ packet adds its own address and the sequence number. After the source node has sent the RREQ packet it waits for RREQ_WAIT_TIME duration. This is a constant value and is fixed at 1000 milliseconds.

Processing of RREQ by other nodes is done as follows. When a node receives the RREQ message it is compared with its own routing table. If the routing table does not contain any information regarding the source node, then an entry is created for the source node. The next hop is to the node from which it had received the packets. This helps in establishing a route back to the originator.

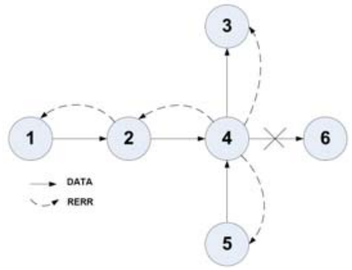


Fig. 1 Route Breakage Scenario in DYMO

Since the network is flooded with RREQ messages almost all the nodes do contain information regarding the source node. If an entry is found to the source node, the node which had received the RREQ packet compares its sequence number and hop count with the information found in its own routing table. If an entry exists and if it is not stale then the node updates its routing table with the latest information or otherwise the RREQ is dropped. Every node that evaluates a valid RREQ is capable of creating a reverse route to all the nodes whose addresses are found in the RREQ. After updating the route table, the node increments the hop count by a value of one to imply the number of hops the RREQ has traveled. Once the packet reaches the destination a RREP message is sent back to the source node through the reverse path that had been created. This RREP packet contains the information regarding its sequence number, number of hop counts and addresses. The same information is added by all the nodes that processes the RREP along the reverse path.

Consider fig 1. When ever there is a break in the path it has to be modified by generating a RERR message. Consider that the path between node 4 and node 6 is broken. Then node 4 has to generate RERR message containing the address and sequence number of the node which cannot be reached. This RERR is broadcasted through out the network. When node 2 receives the RERR message it compares the information found in the RERR message with its own routing table entries. If it has an entry then the route information has to be removed if the next hop node (i.e. node 4) is same as the node from which it had received the RERR message. When node 3 and node 5 receive the RERR message, the information provided in RERR is checked with their corresponding entries. Since they do not use node 4 to reach 6 the RERR message is discarded. In this way by broadcasting the RERR message, the RERR messages the concerned nodes are informed about any breakage in the path to the destination node [7, 8].

3.3 Fish Eye State (FSR) Routing Protocol

The FSR protocol employs a concept called “FISH EYE” technique. The idea behind fish eye technique is that a fish’s eye is able to observe maximum number of pixels near its focal point. The amount of pixels observed decreases as the distance increases from the focal point. If we think of the same concept from a network point of view it means that a node maintains a high quality of information about its immediate neighboring nodes while the information decreases with the increase in the distance.

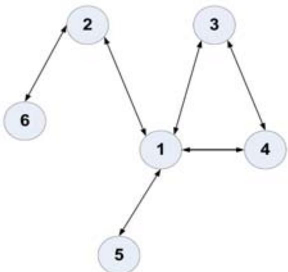


Fig. 2 FSR Demonstration

A node maintains up to date information of the link table by obtaining the latest values from its neighboring nodes. This information is exchanged with the neighboring nodes periodically. These periodical exchanges are not event driven thus reducing the overhead. When the nodes exchange the information the entries with the highest sequence number replaces the entries of a node with the lowest sequence number. FSR routing protocol uses something called “SCOPE”. The Scope of a network can be defined as the group of nodes among whom the communication takes place frequently as they are with in the assumed number of hops (or less number of hops). In fig 2 for source node 1 all the neighboring nodes have one hop except from node 2. For source node 2, the number of hops is 2 for nodes 3, 4 and 5 while it is 1 for node 1 and 6. For source node 3, the number of hops from node 2, 4 and 5 is 2 and 3 hops from node 6 while the number of hops from remaining nodes is less than 1. For source node 4, the number of hops from 2, 3 and 5 is 2 and for 6 it is 3 while from remaining nodes it is less than 2. For source node 5 the number of hops is less than 2 only for node 1. For source node 6 the number of hops is less than 2 only for node 1. These results are obtained by assuming that the scope is less than 2. The nodes with less than 2 hops are the nodes with whom the packets are exchanged at a high rate of frequency than the nodes having a hop count of 2 or more. This may result in keeping improper information regarding the nodes that are far away. But as the packet tends to get closer and closer to the destination node the routes are established [9, 10].

3.4 Optimized Link State Routing (OLSR) Protocol

Optimized Link State Routing Protocol (OLSR) is a table driven, proactive based routing protocol. Multipoint Relay (MPR) nodes are used to optimize the OLSR routing protocol. By MPRs the number of packets broadcasted in the network is minimized. A node selects a set of one hop neighboring nodes to retransmit its packets. This subset of selected neighboring nodes is called the Multipoint Relays of that node.

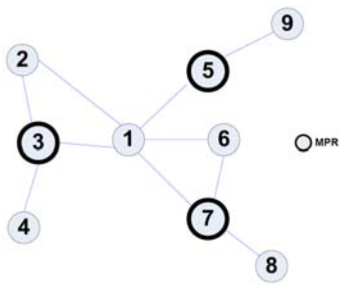


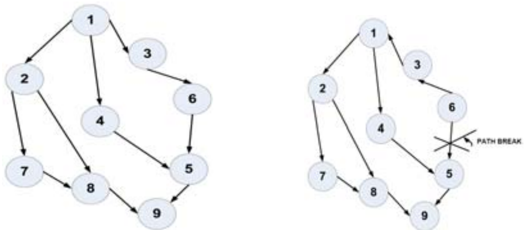
Fig. 3 Transmission of Packets Using MPR

The MPR nodes are the only nodes those forward the packets during broadcasting. All the links between the nodes are assumed to be bidirectional. The MPR node is chosen in such a way that the chosen node is one hop and this one hop node also covers those neighboring nodes which are two hops away from the originating node. The MPR nodes are affiliated to this original node. This reduces the number of messages that needs to be retransmitted.

In fig 3 node 4 is two hops away from node 1. So node 3 is chosen as an MPR. Any node that is not present in the MPR list does not forward the packets. Every node in the network maintains information regarding the subset neighboring nodes that have been selected as MPR nodes. This subset information is called as MPR Selector List.
Optimization in OLSR is achieved in two ways. First the amount packets broadcasted in the network is reduced as only a selected few nodes called MPR broadcast the packets. Secondly the size of the control packets is reduced as the information regarding its multipoint relay selector set is provided instead of providing an entire list of neighboring nodes [11, 12, 13].

3.5 Temporally Ordered Routing Algorithm (TORA)

TORA comes under a category of algorithms called "Link Reversal Algorithms". TORA is an on demand routing protocol. Unlike other algorithms the TORA routing protocol does not uses the concept of shortest path for creating paths from source to destination as it may itself take huge amount of bandwidth in the network. Instead of using the shortest path for computing the routes the TORA algorithm maintains the "direction of the next destination" to forward the packets. Thus a source node maintains one or more "downstream paths" to the destination node through multiple intermediate neighboring nodes. TORA reduces the control messages in the network by having the nodes to query for a path only when it needs to send a packet to a destination.



(a) (b)

Fig. 4 Directed Path in TORA

In TORA three steps are involved in establishing a network. A) Creating routes from source to destination, B) Maintaining the routes and C) Erasing invalid routes. TORA uses the concept of "directed acyclic graph (DAG) to establish downstream paths to the destination". This DAG is called as "Destination Oriented DAG". A node marked as destination oriented DAG is the last node or the destination node and no link originates from this node. It has the lowest height.
Three different messages are used by TORA for establishing a path: the Query (QRY) message for creating a route, Update (UPD) message for creating and maintaining routes and Clear (CLR) message for erasing a route. Each of the nodes is associated with a height in the network. A link is established between the nodes based on the height. The establishment of the route from source to destination is based on the DAG mechanism thus ensuring that all the routes are loop free. Packets move from the source node having the highest height to the destination node with the lowest height. It's the same top to down approach.
When there is no directed link from source to destination the source node trigger the QRY packet. The source node (node 1) broadcasts the QRY packet across all the nodes in the network. This QRY packet is forwarded by all the intermediate nodes which may contain a path to the destination. Consider fig 4(a). When the QRY packet reaches the destination node (node 9) then the destination node replies with a UPD message. Each node receiving this UPD message will set the value of the height to a value greater than the height of the node from which it had received. This results in the creation of the directed link from the source to the destination. This is the concept involved in the link reversal algorithm. This enables to establish a number of multiple routes from the source to destination. Assume that the path between node 5 and node 6 is broken (fig 4(b)). Then node 6 generates an UPD message with a new height value with in a given "defined time". Node 3 reverses its link on receiving the UPD message. This reverse link indicates that the path to destination through that directed link is not available. If there is a break between node 1 and node 3 then it results in partition of the network where the resulting invalid routes are erased using the CLR message [14, 15, 16].

3.6 Random Walk with Wrapping (RW-W)

The special case of wrapping with Random Walk Mobility Model (RW-W) is discussed in [17]. To consider that a mobility model is having a perfect simulation model it should not have a transient time. A trip combines the duration at any given point of time T_n with a P_n position will have a trip duration of $S_n \in R_+$. The next transition time for a mobile node is given by $T_{n+1} = T_n+S_0$ with a position of $P_n\left(\frac{t-T_n}{S_n}\right)$

V_n is the speed at which a node moves. On reaching the end of a boundary (x_0, a_2) the node wraps to the other end, at a location of $(x_0, 0)$. If $R_2 \rightarrow A$ is the wrapping function then

$$\begin{pmatrix} x \\ y \end{pmatrix} \rightarrow b\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} x \bmod a_1 \\ y \bmod a_2 \end{pmatrix}$$

3.7 Random WayPoint with Steady State (RWP-SS)

While considering the Random Waypoint Mobility Model for simulation, a dissimilar mobility pattern is observed during the initial mobility duration and at the later stage of the simulation. In literature, to avoid the mentioned situation, many of the papers follow a procedure where the initial few seconds are discarded and then it is assumed that the remaining seconds of the simulation are assumed to have a similar pattern. But this method is too crude, as it can not be told at which point the dissimilar pattern starts or stops. To overcome this problem the authors of [18] have proposed the Random Way Point-Steady State Mobility Model (RWP-SS). "The initial speed and the stationary distribution location are sampled" to overcome the problem of discarding the initial simulation data. The RWP-SS without pause is given by

$$F^{-1}(u) = \frac{S_1^u}{S_0^{u-1}} \quad (1)$$

Here S is the initial speed chosen uniformly over (0, 1) and F-1 (u) is the inverse of the cumulative distribution function. RWP-SS with pause is given by

$$H_0(p) = \frac{\int_0^p [1 - H(t)]dt}{E(p)} \quad (2)$$

Where, H(p) is the cumulative distribution function, E(p) is the expected length of a pause. (The equations (1) and (2) are from [18])

3.8 Gauss Markov Mobility Model

The Gauss Markov Mobility Model [19] makes use of the probability density function. The Gauss Markov Mobility model determines the future location of a node based on its velocity and the previous location of the node. The location of a node is made known to the entire network at any given point of time. When a node moves, it checks the distance it has covered. If the node has covered a minimum acceptable distance or more, then the node updates the network about its current position. To reach a node, the network inspects the previous location of the node. Based on the velocity and the previous location it sends a message in shorter distance order to locate the current position.
The velocity of a node is given by

$$V_n = \alpha^n v_0 + (1-\alpha^n)\mu + \sqrt{1-\alpha^2}\sum_{i=0}^{n-1}\alpha^{n-i-1}x_i$$

Gauss Markov Mobility model can also be used to mimic other mobility models like fluid flow mobility model and Random Walk Mobility model.

3.9 Community Based Mobility Model

This mobility model can be used to model humans moving in groups or groups of humans which are clustered together. The authors of the community model have evaluated their model by using the real time synthetic mobility traces provided by the Inter Research Laboratory, Cambridge. The first step in establishing a community model is using the "Social network as input" to the community mobility model. It involves two ways i.e. "modeling of social relationships" and "detection of community structures". Modeling of social relationship can be represented as a weighted graph matrix. If any of the elements in the matrix is greater than the specified threshold value then that element in the graph is set to 1 and if it is less than the threshold value then it is set to 0. A value of 1 represents strong social interaction between the groups and a value of 0 represents no interaction. The concept of 1 and 0 is used to emphasize the relation between any two members of a group or any individuals of the group. The next step is to conceptualize the interaction between groups of a social community network.

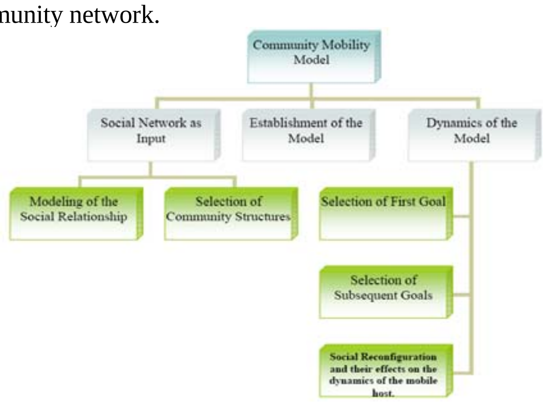


Fig. 5 Steps Involved in the Establishment of the Community Mobility Model [ref 29]

The authors of the community model have implemented this aspect by considering an algorithm provided by [20]. Groups communicate with each other through "inter community edges" and this concept is called as "betweeness of edges". Once the connection between the individuals in the communities and the interaction between the communities itself is established then the next step is the placement of the communities in a square location on a grid. This can be represented by S_{pq} i.e. "a square in position of p, q". The next step is the dynamics of the mobile host. For mobility, a host from each group or community is selected. For each of the host the first goal is randomly chosen inside the square S_{pq}. Here goal represents the mobility position. The next goal is selected by the "social attractivity". Each host will have a certain attraction for another host representing another square location. When a host is attracted to another host then the community moves from the present square location to the square location of another host to which the present host is attracted. Finally, the mobile host needs to be associated with the mobility dynamics [21]. The Community Model can be conceptualized as in fig 5.

3.10 Semi-Markov Smooth (SMS) Mobility Model

Semi-Markov Smooth (SMS) mobility model obeys the physical law of smooth mobility. It has three phases a) speed up phase b) middle smooth phase and c) slow down phase. In the speed up phase or α phase the object is accelerated until it reaches an acceptable speed. The speed up phase time interval is given by $[t_0, t_\alpha] = [t_0 + t_0 + \alpha\Delta t]$ where t_0 is the initial time and t_α is the alpha phase time.
Once the object is moving at an acceptable normal speed then it has to maintain this speed for some time. The middle smooth phase or β phase is represented by $\lfloor t_\alpha, t_\beta = t_\alpha, t_\alpha + \beta\Delta t \rfloor$ where β is uniformly distributed over $[\beta_{min}, \beta_{max}]$. As we know that every moving object at some point of time has to slow down and eventually stop. The node reaches γ phase or slow down phase. The node remains in this phase for a random period of time before the speed reaches to $V_\gamma = 0$. Distance between any two points is treated as the Euclidian distance. Trace length is the actual length traveled by a node during one movement without any change in that direction. Distance evolution is the way the traveling of a node is observed. If the speed of a node increases continuously then the α phase and β phase of the trace length is equivalent to the distance evolution. This results in a smooth trace. When the speed of the node decreases in the γ phase it results in a sharp curve. SMS mobility model can also be considered as a group mobility model. In this scenario a node is selected as a leader. This group leader selects a speed and direction which the other nodes do follow. The velocity of a group member m at its nth step is given by

$$V_n^m = V_n^{Leader} + (1-\rho)\cdot U \cdot \Delta V_{\max}$$

$$\phi_n^m = \phi_n^{Leader} + (1-\rho \cdot U \cdot \Delta\phi_{\max})$$

Where U is a random variable, ΔV_{max} is the maximum speed and ϕ_{max} is the difference in the direction of the common node and the leader node in one step [22, 23].

3.11 Energy Model

The Energy Consumption model considered in this paper is based on a study done in [1, 24]. The amount of energy spent in transmitting and receiving the packets is calculated by using the following equations:

$Energy_{tx}$ = (330*PacketSize)/2*10^6

$Energy_{rx}$ = (230*PacketSize)/2*10^6 where packet size is specified in bits.

Average Energy Consumed is defined as

$$\frac{\sum PercentageEnergyConsumedbyallNodes}{NumberofNodes}$$

4. Simulation Environment

Simulations are performed using Network Simulator NS-2 [25]. The simulated values of the radio network interface card are based on the 914MHz Lucent WaveLan direct sequence spread spectrum radio model. This model has a bit rate of 2 Mbps and a radio transmission range of 250m. The IEEE 802.11 distributed coordinated function with CSMA/CA is used as the underlying MAC protocol. Interface Queue (IFQ) value of 70 is used to queue the routing and data packets

Table 1: Simulation Parameters

Simulator	NS2
Routing Protocols	AOMDV, DYMO, FSR, OLSR and TORA
Mobility Model	Random Way Point with Wrapping, Random Way Point with Steady State, Gauss-Markov Mobility Model, Community Mobility Model and SMS Mobility Model
Simulation Time (sec)	900
Pause Time (sec)	10
Simulation Area (m)	1000 x 1000
Number of Nodes	50
Transmission Range	250 m
Maximum Speed (m/s)	5, 10, 15, 20, 25

Traffic Rate (pkts/sec)	5
Data Payload (Bytes)	512

5. Result Analysis

All the simulations scenarios are averaged for 5 different seeds while running independently. The mobility speed is varied from 5 m/s to 25 m/s in steps of 5. The AOMDV routing protocol consumes more energy under Community based mobility mode (fig 6). The energy consumption is steady for AOMDV protocol at 166 to 168 joules when community model is used. In our simulation we have three groups. Network connectivity has to be maintained these groups. Since AOMDV is a multi-path algorithm we have many paths running between the nodes of different groups resulting in higher energy consumption. Gauss-Markov mobility model comes a near second to community model. SMS mobility model has the highest impact on OLSR routing protocol followed by Community Based Mobility Model (fig 7). At 25 m/s all the mobility models except community based mobility model show same quantity of energy consumption. The multipoint relays in OLSR contribute to the energy consumption in OLSR.

The energy consumption of RW-W mobility model is more than RWP-SS and Gauss Markov Mobility model for FSR routing protocol (fig 8). It is quite unexpected for a random waypoint based mobility model.

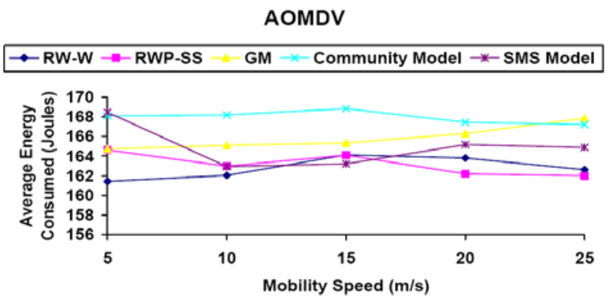


Fig. 6 Average Energy Consumed (J) v/s Mobility Speed (m/s)

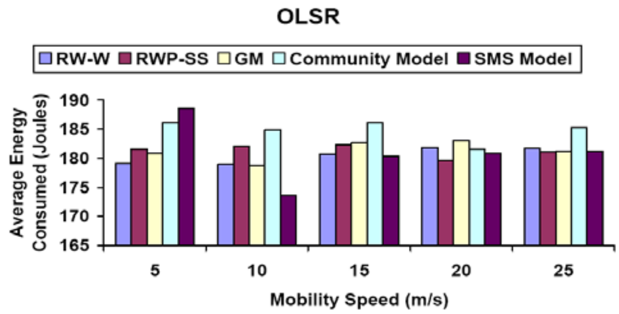


Fig. 7 Average Energy Consumed (J) v/s Mobility Speed (m/s)

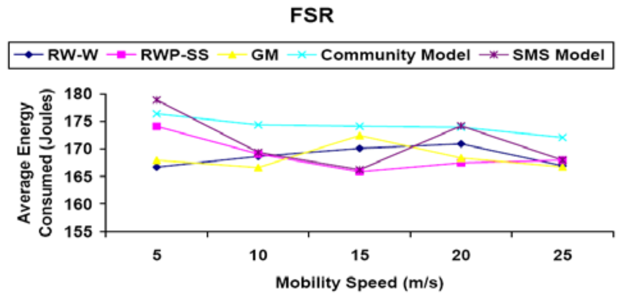


Fig. 8 Average Energy Consumed (J) v/s Mobility Speed (m/s)

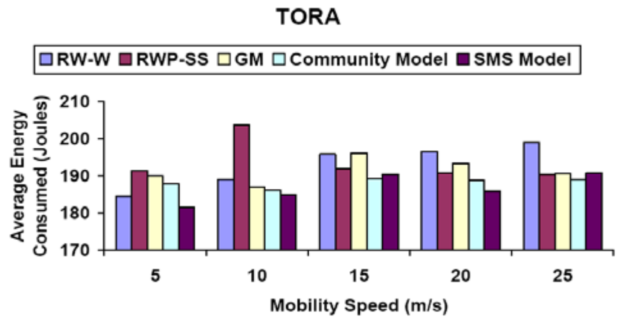


Fig. 9 Average Energy Consumed (J) v/s Mobility Speed (m/s)

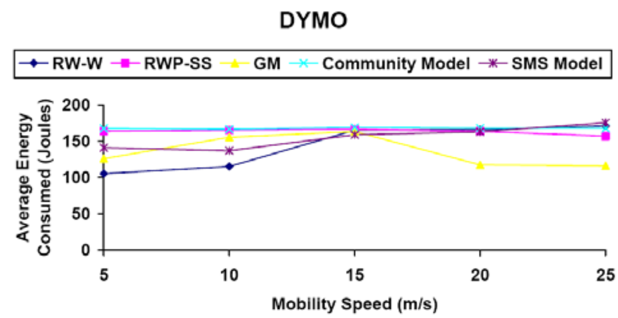


Fig. 10 Average Energy Consumed (J) v/s Mobility Speed (m/s)

Energy consumption of FSR under RW-W increases with the increase in mobility speed. SMS mobility model has the highest energy consumption alternating between 180 J to 170 J.
TORA routing protocol has highest energy consumption for RWP-SS mobility model for up to 10 m/s. After 10 m/s energy consumption is more for RW-W mobility model (fig 9). In literature it has been shown that TORA routing protocol consumes more energy. On observing those results it was found out that those were obtained by having RWP has the underlying mobility model. But TORA routing protocol performs better under Community Mobility Model and SMS model. This indicates that the underlying mobility model has greatest impact on TORA routing protocol. For DYMO routing protocol both RWP-SS and Community Model exhibit same level of energy consumption (fig 10). Gauss Markov mobility model has least energy consumption. For DYMO routing protocol under Gauss markov mobility model the energy consumption decreases with the increase in mobility speed.

6. Conclusion

In this paper we have evaluated five mobility models over five routing protocols. We have evaluated these mobility models by varying the mobility speed. This is the first in-depth study of these mobility models by considering various routing protocols. TORA has the highest energy consumption among all the routing protocols under RWP-SS mobility model. DYMO routing protocol has least energy consumption when deployed under RW-W mobility model. Gauss-Markov mobility model shows promising results under FSR and DYMO routing protocol. FSR is the protocol for SMS mobility model. All the routing protocols show high energy consumption under Community Based Mobility Model. We also recommend a detailed analysis of TORA routing protocol under these modern mobility models before labeling it as the routing protocol which consumes high energy. In future we would like to extend this work to include the amount of energy consumed by these mobility models by varying node density, traffic load, number of sources, transmission range and the network size.

References

[1] Juan Carlos Cano and Pietro Manzoni,”A Performance Comparison of Energy Consumption for Mobile Ad Hoc Network Routing Protocols”, In Proceedings of the 8th International Symposium on Modelling, Analysis and Simulation of Computer and Telecommunication Systems, San Francisco, CA, 2000.

[2] Bor-rong Chen and C Hwa Chang,”Mobility Impact on Energy Conservation of Ad Hoc Routing Protocols”, Department of Electrical and Computer Engineering, Tufts University, Medford, USA.

[3] Preetha Prabhakaran and Ravi Shankar,”Impact of Realistic Mobility models on Wireless Network Performance”, IEEE International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob2006), Montreal, 19-21 June 2006.

[4] Shrirang Ambaji Kulkarni and G Raghavendra Rao,”Mobility and Energy Based Performance Analysis of Temporally Ordered Routing Algorithm for Ad hoc Wireless Network”, IETE Tech Rev, 2008;25:222-7.

[5] Mahesh K. Marina and Samir R.Das, “ On-Demand Multipath Distance Vector Routing in Ad-hoc Networks”, In proceedings of the IEEE International Conference on Network Protocols, 2001 pp 14-23.

[6] M.Caleffi, G.Ferraiuolo and L.Pauro, “On Reliability of Dynamic Addressing Protocols in Mobile Ad hoc Networks”, Proceedings of WRECOM’07, Wireless Rural and Emergency Communications Conference, Roma, Italy, October 2007.

[7] Ian D Chakeres and Charles E Perkins,”Dynamic Manet On Demand Routing Protocol”, IETF Internet Draft, draft-ietf-manet-dymo-12.txt, February 2008.

[8] Rolf Ehrenreich Thorup,”Implementing and Evaluating the DYMO Routing Protocol”, Master’s Thesis, Department of Comptuer Science, University of Aarhus, Denmark.

[9] Guangyu Pei, Mario Gerla and Tsu Wei Chen,”Fisheye State Routing: A Routing Scheme for Ad Hoc Wireless Networks”, In Proceedings of IEEE International Conference on Communications (ICC2000), New Orleans, Louisiana, USA, June 18-22, 2000.

[10] Allen C Sun,”Design and Implementation of Fisheye Routing Protocol for Mobile Ad hoc Networks”, http://www.scanner-group.mit.edu/PDFS/SunA.pdf

[11] S.K.Sarkar, T.G.Basavaraju et al,”Ad hoc Mobile Wireless Networks, Principles, Protocols and Applications”, Auerbach Publications -2008.

[12] T.Clausen and P.Jacquet,”Optimized Link State Routing Protocol for Ad hoc Networks”, http://hipercom.inria.fr/olsr/rfc3626.txt

[13] Mounir Frikha and Manel Maamer,” Implementation and Simulation of OLSR protocol with QOS in ad hoc Networks”, In Proceedings of the Second International Symposium on Communications, Control and Signal Processing (ISCCSP’06), 13-15 March, Marrakech, Morocco.

[14] C.Siva Rama Murthy and B.S. Manoj, “Adhoc Wireless Networks: Architectures and Protocols”, Second Edition, Prentice Hall.

[15] Vincent D Park and M. Scott Corson,”A Performance Comparison of the Temporally Ordered Routing Algorithm and Ideal Link State Routing”, In Proceedings of the 3rd IEEE Symposium on Computers and Communications, Washington D.C, USA, 1998.

[16] Vincent D Park, J P Macket and M Scott Corson,”Applicability of the Temporally Ordered Routing Algorithm for use in Mobile Tactical Networks”, In Proceedings of IEEE Military Communications Conference (MILCOM 98), 1998.

[17] Jean-Yves Le Boudec and Milan Vojnovic,”Perfect Simulation and Stationary of a Class of Mobility Models’, In Proceedings of IEEE INFOCOM 2005, Miami, March 13-17, 2005.

[18] William Navidi, Tracy Camp and Nick Bauer,”Improving the Accuracy of Random Waypoint Simulations Through Steady-State Initialization”, Proceedings of the 15th International Conference on Modeling and Simulation (MS’04), pp 319 -326, March 2004.

[19] Ben Liang and Zygmunt J Haas,"Predictive Distance Based Mobility Management for PCS Networks", In Proceedings of IEEE INFOCOM-99, NewYork, NY, March 21-25, 1999.

[20] Newman and Girvan,"Finding and evaluating community structure in networks", Physical Review E, 69, Februrary 2004.

[21] Mirco Musolesi and Cecilia Mascolo, "A Community Based Mobility Model for Ad hoc Network Research", International Symposium on Mobile Ad hoc Networking and Computing, Proceedings of the 2nd International Workshop on Multi hop ad hoc networks, 2006.

[22] Ming Zhao and Wenye Wang,"A Novel Semi Markov Smooth Mobility Model for Mobile Ad Hoc Networks", In Proceedings of the IEEE GLOBECOM'06, San Francisco, CA, November 2006.

[23] Maig Zhao and Wenye Wang,"Design and Applications of a Smooth Mobility Model for Mobile Ad hoc Networks", In Proceedings of the IEEE Milcom'06, Washington D.C., October 2006.

[24] Laura Marie Feeney,"Investigating the Energy Consumption of a Wireless Network Interface in an Adhoc Networking Environment", In Proceedings of the INFOCOM01 Twentieth Annual Joint Conference of the IEEE Computer and Communication Societies, Vol 3, August 2002, pp 1548-1557.

[25] Information Sciences Institute, "The Network Simulator Ns-2", Http://www.isi.edu/nanam/ns/, University of Southern California.

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